FIELD CROPS IN COLORADO

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Preface

"Field Crops in Colorado" has been written as a supplemental text for "CROP PRODUCTION," a 3-credit Agronomy course taught at Colorado State College. An attempt has been made to collect and organize all available information on the culture of field crops in Colorado. The references cited are either Colorado publications or others that describe conditions found within the state.

It has been the opinion of the authors that a general field crops text inadequately describes the conditions found in the state. Most of these texts deal in principles that apply to large regions, rather than to a single state. The detail given in this manual is an attempt to apply the general principles of crop production to the various climatic and soil conditions found in Colorado.

Acknowledgments

The authors wish to take this opportunity to express their grateful appreciation to Superintendent J. F. Brandon of the Akron Field Station, U. S. Department of Agriculture, for his many valuable suggestions on the preparation of this manuscript. It is our hope that he will receive his reward from the dissemination of more accurate information on dryland conditions in eastern Colorado. His wealth of experience has covered a period of almost a quarter century during which he has been engaged in many different phases of dryland research. The writers also wish to acknowledge the constructive criticisms offered by Robert Gardner, associate agronomist, Colorado Experiment Station.

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Part I

General Principles
FIELD CROPS IN COLORADO

Chapter 1. Introduction

I. Pioneer Agriculture

Indians and buffalo roamed the plains of what is now Colorado 100 years ago. The buffalo grazed on the native grasses, and was in turn hunted by the Indians who depended upon a meat diet. The buffalo had served as the principal source of food for untold centuries before the white man came on the scene.

The first white men came into what is now Colorado about 1500, most of these being explorers, trappers, hunters, or miners. Small garden patches were grown adjacent to camps and settlements. Some livestock was also brought in by the early settlers. A company of trappers raised some grain and vegetables in the Arkansas Valley near Fort Bent in 1839. Shortly afterwards, crops were grown in the South Platte valley near Denver. Irrigated crops were observed in settlements in the San Luis Valley in 1853. These crops consisted of wheat, corn, beans, and field peas. The first flour mill was established in this valley at San Luis in 1859. From 1850 to 1870, crop production extended to most of the river valleys of the state. For example, near Canon City in the Arkansas Valley, it was reported in 1862 that "all kinds of grain or vegetables grown in Illinois will grow here." Some crops, together with their acre yields, were as follows: wheat 35 to 40 bushels, Mexican corn 30 to 40 bushels, American corn 40 to 50 bushels, potatoes 100 to 400 bushels, barley 40 to 50 bushels, and sorghum 200 to 250 gallons of syrup per acre. By 1863, it was reported that 50,000 bushels of wheat were grown on the South Platte watershed. There were many farms along the South Platte river by 1858.

II. Range Livestock Industry

The livestock industry sprang up shortly after the production of crops began. The first cattle were trailed across the plains in 1846. They subsisted entirely on grazing. The practical discovery of the grazing value of the new country was made by wagon bosses in 1858. A small herd of dairy cattle was reported on Cherry Creek near Denver in 1860. Within about 4 years, grass-fed beef production had assumed the character of a distinct industry, but it supplied only local demands until the railroads were built. In the meantime, the buffaloes were ruthlessly slaughtered for their hides. The first trainload of cattle was shipped east from Kit Carson over the Kansas Pacific in 1869. This traffic became important by 1872 when 428 cars were shipped from Denver. The cattle were branded and raised on the open range. The first organized roundup took place below Platteville in 1871. Many large ranches were established during this period. (Steinol, 1926).

III. Early Irrigation

Irrigation for crop production in the semi-arid region is older than the written history of the continent, as shown by archaeological discoveries. The Spanish colonists began irrigation where the Aborigines left off. They started irrigation in the San Luis Valley in the early days, the first irrigation rights being granted in 1852. Corn was planted and irrigated
near Trinidad in 1846. Systematic irrigation farming was started in the Platte Valley near Denver in 1859. The Greeley Union Colony started about 1870 and placed the use of water on a cooperative basis. During the next 25 or 30 years canals and reservoirs were built on all the principal streams, particularly in the eastern part of the state. In fact, by the late 1880’s canals were built out of all proportion to the actual acreage that could be watered. (Steinel, 1926).

IV. Dry Land Settlements

During the early settlement days it was generally accepted that agriculture (crop production) in Colorado was impossible without irrigation. The range men also discouraged homesteaders because they desired to keep the grasslands for their flocks and herds. The first general movement of dryland settlers began about 1870 after some of them had found that wheat could be grown. Crop failures were the rule, with the result that many settlers turned to livestock or left. Gradually, the dryland farmers learned how to produce crops with more certainty through the use of special cultural methods, as well as through the introduction of better adapted crop varieties. In 1886, the use of summer fallow was introduced in the state. Soon it was widely applied, particularly to wheat production. An experiment station, established at Cheyenne Wells in 1894, was devoted to the study of dryland problems. However, lack of financial support has prevented it from becoming more than a small demonstration farm. Another experiment station was established near Akron in 1907 by the U.S. Government to represent the west central Great Plains region. It has acquired much valuable information on the principles basic to non-irrigated agriculture.

V. History of Sugar Beet Production

Sugar beets were suggested as a possible crop as early as 1866. The first sugar analyses were made in 1869 from which it was concluded that sugar beets were adapted to the state. While there was much speculation about the practicability of sugar beets, the first sugar factory was not established until 1892 in Grand Junction on the Western Slope. Many factories were established on the Eastern Slope from 1900 to about 1910. By 1926 there were 17 sugar factories in operation in Colorado.

VI. Important Colorado Crops

Many different kinds of crops are grown in Colorado at the present time. The important cereals are corn, wheat, oats, barley, proso, and rye. Sorghums for both grain and fodder are being grown on large acreages. Broomcorn has assumed considerable importance as a dryland crop in Baca County. Among the legume crops, those grown most extensively are alfalfa, sweet clover, red clover, alsike clover, field beans, and field peas. Soybeans are grown to a limited extent. The sugar beet is the only crop, other than grasses or legumes, that is important in the state.

From the national standpoint, Colorado is one of the chief states in the production of alfalfa and sugar beets.

The relative importance of various crops produced in the state is shown in the diagrams that follow:
ACRES OF CROPS HARVESTED, 1936, AND AVERAGE, 1927-1936

ACRES HARVESTED
10-year average, 1927-36

All Wheat 1,116,000 (19.1%)
Corn 1,461,000 (25.0%)
Oats and Barley 591,000 (10.1%)
All sorghums 233,000 (4.2%)
Alfalfa 73,000 (1.2%)
Other Tame Hay 31,000 (0.5%)
Potatoes and Sugar beets, 293,000 (5.0%)

TOTAL ALL CROPS, 5,835,000 (100%)

ACRES HARVESTED 1936

All Wheat 1,339,000 (22.7%)
Corn 1,078,000 (18.2%)
Oats and Barley 673,000 (11.4%)
All sorghums 705,000 (12.0%)
Alfalfa 681,000 (11.2%)
Other Tame Hay 75,000 (1.3%)
Hy. 201 43,000 (0.8%)
Other Grass Hay 17,000 (0.3%)
Potatoes and sugar beets 228,000 (3.9%)

TOTAL ALL CROPS, 5,907,000 (100%)

VII. Experiment Stations for Field Crop Studies

While new agricultural information may be gained by experience, it is generally a slow and costly process. Experimentation is planned experience. The experiment stations are generally the most reliable sources of new information about Field Crops, and their reaction to soil treatments. A field experiment has the advantage over experience in that varieties, cultural methods, and other factors, can be studied under carefully controlled conditions. Practically all the reliable information on field crops released in this state, as well as in other states, came either directly or indirectly from the agricultural experiment stations. The principal stations in this state that deal with field crop problems are located at Fort Collins, Akron, Rocky Ford, and Fort Lewis.

The Agronomy Farm of the Colorado Experiment Station is located at Fort Collins at an elevation of about 5,000 feet. Experiments are conducted under irrigated conditions that are fairly representative for similar areas of the northeastern part of the state. The frost-free season at Fort Collins is about 120 days.
Chapter 1, cont.

The Fort Lewis Sub-station is located at Hesperus in the extreme southwestern part of the state at an elevation of 7610 feet. Both irrigated and dryland tests are conducted at this station. The climate makes this experimental farm a desirable place to test crops for high altitude conditions.

Another substation is located in the Arkansas Valley at Rocky Ford. Experiments are conducted under irrigation at this station. The results are applicable to irrigated areas in southeastern Colorado.

The U. S. Dryland Field Station is located at Akron. It is a regional station, its results being applicable over the whole of eastern Colorado as well as to parts of nearby states. The Akron experiments are conducted wholly on dryland. The soil is a naturally fertile sandy loam known locally as "hard land." The soil in the vicinity is variable in texture but comparatively free from coarse gravel. The 31-year average precipitation at Akron from 1907 to 1938 was 17.06 inches. The average frost-free period is about 140 days.

References


Questions for Discussion

1. Give the evolutionary stages of agriculture in Colorado.

2. Trace the development of the range livestock industry.

3. Describe the development of irrigation in Colorado.

4. Why was the development of dryland agriculture slow?

5. About what time were sugar beets grown in the state? When were the first factories built?

6. Name the 10 most important crops now grown in the state.

7. Why has the sorghum and barley acreage shown substantial increases in the last 10 years?

8. Name 4 experiment stations in the state, give their locations, and the conditions they serve.

9. Why are experiment stations the most reliable sources of new knowledge on field crops?
Chapter 2. Environmental Conditions

I. Plants under Semi-Arid Conditions

Colorado is located within the semi-arid region of the country. The eastern part is in the Great Plains, formerly covered with short grasses, such as buffalo and grama, as the climax vegetation. Such plants are probably the ones best adapted to this area. All crop plants grown in eastern Colorado on the Great Plains are introductions, generally from more favorable climatic regions. Burr (1931) cites many early authorities who considered crop production impossible on the Great Plains. Present evidence disproves this early viewpoint, altho crop production is far more hazardous than in the more favorable humid areas. In a comment on the semi-arid region, Chilcott (1931) states that "conservation and utilization of the scanty rainfall is of such importance as to completely eliminate some factors and relegate all others to minor positions." Cultural methods are modified principally for the conservation of moisture. Crops are grouped in rotations primarily on the basis of the amount of soil moisture that can be stored from the harvest of one crop to the seeding of the next. Irrigation to supplement rainfall is practiced in places where stream flow can be diverted. Both climatic and soil conditions influence the adaptation of crop plants, climate being the more important.

A -- Climatic Factors

II. Characteristics of Continental Climates

Continental climates, such as that found in Colorado, are characterized by great extremes of temperature between day and night and between winter and summer. The ranges increase in a general way with greater distances from the ocean. On the Great Plains this type of climate is further characterized by an irregular approach of seasons, low humidity, and generally unobstructed winds. The rainfall is usually infrequent and often torrential.

Climatic conditions within the state are extremely diverse. Trimble (1928) states that Colorado has the highest mean altitude of any state. It varies from 3500 to 14,000 feet. The eastern two-fifths of the state lies in the Great Plains. The western slope has a more uneven topography, but contains many mesas and fertile valleys where agriculture is practiced. In the mountain regions there are a number of large upland parks. Robbins (1917) states that there is as much variety in climate in Colorado as a traveller would encounter from Virginia to Greenland.

As climate is outside the control of man, it becomes necessary for him to conform to natural conditions in crop production. It is generally conceded that an annual rainfall below 24 inches and a frost-free season below 125 days constitute effective limitations to the growth of crop plants. The principal climatic factors are temperature, rainfall, humidity, wind, and altitude.
III. Temperature

Temperature is an important climatic factor because some crop plants thrive in cool, and others in warm regions. Many plants are sensitive to temperature changes. Some cool-season crops grown in Colorado are: sugar beets, field peas, wheat, oats, barley, flax, timothy, and redtop. Among the warm-season crops are corn, sorghums, soybeans, proso, and field beans.

(a) Mean Temperatures

In Colorado, extremes in temperature exist between days and nights, as well as between winter and summer. Robbins (1917) gives eastern Colorado with a mean summer temperature (June, July, August) above 70 degrees F. The 70°F isotherm follows very closely the 5,000-foot contour line. The belt along the foothills has a mean summer temperature of 60 to 70 degrees F. High altitude agriculture is practiced between 6500 and 8500 feet where the mean summer temperature ranges between 60 and 65 degrees F. The summer mean for the San Luis Valley is near 60°F. Much of the mountain area is below 55°F, as shown in Figure 1.

As a general rule, it may be stated that in Colorado an increase in elevation of 1,000 feet decreases the mean summer temperature about 3°F. There is a retardation in growth development of the vegetation that amounts to about 13 days for every 1,000-foot increase in altitude.

(b) Length of frost-free Season

The length of frost-free season is the number of days between the last spring and first fall frosts. This is the safe growing season, but hardy field crops, such as sugar beets and field peas, may grow for a longer period. The average frost-free season varies from more than 150 to less than 75 days. The average frost-free period at Fort Collins from 1889 to 1937 was reported by Farshall (1939) as 120 days, from May 21 to September 18. However, it has varied from 90 to 157 days during this 49-year period. The average frost-free period at Akron from 1912 to 1938 was reported as 140 days, from May 7 to September 28. The average length of frostless season is shown in Figure 2.

IV. Precipitation

Precipitation in Colorado varies widely from year to year, and from place to place. It is impossible to forecast dry and wet cycles on the basis of weather records available in the state. In fact, Farshall (1939) reports that precipitation at Fort Collins by years shows almost an exact random distribution. The effectiveness of rainfall in crop production depends upon the total annual amount, the time of year that it falls, the manner in which it falls, and the amount at one time.

A large part of Colorado has an average annual precipitation between 10 and 15 inches. The San Luis Valley has less than 10 inches, while the higher elevations of the state have over 20 inches. The average annual precipitation at Fort Collins for the 50-year period from 1887 to 1936 is 14.70 inches, while that at Akron from 1912 to 1938 is 17.06 inches. There is a gradual increase in precipitation from the foothills to the Kansas line. The mean annual precipitation is shown in Figure 3.
Average number of days of frost-free season in Colorado

- **Below 75**: Areas with fewer than 75 frost-free days.
- **75-100**: Areas with 75 to 100 frost-free days.
- **100-125**: Areas with 100 to 125 frost-free days.
- **125-150**: Areas with 125 to 150 frost-free days.
- **Above 150**: Areas with more than 150 frost-free days.
Legend

- Under 10 inches
- 10 to 15 inches
- 13 inches
- 13 to 15 inches
- 15 to 16 inches
- 16 to 17 inches
- 17 inches
- 15 to 20 inches
- 20 to 30 inches
- 30 to 40 inches
- 40 to 50 inches
- Over 50 inches
Rainfall has its greatest value when it comes during the growing season, ordinarily between April 1 and September 30. On the Great Plains, 70 to 80 percent of the precipitation comes between these dates. Ordinarily, summer showers of less than 0.50 inch are of very little value to crops. This moisture is lost largely by evaporation, since most of it is intercepted by the foliage and evaporated before it reaches the soil surface. Frequently, rain comes in torrential showers on the Great Plains with the result that much of it is lost through run-off, especially on the so-called "hard lands" or heavy soils.

V. Other Climatic Factors

Other factors that influence crop production are humidity, wind, and altitude.

(a) Humidity

Moisture in the air in vapor form is known as humidity. Relative humidity is the ratio of water vapor present in the air at a certain temperature and atmospheric pressure to the amount necessary to saturate the same unit space under the same conditions. The rate of water loss (transpiration) from plants is determined largely by the vapor-pressure gradient between the atmosphere and the air in the sub-stomatal cavities of the leaves. The rate of evaporation throughout Colorado is generally high since the relative humidity is low. Parshall (1939) gives the mean relative humidity at Fort Collins as 66.8 as a 45-year average.

Seasonal evaporation from a free-water surface is conditioned by humidity, temperature, and possibly other factors. The method for its determination has been standardized by the Bureau of Plant Industry, U.S.D.A. Seasonal evaporation is regarded as the amount of water evaporated from a tank 8 feet in diameter, 2 feet deep, and extended 4 inches above the soil surface, for the period from April 1 to September 30. A high seasonal evaporation is generally reflected in a high water requirement of crops. The amount of evaporation varies in Colorado: at Fort Collins it is about 30 inches, while at Akron and Rocky Ford it is 44 and 60 inches, respectively.

(b) Wind

The rate of water loss from plants may be increased materially by wind action since the relative humidity usually is less in a region where high winds prevail. High winds may break or tear the leaves of plants. They also cause a great deal of soil blowing during the spring months, especially on the eastern Colorado plains. The 27-year average wind velocity at Akron from 1912 to 1938 is 6.1 miles per hour. It is low, or 5.0 miles per hour in August, and increases to a maximum of 8.0 miles per hour in April. Unless soil blowing is controlled, any crop on the land may be cut to pieces and the soil surface actually lost.

(c) Altitude

An increase in altitude brings about modifications in climate. The changes to be expected are as follows: (1) Decrease in air temperature, (2) greater difference between sun and shade temperatures, (3) greater
difference between day and night temperatures, (4) increase in the effect of exposure of north vs. south slopes, (5) shortening of the growing season, (6) increase in precipitation, and (7) an increase in the intensity of ultra-violet rays.

B — Soil Conditions

VI. Soils of Colorado

Soils in general are classified into two broad groups and several sub-groups.

(a) General Groups of Soils

The broad groups of soils found in the state are (1) those thru which moisture normally passes to the underground layers, and (2) those thru which moisture does not pass to very great depths. The former have no zone of lime accumulation in the profile and are designated as Pedalfers. The latter develop a zone of lime in the profile and are known as Pedocals. Both of these groups are found in Colorado. Plains areas with less than 20 inches of precipitation and mountainous regions below 7500 feet elevation, generally have Pedocal soils which have developed under short grass or desert shrub vegetation. The important agricultural soils of the state fall in this category. The higher mountain and mesa soils are Pedalfers, having been formed under tall grass or forest cover. These soils are highly leached and have acid surface layers in contrast to the neutral or alkaline surface layers of the pedocal soils. The 3-sub-groups of both Pedocal and Pedalfiler soils are the (1) zonal, (2) intrazonal and (3) azonal.

(b) Zonal Groups in Colorado

The zonal soils of the Pedocal class found in Colorado are the Chestnut, Brown, Sierozem, and Desert groups. The Pedalfers class includes the Prairie, Gray-Brown Podzolic, and Podzol groups. The distribution of the zonal groups in Colorado is shown in figure 4. There is insufficient available information for a separation of the zonal groups in a few areas. These have been marked as "undifferentiated groups." In western Colorado, about 50 percent of the areas marked Chestnut and Brown (undifferentiated), and Sierozem and Desert (undifferentiated), are rough broken land or slopes so steep that zonal soils cannot develop. In the same groups on the western Colorado plains, about 20 percent of the areas are too steep to develop zonal soils.

The Chestnut, Brown, Sierozem, and Desert soils have dark brown, brown, pale gray, and light-brownish gray surface horizons, respectively. They also have progressively less organic matter in the order listed. The thickness of the surface soils also becomes less from the Chestnut to the Desert soils, while the lime accumulation usually reaches its maximum development in the Chestnut and Brown soils. Kellogg (1936) states that the Chestnut soils are fertile and extensively used for wheat, but the climate is hazardous. The Brown soils are also used for wheat, but the climate is so hazardous that about half these soils are used for grazing. The Sierozem and Desert soils, described as low in organic matter and comparatively shallow, are best suited for grazing. It should be emphasized that the better areas in all the Pedocal groups are very productive when put under irrigation.
Figure 4 - Soil Groups found in Colorado
The Prairie, Gra-Brown Podzolic, and Podzol groups are of little importance in Colorado as agricultural soils. They are utilized principally for grazing and forestry purposes, altho a few areas are used to produce feed crops for livestock.

A description of the important zonal groups found in the state, taken from Baldwin and associates (1938), is given as follows:

<table>
<thead>
<tr>
<th>Zonal Soils</th>
<th>Profile</th>
<th>Native Vegetation</th>
<th>Climate</th>
<th>Natural Drainage</th>
<th>Development Processes</th>
<th>Present Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chestnut</td>
<td>Dark-brown friable and platy soil over brown prismatic prairie. soil with lime accumulation at depth 1.5 to 4.5 feet.</td>
<td>Mixed tall and short grass</td>
<td>Temperate to cool</td>
<td>Good</td>
<td>Calcification</td>
<td>Cereal grains, especially wheat and grain sorghums. Excellent grazing.</td>
</tr>
<tr>
<td>Brown</td>
<td>Brown soil grading into a whitish calcareous horizon 1 to 3 ft. from surface</td>
<td>Short grass, and bunch grass prairie</td>
<td>Temperate to cool</td>
<td>Good</td>
<td>Calcification</td>
<td>Large farms of small grain if unirrigated. Ranching in large units.</td>
</tr>
<tr>
<td>Sierzem</td>
<td>Pale grayish soil grading into calcareous material at 1 foot or less</td>
<td>Desert plants, scattered short grass, shrubs.</td>
<td>Temperate to imperfect</td>
<td>Good to imperfect</td>
<td>Calcification</td>
<td>Grazing in large units. Intensively farmed in small units where irrigated.</td>
</tr>
<tr>
<td>Desert</td>
<td>Light gray or light brownish gray, low in organic matter, closely underlain by calcareous material.</td>
<td>Scattered shrubby desert plants.</td>
<td>Temperate to imperfect</td>
<td>Good to imperfect</td>
<td>Calcification</td>
<td>Grazing in large units. Intensively farmed in small units where irrigated.</td>
</tr>
</tbody>
</table>

(c) Intrazonal Soils

Within all the pedocalic zonal soil groups in Colorado there are areas in which excessive salts are found. These areas are usually in low places with poor drainage, such as along river bottoms. These soils are of two classes, saline and alkaline. The processes of formation are known as salinization and solonization.
Salinization is the process of accumulation of excessive amounts of various salts in the soil such as the chlorides, sulfates, and nitrates of sodium, potassium, calcium, and magnesium. When these salts occur in appreciable quantities, the soil is known as a saline or Solonchak soil. These salts, which are not highly basic, are often called "white alkali" salts. They originate from minerals and rocks thru weathering. They may be brought into certain areas in (1) surface water, (2) irrigation water or (3) ground water. As the water evaporates the dissolved salts are deposited. Solonchak soils may contain salts varying in amount from 0.2 to 5.0 percent, or even higher.

The leaching of saline or Solonchak soils that contain considerable amounts of sodium and small amounts of calcium salts results in a soil that is highly alkaline and puddled. It is impervious to both water and air when wet due to excessive swelling. The removal of the saline salts converts the soil into a new type called alkaline or Solonetz soil. This process of eluviation is known as alkalinization or solonization. These soils are not usually high in total salts, but those present are much more injurious than saline salts to both the soil and the plant. These salts are principally the carbonates, bicarbonates, and hydroxides of sodium and potassium. They are commonly called "black alkali" salts since they are very basic in reaction. Consequently, these salts tend to dissolve humus, a black or brown substance.

Neither saline nor alkaline soils have much agricultural value unless reclaimed. Since reclamation involves both time and expense, it is far better to manage the land in such a way as to prevent the accumulation of salts.

(d) Azonal Soils

Azonal soils are without well-developed characteristics either because of their youth, the conditions of the parent material, or their relief. These conditions may be found associated with any of the zonal groups. Azonal soils in Colorado include (1) the sandhills of the plains region, (2) some recent alluvial soils along the principal rivers, (3) shallow soils or lithosols in the foothills, and (4) the rough mountain lands.

VII. Soil Requirements for Economic Plants

Soil requirements for plants can be understood from a recognition of the factors that influence their growth, viz., (1) water supply, (2) supply of plant nutrients, (3) air, (4) temperature, (5) depth of soil, and (6) injurious factors.

Soils favorable for the growth of plants are those which are in a good enough physical condition for the normal chemical and biological processes to occur. They are comparatively deep with the subsoil free from clay pans, impervious lime layers, and high water tables. They have a texture and structure that makes them permeable to water, air, and roots. It should have a good water-holding capacity, an adequate supply of organic matter, and sufficient plant nutrients. Soils of these characteristics, and comparatively free of saline or alkaline salts, toxic heavy metals, or selenium, will produce good yields under favorable climatic conditions.
The lack of moisture limits plant growth in Colorado more often than any other factor. Probably next in importance are excessive salts and high \( \text{pH} \). While Colorado soils are rather high in most of the plant nutrients, available phosphorus is quite often deficient. Since organic matter is rather low, nitrogen deficiency frequently occurs.

II. Alkali-Tolerant Crops

True grasses were found by Kearney (1924) to be more resistant to alkali salts than legumes as a class. In soils with excessive alkali, i.e., more than 1.5 percent of soluble salts by weight, the concentration is too high for agricultural crops. Sugar beets will produce a fair crop where the alkali varies from 2.0 to 2.5 percent, but the crop is not advised. For concentrations from 1.0 to 1.5 percent, good crops of sugar beets and foxtail millet, as well as fair crops of sorghum and barley can be grown. At lower concentrations, good crops of redtop, timothy, orchard grass and rye are possible. Forage plants are preferable for alkali land over cereal crops because the quality of the latter is often injured for market purposes.

The arbitrary limits for white alkali for plant growth used by the Soils Laboratory are as follows: (1) 0.2 percent (2000 p.p.m.) most economic plants injured above this amount; (2) 0.5 percent (5000 p.p.m.) very few agricultural crops produce well; (3) 3.0 percent (30,000 p.p.m.) very few plants of any kind can survive. All crops can tolerate 0.05 percent (500 p.p.m.) of black alkali, and all but the most sensitive can withstand 0.05 to 0.10 percent (500 to 1000 p.p.m.).

C — Crop Adaptation

[X. Indicator Significance of Native Vegetation

The native plant cover, when properly interpreted, can be used as an indicator of the climatic and soil conditions under which it was produced. Dominant plant groups have some indicator significance as to crop possibilities. Robbins (1917), in a study of the native plant communities in Colorado, listed 5 major groups. These are: (1) Grass-steppe or short grassland; (2) shrub-steppe comprised of sagebrush, greasewood, rabbitbrush, etc.; (3) chaparral or brushland; (4) pinyon pine-Juniper woodland; and (5) coniferous forests. A natural vegetation map is given in Figure 5.

(a) Grass-Steppe or Short-grass Formation

The short grasses are the dominant forms of vegetation over the Great Plains of Colorado. The area occupied by these grasses extends from the foothills to the eastern boundary of the state. It is almost uninterrupted except for some bunch grasses on the sandy soils. The two most characteristic grasses in this area are buffalo grass (Buchloe dactyloides) and grama grass (Bouteloua gracilis). These are shallow-rooted plants that indicate a soil of considerable run-off. Adjacent to sandhills, wiregrass (Aristida longiseta) may cover wide stretches. The grass-steppe is a vegetative response to low infrequent rainfall. It occupies a territory with a mean annual precipitation between 10 and 20 inches. Droughts frequently come in late summer, but may occur in any part of the growing season. The length of the frostless season is from 125 to 163 days. The crops that can be
brought to maturity in this area are corn, sorghums, and the common small grains which are wheat, rye, barley, and oats. (See Hanson, 1927).

(b) Shrub-Steppe

Almost 25 percent of Colorado is covered by a shrub type of vegetation. The principal species are sagebrush (Artemesia tridentata), greasewood (Sarcobatus vermiculatus), shadscale (Atriplex confertifolia), Kochia (Kochia vestita), and rabbitbrush (Chrysothamnus spp.).

Sagebrush is characteristic of the arid areas of western Colorado. The average height of sagebrush is about 3.5 feet. It seldom occupies a habitat where soil moisture is near the surface. Typical sagebrush soil is well-drained, low in water content, and always practically free from alkali. The mean annual precipitation of sagebrush areas ranges from 10 to 18 inches, although the community is most typical where it is below 15 inches. Sagebrush flourishes under a wide range of temperature conditions. The frostless season is variable, i.e., 56 to 183 days. Some of the best farms in the state are found on sagebrush land brought under irrigation. This shrub indicates that these crops will mature: timothy, alsike clover, oats, wheat, barley, rye, alfalfa, potatoes, and field peas.

Greasewood is widely distributed throughout the state, particularly in the San Luis Valley. It is almost always an indicator of a high water table, and consequently of a soil high in "alkali" salts. Seeped land in this valley may become almost pure stands of this shrub. The crops that can be grown there under irrigation are: small grains, potatoes, alfalfa, and field peas.

Shadscale, sometimes along with greasewood, is found chiefly on alkaline flats in western Colorado. The soil it occupies is usually fine-grained; the surface layers dry, and the soil below 1 or 2 feet quite high in salt content. Such lands have no agricultural value until reclaimed, even under irrigation.

(c) Chaparral or Brushland

Chaparral is a dense growth of shrubs. In Colorado, it is mainly scrub oak, buckbrush, or mountain mahogany.

Scrub oak forms the most extensive thicket growth in the state. Its northern limit along the eastern slope is between Palmer Lake and Denver. It may form a fringe along the upper edge of the sagebrush association. Scrub oak is seldom found above 8,000 feet. It is commonly associated with buckbrush on the western slope. Both occupy soils that are deep, rich, and suitable for agriculture. Crops that can be matured on these soils are alfalfa, potatoes, and small grains.

Mountain mahogany is generally distributed throughout Colorado in the foothills and on the lower mesas. It covers dry, rocky areas and indicates arid conditions unsuited for agriculture.

(d) Pinyon Pine-Juniper Woodland Zone

These trees form a rather distinct belt just below the yellow pine zone. It is found particularly on the warmer slopes in the southwestern part of the state. The pinyon pine-juniper belt is best developed below
7,000 feet, but it may reach 9,000 feet in the San Luis Valley. It is always found on south exposures at high altitudes. Pinyon pine-juniper usually occupies rough, broken country or shallow stony soil. This association often alternates with sagebrush. The mean annual precipitation in the Pinyon pine-Juniper belt is uniformly under 15 inches. The summer temperature is usually about 65°F, the average frostless season between 100 and 125 days, and the average date of last spring frost about May 20. Pinyon pine-juniper is a reliable indicator of a warm habitat in a cool area when found above 6500 feet. This woodland is a mark of temperature conditions which permit growth of the small grains, flax, sugar beets, potatoes, and alfalfa, but seldom is water available for irrigation.

(e) Coniferous Forests

These forests include several zones or sub-zones, such as the yellow pine-Douglas fir, lodgepole pine, white fir, and Engelmann spruce-balsam fir forests.

The yellow pine forest community belongs to the foothills, particularly at elevations of 6000 to 8000 feet. This tree indicates an area where the annual precipitation is between 15 and 20 inches, and a frostless season of 86 to 125 days. The slopes are generally too steep for cultivation, or the soil too stony and shallow. Such lands are usually grazed. Cattle or barley cut for hay are the most common crops where crop production is practiced.

The lodgepole pine forest is bounded on the lower edge by yellow pine and on the upper by Engelmann spruce. Lodgepole pine usually occurs at 8,000 to 10,000 feet elevation. It indicates a frostless season seldom over 75 days and frequently much shorter. The annual precipitation in this zone averages 18 to 25 inches. The temperatures are too low for the small grains or alfalfa. The lodgepole pine zone is considered to be the upper limit of crop possibilities, and such lands are seldom used for other than pasture.

The white fir belongs to the southern mountains of the state, where it takes the place of the lodgepole pine of the northern mountains. Its indication of climate in relation to agriculture is very similar. The Engelmann spruce-balsam fir forest zone comes in at an altitude about 10,000 feet, and extends to timberline. On account of its low temperatures, the growth of crop plants is excluded. Summer grazing is found in the open areas. Some native hay is cut here and there.

IX. Modification of Soil and Climatic Conditions

It is often possible to modify soil and climatic conditions for crop production.

Irrigation is practiced to supplement rainfall. This makes the culture of some crops with high water requirements possible within the state. For example, alfalfa requires about 40 inches of rainfall annually when grown without irrigation. Sugar beets also have a high water requirement. Many of the true clovers can be grown in the state only with irrigation.
Sometimes it is necessary to add fertilizers to the soil to increase its productivity. Fertilizers make the soil environment more favorable under such conditions. An example is the use of phosphate fertilizers on some soils. Drainage may be used to lower the water table and hence to deepen the root zone. Sometimes the physical condition is improved by turning under a green manure crop.

X. Economic Factors in Crop Choice

The price received for a crop is an important factor in its choice. Cheap lands are often pastured, but as land values rise, more intensive crops are grown. This is particularly true under irrigation. Because of the high over-head, small grain crops are seldom grown under irrigated conditions primarily for sale as grains. Crops that bring higher returns per acre are necessary, as, for example, the sugar beet. Seed crops are sometimes grown in isolated regions where the markets are distant because they can be shipped in a concentrated form. An example is the alfalfa seed industry in northwestern Colorado near Craig. Markets are limited for some crops that are otherwise adapted. Durum wheat is adapted to the drylands, but it must be raised in quantities sufficient for carload lots in order to obtain a comparable price. Durum cannot be mixed with the common bread wheats without a serious reduction in grade. Broomcorn, from which brooms are made, could be more widely grown in the state so far as climate and soil is concerned. However, the market for the brush is limited due to the introduction of feather dusters, oil mops, etc. Early soybeans are adapted to Colorado irrigated conditions, but the yield is too low to compete with alfalfa as a protein feed, or with pinto beans for a seed crop on account of price. Since soybeans produce less than Pintos on the drylands, their production is not practical. Thus, it is apparent that simple climatic and soil adaptation may not justify the production of a crop.

XI. Some Examples of Crop Adaptation

The reasons for the production of certain crops in the state can be readily explained by climatic, soil, or economic factors favorable to them.

1. Corn: This crop was often a failure 25 years ago because of the use of long-season Cornbelt varieties. Early varieties that mature in 120 days or less has extended the Cornbelt to the foothills of the Rocky Mountains.

2. Sorghums: The sorghums are more drought-resistant than corn because they can recover more readily from arrested growth due to moisture shortage. Early grain varieties have been developed for eastern Colorado drylands where they promise to replace corn as a crop to a large extent.

3. Wheat: Winter wheat is grown almost altogether on the drylands in Colorado because it has a larger root development than spring wheat and matures earlier. Winter wheat must be cold-resistant to survive on the drylands.

4. Oats: Common oats are adapted to the cooler regions of the state, while the red oat varieties are more productive in the warmer regions because of their heat resistance.

5. Barley: There has been a great increase in the barley acreage during the past few years because it is more certain as a crop than corn, especially on the drylands. It is also better adapted to alkali soils.
6. **Rye**: Winter rye is more productive than wheat on the sandier drylands, i.e., "semi-hard" lands.

7. **Alfalfa**: This crop is well adapted to climates with low humidity and to calcareous soils, particularly under irrigation. It produces more forage per acre for the season than other hay legumes.

8. **Red Clover**: At one time red clover was widely produced as a seed crop in the Arkansas Valley because of favorable climatic conditions. The acreage has dropped in recent years because of pests.

9. **Field Peas**: Peas are a cool season crop grown in the cooler mountain valleys. They can stand light frosts at any time except when in blossom.

10. **Sugar Beets**: Beets are adapted to the loam soils in Colorado under irrigation. They are unproductive on infertile sandy soils.

References


Questions for Discussion

1. Why is crop production hazardous on the Colorado dry-lands?
2. Give the general characteristics of continental climates.
3. What influence has temperature on agriculture in the state?
4. How does the frostless season vary within the state?
5. What factors determine the effectiveness of precipitation?
6. What is the influence of humidity on crop production? Why?
7. What is seasonal evaporation? How measured?
8. What detrimental effects may be caused on crops by winds?
9. Explain how an increase in altitude influences climatic factors.
10. Distinguish between the pedocals and pedalfers.
11. Name and describe 3 zonal soil groups found in the state.
13. What general soil conditions are required for economic plants?
14. Name several crops that are resistant to alkali.
15. Are grain or forage crops preferred on alkali soils? Why?
16. Name 5 dominant native plant groups found in Colorado.
17. What is the indicator significance of the grass-steppe?
18. Give the conditions under which sagebrush is found. What crops can be grown?
19. Give the soil conditions indicated by the presence of grasswood. For shrubsteppe.
20. Where is scrub oak found? What soil and crop conditions does it indicate?
21. Give the indicator significance (climate, soils, crops) of the pinyon pine-juniper woodland zone.
22. What crop possibilities does yellow pine forest indicate?
23. What is the agricultural significance of the lodgepole pine forest? White fir? Englemann spruce?
24. Give some man-made modifications of soil conditions.
25. Give 3 examples of how economic conditions may influence crop choice in a locality.
26. Name 5 crops and tell why they are adapted in Colorado.
FIELD CROPS IN COLORADO

Chapter 3. Tillage

Reasons for Tillage

Soil is cultivated to place it in condition for plant growth. Some of the reasons for tillage are as follows: (1) mechanical manipulation to permit weathering; influences to operate to the maximum effect; (2) suppression of weeds; (3) restoration of tilth; (4) incorporation of organic matter in the soil; and (5) creation of a rough soil surface to increase the absorption of rain. Childs and Cole (1918) questioned the popular conception that deep tillage was beneficial since the operation does not increase the water content of the soil nor the extent of the root range. In fact, shallow plowing has resulted in higher crop yields than deep tillage in many dryland tests. Plowing is less frequent on irrigated and dry lands than formerly.

Tillage implements vary widely in their effect on the soil. Some leave it pulverized, while others form clods. Some completely turn the surface and other merely stir the topsoil.

A -- General Cultural Methods

I. Primary Implements for Seedbed Preparation

Implements used in seedbed preparation range from the common moldboard plow to some of the more recent special-purpose equipment.

(a) Moldboard Plow

The moldboard plow shears off the furrow slice and inverts it. Some pulverization takes place at the same time. At one extreme is the breaker type with a long moldboard adapted to virgin sod, while at the other extreme is the stubble bottom with an abrupt moldboard for pulverization of old ground. The general-purpose plow is intermediate, being used for small-grain stubble, tame sod, or old ground. It is effective to cover trash and weeds. Adapted for use on irrigated fields, where dead furrows are a hindrance in the control of water flow, is the two-way plow. It may plow in either direction and throw all of the furrows one way. It is very popular in Colorado. Implements developed in recent years have in part replaced the plow, but it still has many advantages. The moldboard plow turns under vegetative residue and trash, kills weeds, rearranges the soil structure, improves the tilth, and prepares the foundation for the seedbed.

(b) One-way Disk Plow

This type of plow works well in soils so dry and hard that moldboard plows penetrate with difficulty, particularly on stubble lands in the wheat belt of the Great Plains. Because the disks of this plow all face one way, it works with its axis at an angle—between 35° and 15°—and the thrust is taken by specially angled wheels. The width cut by these machines varies between 4 and 10 feet, the disk sizes from 20 to 26 inches, and the disk spacings from 6 to 10 inches. The one-way disk plow is used in many localities for summer-fallow work. It should be used with discretion when
conditions favor wind erosion since it causes more pulverization than shovel implements. On stubble fields it leaves the stubble well mixed with the soil but with enough exposed to retard blowing, according to Gray (1938). The one-way disk plow is popular for large-scale operations because it covers about 3 times as much ground as the moldboard plow, the draft being less for the work done because the soil is moved a shorter distance.

(c) Lister

The lister is a double-moldboard plow. It is widely used in the semi-arid region to place the soil in ridges to hold moisture and to prevent wind erosion. The lister is used on Colorado drylands to prepare a seedbed for corn, often for the first cultivation of land to be fallowed, or for the first tillage operation in the preparation of stubble land for small grains. It leaves the land ridged, rougher, and not as loose as does the plow. In the semi-arid region, a planter box is mounted on the lister for seeding corn, sorghum, and other row crops. Cole and Morgan (1938) call attention to its use as an emergency implement to stop wind erosion. Listing for this purpose may be solid, or the furrows spaced 2 rods or more apart, dependent upon the severity of the conditions. The operation is known as "strip listing" when the furrows are spaced at considerable intervals, the purpose being to trap soil and prevent its movement. Recently, Gray (1938) describes the basin lister which throws up dams in the furrows at intervals. The listing is a protection against immediate wind erosion while the blocked, open furrows hold water that might otherwise run off.

III. Secondary Implements for Seedbed Preparation

Various implements are used to level plowed soil, compact it, and destroy weeds. These are generally considered as secondary operations in seedbed preparation, but on the plains or after clean-cultivated crops under irrigation they may be primary seedbed preparations.

(a) Disk-Harrow

The disk-harrow is the most widely used secondary tillage implement on irrigated lands. It pulverizes the soil, reduces large air spaces, and helps form the seedbed. Fall-plowed land should preferably be disked the next spring. Frequently fields can be prepared for planting by double disking alone. Penetration is regulated by the angle of the gangs, the greater the angle the greater the disks will penetrate. Both 16 and 18-inch disks are available in widths from 4 to 20 feet. The disk harrow has proved unsuited for the cultivation of bare or unprotected soil on the drylands. Its use is hazardous when soils blow because it pulverizes the surface, fails to form clods, and leaves a smooth expanse that drifts easily. It can be used to cultivate stubble land but penetration is often difficult in dry soils. On drylands the disk-harrow should be used only when weeds have been allowed to grow or are present on the surface as debris.

(b) Spike-tooth Harrow

The spike-tooth harrow is a material aid in breaking clods and leveling the ground. The desired depth of penetration may be obtained by adjustment of the angle of the teeth, being deeper when the teeth are nearer to vertical. It should not be used on summer fallow or on land that is already fine and in condition to blow.
(c) **Spring-tooth Harrow**

This implement penetrates the soil sufficiently to bring large clods to the surface. It has become popular for the cultivation of clean summer fallow land. It cannot be used where there is a large amount of trash as it gathers on the teeth. The spring-tooth harrow is effective for breaking up crusts that are not too thick. It or the duckfoot cultivator should be used on the plains more generally for the preparation of row-crop land for subsequent crops.

(d) **Field or Duckfoot Cultivator**

The field cultivator, with sweeps at the end of a stiff bar, has come to be widely used in Colorado. The shovels or sweeps are staggered in two rows. It is used both for summer fallow and seedbed preparation on the drylands. This cultivator leaves the soil ridged which reduces wind erosion. When used on the contour, the alternate ridges and furrows tend to prevent run-off loss of rainfall. It can be used on soils with some trash since the shovels are arranged so that there is good clearance. The clods and some trash are brought to the surface. The objections to its use on fallow in late summer are that the cultivated surface soil may dry out, and it may not at all times entirely eradicate weed growth. Like all such shovel implements, it is highly effective in weed eradication at the time of germination or in the seedling stage. It should replace the disk-harrow in many seedbed operations on the drylands.

(e) **Rotary Rod Weeder**

The rotary rod weeder is used on summer fallow, according to Cole and Morgan (1936). The rod, which may be square, oblong, or round, run 2 or more inches below the surface, the depth dependent upon the soil condition. It revolves slowly, the motion being opposite to the direction of pull. It deposits clods and trash near the surface while the fine material remains below. It operates best on fairly loose level soil. The rod weeder is un-adapted to stony soils. It clears itself well, and can be used where there is trash or fairly heavy weed growth. This is an excellent implement for the summer cultivation of fallow, where the soil texture will permit its use. Unless used excessively, the rod weeder leaves a cloddy surface.

IV. **Dryland Cultural Practices**

Many cultural practices depend upon the type of soil or the previous crop on the land.

(a) **Plowing**

Plowing is expensive and often unnecessary except to invert excessively weedy growth, stubble, or a sod crop. Under these conditions, the farmer may still choose between the plow, lister, and the duckfoot cultivator on the drylands. Land tends to become weedy when it is continuosly surface-worked. Plowing is necessary more often under irrigated than under dryland conditions.

Grace (1915) studied fall vs. spring plowed land at Akron as a preparation for small grains during the period of 1909 to 1915. The average yield of spring wheat on fall-plowed land was 9.1 bushels per acre, while on spring-plowed land it was 11.6 bushels, or a difference of 2.6 bushels in favor of spring-plowed land. He attributed the difference to the fact
that the stubble prevented much snow from being blown away on the land plowed the next spring. However, this fall plowing date was about September 1 or about 32 days after harvest. In the preparation for winter wheat after winter wheat, it is advantageous to plow soon after harvest to kill the weeds.

Results at Akron show that deep tillage and subsoiling are unpractical under dryland conditions from the yield standpoint. Brandon (1925) gives data for plots subsoiled 14 to 18 inches deep every 2 years: (1) the yield of the subsequent winter wheat crop on the subsoiled plot was 1.3 bushels per acre less than on deep early fall-plowed land as a 15-year average, and (2) 0.1 bushel more than on shallow late fall-plowed plots. In addition, the yield was 0.9 bushel less than on plots only listed as a seedbed preparation. Brandon recommends that dryland soils should never be plowed deeper than 6 or 7 inches. Prairie sod should be broken in the spring about May 15. It is usually plowed about 3 inches deep or just deep enough so that the sod will lie flat rather than edgewise. Later, it is generally double-disked, harrowed, and planted to winter wheat.

(b) Other Cultural Practices

Small grain stubble land, or ground on which beans or corn have been grown, should be stirred immediately after harvest to prevent weed growth and to save moisture. A common dryland practice for corn is to blank list the land immediately after harvest, planting the corn in the noded out lister furrows in the spring. The one-way disk plow has been popular in some localities for the preparation of small grain stubble land because it leaves the soil surface rough. The duckfoot cultivator has been used at Akron for the same purpose without subsequent soil blowing. Any seedbed preparation for spring crops should be such as to leave the soil receptive to moisture and, at the same time, rough enough to catch snow and to prevent wind erosion.

V. Summer Fallow

Summer fallow is a means to carry over a supply of moisture from one year to the next by the sacrifice of one crop in order to store moisture for the next crop. This practice is followed where the annual precipitation is too low (between 10 and 15 inches) to produce a crop every year. Alternate winter wheat and fallow is a common practice in such areas which include a considerable portion of the eastern Colorado drylands. Mathews and Cole (1938) state that it is possible to store only about 20 to 25 percent of the precipitation that falls during the year in Great Plains soils. Brandon (1925) concludes that nothing is to be gained by fallow for more than one crop season. That is, a single year of fallow will not store soil moisture down beyond the possible root penetration of winter wheat. When inspection shows that there is less than 3 feet of stored moisture, it is entirely practical to fallow a second season. Under dryland conditions the amount of stored moisture should always determine seeding practices.

Mathews and Cole (1938) state that the most common method of fallow is to permit the stubble from a crop to stand over winter, to plow in the spring before weeds have removed much water, and to keep the land free from weeds but in a condition to absorb rains during the summer. Akron results suggest that when the stubble promises to grow weeds that the land be worked immediately after harvest. The best time to plow at Akron appears to be about June 2, when the first weeds become green over the field. It will be
earlier at lower altitudes and in the southern part of the state. The number
of cultivations necessary averaged 2.5. To initiate cultural methods for
fallow the previous fall was found to entail an average of 1.5 extra cultiva-
tions during the period 1923 to 1937.

The first tillage operation for fallow may be done with a plow, duckfoot,
or a lister. So-called "plowless fallow" is sometimes practiced where wind
erosion is serious. The land is worked with a duckfoot cultivator or some
other implement that destroys the weeds without inversion of the stubble.
At Akron, this has created fallow equal to that prepared by the plow or
lister. In several of the Akron tests, the plowed land was worked with the
duckfoot cultivator for about half the summer season, and then with the
spring-tooth harrow or rod weeder on to seeding time for winter wheat. When
used exclusively for fallow, the duckfoot cultivator was found to work so
deeply that the soil was sometimes dried out below the reach of seeding
machinery. The spring-tooth harrow works more shallow.

Regardless of method, there are certain major requirements for good fallow
in the general region of Akron. (1) The precipitation must be stored in
the soil. (2) The soil moisture must be conserved. (3) The top horizon
of stored moisture must be near enough to the surface by fall for seeding
machinery to reach it. (4) The soil surface must be in condition to resist
wind erosion.

VI. Cultural Methods under Irrigated Conditions

There is little to be gained by plowing irrigated land that has been devoted
to clean cultivated crops like potatoes and sugar beets. The seedbed, in
many instances, can be prepared by double disking followed by the harrow.
Light sandy soils need to be plowed less often than heavy soils. It is
advisable to plow the latter in the fall, 5 to 7 inches deep, and leave them
rough over winter to catch the snow and to weather down. Satisfactory fall
plowing depends upon the presence of moisture. The plowed field can be
prepared into a good seedbed the next spring by use of the disk and harrow.
Ordinarily, sod crops like alfalfa should be fall-plowed. Alfalfa may be
crowned, i.e., plowed 3 to 4 inches deep in the fall and then reploved 7 to
8 inches deep in the spring. However, a single spring plowing is often
satisfactory.

VII. Inter-tillage or Cultivation

Tillage of row crops is termed inter-tillage or cultivation.

(a) Reasons for Inter-tillage

The chief value of cultivation is for weed control because most crop
plants are unable to compete with weeds. Greatly reduced crop yields result
when weeds are uncontrolled in a row crop such as corn, sorghums, sugar beets,
or field beans. Inter-tillage should be frequent enough to control weeds.
It also leaves the surface rough enough to reduce surface run-off. This is
particularly important on the so-called "hard lands" on the eastern Colorado
plains. Torrential rains may be largely run-off unless the soil surface is
receptive. The customary cultivation after a rain is sound practice in this
state because it roughens the surface to catch the next shower and, at the
same time, kills many young weeds that were started by the rain. It is a
common practice to cultivate irrigated lands after irrigation or after a
heavy rain for the same reasons. Cultivation to create a soil mulch is
merely incidental to weed control unless the water table is somewhat less
(b) Implements used for Cultivation

Cultivators may be classified into shovel, disk, and surface types. The most common cultivation tool is the shovel cultivator. The shovels are short, narrow, slightly curved, pointed steel pieces which dig into the soil according to the pressure applied. The shovel cultivator is made in 1, 2, and 3-row sizes. The shovels are sometimes replaced by disks or sweeps. The sweeps or surface knives are designed to stir the surface only. Their blades run beneath the surface, cutting off weeds.

The lister cultivator is a sled or low wheel type of disk cultivator widely used for listed crops, especially for the first and second cultivations. The ordinary row cultivator for surface-planted crops cannot be held on the ridges the first time thru the field. The lister cultivator has a hooded shield to prevent the covering of small plants. A common practice in the cultivation of listed corn is to set the disks to throw the soil away from the plants the first time over the field. For the second cultivation the disks are generally set to throw the soil towards the plants and thus fill the furrows. The third and subsequent cultivations can be made with an ordinary surface cultivator.

Regardless of implement used, cultivation should be deep enough to kill the weeds but not deep enough to prune the roots of the crop plants. Shallow cultivation is preferable.

B — Tillage in Relation to Soil Erosion

VIII. Soil Losses by Wind Erosion

Wind erosion is today the most active depleter of soil fertility on the Great Plains. The surface soil, which contains the organic matter, is the most fertile part of Colorado dryland soils. The top soil is the first to be lost as a result of soil blowing. As plains soils have become older, agriculturally, the sod rootlets of the original vegetation which tended to bind the soil, have been disintegrated. As a result, soil blowing has been severe during the past few years. As a result of erosion, a field may be piled high with sand dunes and rendered unfit for cultivation. (See Chilcott, 1937, or Brandon and Kezer, 1936).

IX. Soil Conditions for Wind Erosion

Wind movement of soil is dependent on the surface of a field being free of vegetation, crop residues, and clods or other obstructive materials to such an extent that loose dry soil particles may start to move with the wind. The soils high in sand particles are the ones most seriously subject to wind erosion in Colorado, according to Brandon and Kezer (1936). Soil blowing starts in a small way at a few points, but it may develop to disastrous proportions as wider areas are involved and more soils begin to move. Heavy soil particles can remain suspended only when the wind is high. Obstructions in the path of these sweeping streams of soil will trap a portion. The principle of wind erosion control is to set up obstructions to break the groundline sweep of hard winds. This is the action of furrows made at right angles to the wind direction.

The usual directions of hard winds in eastern Colorado are from the north and northwest, and from the south and southeast. Winds may reach soil blowing velocities occasionally from nearly any point on the compass. Brandon and Kezer (1936) state that it generally takes a velocity of at least 30 miles per hour to start any considerable amount of soil movement on the
hard lands of Colorado. After soil has once started to blow, it will again move with velocities as low as 8 to 12 miles per hour.

The period of the greatest danger of wind erosion is in the spring when the highest average monthly wind velocities of the year are encountered. The land is usually driest at this time because of the low winter precipitation. Due to winter weathering processes, there is a tendency to break down cloddy surfaces and put the soil in condition to blow. Hard winds after May 1 usually cause comparatively little soil movement in cropped areas because of the vegetative cover. They occasionally may bury corn planted in lister furrows on sandy land, making re-planting necessary.

X. Tillage in Relation to Wind Erosion Control

The essential feature in the control of wind erosion by cultural methods is the use of implements that lift clods and other non-blowing materials to the surface rather than implements that pulverize or destroy them. The shovel-type implement is widely used for soil blowing control. The disk harrow and spike-tooth harrow tend to pulverize the soil surface.

The lister, and some of the more shallow furrowing implements like the duck-foot cultivator, are widely used in Colorado to check soil blowing. Bare fields may be blank listed at right angles to the direction of prevailing winds. Dormant crops, such as winter wheat, may be furrowed at intervals across the field. Such furrows will stop the sweep across the field until they are filled with soil and the clods disintegrated. These furrows may be placed 25 to 100 feet apart, depending upon the seriousness of the soil movement. The duckfoot cultivator, with a part of the shovels removed, is very effective for the creation of the small-furrow type of soil blowing protection. The corn cultivator equipped with shovels is also effective. The lister may be used on seeded small grain fields when these other precautions fail to prevent erosion. Enough furrows should be placed at the right intervals to stop the sweep. While the lister is more severe on the crop than the small-furrow implements, it does far less damage than uncontrolled soil blowing. Smooth-surface danger spots can be broken with shovel implements as an emergency measure. Such blow spots must be worked first from the windward side.

XI. Tillage Practices for the Reduction of Run-off

The fact that most of Colorado lies in a low rainfall belt, makes water loss by run-off even more serious. Run-off is influenced by topography, condition of the soil, and plant cover, as well as by the intensity of the rainfall. This last factor is obvious to one who has seen the "flash" floods of the plains region. The most serious damage due to run-off occurs on cultivated land, over-grazed pastures, and hilly lands. The fundamental principle of all water conservation practices is to hold the water where it falls so that it can be absorbed on the spot. The methods used to hold water more or less in place can be classified into (1) cropping practices, and (2) soil tillage.

(a) Contouring

Contouring refers to any tillage practice, or mechanical treatment of land, applied across the slope on the level, i.e., on the contour. In Colorado, the purpose of contour farming is to provide maximum conservation of rainfall by reducing run-off. The furrows, ridges, or roughened surfaces
developed on the level by contour tillage operations act as barriers to the flow of water. Contouring is a necessary adjunct to strip cropping, terracing, listing, furrowing, the construction of diversion ditches, and to the planting of row crops on sloping land. Rows that run up and down even small grades provide excellent channels for water flow. Such action may result in the formation of gullies.

(b) Listing

Listing is considered as one of the most effective types of tillage for the establishment of a ridged and cloddy surface that will offer considerable resistance to wind erosion as well as to run-off. Listing may be straight or on the contour. To retain rainfall, the open furrow should be on the contour. Straight furrows, with small dams across them at intervals, may be constructed with a basin lister. The dams prevent the flow of water in the furrow. Basin lister furrows on steep slopes should also be on the contour. Furrows 6 inches deep, 14 inches wide at the bottom, 25 inches at the top, and spaced at 42-inch intervals, have a mechanical storage capacity of about 2 inches of rainfall. In eastern Colorado, fallow land is rather effectively protected from both wind erosion and water loss when properly listed.

(c) Terracing

Basically, a terrace consists of a channel with a ridge below, constructed across the slope, to intercept water which is either absorbed or slowly diverted from the field. Both channel and ridge usually have a broad cross-section designed to permit cultivation over the entire structure. These are known as broad-base terraces. Occasionally, narrow-base terraces are constructed. These are simply steep narrow ridges of soil which cannot be cultivated.

In some parts of Colorado, the "level" or "absorption" type of broad-base terrace has been found rather satisfactory. The broad-base absorption terrace is best adapted to lands with gentle slopes that have at least 10 to 12 inches of surface soil which may be moderately sandy to moderately heavy. Unproductive subsoil is apt to be turned up in the construction of broad-base terraces on the more shallow soils. This will result in the loss of much of the benefit from the terrace.

The width and height of a terrace is variable. For Colorado, a satisfactory type has a minimum width of 15 feet and a minimum height of 15 inches (when settled) measured from the channel bottom on the upper side to the top of the ridge. A width of 30 to 40 feet is desirable for wheat production with large machinery. The slope of a field determines the space between terraces. The vertical drop in feet between large level terraces can be estimated by taking one-half the percentage of the slope plus one. For instance, the vertical spacing on a 5.5 percent slope would be about 3.5 feet. The absorption type of terrace is constructed on the exact contour line. To carry water from the field, the channel grade should be from 2 to 6 inches per 100 feet of channel length. Specially constructed terracing machines, road graders, or an ordinary plow and V-drag can be used to make the terrace. The effectiveness of this type of terrace has been demonstrated in a few areas in Colorado.

The narrow-base terrace is 15 to 24 inches higher than the level of the field immediately above the terraces, and 4 to 6 feet wide at the base.
These terraces are adapted to steep slopes and shallow soils. In some cases in Colorado, narrow-base terraces have been constructed on the contour in cultivated fields at rather wide intervals. They are seeded to grass or other vegetation, and used as permanent markers for contour farming.

(d) **Diversion Ditches**

Ditches to intercept or divert water from cultivated fields are practical on steep or unusually long slopes. The diversion channels are placed above unprotected fields or at intervals across the fields to prevent concentration of water in the lower portions.

Where possible, the area above the ditch should be in vegetation to prevent silting in. The ditch itself should have a broad flat channel to reduce velocity of flow as well as to facilitate the crossing of farm implements. The water from the ditch should be spread on adjacent pasture land or on other vegetated land. Diversion ditches are useful to prevent the formation of gullies, or to reduce the rate of gully erosion already in progress.

(e) **Subsoiling**

Subsoiling is the process whereby the subsurface material is loosened or fractured in order to increase the infiltration of water, penetration of roots, and aeration. Chisel cultivators, which penetrate to depths of 12 to 30 inches, have been constructed for this purpose. The general benefits to be derived from subsoiling Colorado soils are still in question. Increased intake of water has been reported from some areas, and no permanent effects from others. In a few cases, the subsoil became compacted again very soon with penetration as poor as before treatment. The benefits to be derived depend to a great extent upon the subsoil properties.

(f) **Contour Furrows and Ridges**

Furrows, or furrows and ridges, constructed across the slope on the contour are commonly employed in Colorado to reduce run-off from range lands. In low rainfall areas, furrows alone have been found to re-vegetate more rapidly than ridges. A combination of furrows and ridges have been found effective in some parts of the state. The sizes and intervals of furrows are usually dependent upon the degree of slope encountered and is a matter of individual judgment since there is little experimental data on the subject. These tentative specifications may be used in Colorado: depth 4 inches, width 8 inches, and interval 25 feet.

Corrugation furrows have effectively reduced run-off from pasture lands. These consist of a series of 3 or more closely spaced shallow furrows that follow the contour lines, each series being about 25 feet apart. The furrow is about 4 1/2 inches, and the distance between furrows in each series from 3 to 4 feet. This practice seems to be as good as the construction of deeper furrows. Contour chiseling native pasture lands at intervals in the Hugo region has produced almost immediate benefits.

(g) **Water-Spreading Structures**

Some special structures, called water spreaders, may be built to hold additional water for the restoration of vegetative cover, or to distribute
intercepted water. They usually consist of small diversion channels, earth or rock dikes, or a brush spreader so placed that run-off in natural channels is diverted at intervals for discharge onto more sparsely watered areas. When used in conjunction with pasture contour furrows or ridges, uniform distribution of water over an entire slope is more nearly possible.

XII. Gully Control

The methods for gully control depend upon both the size of the gullies and the economy of the practices. It is difficult to control large gullies. Obviously, it is easier to prevent the development of gullies than to control them after formation. The principal methods for gully control are: (1) Retention of rainfall on the watershed, (2) diversion of run-off from the gully, and (3) safe conveyance of run-off thru the gully. Sometimes one method is efficient, while all three methods may be necessary in some cases.

Retention of run-off generally can be accomplished by the use of ordinary soil conservation practices, while diversion of run-off can be effected by means of channels, ridges, etc. Conveyance of run-off thru gullies is a more difficult problem because the soil must be stabilized to prevent further erosion in the channel, and to prevent cave-ins. The establishment of protective vegetation, as well as the installation of mechanical structures, are requisites. Revetment may be natural or artificial. Trees, shrubs, vines, and grasses may be used. Mechanical structures usually consist of masonry check dams, flumes, or earth dams.
References


Questions for Discussion

1. Give 5 reasons for tillage.
2. Is deep tillage (sub-soiling) beneficial? Explain.
3. Describe different modifications of the moldboard plow.
4. Describe the one-way disk plow. Compare it with the moldboard plow.
5. What are the various uses of the lister?
6. Name and describe 3 secondary implements used in seedbed preparation.
7. Describe the field cultivator and explain where it is used.
8. What is the rotary rod weeder? Where used?
9. What is the most common method of fallow preparation?
10. Name 4 major requirements of good summer fallow.
12. What are the 2 principal advantages of intertillage in Colorado.
13. Explain the lister cultivator and how it is used.
14. What are the principal losses from wind erosion?
15. What soil conditions encourage wind erosion?
16. What is the period of greatest danger from soil blowing? Why?
17. Explain tillage methods to control soil blowing.
18. Why is water erosion a problem in Colorado?
19. What is contouring? Why used?
20. How is lister used to prevent water erosion?
21. What is a terrace? Describe two kinds used in the state.
22. Give the width, height, and explain how to determine the interval for a satisfactory broad-base terrace for Colorado.
23. Under what conditions are narrow-base terraces used?
24. Explain how to construct diversion ditches.
25. How is subsiding used in water erosion control?
26. Describe the construction of furrows, or furrows and ridges, for run-off control.
27. Explain the construction of corrugation furrows for reduction of run-off from pasture lands.
28. Describe the use of water spreaders.
29. Give the principles of gully control.
FIELD CROPS IN COLORADO

Chapter 4. Irrigation Practices

I. Importance of Irrigation

Irrigation may be defined as the artificial application of water to lands whenever the rainfall is insufficient to meet the full water requirements of crops.

Colorado ranks second in the country in the amount of irrigated land, there being 3,400,000 acres under irrigation. Irrigated yields per acre are approximately 3 times those obtained without the use of irrigation, as shown for 5 standard crops in Figure 1.

*Note: The grain sorghums and rye acreage is grown without irrigation.

Figure 1. Comparison of Irrigated and Non-irrigated yields per acre in Colorado as an average for 1923- to 1937.

Thus, soil moisture is the principal limiting factor in crop yields. Irrigation eliminates the hazard which attends crop production in the semi-arid region.

Besides stream and reservoir flow, Colorado farmers have 1629 irrigation wells which are able to deliver 2361 cubic feet per second. About 80 percent of these wells are located in the area north of Denver, and down the South Platte river to Sterling. Most of the wells are located in Weld, Adams, Morgan, Pueblo, and Rio Grande counties. The average capacity per well in the state is 1,415 cubic feet per second. These have been developed largely during the past 10 years when former available surface supplies proved inadequate.

A description of irrigation practice in northern Colorado is given by Hemphill (1922).

II. Water Rights

A system of laws and customs is necessary for the control and use of water. The farmer secures a "water right" because arid land has but little value unless it is assured of water each season. Certain features are common to
water rights: (1) The right of appropriation, which means that water may be taken from public sources in accordance with state regulations; (2) the doctrine of beneficial use, where actual use of the water must be shown; and (3) priority, where the first person or party to divert water has the first right to the amount appropriated. When there is insufficient water for all, water rights are granted to the extent of the supply in the order of the dates the rights were acquired.

There are 2 doctrines of water regulation which are in direct conflict with each other. These are the riparian and appropriation doctrines, as explained by Davis (1915). The riparian doctrine means that a person who owns land on a stream has a right to insist that such stream be allowed to flow past his land "undiminished in quantity, and unchanged in quality." Colorado has set aside this doctrine as antagonistic to irrigation. The doctrine of appropriation permits the waters within the state to be appropriated for beneficial use, but the ownership of the water remains with the state.

III. Natural Water Supply

Most of the irrigation water in Colorado is diverted from natural streams. About 10 percent of the irrigated land and 90 percent of the available water in Colorado are located on the Western Slope. The streams on the eastern slope carry 20 times as much water in May as in August, with the result that over-irrigation is a common practice early in the season when the water is available. Storage reservoirs are used to impound much of the excess stream flow that would otherwise leave the state. Ground waters are an important source of irrigation water because they supply artesian wells, account for the seepage or return water that finds its way back to streams, and because they form a source of water for pump irrigation.

(a) Artesian Wells

A large artesian basin is found in the San Luis Valley. The prerequisite conditions for an artesian well are: (1) A pervious layer that receives water from a catchment area at a higher elevation, (2) underlaid by impervious materials such as shales or slates, and (3) overlaid by another layer of impervious materials such as clay. There are between 5,000 and 6,000 wells in the San Luis Valley which are used for irrigation to supplement river water and for domestic purposes. These wells are located in a distinct area of 30 by 65 miles throughout the valley floor. The towns over this basin are Monte Vista, Alamosa, Center, La Jara, Hanassa, and Sanford. The wells are drilled like oil wells, the usual depth being 200 to 300 feet. The heavier flows come from the greater depths. The stratum comes from the mountains under an impervious layer which must be punctured to obtain the free flow. This basin is amply supplied by streams from the nearby mountains. The wells are shut off in the winter and at other times by valves. Artesian wells are considered a menace to the San Luis Valley because the water often runs wastefully. Thus, a bad physical condition of the soil is often created. The estimated flow of these wells is estimated at 150,000 acre-feet annually, but individual wells have a discharge of only 25 to 50 gallons per minute. The water is generally used in houses and gardens. A few other wells are scattered throughout southeastern Colorado.
(b) Seepage or Return Flow

Much water returns to streams in irrigated areas as seepage. This is particularly true of a vast area in northeastern Colorado. This water has a distinct economic value and tends to stabilize stream flow. A study of return flow on the South Platte river from Kersey to Julesburg was made by Parshall (1922). He measured all waters that returned to the river between the two points and prepared a balance sheet. In some cases, the general ground water level was found to have been raised by irrigation from 100 feet to within a few feet of the surface. This caused greater flow in underground strata toward the river. The estimated average annual return flow into Nebraska is 300,000 acre-feet. The mean return flow between Kersey and Julesburg, a distance of 150 miles, was found to be 5.26 cubic feet per second per mile, or a total of 750 cubic feet per second. The use and re-use of water as it passes down the river increases the available supply for irrigation.

IV. Pump Irrigation

To obtain sufficient water for irrigation by a pump, it is essential to have good water-bearing gravels as well as a reasonably low lift. The type of pump is another consideration.

(a) Water-bearing Strata

Water below ground moves from place to place slowly. Water-bearing strata are open substances like gravel which permit passage of water. Water flows through sand reasonably well, but it must be strained when pumped. The strata should be deep enough to yield water in large quantities. Code (1935) states that water is seldom encountered at depths feasible for pumping on high arid or semi-arid plateaus far removed from mountains or large rivers with sandy beds. Ground water that occurs in gravels near the surface usually results from seepage losses from the application of irrigation water, or the escape of deep water at sandstone outcroppings.

(b) Types of Pumps

The water-bearing strata should be tested before the permanent well is sunk, unless other wells are in the neighborhood. An ideal well is one that lowers 10 to 15 feet during the maximum rate pumped, but returns to within a foot or so of the original level shortly after pumping is stopped. Code (1929, 1936) advises that a test well be drilled to determine the drawdown before a pump is selected.

The pumps in general use operate on the centrifugal principle, there being 3 types used in Colorado. These are the horizontal centrifugal, vertical centrifugal, and deep-well turbine. The deep-well turbine has replaced the others at a rapid rate in recent years, according to Code (1936). This pump is far less restricted in its use than the other two types. It can lift water from 50 to 500 feet.

Code (1935) believes 40 feet to be the maximum profitable lift for ordinary crops, altho the range found in Colorado varies from 20 to 60 feet.
V. Water Measurement

Accurate measurement of irrigation water is necessary because of the great expense attached to the construction of irrigation works. Parshall (1932) adds that certain legal requirements that describe the right to use water from rivers must be met. With an increase in the land under irrigation and the resultant decrease in available water, accurate measurement becomes essential. In Colorado, the doctrine of appropriation is the principal legal requirement to be fulfilled.

(a) Limitations of Weirs

Work on water measurements began at the Colorado Station in 1912, with studies on weirs. A general description of weirs was given by Carpenter (1911). The weir is often unreliable for water measurement under field conditions. Parshall (1932) lists some reasons as follows: (1) sedimentation of the weir pond above the crest, (2) differences in surface tension of the water that passes over the crest for large and small streams, and (3) insufficient grade that permits the downstream water to back up above the crest.

(b) Parshall Flume

The Parshall flume is regarded as the most accurate water measuring device known for free-flow conditions as commonly found in irrigation. This device, widely used in Colorado, was perfected by Parshall (1925, 1932, 1936) for channels of various sizes. The flume consists of three parts: (1) a converging section with a level floor, in which the water speeds up as it enters the flume carrying the sand and debris on throb; (2) the throat or contracted section that slopes downward; and (3) the diverging section in which the floor slopes upward. The side walls are all vertical.

![Diagram of Parshall Flume](diagram.png)

The downstream, or exit end of the floor of the diverging section, is level crosswise and 3 inches lower in elevation than the level floor in the converging section. The Parshall flumes range in size from a 5-inch flume with a maximum flow of one second foot, to the huge flume located at the Fort Lyon headgate in the Arkansas Valley with a maximum capacity of 2,000 second feet. These flumes are constructed of wood, metal, or concrete.

Two flow principles are involved in the Parshall flume, namely, free flow, and submerged flow. (1) Free Flow. This is a condition under which the rate of discharge is dependent solely upon the length of the crest and the depth of the gauge point in the converging section, i.e., an unrestricted
condition of flow. The flume can withstand a relatively high degree of submergence without reduction in the rate of flow. Free flow discharge is obtained even with a rather wide range of backwater conditions downstream from the structure. The free-flow gauge can be used for the 1 to 4-foot flumes when the submergence is less than 70 percent. (2) Submerged Flow. In weirs there is an air space between the head of water and the weir where it falls over. The water flows faster when the water surface below the weir is raised to that point where the air space is crowded out. When the water surface backs up to the crest or higher, the water over the crest is held back. This condition is known as submergence. A 35 percent decrease in discharge is obtained in rectangular weirs for 70 percent submergence. The discharge is not affected in the Parshall flume by that amount of submergence. This is due to the hydraulic jump or ripple in the diverging section which pushes away the downstream condition. There is a decrease in flow, however, when the submergence is greater than 70 percent. A correction must be applied for greater submergence. The amount of water is measured by the

![Diagram of Submerged Flow and Free Flow](image)

$H_a$ and $H_b$ gauges and converted to cubic feet per second from a table.

The Parshall flume meets conditions heretofore beyond the practical capacities of other devices. Certain advantages may be listed as follows: (1) It is accurate enough for practical purposes, (2) It operates successfully with a small loss in head, it having about 25 percent of the requirement for weirs, (3) The Parshall Flume will withstand a high degree of submergence, (4) It operates in sand or silt-laden streams without trouble. (5) It maintains a constancy of conditions. (6) The flume is simple to operate. (7) It has a capacity range that extends over wide limits. (8) The flume is little affected by the velocity of approach. (9) These flumes can be readily constructed of concrete, wood, or metal.

VI. Land Levelling in the San Luis Valley

A large amount of land is leveled in the San Luis Valley for irrigation each year. An early crop like potatoes is very often planted, harvested, and the remainder of the summer spent in levelling the field. The cost varies from 20 to 50 dollars per acre, depending upon the topography of the land. A large amount of the levelling is done by contract. The general slope of the land is uniform, varying from 4 to 6 feet per mile. The land is first levelled by the use of the Jensen or Niskin leveller, the soil being removed from the high spots and dumped in the low places. The most accurate work is done when the high and low places are surveyed by the use of a transit. The Fresno is sometimes used when the farmer does his own work and levels only a small amount of land at a time. The land is usually smoothed by the use of an ordinary float or Eversman level. However, the Schutte level or the rectangular pole drag are sometimes used. The smoothing
operation usually puts the land in condition to plant. Borders are generally constructed about 90 feet apart by two plow furrows being thrown together to prepare the land for the border method of irrigation. This operation is followed by dragging the land on both sides of the border to avoid a ditch next to it. Some farmers alternate borders and ditches so as to facilitate the spread of water over the land. Either before or after the land is levelled, water is run over the land or between the borders to locate the irregular spots. The water leaves a line that conspicuously marks the high spots. Three or 4 days after the water is removed, the soil is sufficiently dry to permit the loosening of the high spots with the spring-tooth harrow or dick. The small spots are then re-levelled.

I. Surface Irrigation Methods

The principal methods of surface irrigation used in Colorado are the wild-flooding, border, furrow, and corrugation methods.

(a) Wild-Flooding method

In this method, water is distributed from field ditches from which it flows over the ground, guided only by the slope of the land. The wild flooding method is widely used in Colorado where only 2 to 4 irrigations are necessary. The water is obtained from a system of permanent ditches, located along the higher boundaries of the field, and from field ditches placed at regular intervals. Each field ditch serves a strip of land, the water being checked by dams, and spread out as a sheet. Field ditches must be close together on steep slopes because the lateral spread is slight. These ditches may be placed more or less parallel to the contours, or they may be run down the steepest slope. The distance between field ditches varies from 30 to 200 feet, it being desirable to have them closer together on sandy porous soils and on steep slopes to obtain uniform irrigation. The amount of water that can be controlled by one man varies from one to three second feet. The wild-flooding method requires less field preparation than the border method. It is also better adapted to irregular hill sides. The drawbacks to the method are that it requires more labor for water distribution, and that more water is wasted.

(b) Border Method

The border method consists of long narrow strips that extend length-wise down the natural slope, separated by parallel levees or borders which confine the water sheet within the strip as it runs down the slope. It is an improvement over the wild-flooding method in that larger streams can be handled and longer lengths of run used without excessive deep percolation. Less labor is required once the land is prepared for irrigation. The border method is used extensively for crops like alfalfa and the small grains. The land should have a moderate and uniform slope, preferably 2 to 3 inches per 100 feet. In preparation for this method, (1) the ditches are planned and excavated, (2) the levees marked and constructed, and (3) the surface between borders or levees smoothed. The strips should be level transversally. The levees are generally made by 2 furrows thrown together, the loose earth being brought together by a ridger or crodder. Usually it is necessary to run a smoother or leveller along both sides of the levee to replace the soil removed by the formation of the levee. The borders or strips are placed from 30 to 60 feet apart, the closer distances being necessary with small heads. The usual ratio of length to width in border
checks varies from 6:1 to 15:1. The lengths vary from 200 feet on sandy land
with small heads of water to 1320 feet on flat slopes with heavy soil. The
principal disadvantages of the border method are the initial cost of land
preparation, and the fact that the levees may interfere with cultural opera-
tions.

(c) Furrow Method

The furrow method consists of the application of irrigation water in
small ditches or furrows arranged close enough together to secure adequate
moisture. Water is applied only to a portion of the soil surface. The
method is used for crops grown in rows and in orchards, the rows being down
the slope. Furrows usually vary in length from 300 to 600 feet. For row
crops, the space between furrows is determined by the row spacing. The rows
are 36 to 42 inches apart for crops like potatoes and corn, but only 20 to 22
inches for sugar beets. Corn is generally irrigated by the application of
water to the cultivator furrows unless the land is so flat that ditches
become necessary to avoid flooding. Sugar beets are ditched for irrigation
with special shovels on the cultivator.

(d) Corrugation Method

The practice is usually called the corrugation method when furrows are
used for forage or small grain crops. It is an adaptation of the furrow
method where the furrows cannot be cultivated after irrigation.

The corrugation method is used (1) on lands where the slopes are so steep
that flooding of the surface would result in erosion, (2) where the stream of
water is too small for flood irrigation, (3) where the soil is so heavy that
it crusts when the surface is flooded, and (4) where the water carries a large
amount of sediment that is undesirable on the soil surface. A small stream
of water is allowed to flow thru a series of narrow, shallow furrows or
corrugations. These are spaced 16 to 48 inches apart, although lateral spread
is more rapid with a spacing of 20 to 24 inches under ordinary conditions.
Water is allowed to run in the furrows until the horizontal seepage from
adjacent corrugations meet. A slope of 1 to 2 feet is the most desirable,
but irrigation can be practiced on slopes as steep as 10 to 20 percent. The
corrugations are run down the steepest slope with erosion avoided by the use
of small streams. The land may be corrugated before or after the crop is
seeded. The corrugations are made with commercial or with home-made
corrugators. In the Arkansas Valley, small grains are sometimes furrowed out
by ditches placed on a beet cultivator.

The corrugation method is widely used for the irrigation of alfalfa and
small grains on the Western Slope. Due to the sodium ions on the soil
colloidal particles, so-called "sick spots" occur in many fields in this
area. The soil becomes deflocculated when wet, i.e., the soil tends to "run
together." When flood irrigated, the surface soil becomes crustated like
concrete with the result that several years may be required for the restora-
tion of good soil tilth. The corrugation method reduces the amount of this damage
because less of the soil surface is wet. The corrugations are usually made
in small grain fields, 15 to 32 inches apart, after the crop is planted.
It is necessary to open the corrugations in hay fields every spring. Due
to the soil colloidal materials, and small size of pores, it requires a long
time for the water to penetrate laterally between corrugations. Generally the corrugations run the full length of the field even though it be a half mile long. Cross ditches are almost unknown on these particular soils.

III. Natural Sub-Irrigation

Sub-irrigation is the application of water to crops from beneath the soil surface. The water may be applied by raising the water table to within a few feet of the surface so that plants can draw on it for their growth.

(a) Conditions for Sub-Irrigation

The conditions necessary for natural sub-irrigation are: (1) A porous surface soil which allows a rapid movement of moisture laterally or upward, (2) an impervious substratum 6 feet or more below the surface, (3) drainage facilities, and (4) land with slight but uniform slope. When the water is raised to within a few feet of the surface, it rises by capillarity to supply plant needs. The method involves less surface evaporation and can be carried on with less elaborate surface-distribution systems. However, sub-irrigation contributes to alkali accumulation when soluble salts are carried in the water because the salts are brought up to the water level in the soil and rise to the surface when water is evaporated from the soil surface. Another disadvantage is the fact that when one farm is irrigated, those nearby are irrigated also.

(b) Sub-Irrigation in the San Luis Valley

Natural sub-irrigation is practiced in the San Luis Valley on porous sandy loam soils underlain at a depth of several feet by an impervious stratum and on land with a slope of 5 to 10 feet per mile. The land must be level laterally for sub-irrigation practice to avoid under-irrigation of high spots and over-irrigation in the low areas. It is customary to run ditches parallel to the section lines in the direction of least slope. Sub-irrigation is generally practiced on potatoes with a ditch placed every 30 rows, although they may vary from 50 to 250 feet apart according to the soil, and the depth to the water table. The water is allowed to run in these ditches as long as 5 weeks, the water table being elevated to where it is only a few feet from the surface. This is made possible by raising the water in the drainage ditches by the aid of checks or dams. The area to be irrigated is virtually surrounded by a ditch that cuts into the porous stratum which is located 3 or 4 feet below a surface soil of light texture. The water goes out into the sand layer where it is raised into the soil by hydrostatic pressure. The height of the water table is controlled by the checks in the drainage ditch. It may be held at 1 to 3 feet from the surface for a few days and then lowered. In the Rio Grande drainage system near Monte Vista, the drains are checked in the spring in time for the water table to be raised about June 1. Sub-irrigation is wasteful of water. There is usually an actual shortage of water in the San Luis Valley in late summer. It has been estimated that 900,000 acre-feet are lost by evaporation and 500,000 acre-feet by seepage. The Morgan drainage ditch (near Alamosa) carries about 1.8 acre-feet per irrigated acre. The farmers who practice sub-irrigation for potatoes usually practice rotation with other crops which are surface-irrigated. This tends to keep down soluble salts to a point where crops can continue to be produced. Formerly, considerable land was ruined by the accumulation of excessive salts in the surface soil.
IX. Residual Effect of Irrigation Water

The carry-over effect of irrigation water in the soil from one season to the next has important practical significance. Residual effect of irrigation water has been studied by Robertson and Keser (1927), and by Robertson and others (1934) at Fort Collins.

(a) Nature of Residual Effect

For several years the critical period of irrigation of spring wheat had been studied to determine the stage at which a single irrigation would result in the highest yield. They applied 6 inches of irrigation water at each of several stages in plant growth as follows: Germination, tillering, jointing, heading, blossoming, and filling. It was soon observed that the bulk wheat crop grown on the plot land the next year showed the effect of the irrigation treatment the previous season. Irrigation was entirely withheld from the residual plots, the only additional moisture being the precipitation from the previous August to the date of harvest. The residual effect of previous irrigation treatments was noticeable whether the seasonal rainfall was 5.64 or 23.26 inches, it being more marked in seasons of low rainfall.

(b) Grain Yields on Residual Plots

The greatest amount of carry-over was on the late-irrigated plots where increased grain and straw yields resulted the next year. The rank in grain yields from the highest to the lowest was on the plots irrigated the previous year at stages as follows: Filling, heading, blossoming, jointing, tillering, and germination. The average yields for the period, 1922 to 1930, in pounds per acre:

<table>
<thead>
<tr>
<th>Stage</th>
<th>Yield (lbs/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germination</td>
<td>1555 ± 56</td>
</tr>
<tr>
<td>Jointing</td>
<td>1625 ± 53</td>
</tr>
<tr>
<td>Blossoming</td>
<td>1795 ± 65</td>
</tr>
<tr>
<td>Tillering</td>
<td>1537 ± 55</td>
</tr>
<tr>
<td>Heading</td>
<td>1763 ± 63</td>
</tr>
<tr>
<td>Filling</td>
<td>1902 ± 68</td>
</tr>
</tbody>
</table>

It is obvious that the moisture supplied by the earlier irrigations had been used by the current wheat crop. The carry-over was apparent for wheat irrigated at the blossom and later stages.

(c) Soil Moisture Determinations

Moisture tests were made on all residual plots at harvest. The moisture percent was highest on those plots which received water the previous year at the filling stage. Crops on the earlier irrigated plots had drawn heavily on the moisture in the first 3 feet of soil. The soil was drier after the early irrigations and wetter after the later irrigations. This indicates that early irrigations are used almost entirely by the current crop, but that water applied late is used only partially by the crop. Much of this moisture is carried over to the next crop year.

X. Effect of Irrigation on Soils

Improper use of irrigation water may cause soil changes, particularly in regard to soluble salts.
Deficient drainage may bring about a gradual rise of the water table. In many cases, this has brought about toxic concentrations of soluble salts in the top soil thru the capillary ascent of water. Such a high water table also limits the range of plant roots due to anaerobic or semi-anaerobic condition in the submerged subsoil. Soil deterioration is frequently rapid due to these causes. There are numerous instances of abandonment in the first years after irrigation has commenced. The accumulation of nitrates at the soil surface due to inadequate drainage has been studied in the Arkansas Valley by Gardner and associates (1934) in the so-called "nitratespots." These excessive nitrates were accumulated in seepage spots where they caused an alkali condition along with other soluble salts. In fact, these other soluble salts were found to be present in sufficiently high concentrations to be more toxic to plants than the nitrates. The obvious preventative is adequate drainage.

Typical "slick spots" in western Colorado were studied by Gardner and others (1937). The majority of the slick spot soils were found to be high in adsorbed sodium at normal moisture but nearly became saturated with calcium and magnesium when washed. There is sufficient swelling of the colloids in these sodium-saturated soils to reduce the pore space of the soil and greatly restrict water movement. To reclaim such soils, the sodium must be removed by drainage. This may be accomplished by lowering the water table and flooding the surface with water, although it may take a long time. The worst spots, especially those that are low in CaSO_4, probably will require additional treatments of organic matter, gypsum, or even sulfur to effect any degree of amelioration. Some spots probably cannot be economically reclaimed. Obviously, it is better to prevent the formation of such spots by maintenance of adequate drainage at all times, than to have to incur the expense of reclamation.

References


Questions for Discussion

1. Compare the average yields of crops grown with and without irrigation in Colorado.
2. What is a water right? Give features common to water rights.
3. Give and explain 2 doctrines of water regulation.
4. What conditions are prerequisite for artesian wells?
5. Discuss artesian wells in the San Luis Valley.
6. What is return flow? How important in the South Platte Valley?
7. Describe water-bearing strata for pump irrigation.
8. What are the characteristics of an ideal well for pump irrigation?
9. Name 3 types of pumps used in irrigation in Colorado.
10. Why is water measurement necessary?
11. Give the limitations of weirs.
12. Describe the Parshall flume.
13. Name 2 flow principles and describe each.
14. Name at least 5 advantages of the Parshall flume.
15. Explain how land is levelled in the San Luis Valley.
16. Describe the wild flooding method of irrigation and give its advantages and disadvantages.
17. Explain the border method of irrigation and the conditions under which it is used.
18. What is the furrow method of irrigation? How used?
19. Give the conditions where the corrugation method is used.
20. Explain how the corrugation method is used on the Western Slope. Why?
21. Describe the conditions necessary for natural sub-irrigation.
22. Tell how sub-irrigation is practiced in the San Luis Valley.
23. What is meant by residual effect of irrigation water? Its significance in spring wheat studies?
24. What conditions bring about so-called "nitre spots"? How remedied?
25. What are "slick spots"? How reclaimed?
FIELD CROPS IN COLORADO

Chapter 5. Pasture Management

I. Role of Pastures

Good pastures provide green feed from early spring to late fall. Sample and others (1934) state that pastures produce about two-thirds the dry matter as the same area in cultivated crops. However, the dry matter of immature grasses is more digestible than the dry matter in hay and in mature grasses. Some of the qualities of a good pasture are given by Rider (1926) as follows: palatability, good feed value, high yield, long life, freedom from injury to livestock, and adaptation. Stock kept on pasture is more comfortable and sanitary than that kept in drylot.

Cultivated pastures are very important in the agricultural economy of the state. Some of these are composed of a single species, while others consist of mixtures of several species. The grasses generally used in pastures, in one combination or other, are: Smooth brome, orchard, meadow fescue, timothy, perennial rye, bluegrass, reed canary, slender wheat, and crested wheat grasses. Among the legumes used are: Alfalfa, sweet clover, ladino clover, strawberry clover, alsike clover, and red clover. Strawberry clover, one of the most alkali resistant crop plants known, offers possibilities as a pasture crop on wet land. Under dryland conditions, the most widely used pasture plants are the native grasses, slender wheat grass, brome grass, crested wheat grass, sudan grass, and sweet clover.

About 71 percent of the total land area of Colorado is used for grazing. Much of this area is range or National Forest land. Native grasses are better adapted to the plains region than other grass species, but range management is necessary to obtain the highest yields per unit area.

A -- Cultivated Pastures

II. Pasture Grass Mixtures

That mixtures are preferred over a single species, has been pointed out by Stewart and associates (1932).

(a) Irrigated Lands

Probably the best known pasture grass mixture used under irrigation is Nortons mixture.

1. Modified Nortons Mixture: The original mixture prescribed 50 pounds of seed per acre, but Hanson (1931) has shown that 50 pounds will produce a stand just as readily. The mixture is as follows: Smooth brome 8 lbs., orchard 6 lbs., meadow fescue 8 lbs., timothy 4 lbs., and yellow-blossom sweet clover 4 lbs. In the warmer regions of the state, such as in the Arkansas Valley, perennial ryegrass should be substituted for timothy in this mixture.

2. Wet Land Mixture: For wet or sewage lands a good mixture is as follows: Redtop 10 lbs., timothy 6 lbs., and alsike clover 4 lbs., or a total of 20 pounds of seed per acre. Two other plants, reed canary grass and strawberry clover, may be useful wet-soil plants in this state.
3. **Alfalfa-Brome Grass Mixture**: This mixture, 10 pounds of each species, has proved satisfactory in the San Luis Valley and is used to a limited extent for sheep. Some death losses occur from bloat, but range men find them less than the various losses encountered on the open range. This type of pasture favors early lambs. The sheep are placed on this pasture early in the spring and kept there.

4. **Other Mixtures**: Various pasture mixtures tried at the Colorado Station are reported by Stewart and associates (1932). The high mixtures were determined on the basis of forage yields, and not under pasture conditions. Red clover appeared in all the high yielding mixtures. A mixture recommended for pasture trials is as follows: Smooth brome 10 lbs., orchard 6 lbs., meadow fescue 5 lbs., and red clover 4 lbs. These plants are all well adapted to Colorado conditions. This mixture yielded an average of 3941 lbs. per acre while modified Hortons mixture yielded 3168 lbs. as an average for several crop years.

(b) **Dryland Pasture Mixtures**

There is little use to attempt a cultivated-grass pasture where the rainfall is less than 10 inches, and where the average summer temperatures are high as on the plains. The native grasses, such as buffalo grass, blue grama grass, and western wheatgrass, are generally more satisfactory. Conditions must be extremely satisfactory to secure a stand of perennial cultivated grasses. Several mixtures are advocated for less severe plains conditions.

1. **Eastern Plains Mixtures**: This mixture may be planted in eastern Colorado as a gamble: brome 5 lbs., slender wheat 5 lbs., and yellow-clover sweet clover 5 lbs. Stewart and associates (1932) state that the land must be free from weeds, the seedbed firm, the grasses seeded early, and the soil surface left rough. Nelson and Shepherd (1940) suggest a mixture of native grasses as follows: Blue grama 4 to 6 lbs., and western wheatgrass 4 to 7 lbs., or a total of 8 to 13 lbs. per acre.

2. **High Altitude Mixtures**: For unirrigated pastures at medium to high altitudes (7500 to 9500 feet), Nelson and Shepherd (1940) suggest a mixture as follows: Smooth Brome 7 to 10 lbs., slender wheatgrass 3 to 5 lbs., and yellow sweetclover 1 to 2 lbs., or a total of 11 to 17 lbs. The lighter rate is advocated for cultivated rows, while the heavier rate is recommended for broadcast or drilled conditions. Created wheatgrass, at the rate of 3 to 5 lbs. in the mixture, may be included at elevations below 8500 feet. Monroe (1937) recommends a mixture as follows for high altitude dryland conditions at Fort Lewis: Smooth brome 10 lbs., orchard 3 lbs., created wheatgrass 8 lbs., and yellow sweet clover 4 lbs., or a total of 30 lbs.

3. **Foothill Mixture**: Seeding at the lower mountain elevations is more hazardous because of lighter rainfall. The mixture suggested by Nelson and Shepherd (1940) for dryland situations above 5000 feet is as follows: Created wheatgrass 3 to 5 lbs., smooth brome 2 to 4 lbs., western wheatgrass 1 to 3 lbs., and yellow sweet clover 1 to 2 lbs., or a total of 7 to 14 lbs. The mixture may be altered to fit specific conditions. For instance, the proportion of western wheatgrass and sweetclover may be increased where the soil is fine-textured (heavy clay) or slightly saline. It may be advisable to omit smooth brome and sweet clover entirely for seeding on very dry sites. The use of blue grama at the rate of 2 or 5 pounds per acre would increase the value of the summer pasture.
III. Cultural Methods for Irrigated Pastures

Cultural practices for the establishment of irrigated pastures are discussed by Kidder (1926), Hanson (1931), and by Stewart and others (1932).

(a) Seedbed Preparation

Since grass seeds are small, they should be planted on a firm well-prepared seedbed. In most Colorado soils, grasses should be planted about one inch deep. Clean-cultivated fields, such as those where sugar beets, potatoes, sorghum, or corn were grown the previous year, can be prepared as seedbeds by the use of the harrow or disk followed by the float. Fields in other crops the previous year under irrigated conditions should be fall-plowed, left rough over winter, and prepared as seedbeds in the spring. It is better to drill grass seed in small-grain stubble than to plow and plant on a loose soil. Under dryland conditions sorghums, particularly Sudan grass, provide the best seedbed for grass plantings.

(b) Seeding Practices

Ordinarily, grass mixtures should be seeded early in the spring. Under irrigated conditions it is advisable to delay seeding until a continuous supply of irrigation water is available. A grain drill with grass-seeder attachment is the best equipment for seeding grasses. Stewart and associates, (1932) suggest that light chaffy grass seed like brome, orchard, meadow fescue, and slender wheatgrass should be mixed together and placed in the drill box. The heavier seeds of sweet clover, alsike clover, red clover, or timothy should be seeded through the grass seeder. Some growers mix cracked wheat or corn chop with the light seed in the drill box to make the grass seed float down.

(c) Companion Crops

A poorer pasture stand generally results when a companion crop is planted with a new seeding. Early barley is one of the best companion crops because it shades the ground less than some of the other small grains. It should be seeded at about one-half the usual rate, and before the grass mixture is planted. Flax is another good companion crop in the northern part of the state. All cultural operations should favor the pasture mixture rather than the companion crop. A better stand will be obtained when the pasture mixture is seeded alone. Companion crops are not advisable under non-irrigated conditions.

(d) Management

The surface soil should be kept moist until the pasture plants are well started. This may require irrigation every 7 to 10 days until they are well established, after which irrigation every 2 weeks is sufficient. Stock should be kept out the first year, especially where a companion crop is used, because a firm sod is necessary before the pasture can withstand trampling. Stock should be removed from the pasture when the soil is wet, or it may become puddled. It is often convenient to divide the pasture into 2 lots so that one may be irrigated while stock is on the other. Alfalfa is sometimes used for hog pasture, but it is usually necessary to plow after 2 or 3 years because of reduced stands.

IV. Cultural Methods for Dryland Pastures

Seedbed preparation for perennial grasses on the drylands must be thorough for pasture establishment. A firm seedbed with an abundance of stored moisture
is the first requisite. This may be obtained on corn land, small grain stubble, or on fallow land that has been kept weed-free. Where wind erosion is a problem, crop residues should be left on the surface. Moreover, all bare surfaces should be rough by the use of shovel implements right up to seeding time, then thoroughly packed. Grasses seeded early in the spring usually have a better chance for establishment than those seeded later. The species planted should be those best adapted. A rate of 12 to 15 pounds of seed per acre is sufficient. A mixture has some advantages over a single grass. Stewart (1932) advises either the common or furrow drill for seeding. To plant grasses in rows for cultivation, holes in the drill may be plugged to provide the desired spacing. In attempts to establish grasses, stock should be kept off of new stands during the first season and until late in the summer of the second year.

V. Influence of Grazing on Species

It is well known that pasture composition is greatly influenced by the time, amount, and intensity of grazing. More than 30 irrigated pastures were studied by Hanson (1929, 1931) in northern Colorado. Probably his most important discovery was the fact that the number of pounds of seed in pasture mixtures had little relation to the different species that grow, or the percentage stand that results. This may be due to size of seed, percentage of live seeds, as well as to plant competition. This investigator used list quadrats for his stand counts.

The Nelson pasture, seeded in 1927, was found to be in good condition at the close of the second season. The mixture consisted of 32 percent orchard grass while the sweet clover was mostly dead. A reduction in the amount of orchard grass seed would have given meadow fescue and bromes more palatable grasses an opportunity to grow. Some of the stand data are given in table 1.

Table 1. Stand Survival in the Nelson Pasture

<table>
<thead>
<tr>
<th>Plants in Mixture</th>
<th>Seeds per Acre (lbs.)</th>
<th>Pure live seed (Pct.)</th>
<th>Stand 1st year</th>
<th>Stand Mixture Ratio Survival (Pct.)</th>
<th>Stand 2nd year (Pct.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brome</td>
<td>15</td>
<td>15</td>
<td>14</td>
<td>25</td>
<td>9.0</td>
</tr>
<tr>
<td>Meadow fescue</td>
<td>10</td>
<td>21</td>
<td>27</td>
<td>35</td>
<td>26.5</td>
</tr>
<tr>
<td>Orchard</td>
<td>15</td>
<td>55</td>
<td>47</td>
<td>23</td>
<td>62.9</td>
</tr>
<tr>
<td>Sweet clover</td>
<td>4</td>
<td>9</td>
<td>12</td>
<td>34</td>
<td>0.0</td>
</tr>
<tr>
<td>Weeds</td>
<td>0</td>
<td>0</td>
<td>--</td>
<td>--</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Another pasture was the Larimer County Farm pasture seeded on about 12 acres of fine-sandy loam soil in April 1928. The mixture, together with subsequent stands, are given in table 2.
Table 2. Composition of Larimer County Farm Pasture (Seed April, 1928)

<table>
<thead>
<tr>
<th>Plants in Mixture</th>
<th>Seed per Acre (lbs)</th>
<th>Pure Seed (Pct)</th>
<th>Stand Oct. 1, 1928 Av. #o. Mixture</th>
<th>Stand Sept. 4, 1930 Surv. (Pct)</th>
<th>Square</th>
<th>Percent on.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brome</td>
<td>10</td>
<td>10.4</td>
<td>149</td>
<td>27</td>
<td>58</td>
<td>136</td>
</tr>
<tr>
<td>Meadow fescue</td>
<td>6</td>
<td>12.8</td>
<td>133</td>
<td>24</td>
<td>42</td>
<td>177</td>
</tr>
<tr>
<td>Slender wheatgrass</td>
<td>5</td>
<td>6.8</td>
<td>141</td>
<td>25</td>
<td>35</td>
<td>25</td>
</tr>
<tr>
<td>Ky. Bluegrass</td>
<td>4</td>
<td>52.4</td>
<td>26</td>
<td>5</td>
<td>2</td>
<td>203</td>
</tr>
<tr>
<td>Yellow sweet clover</td>
<td>3</td>
<td>7.4</td>
<td>54</td>
<td>11</td>
<td>35</td>
<td>6</td>
</tr>
<tr>
<td>White clover</td>
<td>2</td>
<td>10.2</td>
<td>45</td>
<td>8</td>
<td>20</td>
<td>307</td>
</tr>
<tr>
<td>Weeds</td>
<td>0</td>
<td>---</td>
<td>561</td>
<td>---</td>
<td>---</td>
<td>24</td>
</tr>
<tr>
<td>Totals</td>
<td>30</td>
<td>100.0</td>
<td>1149</td>
<td>100.0</td>
<td>378</td>
<td>100.0</td>
</tr>
</tbody>
</table>

During the first 2 seasons yellow sweet clover, brome, and meadow fescue furnished most of the pasture. In the third season brome, meadow fescue, white clover, and Kentucky bluegrass afforded most of the forage. Slender wheatgrass was good only for the first season, especially in the drier places. The weeds decreased after the first season. Kentucky bluegrass and white clover appeared to be the dominant grasses at the close of the third season.

In irrigated pasture studies, Gunson (1929) observed that the number of weeds present in a pasture are greatly influenced by the crop grown the previous year. Weeds were less troublesome after a clean cultivated crop like sugar beets. The character of the stock as well as grazing practices, influence the continuity of the mixture. Competition and succession play an important part. Orchard grass soon gains dominance even when seeded in amounts as small as 1/4 pounds per acre. Timothy suffers greatly from competition. A large part of the brome and meadow fescue was wasted in competition against orchard grass or with sweet clover. Sweet clover was found to largely disappear after the second year, which indicates that reseeding is generally unsuccessful.

Native short grass was pastured by sheep at the rate of one ewe and her lamb for an average seasonal length of 161 days at Akron from 1920 to 1930. It was concluded at the end of that time that the pasture had not been injured by the intensive grazing. Vegetative studies showed that the grass had been driven out but the Buffalo grass had taken its place. Such intensive grazing since 1930 probably would have killed such native grass species (Brandon, 1941, Unpublished data).

VI. Temporary or Annual Pastures

Annual crops are sometimes grown for pastures because they are often productive at seasons when permanent pastures are unproductive. Annual pastures are more easily established under dry-land conditions than cultivated perennial grasses. At Akron, winter rye and weeds produced twice the pasturage for sheep up to September 1 as that obtained from the native grasses during the period from 1920 to 1930.

(a) Temporary Irrigated Pastures

Such pastures are less common under Colorado irrigated conditions than permanent pastures. (1) Sweet clover seeded alone is often used as a temporary pasture, being later used under for green manure. (2) Winter rye
sometimes is used for pasture, particularly for dairy cows. It is seeded at the rate of 50 lbs. per acre, usually between September 1 and 15. (c) Field peas are grown for pasture in the San Luis Valley, only about 10 percent of the acreage being harvested for seed. Generally, hogs are put in for awhile, followed by sheep to clean up the roughage and peas. Field peas are usually planted at the rate of 100 to 120 lbs. per acre, but the rate depends upon the size of the seed. They are usually pastured after the first fall frost, when the peas are very largely formed.

(b) Temporary Dryland Pastures

Some pasturage should be provided on every dryland farm, either as native grasses or annuals. Rye and Sudan grass have made a good combination in eastern Colorado but of course may not completely bridge the entire summer period. Rosin or Proven rye may be planted in the early fall from August 15 to 30 at a rate of 30 to 45 lbs. per acre. The fall pasturage furnished will depend both on the preceding crop on the land and on the precipitation which may fall after the seeding. Corn, sorghum, bean, or millet land very carefully spring and summer cultivated with due regard to rainfall retention and weed control to that date would actually be good fallow. The rye will start promptly, not being so dependent on rain that same fall. This field would also furnish more and more-continuous grazing the next year. At Akron in the sheep grazing experiment from 1920 to 1930 the rye was seeded on after-harvest-pastured barley stubble land at those dates and rates. It furnished short periods of pasturage that same fall in only three of the eleven years. It was available the next spring at an average date of May 15, or 22 days earlier than the native sod. In about half the years the rye pasture was available in April, the earliest date being the 16th. It is necessary to begin pasturing early enough and to stock it heavily enough to keep the growth down, as it becomes unpalatable shortly after the jointing stage. An average of 7.7 ewes and 6.5 lambs grazed 2 acres of rye so closely that there was only one year, 1930, that a partial crop of seed could have been harvested. When properly utilized so that the rye does not head, it and the weeds that sometimes emerge on the field about June 15, should furnish pasturage to about July 10. This will depend on normal May and June rainfall. When not kept under control the rye is likely to become very unpalatable by about June 10.

In the spring, an adjacent field may be planted to Sudan grass in drill-width rows on a carefully prepared seeded about June 1 at a rate of 25 to 35 pounds per acre. This will furnish pasture after about July 1 to frost, depending on normal seasonal precipitation.

A third field may be planted to a spring-sown winter grain like rye or wheat to furnish pasturage during June, and to supplement the rye and Sudan grass. Winter rye or wheat seeded in the spring after about April 1 will not head that year. Some farmers have native sod pastures to carry animals over this period to supplement annual pastures during feed production shortages.

B - Range or Native Pastures

VIII. Composition of Native Pastures

Natural or native pastures are uncultivated lands occupied wholly or mainly by native or naturally introduced plants useful for grazing. A range is a very extensive natural pasture. The short grasses occupy eastern Colorado from the foothills to the eastern boundary. The grasses found there
are largely blue grama (Bouteloua gracilis) and buffalo (Bulbilis dactyloides). These are found particularly on the hard lands, while bunch grasses are found on very sandy soils. Some of the wheat grasses occur in favored locations. On a range near the foothills, Fanson and others (1931) found the vegetation to consist chiefly of western wheatgrass (Agropyron smithii). Other important species were blue grama grass, buffalo grass, porcupine grass (Stipa viridula), threeawn grass (Aristida longiseta), Texas crab grass (Schedonorus paniculatus), and a number of forbs. At Alton the short grasses were found ready to pasture by sheep on an average date of June 5, and held until October 14 over a period from 1920 to 1930. (Norton, 1937).

Some range plants have a distinct indicator significance. Certain plants indicate alkali or sewage conditions, while others appear with overgrazing. Desert salt grass (Distichlis stricta) indicates a high alkali concentration and a shallow water table. Western wheatgrass endures somewhat less alkali and indicates that certain tame pasture grasses will succeed. Wiregrass indicates a gravelly or sandy soil, sometimes overgrazing. Short grasses like buffalo and grama grasses indicate freedom from alkali, long summer droughts, and sometimes a shallow hardpan. Overgrazing is apparent when low mountain sage, cacti, snakeweed, and a large number of poisonous and unpalatable plants appear.

I. Pasture Injury from Over-grazing

One of the first signs of an over-grazed range is that the most palatable grasses, such as bluegrass, needle grass, June grass, wheatgrass, brome grass, and the fescues become less vigorous, produce less forage, and decrease in numbers. Western wheatgrass is one of the first to be killed out by over-grazing. It is 85 to 95 percent palatable for cattle and 65 to 75 percent for sheep. This grass remains green a long time and the herbage cures well on the ground. It is replaced by short grasses and unpalatable plants, such as gameweed, snakeweed, mountain sage, sandhill sage, cactus, and poisonous plants increase in numbers. As the condition becomes more severe, annual weeds tend to replace perennial weeds and shrubs. The last stage is bare ground. The time to check an over-grazed range is before the more palatable plants are seriously reduced in vigor. After the perennial grasses have died and erosion started, a long time is required to restore the range to its original productivity.

II. The Deferred and Rotation Grazing Method

Deferred and rotation grazing means the division of a range so that stock may be grazed alternately on different parts; also that the animals are kept off part of the range until the plants produce seed and are allowed to recover from the effects of previous grazing. It is a method of management of stock based upon the requirements of the plants that compose the pasture. Native pastures produce more forage under the deferred and rotation method than under continuous grazing. (See Morris, 1932).

To apply the deferred and rotation grazing method, a range area can be divided into 2 or 3 parts of equal carrying capacities, generally of equal size. For illustration, suppose the pasture is divided into 3 parts, i.e., areas "A", "B", and "C". Area "A" is grazed throughout the season while area "B" is protected from grazing from the time the plants appear green in the spring until they have matured seed (bunch grasses) or have completed their growth for the year (sod grasses) and are turning yellow in color. This protected or deferred area "B" is then opened to grazing along with area "A" for the
remainder of the season. This is repeated for another year so that seedlings established the first year will have a year of protection, the entire pasture being rested 2 years. The third year the procedure is reversed (rotated). Area "A", grazed during the whole season the previous 2 years, is protected from grazing (deferred) during the growing season for 2 years, while "B" is grazed continuously during this period. The procedure is reversed (rotated) every 2 years until the pasture is returned to a satisfactory grazing condition. It is then rotated at 1-year intervals. This method is satisfactory for range land that provides grazing for 6 to 9 months.

A modification used by a well-managed Larimer county ranch is given by Morris (1932). The cattle graze on the range in the Colorado National Forest during the summer period until about October 15. They are then allowed to graze on one-half the ranch until March 1. From that time until grazing opens on the forest allotment, they graze on the other half. In this manner one-half of the range is protected during the critical spring period. The desirable grasses react to this treatment and increase in numbers.

Results of continuous grazing versus deferred and rotation grazing have been compared for 9 years near the foothills on a typical wheatgrass pasture by Hanson and associates (1931). It was found that western wheatgrass, one of the most valuable forage grasses, was 53 percent more abundant in the deferred and rotation pasture than in the continuously grazed pasture. Other desirable plants showed an increase also. The continuously grazed pasture yielded only 64 percent as many desirable plants as the deferred and rotation-grazed pasture. In addition, it had 22 percent more weeds. The results of this study are discussed by Morris (1932) as well as by Oeland and Rochford (1932). Stewart (1938) suggests that ranges with partial stands i.e., 5 or 6 or more plants per square yard, can be improved more readily by deferred and rotation grazing than by reseeding.

X. Burning Range Lands

There has been considerable controversy on the effect of burning pastures. This effect is largely determined by the type of vegetation on the area.

(a) Effect on Short Grasses

It is known definitely that burning is detrimental to the vigor of short-grass pastures. Hanson (1929) states that the total yield for the season is usually less on burned areas. Shallow-rooted grasses, like bluegrass and the fescues, may be killed by a single burning. The dry forage should be left because it protects the young growth from too close grazing. It also catches more snow when left over a winter period.

(b) Effect on Sagebrush

There are at least 15 million acres of sagebrush land in Colorado used for grazing. The forage production can be increased by destruction of the sagebrush. Scattered grasses occur on sagebrush range as secondary plants. The abundance of sagebrush is due to over-grazing, the palatable grasses having been crowded out. Hanson (1929) and Morris (1931) found that the removal of sagebrush would allow grasses like the fescues, arid bluegrass, and wheatgrasses to become more productive. Sagebrush may be burned late in the fall when it is dry. Some pastures were found to increase their forage 2 to
5 times when the competition of the sagebrush was removed. Hanson (1939) states that the grasses can hold the sagebrush in check for 5 to 10 years.

II. Revegetation of Abandoned Crop Lands

Thousands of acres of abandoned crop land can be made to produce palatable forage by re-seeding or deferred grazing. Hanson (1929) tried some re-seed- ing experiments on a few areas in or near the foothills. Smooth brome grass, slender whe tgrass, and created wheatgrass were found to do well on abandoned plowed areas where the original native vegetation consisted of thin stands of the gaura grasses and fescues. To this list might be added western wheat- grass for the lower mountain ranges. Such land should be disked, the seed broadcast early in the spring, and the field protected from grazing the first season. Nelson and Shepherd (1940) state that a fairly deep soil with good organic matter content is most desirable for re-seeding. Sites with a thin or very poor soil, steep slopes, especially southern exposures, or otherwise unfavorable, are not likely to give sufficient returns to justify re-seeding.

Range re-seeding in the native sod generally has been unsuccessful in the semi-arid region unless the areas were favorably located as to rainfall. Usually an annual precipitation of 18 inches or more is necessary for re-seeding with the cultivated grasses.

III. Poisonous Plants

Poisonous plants are those which contain some deleterious or toxic substance which injures health, causes intoxication, lowers the physical and mental tone, produces at times convulsions and in many cases results in the death of the victim. Overgrazing contributes directly to stock poisoning, according to Durrell and Glover (1931). It is a natural consequence for stock to eat poisonous and other plants after the more palatable range plants have been eaten down. Poisonous plants are generally unpalatable, being eaten only under the stress of necessity. This is particularly true when ranges are grazed too early. Larkspur and milkweed poison are most likely to occur in seasons of drought, short feed, or on over-grazed areas. Under similar conditions, water hemlock is grazed where otherwise it would go untouched. Some plants are more poisonous at certain times than at others. A large number of poisonous plants found in Colorado are described by Darrell and Glover (1931) and by Durrell and Newson (1936). A few of the more important ones are described here.

(a) Death Camas (Zygadenus intermedia)

This plant is a perennial herb 4 to 13 inches tall with grass-like blades which arise from deep-seated bulbs. The flowers are yellowish white, borne in clusters at the top of a tall stalk. It is often mistaken for wild onion. The plant is found in the foothills, and on sandy plains, chiefly in moist low places. Death Camas appears early in the spring before the grasses, but dies down by June 1 after it blossoms. All parts of the plant are poisonous, the poisonous principle being zygadenine. Animals poisoned by it usually froth at the mouth, vomit, or go into convulsions. Death often follows.

(b) Purple Larkspur (Delphinium nelsonii and D. glaucescens).

These plants are perennials 1 to 2 feet tall with leaves divided into a
number of narrow segments. The flowers are blue, prolonged into a spur behind. This is the low larkspur (D. nelsonii). The tall larkspur (D. glaucescens) is 1 to 5 feet high with broad leaves not finely divided. The low larkspur appears in early spring, and dies down after it flowers early in June. The tall larkspur appears about June 15, dependent upon altitude. The tops remain alive until frost, all parts being poisonous. Cattle and horses are most often poisoned by the larkspurs. The poisonous principle is delphinin which has a paralytic action on the heart and respiration. It is generally fatal. The action of larkspur poison differs from Death Camas in that paralysis is present without loss of consciousness. Larkspurs should be (1) grubbed out where practical, or (2) avoid larkspur ranges in early spring and early summer, or (3) pasture with sheep instead of cattle.

(c) Water Hemlock (Cicuta occidentalis)

This plant is a stout perennial 3 to 7 feet tall. The stem is hollow, smooth, and green. The plant has a characteristic bunch of thick, spindle-shaped roots which contain a yellow secretion. They are divided internally into chambers by cross-partitions. The leaves are large and divided. The flowers are borne in white, umbrella-like clusters. It differs from similar plants principally by cross-partitions in the roots. Water hemlock is found throughout the state along streams, ditch banks, and wet swampy places. The plant flowers in June and July. The roots and tops of the young plants are chiefly poisonous, the poisonous principle being cicutoxin. Water hemlock is poisonous to all kinds of stock, and occasionally humans mistake it for wild parsnip. It causes acute abdominal pains, convulsions, and spasmodic contractions of abdominal muscles. Poisoned animals usually die before treatment is possible.

(d) Whorled Milkweed (Asclepias galioides and A. humilio)

Whorled milkweed is a perennial plant 1 to 2 feet tall, growing from horizontal rootstalks. The leaves are narrow, and in whorls at the joints of the stems. The flowers are greenish-white in umbrella-like clusters, while the seeds are borne in cigar-shaped pods. Whorled milkweed differs from the non-poisonous common milkweed in shape of leaf, it being very narrow in the former. This plant is found in southwestern Colorado, throughout the Arkansas Valley, and on the plains south of Pueblo. It grows along ditches and water holes. The plant appears about June 1 and blossoms from July 1 to 15. All above-ground parts are poisonous, with a toxic glucoside as the poisonous principle. Two pounds per 100 pounds of animal is required to poison stock. It affects all classes of livestock, being poisonous even when dried in hay. The poison symptoms are dullness followed by a comatose state manifest 14 to 17 hours after feeding. This is followed by weakness of the hindquarters and staggering. Convulsions then take place at intervals until the animal dies. Animals should be kept away from whorled milkweed patches, especially when forage is scarce.

(e) Arrow Grass (Tridachia maritima)

This plant is a perennial, erect herb, growing from 6 to 30 inches in height. The slender, green, fleshy leaves arise from a sheathed base, the bases of the old leaves often being persistent. The flower stalks are slender with numerous small, greenish, and inconspicuous flowers. It is usually found in saline or alkaline soils about lakes and streams. The plant has
been the cause of considerable losses among cattle. In the presence of other forage, cattle may eat considerable arrow grass without harm but, when grazed on poor pastures, they may eat enough in a short time to produce intoxication or death. The sickness comes on quickly and is usually fatal. Air-dried plants were found experimentally to have lost most of their toxicity. Most of the deaths occur from eating green plants.

(f) Poisonous Vetches (Astragalus bisulcatus and A. hylaphilus)

Milk vetch (A. bisulcatus) is common to Colorado ranges. It is a tall, coarse-growing plant with purple flowers, and 2-grooved seed pods. The plant has an unpleasant odor. All plant parts of milk vetch are poisonous. This species usually appears in June, sheep being the principal animal affected. The symptoms are craziness as found in loco. The only known preventive measure is to avoid the plant.

Recently, Newsom and others (1936) report timber milk vetch as a poisonous plant in western Moffat county, particularly in the Blue and Douglas mountains. The plant is described as tufted with slender stems which branch freely from the base, forming clumps 3 to 16 inches high and as wide or wider. The leaves are compound with 7 to 19 narrow leaflets rather distant from each other and about one-half inch long. The flowering stems are about the length of the leafy ones, with long stems and 6 to 12 flowers. These flowers are white with purple tips, small and pea-like, and may be seen in June and July. The fruit is a straight narrow, smooth pod, less than one inch long, and usually bent down when mature. It is found particularly in the mountains in aspen groves, in sagebrush cover, and the openings in that cover. In cattle, the poison causes general malnutrition and finally muscular tremors, exhaustion, paralysis and death. Some of the animals die of pneumonia. The symptoms are similar in sheep.

(g) Poison Suckleya (Suckleya suckleyana)

Poison suckleya has caused deaths in livestock on the plains of eastern Colorado, particularly in the vicinity of waterholes, lakes, and reservoirs. The poisonous principle was found by Thorp and associates (1937) to be hydrocyanic acid (HCN). The plant is described by Stout (1939) as one that spreads out on the ground from a single long taproot. The stems are flaccid and slightly reddish in color. The leaves are rather round with the margins slightly notched. Care must be used to distinguish it from ordinary purslane. The seeds are triangular in shape with the outer angle or point notched. First symptoms shown by affected animals are anxiety and distress, muscular twitchings, dribbling of urine, and staggering. Finally the animal goes down with convulsions soon followed by paralysis of respiration and death. The weed should be eradicated as far as possible.

References


Questions for Discussion

1. Name several qualities required in a good pasture.
2. Give 5 grasses commonly used in pasture mixtures in Colorado. Name 5 legumes.
3. Give Mortons mixture. What is a mixture for wet lands?
4. Describe two perennial-grass mixtures for eastern Colorado drylands.
5. Name a pasture mixture for dryland conditions at Fort Lewis.
6. Explain seedbed preparation for a permanent irrigated pasture.
7. Tell how to seed an irrigated pasture mixture.
8. Describe the use of companion crops for pasture mixtures.
9. Explain how to manage an irrigated pasture.
11. Explain the relation of pasture mixtures to eventual stands obtained. What factors influence stands?
12. What plants are used for temporary irrigated pastures? Under what conditions?
14. What is the general composition of native pastures?
15. Give the indicator significance of some native grasses.
16. Describe pasture injury from over-grazing.
17. Explain the deferred and rotation grazing system of pasture management.
18. Contrast the effects of continuous vs. deferred and rotation grazing.
19. What are the effects of burning on short grasses? On sagebrush?
20. Under what conditions can abandoned croplands be re-vegetated? Suggest some cultivated grasses to use.
21. Under what conditions are poisonous plants serious on the range? Why?
22. Describe death camas, and poison symptoms caused.
23. Under what conditions is larkspur harmful? Control measures?
24. Describe water hemlock, tell where it is found, and give poison symptoms.
25. Give a description of whorled milkweed and tell where it is found.
26. Where is arrow grass found? Under what conditions is it poisonous?
27. Describe timber milk vetch and its poison symptoms.
28. Where is poison suckleya found? Give poison symptoms.
FIELD CROPS IN COLORADO

Chapter 6. Harvest of Field Crops

I. Classification by Method of Harvest

The principal crops harvested in Colorado for grain are corn, wheat, oats, barley, proso, and the grain sorghums. Hay crops are divided into the tame and wild hays. The most important tame hay crops are alfalfa, red clover, alsike clover, timothy, sweet clover, sorgo, sudan grass, foxtail millet, and small grains cut for hay. Both red or alsike clover often are grown in mixtures with timothy. The principal wild hays are the park and short-grass hays. Field peas are often pastured. The important silage crops are corn, sorghums, and sunflowers. Russian thistles are sometimes cut for silage.

A -- Harvest of Grain Crops

II. Stages for Small Grain Harvest

Small grains are usually considered ready for binder or header harvest when all green color has disappeared from the heads, i.e., the seed is in the hard dough stage. They often contain 30 to 40 percent moisture at this stage. Small grains harvested with a combine must be dead ripe, i.e., contain 14 percent of moisture or less. This usually means that the small grain crop must stand in the field for 10 to 14 days longer than for binder harvest. Proso often is headed and windrowed when the heads are about one-half ripe.

Grain that stands in the field for a prolonged period may become bleached due to weathering. Discolored lots often fail to command the price of bright grain.

III. Methods of Harvest

The principal methods of harvest in Colorado are by means of the binder, the header-barge, the combined harvester-thresher, and the swather pick-up.

(a) Binder Method

Small grains or other crops harvested with a binder are bound in bundles and shocked in the field. Due to the dry weather at harvest time, it is usually unnecessary to cap shocks in Colorado. Ordinarily, small grain is left in the field for 10 days or more to cure in the shock before being threshed. Shocked grain may be stacked where considerable time lapses before it can be threshed. This allows the kernels to go thru the "sweat", a combination of moisture loss plus enzymatic action. It usually reduces the moisture content to 15 percent or less.

(b) Header-Barge Method

The header-barge method of harvest is used in large dryland acreages where the straw is short and erect. Grain can be harvested by this method at a cost considerably less than with the binder. The header cuts the grain high, only the heads being removed. These are collected by header barges and stacked to be threshed later. Wheat should be cut at about the same time as for binder harvest, which is normally when the moisture content of the grain
varies from 35 percent downwards. Wheat has been stacked with as high as
50 percent moisture in the grain and subsequently cured without spoilage.
However, oats and barley must be dead ripe before being headed because they
lack the porosity in the stack that is characteristic of wheat. The small
grain crop should be comparatively free from green weeds like lamb's quarter,
Russian thistle, and pigweed since these increase the opportunity for spoil-
age in the stack. The most satisfactory length of straw for a stack is 18 to
20 inches, which is sufficient to allow the straw to knit well together.
Stacks should be firmly packed, especially in the center, to reduce the da-
mage from rain.

(c) Combined Harvester-Thresher

The "combine" was introduced in the eastern Colorado plains at the time
of the World War. It was used first for wheat, but later it became popular
for the harvest of oats and barley.

The combines most generally used have 12, 15 or 16-foot cuts. Generally
they are pulled by tractors and equipped with an auxiliary engine to drive
the harvester mechanism. A few power-drive machines with 8 to 10-foot cutting
bars are used also. The combine is essentially a threshing with a header at-
tached to one side in such a manner that the cut grain is conveyed directly
to a cylinder thresher. The grain usually is collected in a tank mounted on
the machine. For ordinary conditions, Kifer and associates (1927) state that
one rated drawbar horsepower is required for each foot width of the cutterbar
when the combine is equipped with an auxiliary engine.

There are certain disadvantages to the combine. (1) The grain must be
dead-ripe or else the moisture in it will be too high for storage. (2) The
extra time the grain must stand in the field means extra risk from hail and
other weather damage. (3) Dry weather at harvest time is necessary for use of
the combine. (4) There is danger that dead-ripe grain will shatter in the field
(5) Green weeds in a small grain field will transfer their moisture to the
threshed grain.

(d) Swather Pick-up Method

The swather pick-up method was devised to overcome some of the draw-
backs to the combine. In this method, the small grain is cut, piled in
windrows, picked up when dry, and threshed by the combine. This method allows
the harvest of the grain in advance of the dead-ripe stage necessary for di-
rect combining. The windrower or swather was designed recently. It merely
cuts the grain, carries it by a platform canvas to one end, and deposits it
on the stubble in a windrow. Sometimes a header is used as a windrower by
lowering the discharge end of the elevator. After the windrowed grain is
dry enough to thresh, it is picked up by the combine with the aid of an at-
tachment to the cutterbar, and threshed.

Fields badly infested with weeds, or which ripe unevenly, may be har-
vested successfully in this manner. Under ordinary conditions, Hurst (1929)
states that the weeds and other green plants dry out in 4 to 8 hours when
windrowed. The drying of the grain is also facilitated by the windrower. The
swather is indispensable in fields that contain many weeds, but offers little
advantage in clean fields. The grain should be cut to leave one-third the
total length of the straw as stubble; otherwise the heads fall thru the stub-
ble to the ground. The windrower was first used in northern Colorado in the
Nunn area in 1929. The grain is generally picked up and threshed 4 or 5 days
after it is placed in the windrow. This may be done safely after 1 or 2 days in very dry weather. The swather pick up method has certain advantages in this region: (1) the grain may be marketed 5 to 10 days earlier than where it is harvested directly with the combine; and (2) there is less damage from hail and wet weather, since rain does not seem to damage grain in windrows as in shocks. (3) The grain generally has good color. On the other hand, there are certain limitations to the use of the windrower. Some of these are: (1) The pick-up gathers too many rocks; (2) the wheat may lie too flat on the ground to be picked up by the combine; (3) the tractor cannot be run slow enough to thresh heavy wheat; and (4) hard rains cause too much dirt to lodge in the heads.

IV. Harvest of Corn for Grain

When husked for grain, corn is generally left in the field for several weeks after frost or dry weather has checked the growth. Otherwise, the ears are difficult to husk. Sometimes the corn is pastured by hogs. For large acreages, the mechanical corn picker has a place. There is some waste with this machine, particularly when the corn is lodged.

B—Hay and Hay Making

V. Hay Types and Classes

Hay is the most valuable crop in Colorado, the tame hays being much more important than wild hays.

(a) Alfalfa and Other Tame Hays

Alfalfa, grown under irrigation, is by far the most extensively produced tame hay. It is grown in preference to red clover because it produces more cuttings per season, gives a higher yield, and is perennial in nature. However, there has been a serious decline in alfalfa production during the last 10 years due to the wilt disease. The Colorado yearbook for 1936 gives an estimated 1,892,000 tons of tame hay harvested in the state from 1,084,000 acres during that year. The average annual production for the 10-year period, 1927 to 1936, was 1,893,000 tons. The alfalfa hay crop, included in the tame hay, was 1,390,000 tons for the 10-year average. The other tame hay crops, such as sweet clover, red clover, alsike clover, timothy, foxtail millet, field peas, soybeans, and sudan grass, are of minor importance.

(b) Wild Hay Crops

The most important wild hays in the state are the park hays grown in the mountain areas, viz., North, Middle, and South parks. They are the best horse hays in the world because they are nutritious, free from dust, and free from weeds. In the San Luis Valley, wild hays consist largely of mixtures of sedges and rushes, the two being very similar in feed value. Some redtop and timothy are frequently seeded in wild hay meadows. The North Park hays consist principally of sedges, while those of South Park are practically pure rushes. Considerable South Park hay is shipped east for polo ponies.

In certain seasons considerable wild hay is cut east of the mountains, particularly in low places. This hay is composed principally of western wheat, buffalo, and grama grasses. The last two species reach a height of 4 to 6 inches, the yields being low. This type of hay is usually gathered on a platform attached to the back of the sickle bar on the mower, and dumped
in bunches. This hay is nutritious, and high in protein, but it never enters commerce. The wheatgrass often reaches 30 to 34 inches in height, but the amount of such hay is small.

Colorado mountain meadow hay plants were analyzed by Tobiska and associates (1937). Alfalfa was found to carry approximately twice as much crude protein as mountain meadow plants. These values were 13 percent and 9 percent respectively. Mountain meadow hays carry more nitrogen-free extract (carbohydrates) than alfalfa, or 43 percent and 34 percent, respectively. Alfalfa was superior in mineral content. The crude fiber content of the two types of hays is about equal, or about 32.5 percent. Ether extract of mountain meadow hays averaged about 1.38 percent, which is slightly less than similar values for alfalfa.

The wild hay crop in 1938 was 374,000 tons due to favorable conditions in the San Luis Valley. The 10-year average for 1927 to 1936 was 334,000 tons.

I. Stages of Harvest Hay Crops

The different hay crops vary as to the best stage for harvest. The stage depends to some extent on the class of livestock for which it is intended.

(a) Alfalfa

Alfalfa should be cut for hay when it is in the one-tenth to one-fourth bloom stage, according to Robertson and associates (1938). Where blossoms are scarce, as happens in some seasons, the crop should be cut just before the new basal shoots will be clipped by a mower. Later cutting results in hay with coarse stems, fewer leaves, and lower digestibility.

(b) Other Crops

Sweet clover should be cut just before it blossoms for the best quality of hay. After it blossoms, the stalks become woody and have a bitter taste due to a substance known as coumarin. Red clover is cut for hay when the crop is in full bloom. Field peas for hay should be cut when the lower pods become hard and before the seeds start to shatter. Robertson (1938) states that soybeans should be cut for hay before the leaves begin to turn yellow and drop. Some crops cut early have been found to be higher in protein than when cut at the usual stage. Some unpublished Colorado data by Robertson indicates that immature foxtail millet hay contains as much as 15.2 percent protein and immature ground sorgho 12.9 percent protein. These data also indicate that immature Sudan grass may contain 12.0 to 15.0 percent protein. (See Sorghums).

II. Implements used in Hay Harvest

Various kinds of mowers and rakes are used in the harvest of hay crops. These are described by Cummings (1926).

(a) Mowers

A mower with a 5-foot cutterbar is most commonly used in Colorado. This size is light, requires less draft, and is more convenient to operate along fences and on ditches. The wide-cut mowers are particularly adapted to
large ranches where the stand of hay is not heavy enough to give excessive draft for the average team. The mower leaves strips of grass when the sickle is off center. This occurs also when sickles are sharpened to a point. The heavy "gum" sometimes found on the cutterbar may be due to a mixture of oil and grass juices. Excessive side draft is a good indication of an improperly adjusted cutterbar.

(b) Rakes

There are three general types of rakes in common use in the state, viz., sulky, side-delivery, and sweep rakes.

The sulky rake is used for small fields, rough land, and to bunch hay that has been windrowed by the side-delivery rake. It is also used to advantage along ditches. In mountainous country, and on the western slope, the sulky rake is used almost entirely on account of the rough land and rocks.

The side-delivery rake puts the hay in windrows. It has many advantages for large-scale operations on comparatively level land. Some of these are as follows: (1) It is the most convenient type to use with hay loaders; (2) it makes a straight windrow; (3) the hay is left in a good condition to cure; (4) it may be operated lengthwise of the field; and (5) it is useful for turning windrows. The principal disadvantages of the side-delivery rake are the tendency to "rope" the hay, and the difficulty of raking close to ditches.

The use of the sweep rake is described by Yerkes and McClure (1917). The sweep rake is an economical means to put hay in the stack since it does away with the necessity of pitching hay on a wagon. The use of the sweep rake may reduce the amount of labor required to put up hay by 50 percent. It greatly reduces the size of the crew required, and reduces losses from storms to a minimum. A good team can haul 300 to 1000 pounds of hay with the sweep rake. The principal disadvantages are that the leaves may be shattered badly in dry hay, and that some hay may be left in the field.

II. Curing Alfalfa and Similar Types of Hay

Qualities associated with good hay depend largely upon the curing operations. Successful curing systems have been worked out in most parts of the state which facilitate rapid drying of the forage without undue loss of leaves. Hay is cured in the swath, windrow, cock, or some combination of these methods. Cummings (1923) found that most hay growers allowed alfalfa to lie in the swath until wilted, after which it was raked into windrows where curing was completed. Hay usually is bunched from the windrow to dry further, and to facilitate the work of the sweep-rake. In case of rain, bunched hay dries slowly, but is considered better in quality when allowed to dry out well before being turned. Hay is sometimes cured in cocks. It is raked and piled in cocks as soon as free from external moisture. From 5 to 10 days are required to cure hay in cocks. Such hay is superior in quality. It contains very little bleached hay, and retains a bright green color. A much greater percentage of leaves is saved in hay cocks. However, the method is too slow for large-scale operations.

Green alfalfa may be stacked directly from the mower to produce stack-burned or so-called "tobacco-brown-cured" hay. Green hay produces an immense amount of heat which gives it the dark-brown color. External moisture must
be avoided because it causes molds and results in spoilage. Brown hay is very palatable, although the feed value may be slightly lower than well-cured green hay. Cummings (1933) observed in Colorado that both cattle and sheep relish it more than green hay, but that the process may be overdone and the feed value lowered.

Certain losses are known to take place in weathered hay. Some work has been done on alfalfa in Colorado in this respect. One third or even more of the protein in alfalfa hay may be lost on account of being badly weathered. Hendon (1936) compared prime and weathered alfalfa hays. The prime hay was cut and protected, while the weathered hay was allowed to remain in the field for 15 days exposed to several showers, or a total of 1.75 inches of rain. The greatest loss was in the protein content. The prime hay analyzed 18.71 percent protein, while the weathered hay was found to contain only 11.01 percent. More recently, Douglass and others (1933) studied the effect of rain on the vitamin content of alfalfa hay. They applied 1.0 inch of water to the samples. The amount of vitamin A was definitely lowered, but the damage was less when the hay was in the cock rather than in the windrow. One inch of rain seemed to have no influence on vitamin B, provided the hay was dried quickly. Excessive moldiness was found to diminish vitamin B decisively.

IX. Storage of Hay

Hay is usually stored in barns or sheds, or in stacks in the open. There is very little hay stored in barns or sheds in Colorado, because there is very little spoilage outside. Hay sheds are used in some of the mountainous regions, particularly in southwestern Colorado, where heavy snowfalls occur during the winter.

On the eastern slope, hay is stacked for protection against weather damage. Small stacks that expose relatively large amounts of hay are wasteful. Stack storage may result in over-dry hay in windy climates. They weather badly on the outside and often develop "stack spot" or white mold in depressions and pockets into which rain settles. The percentage of weather-damaged hay on the outside of the stack to the total tonnage is much less in large than in small stacks. There is very little weather damage where the stack is firmly trampled in the center, and the top drawn to a peak. It is generally agreed that stacks of less than 15 tons of hay are wasteful to the producer. In spite of this, there are many 5 to 10-ton stacks built each year in the alfalfa areas of Colorado. Stacks of 15 to 20 tons can be built with the overshot stacker under most conditions.

X. Implements used to Stack Hay

There are a great many different kinds of stackers in use for hay. Some of the important types found in Colorado are described by Cummings (1933), Reynolds and Kinsman (1927), and by Reynolds (1929).

(a) Overshot Stackers

The overshot stacker is used in every part of Colorado except in North Park. Stacks may be built as high as 20 to 26 feet with this implement. It is light in weight, readily moved from place to place, does satisfactory work, and is cheaper than most patent stackers. Its lightness sometimes results in breakage at critical times under heavy loads. The hay is carried
directly over the stacker proper and deposited on the center of the stack. Stop ropes attached to compression springs relieve the stacker of excessive strains when it is stopped in the delivery position. The overshot stacker is used in conjunction with the sweep rake. It insures a stack with a firm center, altho this depends on the condition of the hay, efficiency of the men on the stack, etc. Its maximum capacity is greater than that of any other stacker except the slide stacker because of the shorter time required for operation.

(b) Swinging Stacker

In this type, the hay is carried to the height of the stack, swung around, and dropped at the desired point. The hay slides from the teeth instead of being thrown off. The swinging stacker is extensively used and does satisfactory work. It is built light, thus being subject to breakage under heavy strains. It delivers hay on the stack at the points desired, so as to reduce the labor on the stack. In many cases, one less man is required on the stack than with the overshot stacker. Swinging stackers may be either automatic or hand-controlled.

(c) Combination Rake and Stacker

This type is sometimes called a portable stacker because it can be used either as a sweep-rake or as a stacker. More work is required of the stacker team than with other types. It can be self-loaded from windrows or loaded by sweep rakes. By the aid of the steering wheel and the delivery trip, the stacker head is tilted to deliver the hay to the stack. The most common usage is to carry the hay bunched up near the stack with the sweep-rake and then use the combination stacker. This type is excellent for small crews.

(d) Derrick Stackers

Home-made derrick stackers can be used with either slings or forks. The Mormon type derrick is the most common. It is heavy, reliable, but difficult to move. For its use, the hay is generally put in cocks and pitched on to slipp or wagons. The conditions where the derrick stacker is commonly used are as follows: (1) On small ranches, (2) where large well-built stacks of good-quality hay are desired; (3) where climatic conditions require special care in curing; (4) where the typography interferes with the sweep rake; (5) where the hay must be hauled a long distance to the stack; and (5) where a small investment is essential. This method of stacking is very satisfactory but slow compared with some other methods. About two-thirds as much hay can be put up in a day as with the overshot stacker.

(e) Slide Stackers

The slide stacker, also home-made, is widely used in North Park. The hay is delivered to the base of the stacker by a sweep rake and then carried over by a pusher. The pusher is returned partly by its own weight, and partly by the team turned across the pusher pole. Very little time, care, and accuracy is required to deposit hay at the slide stacker as compared with other types. The capacity of the slide stacker is about 10 tons per hour. Its greatest capacity and efficiency is due to: (1) the fact that native hay is not as bulky as alfalfa; (2) less care is necessary with
native hay to avoid shattering; (3) stack cribs can be built to prevent waste to cattle; and (4) the cooler climate enables men and team to do more work. Patent sweepstakes are used with slide stackers where the hay land is smooth, but usually these are not heavy enough for North Park conditions. Commonly, hay growers use very heavily constructed home-made sweepstakes.

(f) Other Types of Stackers

Cable stackers are used on small ranches where the stack site is permanent and near the barns or feed lots. It is possible to use either forks or slings with this type of stacker.

Rope stackers are used to some extent in the extreme southwestern part of the state, although they are nearly all replaced at present by modern equipment. The hay is rolled on the stack, being deposited at any desired point. A special sling or slip may be carried on the wagon. This type of stacker is very slow.

III. Measurement of Hay in Stacks

Large amounts of hay are bought and sold in the stack in this state. Interested parties agree on the quantity of hay in the stack by measurement, and computing the volume and tonnage by one of several rules in use. Actual weights are the most satisfactory, but often wagon scales are unavailable. Sometimes hay is fed directly from stacks built around the stack. To load it on wagons and haul it to a scale would involve an expense greater than the small possible loss of hay that may occur from estimation. Rules for hay measurement are approximations at best. Those in common use for the determination of volume of both oblong and round stacks were formulated by farmers, stockmen, army officers, and others without thorough investigation. The demand for accurate measurements brought about a study to ascertain the accuracy of the rules in use, and to develop new ones to replace those found inaccurate. Thousands of stacks were measured and weighed out, the results being reported by Hosterman (1931).

(a) Oblong or Rectangular Stacks

The volume of a rectangular stack is equal to its length multiplied by the area of the cross-section. The length is easily determined, but the exact area of the cross-section is not so readily obtained because an accurate formula is necessary from only two measurements, the width and "over". The formulas commonly used involve length, width, and "over". The "over" is the distance from the ground on one side to the ground on the other side.

Hosterman (1931) found that the Quartermaster and Frye-Bruhn formulas were inaccurate when compared with the actual cross-section area of the stacks. They were accurate for certain types of stacks but inaccurate for others. The cross-section areas determined by the Frye-Bruhn rule averaged only 86 percent of the actual cross-section areas. The estimated volume, therefore, was 14 percent less than the actual volume. The cross-section areas determined by the Quartermaster rule averaged 96 percent of the actual cross-section areas, but in some instances 25 percent less to 30 percent more.
As a result of research, Hosterman (1931) reports new rules or formulas that are more accurate, and that still use the same type of measurements as the old rules. The stacks are divided into three different types based on shape, a rule being developed for each shape of stack. These are shown in figure 1.

(1) Low round-topped stacks: \((0.52 \times \text{over}) - (0.44 \times \text{width}) \times W \times L\).
(2) High round-topped stacks: \((0.32 \times \text{over}) - (0.46 \times \text{width}) \times W \times L\).
(3) Square flat-topped stacks: \((0.36 \times \text{over}) - (0.55 \times \text{width}) \times W \times L\).

The low round-topped stack is the type usually built in Colorado with the overshot stacker.

(b) Cubic feet per Ton

Many factors affect the density of hay in the stack, and thus the number of cubic feet per ton. Moisture at the time the hay is stacked probably causes the greatest variation. Texture and foreign material may also influence it. For these reasons, there is often considerable difference in the number of cubic feet required per ton in different stacks. These averages for a large number of stacks can be used with fairly good results:

<table>
<thead>
<tr>
<th>Kind of Hay</th>
<th>30-90 days (Cu. ft. per ton)</th>
<th>Over 90 days (Cu. ft. per ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>485</td>
<td>470</td>
</tr>
<tr>
<td>Timothy and Timothy mixed</td>
<td>640</td>
<td>625</td>
</tr>
<tr>
<td>Wild</td>
<td>600</td>
<td>450</td>
</tr>
</tbody>
</table>

C — Silage

XII. Advantages of Silage

Silage is green herbage compacted in an air-tight receptacle in which it is allowed to undergo fermentation. Great losses may occur in fodder stored in the open, which may be prevented when the material is made into silage. Some of the advantages of silage are: (1) Succulence, (2) reduced waste,
(3) means to save an immature crop, (4) surplus feed may be carried over, and
(5) it serves as a pasture equivalent in the winter.

XIII. Crops used for Silage

Most of the silage in Colorado is made from corn. Other crops used to
some extent are sorghums, sunflowers, field peas and small grains, Russian
thistles, and potatoes.

(a) Corn or Maize

Corn furnishes the most ideal single plant material for silage. It
should be ensiled in the glazed stage for the most desirable silage, that
is, when the husks have turned golden yellow, but the leaves are still
green. The amount of acid has been found to increase in corn ensiled in
the more immature stages. However, corn may be successfully ensiled at any
stage of growth. A large amount of water must be added to the silage when
corn is ensiled at very dry stages. For the highest value, it is inadvis-
able to use late corn varieties or corn planted too thickly.

(b) Sorghums

The sorghums are used for silage in climates too hot and dry for corn.
Red and black amber sorgos are among the most satisfactory in Colorado from
the tonnage standpoint. Fremont sorgo is popular in dryland areas. Grain
sorghums make a good quality of silage but the tonnage is usually low.
There is very little difference in feed value between corn and sorghum
silages. However, sorghums should be fully mature at the time they are
ensiled or sour silage is apt to result.

(c) Sunflowers

Sunflowers are used for silage in regions where the climate is too
cool for high corn or sorghum yields. They are grown in western Colorado,
particularly at the higher altitudes. Sunflowers should not be grown where
corn or the sorghums will outyield them. Sunflower silage is readily eaten
by all types of livestock when succulent. Roy (1919) recommends that sun-
flowers be cut for silage when the seeds are in the soft dough stage, be-
cause of the resinous nature when more mature.

(d) Field Peas and Small Grains

Legumes seldom make good silage due to their putrefaction when ex-
posed to air (unless the A.I.V. process is used). Sometimes they are mixed
with corn or small grains. Field peas and small grains are occasionally
ensiled together in Colorado. The silage must be well trampled when small
grains are used because of the hollow stems. This kind of silage is gen-
erally unprofitable when good quality hay can be made of the same crops.

(e) Other Crops for Silage

Russian thistles are sometimes used as an emergency silage crop. They
should be cut for silage after the plants start to become hard or have
actually matured. The ensiled thistles must be firmly packed. Ensiling
immature thistles requires less water but usually results in sour silage.
Osland (1931) experimented with potatoes as silage. He mixed 82 percent of
cull potatoes and 18 percent of corn fodder by weight with good results. Potatoes alone produced a silage difficult to handle.

XIV. Preservation of Sugar Beet Tops

Sugar beet tops provide a valuable feed when properly preserved. Experience indicates that preservation in compost piles gives a better quality of feed than beet top silage which is protein in nature. Beet-top preservation is discussed by Osland (1933).

(a) Field Piles

Beet tops should be placed in small piles in the field, whether pastured there or hauled to the feedlot. These piles should be 2 to 3 feet wide and 1 to 2 feet high. This allows the tops to cure, and still hold sufficient moisture to keep the leaves from shattering. In this manner the tops are air-dried with a minimum amount of mold. Tops heat when placed in large piles. Piled tops can be pastured or hauled regardless of snow. The soil becomes puddled in wet weather when tops are pastured in the field. This is a serious objection.

(b) Compost Piles

Compost piles are satisfactory for the preservation of beet tops. They are made of alternate layers of tops and straw. Generally 4 to 6 inches of beet tops are alternated with the same thickness of straw. The pile can be 12 to 14 feet wide, as high as 3 feet, and as long as necessary. A small amount of a white mold, which is harmless, may develop in the compost. Tops can be composted as green as desired. Green tops are preferred to cured ones because the straw becomes impregnated with the juices. Cured tops are apt to char when composted. Properly made compost is practical, both tops and straw being consumed.

XV. General Types of Silos

A large number of silos have been built in Colorado. In recent years, many have been trench silos.

(a) Above-Ground Silos

There are many types of above-ground silos in the state. Silage will keep well in any of them so long as the walls are tight. Dvorachek (1914) suggests that wooden silos are poorly adapted to Colorado because of the dry climate that loosens the staves, and because high winds may bring about their collapse while empty. The hollow tile silo has been popular in the state. It costs more than wood, but it is strong, permanent, and attractive. This silo has one or more dead air spaces in the walls which keep the silage warmer in cold weather than solid-wall types. The monolithic concrete silo is widely used. The only upkeep is an occasional wash inside. The walls are usually reinforced with wire. Cost of construction may be reduced where sand is close at hand. The principal objection to the upright silo is the cost.

(b) Circular Pit Silo

The circular pit silo is usually built with a retaining wall for 3 feet or so at the top, and then plastered on the sides the rest of the way
to the bottom. A hoist is usually constructed for removal of the silage. The size varies with the amount of stock to be fed. There are certain advantages of the pit silo which may be enumerated as follows: (1) It costs less than an upright silo, (2) the silage does not freeze, and (3) less power is required in the operation of the silage cutter. However, there are some disadvantages to the pit silo: (1) It is uneconomical to construct in regions where the soil has a tendency to cave-in, (2) the silage is removed with difficulty, and (3) carbon dioxide gas may accumulate in these silos at the lower levels. This gas may prevail for 10 to 14 days on the surface of the silage after the silo has been filled. It may accumulate in pit silos that have been partially filled and allowed to stand for some time without the silage being removed. To be safe, Sjogren (1923) recommends that a lighted lantern or candle be lowered into the silo before it is entered. Danger exists when the flame is extinguished. The gases may be driven out by lowering a blanket or other light object tied to a rope. It should be swung near the bottom for some time, or until the relatively heavy gases have been dissipated. Pit silos may be dangerous at any time, especially when located inside of a building.

(c) Trench Silos

Osland (1931) gives directions for the construction of a trench silo. It is essentially a large ditch with sloped ends. The trench silo should be located near a water supply on soil with good drainage. It is usually trapezoidal in shape, 12 feet wide at the top and 8 feet wide at the bottom. The length is determined by the amount of silage. The top is sealed with 12 to 15 inches of wet soil on a layer of straw. The silage must be thoroughly wet and packed at the time the trench is filled to avoid spoilage. This is a very cheap method to ensile crops, and a popular one at this time.

XVI. Measurement of Silage in the Silo

The one accurate means to determine the amount of silage in a silo is to weigh the material, but since few farms are equipped with wagon scales, some rule or method of estimation often is necessary. Tables have been prepared for the calculation of the amount of silage. The ones published by Sjogren (1923) are given as Tables I and II in the appendix.

(a) Tonnage in Round Silo at Time of Filling

The amount of silage in a recently filled silo can be determined from Table I (appendix). This is based on the assumption that 2 men have kept the material trampled at the time it was filled, and also that the silage was allowed to re-settle 2 days, and then the silo re-filled. Corrections to the table are necessary for extreme conditions: (1) deduct 10 percent when the corn is unusually dry; (2) deduct 15 percent when the corn is unusually dry and very little grain is present; and (3) deduct 10 percent when the corn is average and no time is allowed for the silage to settle.

(b) Estimated Weights of Settled Silage in Round Silos

The amount of settled silage can be determined from Table 2 (appendix). It is designed to estimate the amount of silage after it has settled for at least 50 days. It may be used to estimate the amount of silage remaining when a portion has been removed from the silo. When no silage has been
taken out, the depth is found, the inside diameter determined and the estimated weight read directly from the table. When a portion has been removed, it is necessary to determine the amount of silage before any was removed, and then the amount removed. The difference is the amount on hand. When extreme conditions occur, it is wise to make these allowances: (1) Add 10 to 15 percent to the figures found in the table when the corn was put in the silo in the milk stage, or less mature stages than usual; (2) deduct 10 to 15 percent when the corn is past the usual stage of maturity and contains less water than usual; (3) add 5 to 10 percent when the grain is unusually heavy in proportion to stalk; and (4) deduct 10 percent when very little grain is present.

(c) Tonnage in Trench Silos

The volume is obtained as for any rectangular structure, that is, width by length by depth. The volume is then divided by 58 which is the average number of cubic feet in one ton. Osland (1921) gives a rough rule as follows: depth in feet x average width x length divided by 60. This is equal to the number of tons of silage. Volume determinations for silos of other shapes depend upon the geometrical configuration involved.

References

Questions for Discussion

1. Explain how method of harvest influences the time to harvest small grains. Why is this true?
2. Describe binder harvest of small grains.
4. Describe the combine harvester-thresher.
5. Give 5 disadvantages of the combine.
6. What is the swather pickup method? Under what conditions is it used?
7. Name the tame hay crops important in Colorado.
8. Compare alfalfa and mountain meadow plants in nutritive value.
10. Describe these types of rakes and tell where they are used to advantage: sulkly rake, side-delivery rake, and sweep-rake.
11. Briefly describe how alfalfa should be cured for hay.
12. What is "tobacco brown cured" hay? Its value?
13. What losses occur in weathered alfalfa hay?
14. Explain how stacks should be built for minimum loss.
15. Describe the use of 3 types of stackers used in Colorado.
16. Why is hay measured in the stack?
17. What are the objections to the Frye-Bruhn and Quartermaster rules?
18. What are the principles of the new government rule? Its accuracy?
19. What factors influence the cubic feet per ton?
20. At what stages should these crops be harvested for silage: corn, sorghums, sunflowers, Russian thistles?
21. Give the advantages of silage.
22. Under what conditions can field peas and small grains be used for silage?
23. Discuss potatoes as silage.
24. Explain how to preserve sugar beet tops in compost piles.
25. Describe the above-ground types of silos most satisfactory in Colorado.
26. How is a circular pit silo built? Advantages? Disadvantages?
27. What gas may accumulate in pit silos? What precautions should be taken?
28. Tell how to construct and fill a trench silo.
29. How should silage be measured in a silo after some of it has been removed?
FIELD CROPS IN COLORADO

Chapter 7. Maintenance of Soil Productivity

I. Soil Productivity

Plants depend upon the soil for water, air, nutrients, and mechanical support. Reduced yields result when these factors are out of balance. Permanent agriculture must be based on practices that will insure the adequate operation of these factors.

The principle methods for the maintenance of soil productivity in Colorado are: (1) the application of irrigation water under conditions of adequate drainage; (2) the practice of crop rotation; (3) the addition of barnyard manure, green manure, crop residues, and commercial fertilizers; and (4) the proper tillage of the land.

II. Factors that Affect Crop Production

A. Water Supply

Water exists in films around the soil particles and in the wedges between them. It is adsorbed by forces of different intensity, depending upon the amount present. Plant roots assimilate the water osmotically until the force by which the remainder of the water held by the soil particles become so great that the intake of water is slower than the loss from the plant by transpiration. At this point, the plant will wilt unless the water supply of the soil is augmented. In order for the plants to grow normally, the water supply of the soil must be maintained above the permanent wilting percentage.

The yield of crop plants tends to increase as the water supply increases up to a certain point. Above this water level, yields drop off probably due to a deficiency of oxygen. Oxygen is essential for the assimilation of both water and nutrients by plant roots, and for normal aerobic decomposition of organic matter. The oxygen balance is upset when a soil becomes waterlogged. The common crop plants seem to produce almost equally well so long as the moisture content of the soil lies slightly above the permanent wilting percentage but below the point of saturation.

Water is probably the most important factor that limits plant growth in Colorado. For this reason, soil management in this state should include the artificial application of water, and the conservation of moisture by tillage methods.

III. Plant Nutrients

One of the important problems of soil management is to keep an adequate supply of plant nutrients available for plant use. Many soils are high in the total amount of nutrients, but plants may suffer for lack of certain ones because they occur in unavailable forms. (See Swett, 1938). Because they are most often deficient, nitrogen, phosphorus, and potassium are often called the "fertilizer elements." They must be applied to the soil in manure or fertilizer treatments.

(a) Nitrogen Relations

The amount of nitrogen in soils at different elevations from Fort Collins (5,000 feet) to the Continental Divide (12,200 feet) was determined by
Hockensmith and Tucker (1933). It was found to increase with an increase in altitude, although it varied considerably above 10,000 feet elevation. These fluctuations were due to variations in the amount of vegetation rather than to differences in the rate of decomposition. As the altitude increases, there is an increase in rainfall and a decrease in temperature. These are conditions that generally favor nitrogen accumulation in the soil.

The agricultural soils of Colorado contain from 3 - 4,000 pounds of nitrogen per acre. About 99 percent occurs in the upper 6 inches of the soil as a constituent of the organic matter. Nitrogen in the latter form is unavailable to crop plants. The forms of nitrogen that are available include the nitrate and ammonium ions. At any one time, the average Colorado soils contain about 20 pounds of nitrogen per acre in these available forms.

The nitrogen in organic matter is not available to plants until the organic matter has been decomposed by the soil organisms, and until it appears as ammonium and nitrate salts in the soil solution. The biological process of forming ammonia from organic nitrogen is called "ammonification". The process of converting ammonia to the more highly oxidized compounds such as nitrite and nitrate is referred to as "nitrification". Organic matter is rather rapidly ammonified and nitrified in Colorado soils, especially when there is plenty of water present. This is true because other conditions are excellent for the activities of the various micro-organisms involved in these transformations. A period of several weeks should intervene between the addition of the organic matter and crop seeding because, regardless of the rapidity of decay, ammonia and nitrites will not appear in the soil solution in appreciable quantities until the nitrogen-carbon ratio of the added residue has been narrowed considerably. This ratio is narrowed in time, since some of the original carbon is continually being transformed into carbon dioxide which passes off as a gas.

Crops harvested from the land remove from 50 to 150 pounds of nitrogen per acre per year. Except for an outside source of nitrogen, it would be impossible to maintain the supply indefinitely because large quantities are sold in farm products. Fortunately, leguminous plants act as hosts for certain bacteria that form nodules on their roots. Such organisms can use gaseous nitrogen and change it into a form available both to the bacteria and the host plant. This nitrogen transformation is known as "symbiotic nitrogen fixation." By this process, nitrogen may be added to the soil in a very natural way. The nitrogen fixed in this manner is not available to plants other than the host. When the legume dies, or is plowed under, it becomes an excellent source of nitrogen available to other plants as soon as it is ammonified and nitrified. The plowing under of a legume, or the crop residues, constitutes one method for the maintenance of the nitrogen supply of the soil.

Different legumes require different bacterial strains for nitrogen fixation. The commonly accepted groups of nodule bacteria are as follows: (1) Alfalfa and sweet clover; (2) red clover, white clover, etc.; (3) garden peas, field peas, vetch, etc.; (4) soybean, beans; (5) Lupine and Sesbania; (6) cotton, peanuts, velvet beans, and lima beans; (7) sorghum; and (8) wood clover. Some soil tests were carried out by Dr. W. G. Sackett (unpublished data) for 5 or 6 years to determine the natural inoculation of Colorado soils. He found about 70 percent of the land naturally inoculated for alfalfa and sweet clover, while 50 or 60 percent of the soils were naturally inoculated for field peas. There was practically no inoculation for the true clovers (Trifolium species) when grown on the land for the first time, it is advisable to inoculate in Colorado for field peas, sorghum, and for all the true clovers.
There is little value in the inoculation of legumes where nodules appear on the roots. The culture method is reliable for inoculation. Pure bacterial cultures for a particular crop can be obtained thru the seed houses. To inoculate a bushel of seed, the general procedure is to (1) dissolve 4 tablespoonfuls of sugar in one pint of cold water; (2) mix the culture with the sugar-water solution; and (3) sprinkle the mixture over the seed heaped on a clean floor. The seed is shovelled until it is thoroughly mixed with the culture, after which it is dried in a layer 2 or 3 inches deep. It should be planted as soon as it is dry enough to feed thru a drill.

Another group of bacteria exist that also can convert atmospheric nitrogen into organic combinations. They are independent organisms that obtain their energy from the decay of organic matter in the soil. This process of nitrogen transformation is called "non-symbiotic nitrogen fixation". Non-symbiotic fixation can be demonstrated in laboratory cultures, but the extent to which it occurs under field conditions is unknown. At one time, it was believed that the Azotobacter fixed enormous quantities of nitrogen in Colorado soils. (See Headden, 1925). After further check, Reuszer (1939) found only a few Azotobacter in Colorado soils. From this fact, he concluded that they could not be responsible for a very great addition of nitrogen. However, there may be other strains of bacteria present which are able to fix nitrogen. In case of such fixation, the nitrogen would not be available to plants until the organisms die and their nitrogen ammonified and nitrified.

(b) Phosphorus Relations

In the case of phosphorus, it is necessary to depend upon the supply already in the soil or to add it in commercial fertilizers or manures.

Colorado soils contain a total of 3-4,000 pounds of phosphorus (P₂O₅), but only a small amount is soluble and available to plants at any one time. Crops remove from 15 to 45 pounds of phosphorus (P₂O₅) per acre per year. While this appears to be a small amount compared with the total, there is a deficiency in phosphorus in many fields, particularly in irrigated areas.

The solubility of phosphorus in soils may be increased by plowing under organic matter. This tends to make the soil reaction more favorable for the solution and availability of that element. Commercial phosphate fertilizers should be applied when this method fails or it is impractical. Phosphorus shortage generally does not occur on dryland soils.

(c) Potassium Relations

Colorado soils generally are rather high in total potassium, containing from 1 to 2 percent of K₂O. It occurs principally as a constituent of some feldspar and mica minerals, and as simple salts, and is adsorbed by the soil colloidal complex. The adsorbed potassium becomes available to plants after it has been released by base exchange. Crops remove from 40 to 135 pounds of potassium (K₂O) per acre per year.

There appears to be sufficient available potassium in Colorado soils at the present time. Increased yields have not been reported from the application of potassium salts alone. There is a little indication that potassium may give increased yields when used in combinations with nitrogen and phosphorus, especially on very sandy leached soils and on soils high in lime. In this case, the increased yields are probably due to the fact that a complete fertilizer has been added, with the result that the entire fertility level of the soil has been raised.
(d) Other Nutrient Elements

Other essential elements obtained from the soil are calcium, magnesium, sulfur, iron, manganese, boron, zinc, and copper. Available calcium, magnesium, and sulfur are all sufficiently abundant in most Colorado soils. Iron becomes unavailable in some instances with the result that the plant leaves turn yellow (chlorosis). This may occur in soils high in lime as well as in those with a high pH. The deficiency is often overcome by plowing under green manures. In some cases, it is necessary to treat the soil with some soluble iron salt. Deficiencies of manganese, boron, or copper have not been reported in the state.

IV. Soil Alkali

Crop growth may be retarded or prevented by certain injurious substances that may occur in the soil.

In some areas, white alkali salts have accumulated in such large quantities that crop production is practically impossible. When present in larger than 0.2 to 0.3 percent, these salts become injurious to most plants. A low yield of some plants may be obtained with concentrations as high as 0.5 to 0.3 percent. Readen (1925) believed that nitrates had accumulated in soils in certain areas of Colorado in quantities sufficient to be injurious to plant growth. Nitrate nitrogen was found in those so-called "nitre spots" in concentrations as high as 1000 p.p.m. nitrate nitrogen. More recently, Gardner and associates (1934) found that soils high in nitrates were also high in other soluble salts. Quantitatively, soils with nitrates in large amounts contained 8 to 20 times the amount of other soluble salts. These "nitre spots" are now regarded as alkali seepage areas where poor drainage has caused the accumulation of nitrates along with other soluble salts. The damage to plants is due to excessive quantities of soluble salts, nitrates merely being one of them.

When black alkali salts appear, the soil becomes very alkaline, puddled, poorly aerated, and usually poorly drained. Reduced yields or complete failure may occur when the pH is 8.5 or above.

Occasionally arsenic may occur in soils in such large quantities that yields are reduced. This has been the case in a few orchards where spray residues have accumulated, as well as in cases where irrigation water with arsenic from mine tailings have been used continuously. Low productivity due to selenium has been reported. This element is a constituent of some shales. The selenium may be sufficiently high in plants to injure animals when fed or grazed on them.

V. Aeration and other Factors

Normal growth of most crop plants seldom occurs when the soil is insufficiently aerated. The oxygen of the soil air is replaced by carbon dioxide as the result of respiration of plant roots and micro-organisms. This vitiated soil air must be replaced by fresh air for plant growth to continue. Aeration of soils occurs by diffusion, the rate being proportional to the amount of free pore space, that is, the pore space free of water. A puddled soil may give poor crop production due to an anaerobic or a semi-aerobic condition in the lower soil layers. Such conditions occur when the soil becomes water-logged. Hard-pan may interfere with normal aeration. Proper aeration involves the maintenance of good soil structure, the opening of hard-pan layers, and drainage.
The relation of soil temperature to productivity is obvious. Soil temperatures are beyond control except in water-logged soils. These will become warm sooner after being properly drained.

The depth of a soil influences productivity because it affects the amount of nutrients and water that a crop can obtain from it. A very shallow soil is generally an unproductive soil. Frequent rains or irrigations and the addition of plant nutrients are necessary to make such soils productive.

VI. Diagnosis of Factors that Cause Reduced Yields
Diagnosis of the cause of unproductivity should begin with a field examination of the soil. The soil profile should be exposed to a depth of at least 5 to 5 feet by use of a spade or a soil auger. The profile should be checked for hard impervious layers that might impede root penetration, percolation of water, and aeration. These pans may be high in lime or merely hard layers of clay. All white-appearing lime layers are not necessarily impervious to water. In addition, the subsoil should be checked for: (1) depth; (2) presence of coarse gravel, sand, or shale; and (3) for drainage. A high water table is usually accompanied by alkali salts. The nature of the surface and sub-soils reveals the cause of low yields in many instances.

The entire profile may have good structure, texture, and drainage. In such a case, the low productivity may be due to the presence of injurious substances or lack of fertility. A laboratory analysis may reveal the cause. The sample should be checked for total salt content and pH. Then these factors are satisfactory, an analysis for organic matter and plant nutrients should be made. The determination of total organic content is a simple matter, but none of the tests for nutrient elements are entirely satisfactory. However, these tests are useful in the hands of a technician who is familiar with the past history of crop sequences, and who has a complete description of the soil as it exists in the field. When the tests indicate that commercial fertilizers should be added to correct a deficiency, it is advisable to treat only a small strip in the field the first season. A definite field response is justification for more widespread fertilizer application (See Hoekensmith, 1950).

VII. Application of Irrigation Water
To offset the low precipitation in Colorado, over 3 million acres of land have been put under irrigation. This practice gives greater assurance of high crop yields, but it introduces or intensifies many soil problems (See chapter 4, Irrigation Practices).

Adequate soil drainage is necessary in irrigation practice. The subsoil or the topography of the land may be such as cause an accumulation of excess irrigation water in the soil. This may cause it to become water-logged. The undesirable effects that attend water-logging are as follows: (1) alkali salts very frequently accompany the accumulation of the excess water; (2) the lower soil layers become poorly aerated so that decreased root growth results; (3) the soil often becomes puddled, i.e., the structure is destroyed; and (4) high alkalinity often occurs. These conditions can be corrected or improved by the installation of drains as well as by more economical use of irrigation water.

Over-irrigation is frequently caused by long "runs" or "sets". As a result, the upper end of a field may be over-irrigated before the water reaches the lower end. The use of shorter runs will correct this situation. Gardner and associates (1940) estimate that a field will seldom hold more than 6 inches of
water at one application, and often only 2 or 3 inches. Excess water either 
drains beyond the root zone or accumulates to water-logged the soil. Robertson 
and associates (1937) proved that the application of extra water to a well-
drained soil often results in the leaching of soluble nitrate salts. Wheat 
was observed to turn yellow as a result.

The storage of water in dryland soils may be accomplished by the reduction of 
run-off losses as well as by fallow.

VIII. Crop Rotation
Crop rotation is the practice of growing crops in a more or less fixed order 
where one crop follows another in a definite sequence on a field. So far 
as possible, rotation should include (1) a cultivated crop, (2) a legume sod 
crop, and (3) a small grain crop. Under Colorado irrigated conditions, small 
grains should be planted only as companion crop for the establishment of per-
ennials. Barnyard manure should be applied because a rotation alone is not 
sufficient to maintain soil fertility. In dryland rotations the legume sod 
crop is impossible. Such rotations often include fallow periods. Some crop 
rotations have been suggested for Colorado conditions by Stewart (1930).

(a) Northern Colorado Irrigated Lands
The principal crops grown in this region are the small grains, corn, 
sugar beets, alfalfa, and potatoes.

A 5-year rotation for a general farm could be as follows: Barley seeded to 
alalfa, alfalfa, alfalfa, corn and sugar beets.

For areas where potatoes are grown, a 7-year rotation may prove satisfactory. 
It is as follows: small grain seeded to alfalfa, alfalfa, alfalfa, alfalfa, 
potatoes, sugar beets, and sugar beets manured. Corn may be substituted on 
lands too heavy for potatoes.

A good sweet clover rotation is as follows: small grain and sweet clover for 
hay, sweet clover plowed under as a green manure crop for potatoes, sugar 
beets, and sugar beets manured.

(b) Arkansas Valley Irrigated Conditions
Several special crops are grown in the Arkansas Valley, among them 
being lima beans, vine crops, and onions.

A short rotation with alfalfa is as follows: small grain seeded to alfalfa 
alalfa, alfalfa, sugar beets and vines or onions.

A suggested rotation for a 40 to 50-acre truck farm is: small grain seeded 
to alfalfa, alfalfa, beans or corn, vines, onions, and sugar beets.

(c) Dryland Conditions
It is comparatively simple to plan a rotation for dryland conditions 
because the main requirement, aside from the selection of adapted crop vari-
eties, is to have appreciable soil moisture stores at the time each crop is 
planted. Diversification, thru choice of a wide variety of standard crops, 
will insure the grower against a complete crop failure.

In the drier regions with less than 15 inches of annual precipitation, alter-
nate fallow and winter wheat is practiced.
In regions with sandy-textured surface soils, and with 18 to 20 inches of precipitation, alternate winter wheat and corn is sometimes followed. Another crop sequence for "hard lands" of similar regions is corn, corn, barley, fallow, and winter wheat. Sorghums should also follow sorghums one or more years, but such land should then be fallowed or planted to proso and field beans in strip seedings. Small grain stubble worked immediately after harvest will produce greater yields of subsequent crops than when those crops come after sorghums. Thus, two different sequences are possible: (1) sorghum, sorghum, proso and beans, barley, fallow, and winter wheat; or (2) sorghum, sorghum, fallow, winter wheat, proso and beans and barley.

Fallow will increase the yield of all standard crops in eastern Colorado, but it is chiefly used as a preparation for winter wheat. Beans alone should not occupy large fields, but should be planted in strips with corn, sorghums, or proso. Soil moisture is stored thru the whole or a part of the period from April 1 to September 30 when 70 to 80 percent of the Great Plains rainfall generally occurs. The sequence of crops in a dryland rotation should more or less be determined by the inter-crop fallow period available.

(d) High Altitude Conditions
A simple crop rotation for San Luis Valley conditions is as follows: potatoes, small grain, field peas seeded to sweet clover, and sweet clover for pasture or hay or green manure.

A rotation used for truck crops at Avon is as follows: barley seeded to alfalfa, alfalfa, alfalfa, alfalfa, alfalfa, potatoes, garden peas, and head lettuce.

IX. Applications of Organic Matter
The practices of continuous cropping, together with the removal of the crop from the land, results in the ultimate depletion of soil fertility. The time of nutrient deficiency may be deferred many years. The yields of Colorado irrigated farms can be maintained by periodic fertilization of the soil, while the prevention of erosion accomplishes the same result under dryland conditions. Many Colorado irrigated soils respond to organic matter, nitrogen, and phosphorus. Some dryland sandy soils respond to increased organic matter.

(a) Barnyard Manure
Barnyard manure, an important organic fertilizer, should be applied to all the land at least once during the rotation period. Manure is extremely variable in composition, generally being a good source of nitrogen and potassium. It is usually low in phosphorus. Manure carries a very active bacterial flora, and the preliminary stages of decay have already occurred.

Gardner and others (1940) point out that greater returns per ton of manure are usually obtained where light applications have been made, although larger yields probably would be obtained from heavier applications. The general practice is to apply from 6 to 15 tons per acre, usually to the cash crop. Stewart (1940) reports that about 70 percent of the farmers on irrigated land in the state apply 10 tons or more manure per acre. A period of time should elapse between the application of the manure and seeding. This may vary from a few weeks to several months to allow for the liberation of nutrients. Good results under irrigation have been obtained with strawy manure when plowed under in the fall. Well-rotted manure can be plowed under a few weeks before planting.
Because moisture is required for decomposition, barnyard manure must be used in small amounts under dryland conditions. It should be applied in light surface dressings, but not plowed under. Large amounts have been found to depress yields. Good results have been obtained with manure on sandy corn lands that have been cropped many years.

In addition to nutrients, barnyard manure is a good source of organic matter. It will improve the tilth of the field.

(b) Green Manures

Green manure crops are plowed under to increase the organic matter content of the soil. Green manures have given poor results under dryland conditions in Colorado even the many soils are low in organic matter. The cost of the seed, as well as the cost of the cultural operations for a green manure crop to be plowed under, makes it more expensive than bare fallow. In addition, it requires the sacrifice of a crop already produced.

From rather complete cultural experiments conducted at the Akron Field Station from 1909 to 1939, crops that followed green manures were found by Brandon (1925, 1940) to yield less than the same crop on bare fallow. As a 30-year average, winter wheat after fallow plowed June 3 yielded 16.3 bushels per acre. After rye plowed under on the average date of June 12, winter wheat yielded 11.5 bushels per acre. After field peas plowed under on July 17, the winter wheat yield was 9.0 bushels. The latter yield was only 1.7 bushels per acre more than that obtained on land cropped to wheat each year. The soil moisture was exhausted by the green manure crop up to the time it was plowed under. In fact, there was little opportunity after July 17 to store soil moisture because the season of heaviest rainfall was past. Actually, there was little choice between weeds and field peas when both were plowed under on July 17. Both more or less completely exhausted the soil moisture before they were plowed under. Brandon (1925, 1940) believed that the greater moisture content of the fallow soil accounted almost entirely for the greater yields. He found that the first crop after a green manure did not restore the soil to uniformity in moisture. The second and third crops after green manures failed to show increases over crops in the same positions after fallow. Moreover, successive green manure treatments failed to show any cumulative advantage as the crop rotations were repeated. Sweet clover produced the same general effects as rye and field peas.

The principal green manure crops in Colorado are alfalfa, sweet clover, field peas, and rye. Biennial sweet clover has been one of the best green manure crops under irrigation. It is usually seeded with small grain. Sweet clover may be pastured in the fall of the first year, or a hay crop removed. It is plowed under the next spring after it has attained a height of 12 to 15 inches. The land should be irrigated either before or after it is plowed to bring about the rapid decomposition of the sweet clover. Sugar beets can follow with good results as soon as the seedbed is prepared. A number of valuable records have been obtained by northeastern Colorado farmers by the use of green manures for sugar beets. Pieters (1927) reports several cases. (1) One field yielded 7.0 tons of sugar beets per acre in 1922. The next year it was seeded to oats and sweet clover. The field was replanted to sugar beets in 1924 which yielded 14.0 tons per acre. In 1925, the same field yielded 16.0 tons per acre. (2) The average yield of sugar beets on another field had been 9.0 tons per acre for several years. Sweet clover was turned under in the fall of the first season with the result that sugar beets yielded 13.0 tons per acre on the land the next year. (3) One farmer produced 21.0 tons of sugar
beets per acre on a 17-acre field green manured with sweet clover, while the balance of the farm yielded 16.6 tons per acre. The experiences of some sugar beet farmers show that the yields may be increased from 50 to 100 percent by green manuring when the organic matter in the soil is low.

(c) Crop Residues

Crop residues, such as straw, should be utilized on the farm and returned to the land. The most satisfactory way to make use of such material is to use it as bedding. It can be applied to the soil later as manure.

X. Commercial Fertilizers

Nutrient material that is regularly on the market for application to the soil to promote plant growth is considered a commercial fertilizer. Such fertilizers are generally applied to supplement native soil constituents rather than to act as the sole source of plant nutrients.

Commercial fertilizers on the market include both organic and inorganic substances. Organic fertilizers include animal residues (by-products), while inorganic fertilizers are composed of naturally mined, synthetic, or by-product salts. These fertilizers can be purchased in the form of "single carriers", or in mixtures of more than one nutrient element. Typical analyses on a bag of fertilizer are as follows: 0-45-0, 5-10-0, and 5-10-5. The first figure refers to the percentage of total nitrogen (N), the second to the percentage of available phosphorus (P₂O₅), and the third to the percentage of water-soluble potassium (K₂O).

It is probable that nitrogen in Colorado can be maintained by barnyard manure and legumes. For this reason, commercial nitrogen is seldom used in Colorado. The best commercial nitrogen fertilizer is ammonium sulfate (20-0-0), should applications of nitrogen become necessary.

There is a marked tendency toward a deficiency of available phosphorus in some Colorado irrigated soils. Triple-superphosphate (0-45-0) is the most economical source of phosphorus, especially for alkaline calcareous soils. Hockensmith and others (1933) have shown that phosphorus fertilizer remains largely where it is placed in the soil. Therefore, it must be placed below and to the side of the seed to enable the roots to obtain it.

Colorado soils appear to be well supplied with potash. While applications alone is probably wasteful, potassium may be used economically in a few cases in a complete fertilizer.

The addition of other essential elements to Colorado soils appears to be unnecessary at the present time.

II. Productivity Ratings

Crop yield and precipitation records from in and near eastern Colorado have been used by Brown (1938) as a basis for the estimation of probable yields on soils developed in the plains region. Altho Keith silt loam and Fowers loam were given the same productivity ratings under similar precipitations, it was shown that the average yield on the Keith soil was nearly 3 times as much as on the Fowers soils when the region in which they occur in eastern Colorado was considered and the distribution of good, fair, poor, and failure years accounted for.
REFERENCES

Questions for Discussion

1. What are the principal methods for the maintenance of soil productivity in Colorado?
2. Explain how water supply is used by the plant. To what extent?
3. How does nitrogen content of the soil vary with elevation? Why?
4. In what forms are nitrates used by plants? Describe their formation.
5. Distinguish between ammonification and nitrification.
6. What is symbiotic nitrogen fixation?
   Explain it.
7. Name the different nodule bacteria groups.
8. Under what conditions is artificial inoculation advisable in Colorado?
9. Explain how to inoculate legumes with bacterial cultures.
10. Describe non-symbiotic fixation of nitrogen.
11. How much phosphorus exists in Colorado soils? How is it made soluble?
12. What is soil alkali? White Alkali? Black Alkali?
13. Account for high nitrates under some soil conditions.
14. What soil conditions accompany black alkali?
15. Under what conditions are arsenic and selenium harmful?
16. Explain how aeration affects soil productivity.
17. Describe how to diagnose a soil for factors that cause reduced yields.
18. What undesirable effects occur in water-logged soils?
19. What are the effects of over-irrigation on a well-drained soil?
20. What are the essentials of a good crop rotation for Colorado conditions?
21. Describe a rotation for each of these regions: northern Colorado irrigated lands, Arkansas Valley irrigated lands, eastern Colorado drylands, and for the San Luis Valley.
22. What is the general composition of barnyard manure? How applied in Colorado?
23. Why have green manures given poor results under dryland conditions?
24. How may sweet clover be used as a green manure crop under irrigation?
25. Under what conditions have green manures resulted in high yields of sugar beets? Cite one case.
26. What is a commercial fertilizer?
   Explain what is meant by a 5-10-5 fertilizer.
27. Why is commercial nitrogen seldom applied in Colorado?
   Name a good commercial nitrogen fertilizer for the state.
Chapter 2. Field Crop Pests

I. Problem of Crop Pests

The problem of crop production is seldom so simple as the mere application of cultural methods. Various pests may attack the crop and either reduce the yield or quality of the harvested product. In extreme cases the crop may be destroyed.

Crop pests may be classified as weeds, plant diseases and insects. Thornton and Durwell (1933) conservatively estimate the weed loss in Colorado between 10 and 20 million dollars. Plant diseases are also known to cause great losses on some crops in years favorable for epidemics.

A. Weeds and their Control

II. Types of Weeds

The principles involved in weed control are based upon their growth habits. Weeds are classified as annuals, biennials, and perennials.

(a) Annuals

Annual weeds depend entirely upon seed for their reproduction. They live for a single year and die after the seeds have matured. Most of the common farm weeds are in this group. Summer annuals germinate in the spring, develop and produce seeds, and die the same season. Some examples are lamb's quarters, pigweeds, Russian thistle, cocklebur, buffalo-bur, and many others. Winter annuals are plants that germinate in late summer, and over-winter as small tufts of leaves or rosettes. They resume growth in the spring and mature seeds early in the summer. Some winter annuals found in Colorado are: Wild barley, fanweed, downy bromegrass, and tumbling mustard.

(b) Biennials

Biennial weeds require two seasons to complete their growth. They grow from seeds and devote the first season to food storage, usually in short fleshy roots. During the next season they draw on the stored food to produce a vigorous vegetative growth and to mature seeds. Among the biennial weeds are burdock, bull thistle, mullen, and wild parsnip.

(c) Perennials

Perennial weeds live for 3 or more years. They are generally reproduced from both seeds and roots. The most serious weeds belong to this group.

The majority of simple perennials possess root crevms which produce new plants year after year, being supported by a fleshy taproot or by a mass of fibrous roots. Plants of this type depend upon the production of seed for their spread except in the few instances where pieces of the crown may be broken off and carried elsewhere. Some examples are dock and plantain.
Creeping perennials propagate by either rootstalks or rhizomes. Rootstalks are true roots, being irregular in their growth, and without nodes and leaf structures. They give rise to adventitious aerial shoots and to lateral roots at any place along their length. Some examples are field bindweed, Canada thistle, perennial sow thistle, and leafy spurge. Rhizomes are underground stems that possess typical stem structures. The roots, aerial shoots, and secondary branches always arise at the nodes. Quackgrass is an example of this class.

III. Losses Caused by Weeds

There are many ways in which weeds may cause losses. Some of these are discussed by Robbins and Boyack (1919), and by Thornton and Durrell (1933).

1. Decrease in Crop Yield: Weeds decrease crop yields by the removal of soil moisture, as well as soil nutrients, used by crop plants. The water requirement ratios of some weeds are as follows: pigweed 287, Russian thistle 336, gumweed 608, wild sunflower 633, Lambs quarters 201, and ragweed 948. Weeds require as much or more water to produce a pound of dry matter than the cereal crops.

2. Impairment of Crop Quality: Weeds delay the harvest of small grains, increase the moisture content of combined grains, and increase the dockage at the elevator. Weeds in hay may lower the grade materially. Freedom from weed seeds, especially those of noxious weeds, is one of the important requirements for registration of crop varieties.

3. Harbor Plant Pests: Often plant pests are harbored along roadsides and on ditchbanks. Curly top, a serious virus disease of the sugar beet, is carried from such weeds as the common mallow, chickweed, and lamb's quarters, to the sugar beet by an insect known as the sugar beet leafhopper which breeds upon these weeds. The sugar beet webworm prefers to deposit its eggs on the Russian thistle and similar weeds. Weedy roadside fence lines is a favorable place for the deposition of grasshopper eggs.

4. Increased Irrigation Costs: Weeds on ditchbanks may seriously impair the efficiency of canals and ditches as water carriers. They may grow into the channel and retard the flow of water. Windblown weeds often obstruct headgates, diversions boxes, etc. As a result, ditches must be cleaned every year.

5. Injury to Livestock: Some weeds may cause injury and death to livestock. Among the serious poisonous plants are larkspur, loco, whorled milkweed, Sucklea suckliana, and death camas. The seedlings of cockleburs are poisonous at times. Plants such as sandbur, three-awned grass, porcupine grass, and squirrel-tail grass may cause mechanical injury to stock when mature.

IV. Dissemination of Weeds

Weeds are usually able to survive in competition with crop plants because of better adaptation as well as effective means of propagation. Some of these characteristics are described by Thornton and Durrell (1933).

1. Number of Weed Seeds per Plant: Some weeds produce a large number of seeds per plant. Tumbling mustard may produce as many as 1,500,000 seeds on a single plant. The Russian thistle may produce 150,000 seeds, while the lamb's quarter plant has been known to have as many as 600,000 seeds.
2. Viability of Weed Seeds: The seeds of many weeds retain their viability over a long period of time, especially when buried in the soil. For example, seeds of mustard, purslane, and narrow-leaved dock germinated after 30 years. Crop seeds generally lose their viability within one year when buried in the soil.

3. Means of Seed-Dispersal: Many weed seeds are adapted to wind dissemination. The so-called tumble weeds, like the Russian thistle, release their seeds while being blown along the ground. Some weeds, like the Canada thistle, have a tuft of hairs on the seeds to aid their dissemination by wind. Weed seeds may be carried by water, especially in irrigation ditches. Egginton and Robbins (1920) found that several million weed seeds may pass a given point in a 12-foot ditch in a 24-hour period. They identified 31 species in 156 weed-seed catches. Other weed seeds may be carried from place to place by animals, especially those that stick in the hair or wool like burdock, sandburrs, and cockleburs. Weed seeds may be disseminated in manure from weedy forage.

4. Vegetative Propagation: Many of the most pernicious weeds are able to reproduce vegetatively, as well as from seed. They may spread by bulbs, stolons, rhizomes, or rootstalks. Some of these are bindweed, Canada thistle, and perennial peppergrass.

5. Dissemination in Crop Seeds: Weed seeds are widely spread in impure crop seeds. Most noxious weeds have been introduced in poor seed. Both perennial peppergrass and Russian knapweed were introduced into Colorado in Turkestan alfalfa seed. Field bindweed has been distributed in sugar beet seed imported from Europe.

V. Control of Common Farm Weeds

There are many practices that may be employed for the control of common weeds on the farm. Some of these are listed below.

1. Clean Seed: The first step in weed control is the use of crop seeds that are free from weed seeds. The farmer who buys seed should insist on a purity test from the Colorado Seed Laboratory. Seeds of high purity should be planted, preferably free of noxious weeds.

2. Cultivation: Cultivated crops should be planted periodically to clean the land of weeds. Weeds are killed most easily while they are small. The greatest benefit of bare fallow under dryland conditions is the prevention of weed growth.

3. Prevention of Seed Formation: Weeds along ditchbanks, fences, and roads should be cut before they form seeds.

4. Burning Weeds: Burning dead weeds may kill many seeds. This applies particularly to weeds that collect in irrigation ditches, drains, fence corners, etc.

5. Crop Rotation: Many weeds are more or less associated with certain crops. Continuous culture to one crop makes the control of these associated weeds almost impossible. For example, dodder and Russian thistles may be troublesome in alfalfa, but readily eliminated in cultivated crops. Wild oats and the mustards are serious pests on land continuously cropped to small grains. A crop rotation that involves cultivated, small grain, and leguminous sod crops will reduce weed troubles materially.
6. Smother Crops: So-called smother crops make a rapid growth and shade out other plants. Several crops, when planted thickly, may serve as smother crops, such as alfalfa, foxtail millet, sweet clover, and sorghums.

7. Clean Farm Machinery: All types of community farm machinery should be cleaned before it is brought to the farm. This applies particularly to small grain separators, combines, and hay balers. Care should also be exercised with wagons and trucks. Cultivators may carry noxious weeds from one part of a farm to another.

VI. Clean Cultivation for Noxious Weed Control

Clean cultivation is the most practical means for the eradication of noxious perennial weeds, especially for large infested areas. The principle involved is the depletion of the root reserves by repeatedly cutting the new shoots. Plant food cannot be stored without leaf growth.

Ordinarily, the weed area should be plowed in the spring and cultivated frequently enough to prevent all appearances of weeds above the surface of the ground. It is advisable to follow the land the first season and cultivate it 10 to 15 times, according to Thornton and Durrell (1935). The appearance of new shoots thru the ground is the signal for the next cultivation. At first, this may require cultivation every few days with a gradual increase in the interval between cultivations as the plants become weakened. Cultivation at a depth of 3 inches appears to be as effective as tillage at greater depths. An occasional irrigation will hasten the exhaustion of the plants. Each failure to cultivate at the proper time will prolong the eradication period. Experiments indicate a wide blade is more effective than duckfoot or ordinary shovels. A blade sharpened on one edge may be bolted to the cultivator. The draft on shovels is much greater than with a single wide blade, according to Tucker (1936, 1937).

Recent work indicates that clean cultivation may start to advantage after the weed patch has attained a reasonable degree of maturity. This appears to be especially true of weeds such as perennial peppergrass or whorled milkweed that bloom all at one time. For these weeds, Tucker (1937) advises that the land be plowed deeply after the plants have bloomed but before they have matured seed. Subsequent cultivations should be given often enough to prevent all top growth.

Cultivation, to effect complete eradication, will usually require at least a part of the second season. In practice, a combination of clean cultivation and another crop may either weaken or eliminate perennial weeds. One of the best plans in the irrigated regions is to clean cultivate from early spring until August, and then plant alfalfa without a companion crop. The alfalfa makes a rapid growth during the next spring and tends to shade out the weakened weeds. Frequent cutting of the hay crop tends to prevent seed formation. Another method is to clean cultivate until July and drill a forage sorghum crop at the rate of 8 pecks per acre. The sorghum shades the weeds and limits their growth. The sorghum crop is harvested for hay at the proper time. This procedure is followed the next year in the same manner. Another adaptation is to bare fallow from early spring to late fall the first season, fallow the second season until July 1, and plant the heavy seeding of sorghum.
VII. Chemical Control of Noxious Weeds

Chemical eradication of weeds is advisable only on small areas or those inaccessible to cultural implements. It is comparatively easy to obtain a 90 percent kill, but all noxious weeds must be eradicated to prevent their reappearance. While the chemical must be toxic enough to kill the weeds, it should not remain in the soil indefinitely to prevent the growth of subsequent crops. Weed areas to be treated should be isolated early in the season and left undisturbed. Several chemicals, used for weed eradication in Colorado, will be described.

(a) Sodium Chlorate

Sodium chlorate is the most generally effective herbicide at the present time. It is usually necessary to make 2 or 3 applications for complete kills. This chemical leaves the soil sterile for various periods of time up to 3 years in Colorado.

Sodium chlorate may be applied as a foliage treatment or spray. It is used in solution at the rate of 3 pounds in 2 gallons of water, per square rod at the blossom stage. Further sprays are applied as often as regrowth reaches the proper stage. Some type of pressure sprayer is required for this method in order to apply the solution to the foliage as a fine mist. Plant growth should be undisturbed both before and after treatment. For the best results, the soil should be dry at the time of application.

The second method of sodium chlorate application is a soil treatment. The chemical is applied to the soil at the rate of 5 to 6 pounds per square rod, either dry or in solution. This is usually applied late in the fall or early in the spring, although early summertime treatment has proved better for perennial peppergrass. A sprinkler can be adequate equipment when the chemical is applied in solution. The soil should be moist at the time of application.

Sodium chlorate presents a serious fire hazard when used as a spray. When solutions of sodium chlorate dry on foliage, clothes, or wood, the material becomes highly inflammable. It may burst into flames from the slightest friction. The chemical should be kept in metal containers, mixed in the open, and never applied close to wooden structures. The operator should wear rubber boots. None of the solution should be allowed to dry on his clothes, or on other organic material.

(b) Calcium Chlorate

This material is available only in a proprietary form. Calcium chlorate has the ability to draw moisture from the air under conditions of normal humidity. This eliminates to a large degree the danger from fire. Calcium chlorate is less effective, pound for pound, than sodium chlorate. The difference can be overcome by the application of more chemical. The commercial product is sold as Atlacide. The methods of application are the same as for sodium chlorate.

(c) Common Salt

Common salt, sodium chloride, may be used on noxious perennial weeds. To be effective, it is usually applied in solution at the rate of 2 pounds of salt to 1 gallon of water to 1 square foot of ground. This concentration
will kill all vegetation. The salt must be washed out of the soil by heavy irrigations or rain before crop growth is possible. This may require 4 years or more. Common salt is used to advantage on small patches of weeds on ditchbanks or near barns where vegetation is undesirable. Its expense, together with the residual effect, makes it impractical for field use. The cost may be as high as four-hundred dollars per acre.

(d) Acid Arsenicals

Acid arsenical weed sprays are being used in this state. Applied under proper conditions, this material will kill some of the roots as well as topgrowth. So far, the use of acid arsenicals has been confined mostly to field bindweed. The stock solution is an arsenical compound. To make up the spray solution, one part of the arsenical compound (by measure) is added to 200 parts of water (by measure) in the spray tank. This is stirred slowly while 5 parts (by measure) of concentrated sulfuric acid are added. Water should never be added to concentrated sulfuric acid. The spray should be applied to reasonably mature plants, i.e., at least 12 to 18 inches of growth being necessary for bindweed. The best weed kills are obtained on dry soil. The spray should be applied after 6 p.m. Ordinarily, 3 gallons of solution will be required per square rod, or from 500 to 700 gallons per acre. The solution should be applied by pressure spray equipment, preferably acid-proof. This spray has no detrimental effect on the soil. A second application should be made before frost on the regrowth.

(e) Carbon Disulfide

This chemical is highly explosive and volatile. It is poured into holes in the soil where it volatilizes and spreads laterally to kill the roots. Sometimes carbon disulfide is ineffective even then an application may cost two hundred dollars per acre. The soil moisture conditions must be right for its penetration. In a description of the method of application, Rogers and Hatfield (1929) state that holes are bored at 2-foot intervals in rows 21 inches apart. Two ounces of carbon disulfide are placed in each hole, the openings being closed with soil to prevent evaporation into the air. Penetration is faster at high temperatures and in dry soil. The method is practicable only on small areas.

VIII. Descriptions of Important Noxious Weeds

Several weeds found in Colorado are very difficult to control. They are considered noxious for that reason. They are described by Thornton and Durrell (1933).

1. Quackgrass (Agropyron repens): Quackgrass is a perennial that propagates by seed as well as by long jointed yellow rhizomes. This grass is erect, 1 to 3 feet high, with slender stems and narrow leaves, rough above but smooth beneath. The seed is borne in spikes 3 to 7 inches long. It grows along ditchbanks, roadsides, and in cultivated fields. While it has forage value, quackgrass becomes a very bad weed because of its persistence.

2. Perennial Peppergrass (Lepidium draba): This plant, sometimes called Whiteweed, belongs to the mustard family. It is a perennial that propagates both by seed and creeping roots. The plant is erect, 10 to 18 inches high, and grayish white in color. The leaves are oval or obovate, with toothed or almost smooth margins, and 0.5-2.0 inches long with blunt ends. The flowers are numerous, white, and small. The seed pods are heart-shaped.
and contain small reddish-brown seeds about the size of those of alfalfa. This plant makes a vigorous growth on irrigated alkaline soils.

Perennial peppergrass is a serious pest in the San Luis Valley and in certain areas of the Western Slope. The plant is described in some detail by Peitersen and Burdick (1920) and by Simonds (1938). Two similar species, Lepidium repens and Erythrostachys pubescens, are found in Colorado. The Perennial peppergrasses are especially resistant to chemical control.

3. Leafy Spurge (Euphorbia virgata): This plant, a member of the spurge family, is a perennial that propagates by seed and by creeping roots. The plants are erect, 1 to 3 feet high, and unbranched except for flower clusters. The leaves are long and narrow with smooth margins. The flowers are small, greenish yellow, and occur in small umbrella-like clusters at the top of the stem. The pods are 3-seeded, the seeds being light gray, smooth, and about twice the size of alfalfa. The plant is characterized by a milky sap. This plant is barely known in Colorado, but it is a serious pest in other states.

4. Field Bindweed (Convolvulus arvensis): This plant is a member of the morning glory family. Field bindweed is a perennial that propagates by seeds and creeping roots. The stems are smooth, slender, slightly angled, and 1 to 4 feet long. They spread thickly over the ground or twine around erect plants. The leaves are 1 to 2 inches long, more or less arrow-shaped, round pointed at the tip, and with pointed or blunt lobes at the base. The flowers are bell-shaped, white or pink, and about 1.75 to 1.00 inch broad. The fruits are small round capsules and usually 4-seeded. The seeds are dark brown, rough, pear-shaped, and flattened on 2 sides. Field bindweed is widely distributed in Colorado, according to Rogers and others (1926).

5. Mouse-Ear Poverty Weed (Iva axillaris): This poverty weed is classified in the ragweed family. It is a perennial that propagates both from seed and creeping roots. It is erect, much-branched, 6 to 18 inches high, and smooth or slightly hairy. The leaves are numerous, sessile, entire, rather thick, narrowly oblanceolate, 0.5 to 1.5 inches long, rough-hairy, and harsh and stiff to the touch. The flowers are in small heads which hang down upon short stalks from the axils of the upper leaves. The seeds are deep gray to almost black, wedge-shaped, and about 0.25-4 inch long.

6. Canada Thistle (Cirsium arvense): Canada thistle is classified in the thistle family. It is a perennial that reproduces both by seeds and creeping roots. The stems are erect, hollow, smooth to slightly hairy, 1 to 4 feet tall, simple, and branched at the top. The leaves are set close on the stem, slightly clasping, typically green on both sides, sometimes white hairy beneath, deeply and irregularly cut or pinnatifid into lobes tipped with sharp spines, or sometimes entire or nearly so. The typical thistle flowers occur in numerous heads about 0.50-inch broad and 0.75-inch long, usually rose-purple, sometimes white, all flowers on a plant being either male or female (dioecious). The seeds are tan color, about one-eighth-inch long, slightly flattened and curved with a white downy tuft easily detached. Canada thistle is widely distributed in Colorado in cultivated fields, pastures, and meadows.

7. Russian Knapweed (Centaurea picris): Russian knapweed also belongs to the thistle family. It propagates by seeds and black creeping roots. The plant is erect, rather stiff, branched, and 1 to 3 feet high. The young stems are covered with soft gray hairs or nap. The lower leaves are 1 to 2 inches long with toothed margins that become narrower, smaller,
and with entire margins as they approach the top of the plant. The flowers are in heads, like thistles, about 0.50-inch in diameter, and lavender to whitish in color. The seeds are chalky white or grayish, oblong, about one-eighth-inch long, and with a bristly tuft easily detached. It is generally distributed in Colorado. This weed is described in detail by Rogers (1928).

B — Plant Diseases

IX. Nature of Plant Diseases

Most of the important crop-plant diseases found in Colorado are caused by microscopic plants which draw all their food from the diseased plant. Diseases caused by one organism living on another are called parasitic diseases. Parasitic diseases may be caused by bacteria, fungi, and sometimes other organisms. Bacteria enter the stems, leaves, and roots of plants thru the stomata or injuries. They live on the substance of the plant and either kill it or cause it to make abnormal growth. Stem blight of alfalfa is an example of a bacterial disease. Fungi are responsible for about 90 percent of the common plant diseases. As fungi lack the green pigment chlorophyll, they obtain their food from green plants or from decaying organic material. The fungus consists of a fine threadlike structure known as a mycelium which penetrates the host plant. The rusts and smuts of cereals are important fungus diseases.

Certain plants are subject to virus diseases. These are often characterized by a mottled or mosaic condition of the leaves of an affected plant. While parasitic organisms have not been associated with these diseases, they are known to be highly infectious. The juice from a diseased leaf injected into a healthy one will cause the new plant to become diseased after 8 or 10 days. Curly-top of sugar beets is a virus disease found in some parts of the state. (See Leach, 1921).

Some physiological diseases occur in the state. Yellowhead in wheat is due to an unfavorable ratio of potassium to nitrogen in the soil (See Wheat). Chlorosis is a chlorophyll-deficient condition due frequently to the lack of available iron in the soil.

X. Stem Rusts of Cereals

Stem rusts are destructive to wheat, rye, barley, and oats. These rusts attack both stems and leaves. Each cereal has its own specialized form of stem rust.

The life cycle of stem rust (Puccinia graminis) is given by Lungren and Durrell (1938). There are several stages in the annual life cycle of this fungus. Probably the one most familiar is the black spore stage which occurs on the stems of mature grain plants. The black spots or pustules found on stubble and straw at harvest time are composed of thousands of tiny spores which live through the winter in a dormant state. Early in the spring the black spores germinate and produce very small, colorless, secondary spores which may be carried for miles by the wind. These tiny spring spores can cause infection only on the leaves of certain kinds of barberry bushes. A third kind of spore appears in cluster cups on the lower side of infected barberry leaves. These in turn infect nearby grains and grasses, producing the red or summer stage of the fungus. During warm
moist weather, this stage of the rust spreads rapidly from one grain plant to another, and from field to field. As the weather becomes cooler and crops begin to mature, the black or winter spores again appear. Thus, in Colorado, the common barberry (Berberis vulgaris) and other susceptible species, play a vital part in the occurrence and spread of the stem rust disease.

Figure 1.—Life cycle of stem rust of wheat, oats, barley, and rye: Overwintering black spores (teliospores) germinate (1) in the spring. They produce several very small spores (basidiospores) (2) that are carried by air currents to nearby barberry bushes, where they germinate. The resulting infection of the barberry (3) produces spermogonia and cluster cups (aecia) (4). Cluster-cup spores (aeciospores) are blown to grainfields and germinate on the grain plants (5), where they produce rust-infection pustules on the stems and leaves (6). These pustules contain the red or summer spores (urediospores) (7) which reinfect the crop, producing more of their kind (8), until toward the end of the growing season, when the black-spore pustules develop and the teliospores (9) mature and spend the winter on straw and stubble (10), where they germinate in the spring.

The losses from stem rust may be reduced by: (1) eradication of the barberry bushes, (2) the use of rust-resistant small grain varieties such as Thatcher wheat, and (3) planting spring wheat as early as the land can
be prepared. Early spring wheat stands a better chance to escape rust damage, especially from spores blown into the state from the South.

XI. Smuts of Cereals

There are 3 general types of smut based on their methods of infection, viz. seed, flower, and local.

(a) Covered Smut of Wheat (*Tilletia laevis*)

Covered smut of wheat is an example of the seed infection type. The spores adhere to the outside of the seed where they germinate and infect the young seedling. The life cycle, given by Durrell (1931), is shown in figure 2.

![Diagram showing the life history of stinking smut.](image)

Fig. 2. Diagram showing the life history of stinking smut.

Seed treatments are effective controls for covered smut of wheat. In the last few years, dust treatments have been widely used to control the disease. The application of 2 ounces of copper carbonate per bushel of seed by use of a barrel mixer is the standard method. More recently, organic mercury compounds have become popular. The application of one-half ounce of New Improved Ceresan per bushel of seed has given satisfactory control of the disease.
Several other smuts that can be controlled by seed treatment with the organic mercury compounds are: the oat smuts, covered smut of barley (Ustilago hordei), Intermediate smut of barley (U. medians), millet smut (U. crameri), and kernel smut of sorghum (Sphacelotheca sorghi).

(b) **Loose Smut of Wheat (Ustilago tritici)**

Loose smut of wheat is an example of the floral-infection type of smut. The spores are carried from a diseased plant to the open flowers of a healthy plant where they grow into the new seed. In the spring, the fungus, dormant in the seed, starts to grow at the same time as the seedling. It grows up with the plant and produces a smutty mass in the grain head. The life cycle is given by Durrell (1931) and shown in Figure 3. Loose smut of barley (U. nuda) has a similar life cycle.

![The Life Story of Loose Smut of Wheat](image_url)

**Figure 3**
The control measures for these loose smuts is by what is known as the hot water treatment. This treatment is discussed under "Wheat" (lecture 11).

(c) Corn Smut (Ustilago zeae)

Corn smut is an example of the local-infection type. Infection takes place in meristematic regions of the plant after it is above ground. The tassels, ears, and stalks are the chief points attacked. The smut spores are blown from the soil, where they have over-wintered, to the corn plant where they germinate and infect the growing tissues. After infection, abnormal growths are produced on the corn plant by the fungus which result in a mass of spores.

It is impossible to control corn smut by seed treatment because the spores are not seed-born. Where the infection is heavy, the spores may be killed when the corn is put in the silo. Infected manure should not be returned to cornland. Some corn hybrids show some resistance to smut.

References

Questions for Discussion

1. Describe annual weeds and give 5 examples.
2. What are biennial weeds? Name 4 found in Colorado.
3. Describe 2 types of perennial and give an example of each.
4. Name and explain 5 losses caused by weeds.
5. Name and describe 5 methods of weed dissemination.
6. Give 7 methods for the control of common farm weeds.
7. Describe the use of clean cultivation for noxious weed control.
8. Explain one example of how clean cultivation may be used in conjunction with smother crop for noxious weed control.
9. What conditions are necessary for the chemical control of noxious weeds.
10. Explain how to apply sodium chlorate for weed control, both as a foliage treatment and as a soil treatment.
11. Give precautions to avoid the fire hazard of sodium chlorate.
12. How does calcium chlorate differ from sodium chlorate as a weed chemical?
13. Describe the use of common salt for noxious weed control.
14. Explain how to use acid arsenicals for weed control.
15. Give the method for the application of carbon disulfide for the control of weeds. Its effectiveness?
16. Describe in detail 3 weeds in this list: quackgrass, perennial peppergrass, leafy spurge, field bindweed, mouse-ear poverty weed, Canada thistle, and Russian knapweed.
17. Name and briefly describe 3 causes of plant diseases.
18. Give the life cycle of stem rust of wheat.
19. How is stem rust controlled?
20. Describe covered smut of wheat.
21. Explain the application of dusts for seed treatment.
22. Name the different crop smuts that can be controlled by seed treatment.
23. Give the life cycle of loose smut of wheat.
24. Describe the mode of infection of corn smut.
FIELD CROPS IN COLORADO

Part II

Crops of the Grass Family
FIELD CROPS IN COLORADO

Chapter 9. Corn or Maize

I. Economic Importance

Corn (Zea mays, L.) has become one of the important Colorado crops in the past 25 years due to the culture of adapted varieties. For the 10-year period from 1927 to 1936 an average of 1,461,300 acres has been grown in the state each year with an average annual production of 17,038,700 bushels. The quantity produced varies considerably from year to year because of rainfall fluctuation and other variable climatic factors. From 85 to 90 percent of the acreage and 75 to 80 percent of the production is from the non-irrigated regions. The average yield per acre for the 10-year period from 1923 to 1932 was 32.2 bushels from irrigated and 11.6 bushels from non-irrigated corn.

In normal years it has been estimated that 85 percent of the corn crop is consumed on the farm where grown, while 15 percent is marketed. A large quantity of corn is shipped into the state from the Cornbelt to meet local needs in seasons of low production.

II. Botanical Description

Maize belongs to the grass family and to the tribe Tripsaceae which is composed of several monocious genera.

(a) Inflorescence. The tassel or staminate inflorescence terminates the main stem. The spikelets on the tassel are usually arranged in pairs, one sessile and the other pedicellate. Each spikelet has 2 glumes which enclose 2 florets. The florets contain 3 stamens and a rudimentary pistil. The pistillate inflorescence arises on a specialized lateral branch known as the "ear." The ear is a spiky on whose thickened axis the paired spikelets are borne in several longitudinal rows. There is always an even number of rows because the spikelets are borne in pairs. Each spikelet has 2 glumes which enclose 2 florets, one of which is almost always rudimentary. Corn is regarded as a naturally cross-pollinated plant.

(b) Vegetative Parts. Corn has the same general characteristics as other grasses. The stem, which consists of nodes and internodes, contains a solid pith. The leaf is composed of a blade and a sheath, the two being separated by a collar-like ligule. The roots are fibrous. Primary roots arise when the seed germinates. Soon afterwards the secondary roots arise from the nodes of the stem below the soil surface. Buttress roots may arise from the nodes above ground, but almost never under non-irrigated conditions.

III. Species or Groups

Maize has been divided into 6 species or groups. Distinction as separate species is hardly justified because all of them inter-cross readily. These groups are: dent, flint, flour, pop, sweet, and pod corns. Except for pod corn, the differences between these so-called species are based on endosperm characters. The types of field corn grown in Colorado are dent, flint, and flour corns. Dent corn is by far the most important commercially, both field varieties and hybrids being grown. Dent corn is distinguished by the characteristic indentation in the top of the kernel. Coarse starch is located along the sides of the kernel while soft starch extends to the top. The indentation occurs because the soft starch shrinks more on drying than the coarse one. In flint corn, the soft starch is entirely surrounded by coarse starch. The
endosperm of flour corn is composed of soft starch.

IV. Kernel or Seed Characteristics

Viability is extremely important in the corn kernel, especially for seed corn.

(a) Longevity of Seed

There has been a general opinion among growers that seed corn loses most of its viability after being stored for even a single year. This may be true to some extent in the Cornbelt, but not under the dry climatic conditions in Colorado where it may retain its viability for a much longer period. Experiments were conducted at Fort Collins by Robertson and Lute (1933, 1937) on the reduction in viability of corn stored in a dry room for as long as 15 years. Some of their results for yellow dent corn are shown in Table 1.

Table 1. Percentage Germination in Corn Stored at Fort Collins for Several Years.

<table>
<thead>
<tr>
<th>No. Years Stored</th>
<th>No. Samples</th>
<th>Percentage Germination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>92.0</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>87.0</td>
</tr>
<tr>
<td>10</td>
<td>6</td>
<td>69.6</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>36.0</td>
</tr>
</tbody>
</table>

It was found that yellow dent corn germinated well for the first 6 years, but dropped off rapidly between the ninth and tenth years. These data indicate that the corn grower may save a seed supply from good years sufficient for 2 or even more years without a serious reduction in germination.

(b) Bushel Weight in Relation to Maturity

Bushel weight has been found to be an index of maturity in shelled corn, a fact that may aid in the detection of immature seed. Robertson and others (1930) recorded bushel weights of corn planted at 10-day intervals, the results being given in Table 2.

Table 2. Bushel Weights of Corn Planted at 10-day Intervals, 1923-29.

<table>
<thead>
<tr>
<th>Date Planted</th>
<th>Bushel Wt. (lbs.)</th>
<th>Grade No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 20</td>
<td>57.8</td>
<td>1</td>
</tr>
<tr>
<td>May 1</td>
<td>56.8</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>55.2</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>54.0</td>
<td>2</td>
</tr>
<tr>
<td>30</td>
<td>51.6</td>
<td>3</td>
</tr>
<tr>
<td>June 10</td>
<td>45.4</td>
<td>6</td>
</tr>
</tbody>
</table>

Corn planted after May 10 dropped progressively in bushel weight, being much more immature at harvest than that planted at the earlier dates.

Bushel weight determinations were also made at Fort Collins over a 3-year period on individual ears of corn harvested at 10-day intervals from August 22 to October 1. The results in Table 3 show that the bushel weight of Golden Glow progressively increased as it became more nearly mature at the time of harvest. When harvested after maturity in the field (about September 11) there was little change in bushel weight. (Leonard, 1935).
Table 3, Bushel Weights of Golden Glow Corn Harvested at 10-day Intervals.

<table>
<thead>
<tr>
<th>Date</th>
<th>Mean Weights per Measured Bushel (lbs.)</th>
<th>U. S. Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvested</td>
<td>1931</td>
<td>1932</td>
</tr>
<tr>
<td>August 22</td>
<td>49.8</td>
<td></td>
</tr>
<tr>
<td>September 1</td>
<td>51.4</td>
<td>53.7</td>
</tr>
<tr>
<td>11</td>
<td>58.0</td>
<td>56.2</td>
</tr>
<tr>
<td>21</td>
<td>59.4</td>
<td>57.6</td>
</tr>
<tr>
<td>October 1</td>
<td>59.3</td>
<td>68.4</td>
</tr>
</tbody>
</table>

1 Insufficient corn for individual ear determinations.

Mature corn, harvested September 11 or later, weighed well over 54 pounds, the minimum requirement for U. S. No. 1 corn. The seed buyer should suspect the maturity of corn at harvest when the bushel weight falls below 54 pounds.

V. Adaptation

The climate and soil conditions are important in the adaptation of corn because it is a full-season crop. For maximum yields, it is essential that a variety be grown that will utilize the entire frost-free season and produce mature corn (Leonard and associates, 1940).

(a) Climatic Factors

The natural habitat of corn is a region of abundant moisture, high mean summer temperatures, and a long frost-free season. The temperatures in Colorado are comparatively lower during the growing season than those found in the Cornbelt, especially the mean temperature. The seasons are comparatively short, being less than 150 days in most parts of the state. In some places the frost-free season averages less than 90 days. Most of the corn is grown east of the mountains, but it can be produced in the warmer mountain valleys, particularly on the Western Slope. Conditions favorable to corn production are usually limited to elevations below 6,000 feet. It is seldom grown successfully when the normal rainfall is less than 14 inches, except under irrigation. (See Kezer and Ray, 1919).

(b) Soil Conditions

In Colorado, dryland soils that most successfully produce corn are either sandy loams or light sandy loams, i.e., "semi-hard lands." These soils warm up earlier in the spring than the heavier or so-called "hard land" soils, a fact which permits corn to be planted earlier on them. The "semi-hard" lands absorb more rainfall than the "hard lands." Some yields compiled from dry land experiments on "hard lands" by Brown (1938) indicate that an annual precipitation of more than 20 inches will produce a high yield about one-half the time. High yields were rarely obtained at Akron ("hard land") on less than this amount, although fair yields were produced about one-half the time with 17 to 20 inches annual rainfall. Observation has indicated that the corn crop is more frequently a failure on the "hard lands" than on the "semi-hard lands."

Most Colorado soil types are suitable for corn when ample soil moisture is available.

VI. Corn Types and Varieties

Because of the great variation in climatic conditions within the state, no one variety is suitable to all regions.
(a) Relation of Corn Type to Climatic Conditions

For adaptation of corn, the inherited vegetative characteristics of the type grown should be suited to local environmental conditions. In general, open-pollinated corn that has been grown locally for a period of years has become adjusted to such conditions as moisture supply, temperature, and length of frost-free season. Locally adapted varieties have been shown by many experimental tests to outyield those brought in from other localities unless the climatic conditions in the two areas are similar. A variety will yield its maximum in a locality when it makes full use of the average growing season. An early variety that matures short of a full season, or a late one that fails to mature, will yield less as an average than adapted local sorts. Adapted varieties may be said to be in equilibrium with the environmental conditions. Of all crops grown in Colorado, corn is the most sensitive to changes in the balance between growth habit and environment.

That locally adapted varieties within the state vary widely in their vegetative characteristics as a result of adjustments to environment, is shown by some data collected at Fort Collins in 1933. Seed of varieties adapted locally for 5 years or more were planted in a comparative test. Some of the results, with the strains arranged in order of length of frost-free season, are given in table 4.

Table 4. Plant Characters in Relation to Adaptation in Some Colorado Corn Varieties Grown at Fort Collins, 1933.

<table>
<thead>
<tr>
<th>Corn Variety</th>
<th>Grower and Location</th>
<th>No. leaves Per Plant</th>
<th>No. Nodes</th>
<th>Plant Ht. (ft.)</th>
<th>Grain Yield (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northwestern Dent</td>
<td>Will Rogers, Craig</td>
<td>10.2</td>
<td>7.5</td>
<td>5.8</td>
<td>110.8</td>
</tr>
<tr>
<td>Logan County White</td>
<td>G. Hoffman, Illiff</td>
<td>15.0</td>
<td>11.8</td>
<td>8.4</td>
<td>215.5</td>
</tr>
<tr>
<td>Minnesota 13</td>
<td>E. L. Johnson, Sligo</td>
<td>13.7</td>
<td>11.0</td>
<td>8.5</td>
<td>163.7</td>
</tr>
<tr>
<td></td>
<td>R. Condon, Platteville</td>
<td>14.3</td>
<td>11.6</td>
<td>8.9</td>
<td>186.3</td>
</tr>
<tr>
<td></td>
<td>D. Burkett, Pueblo</td>
<td>15.3</td>
<td>12.6</td>
<td>8.6</td>
<td>217.9</td>
</tr>
<tr>
<td>Talbot Yellow Dent</td>
<td>H. Talbot, Austin</td>
<td>15.0</td>
<td>12.5</td>
<td>8.7</td>
<td>214.9</td>
</tr>
<tr>
<td>Iowa Silvermine</td>
<td>J. G. Erion, Pueblo</td>
<td>16.0</td>
<td>12.8</td>
<td>9.8</td>
<td>252.7</td>
</tr>
<tr>
<td>Reid Yellow Dent</td>
<td>J. G. Erion, Pueblo</td>
<td>15.7</td>
<td>13.7</td>
<td>9.7</td>
<td>259.6</td>
</tr>
<tr>
<td></td>
<td>G. McClave, McClave</td>
<td>17.0</td>
<td>14.5</td>
<td>10.1</td>
<td>256.2</td>
</tr>
</tbody>
</table>

The data indicate that the varieties with the greatest number of leaves, number of nodes, plant heights, and grain weights per plant are those adapted to the longer growing seasons in the state. Within the Minnesota 13 variety, the strain from Pueblo is a slightly larger vegetative type than the ones adapted to areas with a shorter season. Such late varieties may outyield the earlier, better-adapted ones in a single year and yet be unsafe to grow.

A similar comparison is available for Minnesota 15. The Condon strain, seed of which was brought from Weld County each year, was compared with the same strain taken to Akron in 1928 and grown locally every year. The Minnesota 13 strain imported each year yielded appreciably less than the Akron White check. The Condon strain grown from local seed each year averaged 2.6 bushels more than that grown from seed brought in from Weld County each year. The 8-year average yields (1929-1936) were as follows: Seed from Weld County each year 13.5 bushels, seed from Akron each year 15.9 bushels, and Akron white 19.5 bushels per acre. This test also indicates that it takes several years to adapt an outside strain to local Colorado conditions.

A variety of corn grown in a locality for many years, with the seed properly selected each season, is superior for that particular area. The opinion occasionally expressed that it is advisable to "change seed" every few years is erroneous. Such a procedure is justified only when another variety has proved
to be better, or when good home-grown seed is unavailable. The Colorado corn grower should exercise caution when he obtains seed from a radius greater than 25 miles from where he intends to plant it.

(b) Yield Tests with Field Varieties

The best adapted corn varieties have been determined by yield tests conducted under comparable conditions over a period of years. There has been a tendency in the past for the grower to import the large Cornbelt varieties, most of which have failed to mature in the shorter season in Colorado. These varieties are not grown to advantage until after they have become well enough adapted thru selection to mature in the average season.

Many corn varieties were given a trial under irrigation in the early days, but it was not until Minnesota 13 was introduced in 1916 that field corn became commercially important in the northern part of the state. A yield test at Fort Collins conducted over a 5-year period indicates that locally adapted sorts, as for example, Colorado grown Minnesota 15, outyield varieties from other regions. The data in table 5 indicate that Minnesota 13 (Colorado 15) is satisfactory for northern Colorado irrigated lands. Golden Glow, while also well adapted, is not appreciably better than Minnesota 13.

Table 5. Relative Yields of Minnesota 13 and other varieties at Fort Collins from 1926 to 1929.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Strain</th>
<th>1926</th>
<th>1927</th>
<th>1928</th>
<th>1929</th>
<th>4 yr.</th>
<th>5 yr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minnesota 13</td>
<td>Exp. Sta. (check)</td>
<td>78.7</td>
<td>69.2</td>
<td>73.8</td>
<td>69.0</td>
<td>67.0</td>
<td>70.4</td>
</tr>
<tr>
<td></td>
<td>R. Condon, Platteville</td>
<td>74.0</td>
<td>74.0</td>
<td>75.8</td>
<td>63.2</td>
<td>66.8</td>
<td>74.3</td>
</tr>
<tr>
<td></td>
<td>E. D. Hill, Eaton</td>
<td>75.1</td>
<td>72.1</td>
<td>75.9</td>
<td>71.4</td>
<td>71.2</td>
<td>73.6</td>
</tr>
<tr>
<td>Golden Glow</td>
<td>Exp. Str.</td>
<td>65.0</td>
<td>69.3</td>
<td>79.9</td>
<td>66.1</td>
<td>66.5</td>
<td>75.6</td>
</tr>
<tr>
<td>Akron White</td>
<td>Akron Field Station</td>
<td>75.6</td>
<td>62.2</td>
<td>81.7</td>
<td>65.6</td>
<td>--</td>
<td>71.5</td>
</tr>
<tr>
<td>Reid Yellow Dent</td>
<td></td>
<td>79.6</td>
<td>51.8</td>
<td>71.7</td>
<td>58.4</td>
<td>--</td>
<td>55.4</td>
</tr>
<tr>
<td>Logan Co. White</td>
<td>Hoffman, Cliff</td>
<td>71.0</td>
<td>58.5</td>
<td>73.1</td>
<td>66.6</td>
<td>67.9</td>
<td>67.3</td>
</tr>
</tbody>
</table>

It should be noted that Reid Yellow Dent, an extremely late variety, yielded distinctly less than all strains of Minnesota 13. Akron White moved only a short distance from the drylands of eastern Colorado failed to yield as much as locally adapted varieties.

Corn improvement under dryland conditions was started at the Akron Field Station in 1917 when a strain of Swadley Dent was selected by the ear-to-row method and named Akron White. Coffman (1926) found this variety to outyield the parent Swadley variety materially the first few years. Over a later 11-year period it averaged 2.6 bushels per acre more than its parent. Akron Yellow was isolated in a similar manner. These are excellent examples of yield improvement by the ear-to-row method which was widely used in the early days. A large number of corn types, varieties, and strains were tested at Akron from 1922 to 1937. For the most part, this test reflects the importance of locally adapted types as shown in table 6.
Table 6. Corn Varieties grown under Dryland Conditions at Akron (1922-1937)

<table>
<thead>
<tr>
<th>Type and Variety</th>
<th>Seed Source Each Year</th>
<th>Avg. Yield Years per Acre Grown</th>
<th>Yield Akron White for Same Period</th>
<th>Yield in Fert. of Akron White</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dent Corn</td>
<td></td>
<td>Bus. No.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Akron White</td>
<td>Akron</td>
<td>15.4 16</td>
<td>15.4</td>
<td>100.3</td>
</tr>
<tr>
<td>Akron Yellow</td>
<td>Akron</td>
<td>14.2 16</td>
<td>15.4</td>
<td>92.2</td>
</tr>
<tr>
<td>Logan Co. White</td>
<td>IIiff</td>
<td>18.5 5</td>
<td>16.5</td>
<td>110.3</td>
</tr>
<tr>
<td>inn.13(Cordon Strain) Platteville</td>
<td></td>
<td>11.3 10</td>
<td>17.3</td>
<td>65.3</td>
</tr>
<tr>
<td>Swadley (Vance Strain) Akron</td>
<td></td>
<td>13.5 11</td>
<td>16.1</td>
<td>83.9</td>
</tr>
<tr>
<td>Bloody Butcher</td>
<td>Colby, Kansas</td>
<td>15.9 12</td>
<td>17.1</td>
<td>93.0</td>
</tr>
<tr>
<td>Substation White</td>
<td>N. Platte, Nebr.</td>
<td>18.0 12</td>
<td>17.1</td>
<td>105.3</td>
</tr>
<tr>
<td>Northwestern Dent</td>
<td>Akron</td>
<td>14.6 15</td>
<td>15.7</td>
<td>93.0</td>
</tr>
<tr>
<td>Flint Corn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australian White</td>
<td>N. Platte, Nebr.</td>
<td>17.2 14</td>
<td>15.1</td>
<td>113.9</td>
</tr>
<tr>
<td>Rainbow Flint</td>
<td>N. Platte, Nebr.</td>
<td>16.8 13</td>
<td>15.3</td>
<td>95.4</td>
</tr>
<tr>
<td>Flour Corn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue Flour</td>
<td></td>
<td>17.8 14</td>
<td>15.1</td>
<td>114.6</td>
</tr>
<tr>
<td>Squaw Corn</td>
<td></td>
<td>22.5 6</td>
<td>21.4</td>
<td>114.5</td>
</tr>
</tbody>
</table>

All factors considered, Akron White or some other locally adapted variety appears to be the most dependable under dryland conditions similar to those found at Akron. The white dents tended to outyield the yellow dents in this experiment. Colby Bloody Butcher appears to be too late for Akron, but may be suitable at lower elevations in the extreme eastern part of the state. As a market corn, its color is undesirable. Altho commercially unimportant, the flint and flour varieties have yielded more than the dent varieties. White Australian Flint and Blue Flour have given the best results, but they are objectionable from the standpoint of the market. They are also difficult to husk.

(c) Yield Tests with Hybrid Varieties

Many different corn hybrids have been tested under irrigated conditions at Fort Collins from 1937 to 1939. Some results for 2 years are given in table 7.

Table 7. Average Yields of Corn Hybrids at Fort Collins, 1938-39.

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Relative Maturity</th>
<th>Time to Silk (days)</th>
<th>Percent Suckers</th>
<th>Yield per Acre (Bu.)</th>
<th>Fert. of Minn. 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iowa 939</td>
<td>Late</td>
<td>88.8</td>
<td>31.3</td>
<td>135.9</td>
<td>117.1</td>
</tr>
<tr>
<td>Wisconsin 570</td>
<td>Slightly late</td>
<td>83.1</td>
<td>3.6</td>
<td>128.0</td>
<td>110.2</td>
</tr>
<tr>
<td>Minhybrid 403</td>
<td>Same as check</td>
<td>85.4</td>
<td>17.0</td>
<td>125.6</td>
<td>108.4</td>
</tr>
<tr>
<td>Minnesota 13</td>
<td>Check</td>
<td>81.8</td>
<td>1.9</td>
<td>116.1</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Both Wisconsin 570 and Minhybrid 403 are satisfactory for grain production under northern Colorado irrigated conditions. Iowa 939 is a little too late for average season conditions at Fort Collins, but it has promise at slightly lower elevations on the more sandy soils. It may have a place in southern Weld County and in the Platte Valley in the Fort Morgan area.
Among the hybrids tested under Arkansas Valley conditions at Rocky Ford, Funk G-212 and Iowa 939 have materially outyielded Reid Yellow Dent. This field variety is regarded as the standard under irrigation in that locality. Some data are given in Table 8.

Table 8. Average Yields of Corn Hybrids at Rocky Ford, 1937-39.

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Relative Maturity</th>
<th>Time to Silk (Days)</th>
<th>Yield Shelled Corn Bu./A.</th>
<th>Percent of Reid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Funk G-212</td>
<td>Late milk</td>
<td>82.9</td>
<td>112.8</td>
<td>153.5</td>
</tr>
<tr>
<td>Iowa 939</td>
<td>Early Glazed</td>
<td>60.3</td>
<td>106.4</td>
<td>161.1</td>
</tr>
<tr>
<td>Reid Yellow Dent</td>
<td>Glazed</td>
<td>77.3</td>
<td>98.2</td>
<td>139.5</td>
</tr>
</tbody>
</table>

Iowa 939 was slightly early for Rocky Ford conditions, but it should be adapted in the upper part of the Arkansas Valley.

(c) Significance of Field-Variety Names

The results of corn variety tests in Colorado indicate that variety names mean less than those of almost any other crop. Because of its cross pollination, corn is maintained in an extremely heterozygous condition. As a result of long-time selection, innumerable strains have been isolated within all of the important varieties. In fact, it has often been shown in yield trials that there may be larger differences among strains within a variety than between varieties. In spite of these difficulties, variety names have some significance when used with reference to adapted strains.

The results with Northwestern Dent at Akron may be used to show the differences of strains within a variety. Seed of this variety, brought in each year from Minnesota and Wyoming, was compared with a locally adapted strain called Local White Cap. Five year average results were as follows: Local White Cap (Akron) 24.3 bushels, Crookston Strain (Minnesota) 10.7 bushels, and Archer Strain (Wyoming) 12.7 bushels per acre. The two out-of-state strains of Northwestern Dent yielded appreciably less than the locally adapted strain of that variety each year.

(e) Description of Field Varieties

The descriptions of Colorado corn varieties apply to them as grown in the regions where they are adapted.

1. Minnesota 13: Probably this is the most widely grown dent variety in the state, being particularly concentrated over an area that centers in Weld County. It is a yellow dent variety that requires approximately 120 days to mature at an altitude of 5,000 feet. Various locally adapted strains exist in the state. The variety has been field selected by Raymond Condon near Platteville since 1922. The improved strains were designated as Colorado 13 in 1930. Minnesota 13 is particularly adapted to northern and eastern Colorado but is grown in other areas where climatic conditions are similar.

2. Reid Yellow Dent: Locally adapted strains of this variety are widely grown under irrigation in the Arkansas Valley. In Colorado, this variety requires about 140 days to mature, and usually is found at altitudes below 4,500 feet. It is a large yellow dent with cylindrical ears and deep, rectangular kernels. The Ezra Moore strain is widely grown in the Rocky Ford area. Many of the local dryland yellow strains trace back many years to Reid Yellow Dent.
3. Iowa Silvermine: This variety is adapted to about the same conditions as Reid Yellow Dent. It is a white dent corn that has been grown and improved by J. G. Bion near Pueblo for a number of years. This strain is the most widely grown white corn in southern Colorado. Most dryland white strains also trace back many years to this variety.

4. Logan County White: This variety is a white dent corn grown to some extent in northeastern Colorado, both under irrigated and dryland conditions. It is an adapted selection of either Iowa Silvermine or Rustler White Dent with about the same climatic requirements as Minnesota 13. George Hoffman, a farmer near Iliff, developed the variety.

5. Akron White: This variety originated at the Akron Field Station as a selection from Swadley Dent made in 1917 by Coffman (1925). It is adapted to eastern Colorado dryland conditions. Akron White has been described as being 5.5 to 7.0 feet in height, with medium to small ears. The kernels are white-capped yellow, medium to shallow in depth, and dimple-dented. It requires from 120 to 130 days to mature. Being rated commercially as mixed, and sometimes as Swadley, it has never met with much enthusiasm on the part of growers.

6. Akron Yellow: This variety was also developed at the Akron Field Station from a selection made in 1917 from a local field of yellow dent corn. It yields as well or better than other yellow dent strains tested at Akron.

7. Crawford Yellow Dent: This is a midseason type that has been grown to some extent in the Delta region where the frost-free season is longer than 120 days. It is a medium, rough, yellow dent with large kernels as grown in this area. Recently, it has met with some favor in the Platte Valley in the vicinity of Fort Morgan.

8. Other Dent Varieties: Many other named field varieties are grown in Colorado, various strains being adapted to local areas. Pride of the North, a yellow dent variety, is occasionally grown under short-season conditions. Several dent varieties with more or less red kernels are grown under dryland conditions, but their spread is limited by the market prejudice against colored kernels. These are Bloody Butcher (deep red kernels), Northwestern Dent (yellow-capped red kernels), and Jalisco (variegated kernels).

9. Flint Corn Varieties: Flint corns as grown in Colorado are extremely early sorts, the best known variety being White Australian Flint. The stalks are generally very short, i.e., 3.5 to 6.0 feet in height with numerous suckers, their long and slender ears being borne very close to the soil surface. It can be grown at higher altitudes than most varieties. Gahnu Yellow Flint, also very early, is sometimes grown in the lower foothills in northern Colorado. It is practically necessary to grind flint corn to obtain the most economical use as feed.

10. Flour Corn Varieties: Blue Flour Corn is occasionally grown under dryland conditions, being extremely early in maturity. It is also very reliable, being rated by some as the most drought-resistant strain among corn varieties. Its growth characteristics are very similar to those of White Australian Flint. The cobs are white, while the kernels are blue with rather soft texture. Types with bluish-black kernels are sometimes called Squaw corn. This term is loosely applied by many to include both flint and flour corns.

VII. Crop Rotations for Corn

Crop rotation studies conducted under dryland conditions have been reported
by Brandon (1925) for a long period of years. The practices followed by corn under irrigation have been determined by general experience.

(a) Dryland Rotation Experiments

Dryland experiments at Akron indicate that the highest yields were obtained from corn after fallow, the 30-year average being 17.5 bushels per acre. The next highest yields were obtained from plots planted continuously to corn (corn after corn), but commercially the practice must be avoided when rootworms, insect pests, or diseases become serious. From crop sequence studies with small grains, corn appears to follow either oats or barley better than spring or winter wheat. The results with different sequences are presented in Table 9.

Table 9. Average Acre Yields for Corn for Different Crop Sequences under Dryland Conditions at Akron, 1903 to 1938.

<table>
<thead>
<tr>
<th>Previous Crop or Condition</th>
<th>Fall Plowed (Bu.)</th>
<th>Spring Plowed (Bu.)</th>
<th>Average (Bu.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oats</td>
<td>10.5</td>
<td>10.5</td>
<td>10.5</td>
</tr>
<tr>
<td>Barley</td>
<td>--</td>
<td>11.0</td>
<td>11.0</td>
</tr>
<tr>
<td>Spring Wheat</td>
<td>9.3</td>
<td>9.6</td>
<td>9.6</td>
</tr>
<tr>
<td>Winter Wheat</td>
<td>9.2</td>
<td>10.2</td>
<td>9.7</td>
</tr>
<tr>
<td>Corn</td>
<td>12.6</td>
<td>13.1</td>
<td>12.8</td>
</tr>
<tr>
<td>Fallow</td>
<td>--</td>
<td>17.5</td>
<td>17.5</td>
</tr>
</tbody>
</table>

For a simple rotation, alternation of corn and a small grain has been practiced successfully on many dryland farms. However, experience in the drought periods indicates that a rotation of fallow, winter wheat, corn, and barley has been practiced by many dryland farmers. This rotation may be modified by the substitution of row-produced feed crops, such as forage or dual-purpose sorghums for a part of the corn in the third year or even the barley in the fifth year.

(b) Irrigated Rotations

Under irrigation, the highest yields of corn have been obtained when it follows alfalfa, sweet clover, or some cultivated crop like sugar beets or potatoes. Farmers generally prefer to follow alfalfa with corn, this crop in turn being followed by sugar beets. Results at Fort Collins under irrigation, reported by Robertson and others (1930), indicate that it is hazardous to plant corn after corn because of possible injury by the Colorado corn rootworm. A 5-year rotation that may be followed is: Alfalfa, alfalfa, corn, sugar beets, and barley seeded to alfalfa.

VIII. Seedbed Preparation

The type of seedbed preparation depends upon the soil, the amount of precipitation (or irrigation), the previous crop on the land, susceptibility to wind erosion, and the method of planting.

(a) Lister for Seedbed Preparation

On small grain stubble land, weeds can be controlled by listing in the early fall immediately after the previous small grain crop has been removed. Listing stubble land may be delayed until spring so that the plant cover may be left to catch winter snows and to reduce soil blowing. Previous cultivations in the fall or spring may be necessary for weed control. A popular practice in the region is to "nose out" the old lister furrows in the spring and plant in them. It is inadvisable to split the ridges of early fall or
spring listed stubble land being planted to corn. Corn at Akron has yielded low when this practice has been followed, as indicated in table 10. This method is also condemned at most other dryland experiment stations.

Table 10. Different Methods of Listing vs. Spring Moldboard Plowing of Barley Land at Akron, 1933 to 1938.

<table>
<thead>
<tr>
<th>Treatment of Barley Stubble Land</th>
<th>Avg. Yield Corn per Acre (bu.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early spring listed; ridges split</td>
<td>4.15</td>
</tr>
<tr>
<td>Early spring listed; furrows &quot;nosed out&quot;</td>
<td>7.62</td>
</tr>
<tr>
<td>Spring plowed; surface planted</td>
<td>4.35</td>
</tr>
</tbody>
</table>

Corn stubble land may be listed to leave the soil in a roughened condition to prevent wind erosion, as well as to catch snow. During 11 years of the period from 1909 to 1923, Brandon (1925) reported that the fall-listed land produced 2.5 bushels more per acre than the spring-listed land. Listing is regarded as the most economical method for the preparation of harvested row-crop land for corn. Comparative results are given in table 11.

Table 11. Different Methods of Seedbed Preparation for Corn at Akron, 1909 to 1938.

<table>
<thead>
<tr>
<th>Previous Treatment</th>
<th>Average Yield per Acre (bu.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1909 to 1933</td>
<td>1911 to 1922</td>
</tr>
<tr>
<td>Spring plowed</td>
<td>13.1</td>
</tr>
<tr>
<td>Fall plowed</td>
<td>12.6</td>
</tr>
<tr>
<td>Sub-soiled</td>
<td>11.4</td>
</tr>
<tr>
<td>Listed</td>
<td>12.1</td>
</tr>
<tr>
<td>Spring listed and seeded</td>
<td>--</td>
</tr>
<tr>
<td>Fall listed and &quot;nosed out&quot;</td>
<td>--</td>
</tr>
</tbody>
</table>

(b) Moldboard Plow for Seedbed Preparation

From table 10, it is apparent that plowing as a method of seedbed preparation for plains small grain stubble land for corn is less satisfactory than the better listing method. The results obtained at Akron with continuous corn indicate little difference for fall over spring plowing. The results in table 11 indicate that the 30-year average yield was 12.6 bushels per acre for fall and 13.1 bushels for spring-plowed land. Plowing as a seedbed preparation resulted in only a slight yield increase over listing which averaged 12.1 bushels per acre over the same 30 years. The lower cost of listing, as compared to plowing, makes it the preferable method of seedbed preparation for dryland conditions even where corn follows corn.

Altho experimental results are unavailable, the general experience on irrigated lands indicates that it is unnecessary to plow as a preparation for corn grown after clean cultivated crops such as sugar beets or potatoes. Often the land is merely disked and harrowed to place it in condition to plant. Where corn follows crops like alfalfa, sweet clover, or pastures, the land must be plowed. The field may be fall-plowed and left over winter in a roughened condition to catch snow as well as to prevent wind erosion. Alfalfa may be crowned in the fall, i.e., plowed 3 or 4 inches deep, then re-plowed to a depth of 7 or 8 inches in the spring to insure that the plants are completely killed. Good results have been obtained with one plowing in the fall or spring to a depth of 7 or 8 inches.
IX. Seeding Practices

Two general methods of planting corn are followed in Colorado, surface planting and listing. The rates depend upon moisture supply, while dates are influenced by the average time of the last spring frost which varies in different parts of the state. In the drylands the seeding should be late, but still early enough to escape fall frosts.

(a) Methods of Planting

Corn is either surface-planted or listed in Colorado. Listing is adapted to all types of soils under dryland conditions. Some of the advantages of the lister are: (1) It can be made to cover large acreages adequately in a comparatively short period of time, and (2) the seed is planted in moist soil. (3) Another reason commonly given is that spring growth of listed corn is slower than that of surface-planted corn. This tends to reduce the amount of succulent growth that may be severely injured by early drought. (4) Another advantage claimed by farmers, which is verified by recent experimental results, is that lister-planted corn withstands drought better on stubble lands. (5) Furthermore, greater protection from late spring frosts generally has been observed for corn planted in furrows. However, listed corn may be greatly retarded by cold, wet weather, but apparently not seriously. A common practice with the lister is to drop the subsoiler to the depth it is desired to plant, the seed being covered by the trailer wheels and a section of heavy chain.

Under irrigation, a large part of the corn acreage is surface-planted. This permits better germination and more rapid growth in the early part of the season because the conditions for growth are more favorable near the surface than at the bottom of lister furrows.

Corn may also be planted in hills (checked) so that it can be cultivated at right angles, or it may be drilled in the row. In Colorado, corn is generally drilled in the row whether surface-planted or listed. In either case, the seed should be planted deep enough to place it in moist soil to insure immediate germination. A depth of 2 to 4 inches is generally sufficient.

(b) Dates for Planting

The time to plant corn varies with the season and locality. The season becomes progressively shorter from the southern to the northern part of the state, as well as from the eastern boundary to the foothills. Under average conditions, corn is usually planted in Colorado sometime between May 1 and 25, although it may be planted as early as April 20 in the Arkansas Valley and in areas of similar conditions. It is usually advisable to seed at about the same average spring date and risk a light frost rather than plant late with the subsequent risk of frost injury to immature corn in the fall.

Under northern Colorado irrigated conditions at Fort Collins, Robertson and others (1930) planted corn at 10-day intervals from April 20 to June 10 with the results shown in Table 12.

Table 12. Relation of Date of Planting Yield and Quality of Corn at Fort Collins, 1923 to 1929.

<table>
<thead>
<tr>
<th>Date Planted</th>
<th>Av. Yield Shelled Corn per Acre (Bu.)</th>
<th>Bushel Wt. (lbs.)</th>
<th>U.S. Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 20</td>
<td>53.3</td>
<td>57.5</td>
<td>1</td>
</tr>
<tr>
<td>May 1</td>
<td>51.3</td>
<td>56.3</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>49.2</td>
<td>55.2</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>45.7</td>
<td>54.0</td>
<td>2</td>
</tr>
<tr>
<td>30</td>
<td>41.2</td>
<td>51.6</td>
<td>3</td>
</tr>
<tr>
<td>June 10</td>
<td>30.9</td>
<td>45.4</td>
<td>6</td>
</tr>
</tbody>
</table>
In these experiments, which were conducted 5 years, there was little difference in yield for dates between April 20 and May 10. However, there has been little to gain when corn was planted as early as April 20 due to the fact that it usually emerged about the same time as that planted May 1. Corn was not killed by frost, even when planted as early as April 20, in a single year from 1921 to 1929. The yields decreased rapidly for planting dates after May 20.

Corn has been planted at the Akron Field Station from April 20 to June 20. The 8-year average yields, for the period 1931 to 1938, were as follows: April 20, 6.7 bushels; May 5, 10.7 bushels; May 20, 13.0 bushels; June 5, 15.0 bushels; and June 20, 10.8 bushels per acre. The results indicate that May 20 is a satisfactory time to plant corn in that vicinity. Since the corn was seeded with a lister, that planted earlier often gave poor stands due to cold soil together with other unfavorable conditions for germination. It is dangerous to plant corn in this region much after June 1.

(c) Seeding Rates

It is sometimes difficult to obtain the desired stand of corn due to the many factors beyond the control of the grower. The rate of planting varies with the variety, soil fertility, and soil moisture likely to be available. A small early variety may be planted at a thicker rate than a large late one, while higher rates can be used on fertile soils with plenty of moisture available throughout the growing season. It is the general practice to plant corn more thickly under irrigation than under dryland conditions.

Most of the corn under irrigation is surface-drilled in 36 or 42-inch rows, although some corn is planted in hills (checked). Tests were made at Fort Collins by Leonard and Robertson (1935) to determine the best rate on highly fertile land with good water rights. Two varieties were planted in 42-inch rows with the hills spaced 36 inches apart in the row. For grain yields, the data in table 13 indicate that 4 or 5 plants per hill result in significantly higher yields than the customary 3-plant rate used in much of the Cornbelt. Incidentally, some earlier work on the experiment station between 1894 and 1898 showed that 5 plants per hill resulted in the highest grain yields (Cooke, 1900).

Table 13. Average Yields for Corn Planted in Hills at Fort Collins, 1931 to 1933.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Plants per Hill (No.)</th>
<th>Average Air-Dry Bushels</th>
<th>Yields per Acre Pounds Fodder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pride of the North</td>
<td>3</td>
<td>76.6</td>
<td>7299</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>87.0</td>
<td>8546</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>90.1</td>
<td>8641</td>
</tr>
<tr>
<td>Golden Glow</td>
<td>3</td>
<td>80.7</td>
<td>7975</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>86.8</td>
<td>8620</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>83.0</td>
<td>8376</td>
</tr>
</tbody>
</table>

Difference for Significance (5 percent point) 6.5 878

Drill-planted corn was found to give the highest grain and fodder yields when the plants were 6 to 9 inches apart in the row. So long as the same number of plants is obtained per acre, it appears to make little difference whether corn is drilled or planted in hills. In further tests, Leonard and Clark (1935) found the seeding rate to influence the protein content of shelled
corn, the thinner rates resulting in the highest percentage. However, it is impractical to plant corn at 3 plants per hill or drill it so that they would be 12 inches apart in the row to increase the amount of protein because such an increase would be obtained at the expense of yield per acre. The amount of seed required to plant an acre of corn under irrigation varies from 8 to 10 pounds.

Due to the normal shortage of moisture, fewer plants per unit area under dryland conditions will result in maximum yields. Brandon (1937) conducted an experiment at Akron over a 12-year period from 1924 to 1935 to determine the response of corn to different spacings. The corn was thinned to 12, 18, 24, 30, and 36 inches between plants in 1/4-inch rows, and 12 inches in 8-inch rows so far as possible. The yields are given in table 14.

Table 14. Average Corn Yields for Different Spacings under Dryland Conditions at Akron, 1924-1935.

<table>
<thead>
<tr>
<th>Planned Spacing (In.)</th>
<th>Distance between Rows (In.)</th>
<th>Grain Yields per Acre (Bu.)</th>
<th>Stover Yields per Acre (Lbs.)</th>
<th>Fodder Yields (Lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>44</td>
<td>12.5</td>
<td>2160</td>
<td>3038</td>
</tr>
<tr>
<td>18</td>
<td>44</td>
<td>12.5</td>
<td>2038</td>
<td>2916</td>
</tr>
<tr>
<td>24</td>
<td>44</td>
<td>13.3</td>
<td>1794</td>
<td>2723</td>
</tr>
<tr>
<td>30</td>
<td>44</td>
<td>13.1</td>
<td>1523</td>
<td>2437</td>
</tr>
<tr>
<td>36</td>
<td>44</td>
<td>12.3</td>
<td>1405</td>
<td>2265</td>
</tr>
<tr>
<td>12</td>
<td>88</td>
<td>9.2</td>
<td>1190</td>
<td>1831</td>
</tr>
</tbody>
</table>

1/ Grain and stover.

The highest 12-year average yield was 13.3 bushels per acre for the plants spaced 24 inches apart in 1/4-inch rows. This spacing is advocated for dryland conditions similar to those at Akron for grain production. It is advisable to have corn thinner rather than thicker, because the 30-inch spacing produced more than the 18-inch spacing. The double-spaced or 32-inch row method failed to produce the highest grain yield in a single one of the 10 years when grain was produced. It is no more certain in dry years than the 36-inch spacing in the customary 1/4-inch rows. The yield was 28 percent less than the average for the 5 spacings in the 1/4-inch rows. Plants spaced from 12 to 18 inches apart in 1/4-inch rows is advised for silage production in the locality. It has been estimated that 5 pounds of seed per acre will be enough to plant one kernel every 24 inches in 42-inch rows.

X: Cultivation

Inter-tillage is primarily for weed control. An additional advantage of cultivation on the drylands is that it may leave the soil in a loosened, flocculent condition to take up rainfall readily. The type of tillage implement is dependent upon whether corn is surface-planted or listed. The first cultivation of surface-planted corn can be made with the spike tooth harrow. This is an effective way to kill small weeds, either before the corn comes up, or after the plants are 3 or 4 inches high. Later cultivations may be made with the ordinary 4 or 6-shovel cultivator. Tillage should be deep enough to kill weeds, but not so deep as to prune the corn roots. Two or 3 cultivations are generally sufficient for weed control. The harrow may be used also for the first cultivation of listed corn, after which the disk-type lister cultivator is suitable. In the first cultivation, the soil is generally thrown away from the plants. When the corn is cultivated
the second time, the soil is thrown towards the plants. Later cultivations are generally made with the shovel-type cultivator. Sled-knife weeder are commonly used on listen-planted corn on the more sandy soils because they induce less soil blowing.

XII. Irrigation

Corn is generally irrigated by the furrow method, water being run slowly down the furrows between the rows. When only one irrigation is possible, the maximum grain yield will generally be obtained when water is applied at the tasseling stage. This is sometimes called the critical period of irrigation. It has been observed that dry conditions at the tasseling stage tend to hasten pollen shedding but delay the emergence of silks. Thus, the pollen may be shed before all the silks are fertilized. Later rain or irrigation will not repair the damage done at this stage. Under dryland conditions, moisture shortage at this stage may be disastrous.

General experience in Colorado indicates that 2 irrigations are usually sufficient to produce a corn crop, although may be necessary on the more sandy soils. This observation was made by Huntley (1934) in the 1930's, who also stated that irrigation can be withheld until the tassels begin to appear so long as growth has not been retarded. Corn is very sensitive to over-irrigation, a condition readily detected by a yellow appearance of the plants. The first irrigation is generally applied when the plants begin to joint, generally between June 20 and 30, while the second is made when the plants begin to tassel. Adapted corn in Colorado generally tassels between July 20 and 30. Emergency conditions may require irrigation at other times. Corn needs water when the leaves roll during the day and fail to unroll by the next morning. Growth has practically ceased under such conditions. Application of water late in the season is inadvisable as it may delay crop maturity. In northern Colorado the general practice has been to withhold water after August 15.

XII. Methods of Harvest

The general methods of harvest for corn in Colorado are: (1) cutting for silage, (2) cutting for fodder, and (3) husking the ears from the stalks in the field.

(a) Silage

Corn for silage should be cut when the ears are in the glazed stage. At that time, the husks are usually brown while the leaves are still green. Immature corn may be used for silage, but it is apt to be rather acid (Osland, 1931). Dry corn fodder has been ensiled successfully where plenty of water has been added. Corn for silage is cut with a corn binder, being hauled directly to the silage cutter. This applies particularly to farms with upright silos. The most efficient machine is probably the combination cutter-harvester which harvests the stalks and cuts them into silage lengths in the field. The chopped material is delivered into a wagon, truck, or header- barge as the cutter moves down the row. These loads of silage may be delivered either to a trench or a pit silo or to a blower for an upright silo. After the trench is filled, a 2-foot layer of straw is usually placed over the silage together with 10 to 15 inches of soil to seal it for later use. For storage over a number of years the trench cover should be kept up to the ground level.

(b) Fodder

Corn is generally cut for fodder when the bottom leaves become dry.
This is shortly after the ears have reached the glazed stage. Fodder corn may be harvested by a binder or by a sled-cutter with heavy knives set at an angle on the front edge, as described by Kezer and Ray (1919). Colorado experiments indicate that corn shocked and cured in the field losses from 25 to 35 percent of its value by loss of leaves, etc. One report by Cooke and Watrous (1895) indicated that the losses in dry matter were 31 percent for fodder placed in large shocks, 43 percent for small shocks, and 55 percent where the plants were left on the ground. Many farmers in northern Colorado cut or shred corn fodder or stover before it is used for feed in order to reduce the amount of waste. This may be done with a shredder, hammer-mill, or silage cutter. Portable grinders that are taken from farm to farm are available in some localities.

(c) Grain
In the case of corn husked for grain, the common practice is to allow it to stand in the field until thoroughly dried out. This is usually 2 to 3 weeks after growth has ceased, i.e., the plants either dried up or killed by frost. This is generally sometime after October 15. High moisture in the ears makes the corn difficult to husk and may also cause it to heat in storage. Small fields are husked by hand, while some growers with large acreages favor the mechanical corn pickers which are available in 1-, 2-, and 3-row sizes.

XIII. Diseases and Insect Pests

The most common corn diseases are smut and possibly seedling blight. The Colorado Corn Root Worm may be troublesome under some conditions. Grasshoppers are often troublesome pests in dryland areas.

(a) Corn Smut
The most serious corn disease in Colorado is smut (Ustilago zeea). In fact, the greatest losses from corn smut in the country occur in the semiarid portion of the Great Plains. Galls caused by this disease develop on any of the above-ground parts of the plant and may become several inches in diameter. In the earlier stages the galls are white or gray, but become black as the season advances. When mature, they rupture to release a dense powdery mass of black spores. Studies made in Colorado by Coffman and others (1926) indicate that the prevalence of smut is influenced by environmental conditions. Some data on smut in relation to seasonal conditions are given in Table 15.

Table 15. Smut Infection Percentages and Precipitation and Temperature Records at Akron, 1920 to 1923.

<table>
<thead>
<tr>
<th>Year Observed</th>
<th>No. plants</th>
<th>Precipitation (Inches)</th>
<th>Mean Temperature (Degrees F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plants</td>
<td>May</td>
<td>June</td>
</tr>
<tr>
<td>1920</td>
<td>12,461</td>
<td>1.78</td>
<td>4.39</td>
</tr>
<tr>
<td>1921</td>
<td>16,754</td>
<td>25.50</td>
<td>0.50</td>
</tr>
<tr>
<td>1922</td>
<td>17,645</td>
<td>13.54</td>
<td>3.52</td>
</tr>
<tr>
<td>1923</td>
<td>8,477</td>
<td>4.24</td>
<td>4.94</td>
</tr>
</tbody>
</table>

The percentages of smut were found to vary in different years, but the greatest amount occurred in dry seasons. Scant precipitation in May and June, followed by moderate rainfall and comparatively high temperatures, seemed to favor the disease. A rather heavy precipitation in the early part of the season followed by scant rainfall and low temperatures in the
later summer was not conducive to heavy infection. Since the spores live over from one year to another in the soil, control by seed treatment is impossible. There is no satisfactory control for the disease. Adapted varieties in general tend to be more resistant than unadapted sorts, but no highly resistant field varieties are available at the present time.

(b) Seedling Blight

Recently, there has been some indication that ear-rot organisms on the seed may reduce field stands in the early spring due to seedling blight. Some of these organisms also may be soil-borne. In many instances, demonstrations on farms in various counties of the state have indicated that improved stands and, as a consequence, increased yields may be expected as a result of seedling blight control by seed treatment with organic mercury compounds. The results of 23 farm tests by the Extension Service in 1937 indicate an average increase in stand of 20 percent, while the same number of tests in 1938 showed an average stand increase of 16 percent. Experiment Station results with seed treatment have been negative where corn was planted at the proper time. Corn growers may find it desirable to treat their seed as a precautionary measure. The organic mercury dusts, such as New Improved Semesan Jr., are usually applied to the seed in a barrel mixer at the rate of 2 ounces per bushel.

(c) Colorado Corn Root Worm

The Colorado Corn Root Worm (Diabrotica virgifera) may be a serious pest, particularly under irrigation, where corn follows corn on the same field. This worm is a small white larva about one-half inch long when full grown. It feeds on the roots and may practically destroy them. Corn infested by this pest is very likely to lodge badly. Insect damage was found by Robertson and others (1930) to increase as the date of planting was delayed. This insect can be controlled by crop rotation where corn does not appear on the same land more than one year in succession in corn root-worm-infested soil.

(d) Miscellaneous Insect Pests

Cutworms often destroy stands of early planted corn in the dryland areas. The worms are troublesome for only about 10 days. The best method to combat this pest, when it appears all over a field, is to replant after about 10 days or reserve the land for sorghums, beans, or prose. Small areas can be controlled by poison bran mash.

Grasshoppers sometimes cause serious damage to young corn plants on the drylands. Poison bran mash and mechanical killers are the only control measures after the hoppers have hatched.

XIV. Corn Improvement

Field selection is regarded as the most effective method for the improvement of an open-pollinated variety. Tests in other states indicate that the ear-to-row method, widely practiced a few years ago, has failed to increase yields when applied over a period of years. Recently, the production of hybrids by crosses among inbred lines has resulted in improved corn yields.

(a) Field Selection

Selection of mature ears, together with their removal from the field before frost, is the most important reason for field selection. It allows the grower to select seed from plants at the time corn should mature for the locality. Field selections are usually made on the average date of the first fall frost, which varies from September 15 to 30 in most Colorado corn regions. It is well known that corn is extremely heterozygous, that is, there may be all ranges of maturity represented in an ordinary field. Some plants are too early while others may be too late for the locality. The grower usually selects ears that mature at the proper time on vigorous plants free from suckers. He should disregard fine score-card points for the individual ears since close
selection tends broadly to inbreed the variety with consequent reduction in yield. Mature ears in the field commonly contain 30 to 40 percent moisture. They should be laid out to dry so as not to touch each other. The moisture content should be reduced to less than 15 percent before they are exposed to freezing temperatures.

(b) Hybrids among Inbred Lines

Hybrid corn should be defined as the first generation cross between strains that involve inbred lines, i.e., true-breeding lines developed by several successive generations of self-pollination. The hybrid method of seed corn production consists essentially in (1) the isolation of self-fertilization and selection of lines that breed more or less true for certain characters, (2) the determination of the most productive inbred lines, and (3) the utilization of these selfed lines in crosses or hybrids. A single cross involves a cross of two inbred lines, for example, \( A \times B \). The single cross is not widely used commercially because the seed yield is low and the seed small. The 3-way cross is made from an \( F_1 \) single cross and an inbred line, i.e., \( (A \times B) \times C \). The double cross is a cross between two \( F_1 \) single crosses, for example, \( (A \times B) \times (C \times D) \). The commercial field corn hybrids now in production in Colorado are double crosses.

Under experimental conditions, crosses are made by hand pollination methods. For commercial production, the strains may be grown in alternate blocks in an isolated plot. All of the plants on which seed is to be produced are dottaselled before they shed any pollen. In these cross-pollination plots the parent which furnishes the pollen is called the male parent, while the one dottaselled is called the female parent. The ratio of male to female rows depends upon the cross to be made, particularly on the abundance of pollen produced by the male parent. Inbred lines are usually low pollen producers. When they are used to supply pollen, 1 row of the male parent is generally planted to every 2 rows of the female parent. When single crossed plants supply the pollen, 1 row of male parent to 4 rows of female parent is satisfactory.

The use of corn hybrids allows the growers to utilize the hybrid vigor of the first generation (\( F_1 \)). Seed saved from a hybrid corn crop will result in loss in vigor in the next crop. This loss may reduce the yield to as little as two-thirds that of an adapted field variety. The grower must produce or purchase new hybrid seed each year.
Questions for Discussion

1. About what acreage of corn is produced in Colorado each year? What production? What percentage is produced on the drylands?
2. Describe the maize plant botanically.
3. Distinguish between the field corn species grown in Colorado.
4. How long may seed corn remain viable in the state? Under what conditions?
5. Discuss bushel weight as an index of maturity in corn.
6. What climatic factors are found for corn production in Colorado?
7. Why are "semi-hard" lands more suitable for corn than the "hard" lands?
8. Explain the relation of corn type to climatic conditions.
9. Is it advisable to "change seed" every few years? Why?
10. What varieties are best adapted to northern Colorado irrigated conditions? Eastern Colorado dryland conditions?
11. Name hybrids for different parts of the state.
12. What is the significance of variety names?
13. Describe these field varieties: Minnesota 13, Reid Yellow Dent, Iowa Silvermine, Logan County White, Crawford Yellow Dent.
14. Distinguish between these varieties: Bloody Butcher, Northwestern Dent, Calico, Blue Flour, and Squaw Corn.
15. Give a corn rotation for dryland conditions. Irrigated conditions.
16. Describe the use of the lister for seedbed preparation on small grain stubble. On corn stubble.
17. Under what conditions is the moldboard plow recommended for seedbed preparation?
18. What are the advantages of the lister in dryland planting of corn?
19. Give the dates of planting for Akron and Fort Collins conditions.
20. What rates of seeding corn give the highest yields at Fort Collins? At Akron?
21. Should corn be planted in hills or in drills? Why?
22. Are 33-inch rows advisable on the drylands? Why?
23. Describe cultivation procedures for listed corn.

24. Why is the tasseling stage regarded as the critical period for the irrigation of corn?
25. Describe irrigation practices for corn in Colorado.
26. Explain when and how corn is harvested for silage in the state.
27. Under what conditions may fodder corn losses be heavy?
28. When is corn husked for grain? Why?
29. Describe corn smut. When is it most prevalent?
30. What is seedling blight? How controlled?
31. Describe the Colorado Corn Root Worm and give control measures.
32. Explain how to improve a field variety of corn.
33. What is a corn hybrid? Describe the different kinds.
34. What are the essential steps in the hybrid corn method of seed production?
35. Explain how to make corn crosses under commercial conditions.
36. Can a grower save seed out of a hybrid crop? Why?
References

FIELD CROPS IN COLORADO

Chapter 10. Sorghums

I. Economic Importance

Sorghums have increased in favor in Colorado in recent years due to the introduction of improved varieties and because of their drought-resistant properties. The principal uses of sorghums in the state are for grain, fodder, and brooms. Some Sudan grass is grown both for hay and pasture.

Grain sorghums for all purposes, as an average for the 10-year period from 1928 to 1937, were grown on 226,628 acres with a production of 1,776,400 bushels each year. The average acre yield for the period was 9.3 bushels. In 1938, a total of 421,000 acres were harvested on which 4,677,000 bushels were produced. This is the largest state production since 1920. The counties that led in acreage were: Baca, Kit Carson, Yuma, Kiowa, and Washington.

Sweet sorghums or sorgos were grown for feed on 139,933 acres with a production of 112,600 tons as an annual average for the 10-year period from 1928 to 1937. The average yearly acre yield for this period was 0.9 ton. During 1938, there were 280,120 harvested acres with a total production of 288,455 tons. The important counties from the acreage standpoint were: Washington, Yuma, Kit Carson, Cheyenne, and Kiowa.

Practically all the broomcorn grown in Colorado is produced in Baca county. As a 10-year average for the period from 1928 to 1937, there were 52,000 acres harvested with a production of 5,570 tons, or an average acre yield of 206 pounds. Only 32,000 acres were harvested in 1938.

II. Botanical Description

The sorghums are classified in the grass tribe Andropogoneae in which the spikelets are borne in pairs, one sessile and the other pedicellate. The genus Sorghum has the spikelets in pairs, one sessile and fertile, and the other pedicellate, sterile, usually staminate, the terminal sessile spikelet with two pedicellate spikelets. The sorghums are tall, robust grasses with flat leaf blades and terminal panicles.

(a) Inflorescence

The inflorescence of sorghums is described by Vinall and associates (1936) as a panicle of varying size and density with many primary branches borne on a hairy axis. The spikelets are ellipsoidal, and usually somewhat compressed dorsiventrally. The sessile spikelets are perfect and usually fertile, but the pedicellate are sterile or staminate. The fertile spikelet has 3 thick, leathery glumes within which are two florets, the lower being sterile and the upper fertile. The lemma and palea are thin and translucent. The lemma may be either awned or awnless.

(b) Vegetative Part

The sorghum plant is a coarse annual with culms 2 to 15 feet and
sometimes more in height. The culms consist of a hard cortical layer filled with pith. They are made up of 7 to 18 or more internodes. The surface of the culms, sheaths, and leaves is glaucous. The leaf blades are glabrous with a glossy or waxy surface, altho some hairs occur on the upper surface. The roots are similar to those of corn, but finer and more fibrous.

III. Classification into Groups

The sorghums grown in Colorado are annuals which are classified in the botanical species, Sorghum vulgare. Sorghums may be divided into four more or less distinct agronomic groups which overlap to some extent due to numerous hybrids between them.

(a) Sorgo

These sorghums, so-called saccharine sorghums, are used in this state for forage. Martin and Stephens (1940) describe sorgos as having sweet juicy stems. The seeds usually are smaller than grain sorghums, and often unpalatable because of their bitter taste. The sorgos usually produce lower seed yields because of the smaller seeds and heads, and the thicker rate of planting.

(b) Grain Sorghums

These are sometimes called non-saccharine sorghums, altho Hegari and the kafirs have somewhat juicy stalks. The grain sorghums have comparatively large seeds that thresh free from the glumes. The juicy ones generally produce palatable stover. Many of the older well-known varieties found in the state can be grouped as kafir, milo, feterito, and hegari. Some others are of miscellaneous origin.

(c) Broomcorn

The principal characteristic of broomcorn is the very short rachis with extremely long branches that bear the seeds. The brush is used in the manufacture of brooms. The plant has woody stalks, dry pith, and scant foliage which makes it almost worthless for forage. The chief types in Colorado are standard and western dwarf.

(d) Grass Sorghums

The only grass sorghum grown in Colorado is Sudan grass. The stems are fine, leafy, perfectly erect, and the panicle open. The stems rarely exceed 6 mm. in diameter while the sorghums of the other groups vary from 18 to 30 mm. in diameter. For forage purposes, it should be cut in the pre-heading stage.

IV. Adaptation

Sorghums are particularly adapted to the semi-arid region because of their drought resistance. In periods unfavorable for growth, the plants have the ability to go into a more or less inactive state until suitable growth conditions again prevail. This particular property of sorghum, together with its efficient root-system, makes it one of the surest crops to grow in regions of moisture-shortage such as found in eastern Colorado.
Sorghum is primarily a warm weather crop. Brandon and associates (1938) found sorghums to be very sensitive to temperature for both germination and growth. The mean summer temperature, as well as the length of the frostless season, should be considered in the selection of sorghum varieties. The most favorable temperature for growth is about 80°F, there being very little growth at temperatures below 60°F. Cool temperatures prevent sorghums from being grown at very high altitudes, the limit in Colorado being between 5000 and 6000 feet. Only the earliest varieties will mature in the state, except possibly in the lower Arkansas Valley.

V. Sorghum Varieties

Varieties differ in time of maturity, height, juiciness of stalk, size and color of grain, leafiness, compactness of heads, and many other characters.

(a) Sorgo Variety Tests

Many sorgo varieties have been tested for yield at the Akron Field Station since 1909. Brandon and associates (1938) give the comparative yields of the principal varieties for the period from 1925 to 1937 in table 1.

Table 1. Percentage forage yields of Sorgos at Akron, 1925-37.

<table>
<thead>
<tr>
<th>Variety</th>
<th>No. Years Tested</th>
<th>Percentage Yield On Stubble Land</th>
<th>Percentage Yield On Fallow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecot Red</td>
<td>13</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Black Amber</td>
<td>13</td>
<td>98.7</td>
<td>101.2</td>
</tr>
<tr>
<td>Fremont</td>
<td>12</td>
<td>85.9</td>
<td>91.6</td>
</tr>
<tr>
<td>Minnesota Amber</td>
<td>13</td>
<td>82.7</td>
<td>78.6</td>
</tr>
<tr>
<td>Red Amber</td>
<td>13</td>
<td>77.0</td>
<td>74.9</td>
</tr>
<tr>
<td>Sudan Grass</td>
<td>11</td>
<td>40.9</td>
<td>48.9</td>
</tr>
</tbody>
</table>

Lecot Red, Black Amber, and Fremont have given good yields on stubble land. These varieties mature regularly at altitudes below 5000 feet in northeastern Colorado. Sudan grass, cut ripe in this experiment, produced about half the tonnage of the higher yielding sorgos. The increase in yield from fallow over stubble land during the 13-year period was almost one-third. When stubble land was depleted of moisture, as it was from 1930 to 1936, the yield on fallow was double that on Sudan grass stubble. For example, the average yield of Lecot Red on fallow from 1931 to 1937 was 2797 pounds, and on stubble land 5685 pounds per acre.

(b) Grain Sorghum Variety Tests

Fifty grain, dual-purpose, and combine type sorghums have been tested at Akron during the 13-year period from 1925 to 1937. Sorghums on fallow tended to mature earlier than those on stubble land because their growth is uninterrupted by lack of moisture. Brandon and others (1938) report the comparative yields of several grain sorghum varieties in Table 2.
Table 2. Percentage Grain Sorghum Yields at Akron, 1925-27.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Type</th>
<th>No. Years Grown</th>
<th>Percentage Yield On Stubble Land</th>
<th>On Fallow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highland Kafir</td>
<td>Early Dual-Purpose</td>
<td>10</td>
<td>149.4</td>
<td>155.9</td>
</tr>
<tr>
<td>Improved Coes</td>
<td></td>
<td>12</td>
<td>155.9</td>
<td>145.9</td>
</tr>
<tr>
<td>Freed</td>
<td></td>
<td>13</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Pygmy</td>
<td>Early Combine</td>
<td>5</td>
<td>114.5</td>
<td>100.7</td>
</tr>
<tr>
<td>Sooner</td>
<td></td>
<td>9</td>
<td>103.3</td>
<td>113.7</td>
</tr>
</tbody>
</table>

Highland, a white-seeded, dual-purpose variety that threshes free from the hulls, has given the highest yields on stubble land, followed closely by Improved Coes. Pygmy and Sooner are two milos that will mature at Akron, but yield considerably less than Highland. Pygmy is an extremely, short, stocky, and straight-shanked milo type that lends itself to combine-harvest. Sooner usually lodges before the grain is dry enough to harvest.

Highland and Improved Coes produced 19.1 and 16.9 bushels of grain per acre on the 2 soil preparations in a comparable 9-year period (1929-37). Field corn in the same experiment produced only 9.9 bushels per acre. Highland and Improved Coes are well adapted to the grain sorghum region of Colorado. These varieties are not combine types, since they usually lodge before the grain is dry enough to combine.

Several other grain sorghum varieties are grown in the lower Arkansas Valley. These include Dwarf Blackhull Kafir, Pink Kafir, Dwarf Hegari, Dwarf Yellow Milo, and Standard Feterita. These are generally too late for Akron conditions. Grohoma, which matures in that region, is favored by some growers for sheep pasture.

(c) Broomcorn Variety Test

Three broomcorn varieties were tested at Akron during the 8-year period from 1930 to 1937. The data are given in table 3.

Table 3. Average Broomcorn Brush Yields at Akron, 1930 to 1937.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Type</th>
<th>Average Yields of Brush On Stubble Land</th>
<th>On Fallow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Spanish</td>
<td>Standard</td>
<td>196</td>
<td>100.0</td>
</tr>
<tr>
<td>Scarborough</td>
<td>Western Dwarf</td>
<td>188</td>
<td>95.9</td>
</tr>
<tr>
<td>Dwarf Evergreen</td>
<td></td>
<td>192</td>
<td>98.0</td>
</tr>
</tbody>
</table>

Only on fallow has any variety produced an average yield that approaches the yields obtained where broomcorn is grown as a commercial crop. There were 2 failures, even on fallow, in the 8-year period. The quality of the brush generally was rather poor. Broomcorn is not adapted to the hard lands in eastern Colorado.

The important commercial varieties in Baca county are Black Spanish and Scarborough.

(d) Description of Sorghum Varieties in Colorado

The time of maturity is the chief factor that determines the adaptation
of a variety to a particular locality. Varieties most widely grown in Colorado are described by Brandon and associates (1933) or by Vinall and others (1936).

1. **Lecti Red**: A sorgo with a compact reddish head which droops slightly at the tip when ripe. The light-brown seeds usually remain enclosed in the yellowish-red glumes, which fade at the tips to a straw color. The glumes are awned, the awns being more or less deciduous. The average stalk height at Akron is 52 inches. It produces a juicy sweet leafy stalk. This variety matures at Akron.

2. **Black Amber**: A sorgo which produces a medium-long, side-lobed, jet-black head. The light-brown seeds are only slightly exposed in the awned glumes which adhere after threshing. It is taller than Lecti Red, i.e., about 60 inches in height and ripens about 4 days earlier. It produces a juicy sweet leafy stalk.

3. **Fremont**: A sorgo with a small, dark brown, compact, cylindrical head. The brown seeds thresh free from the dark-brown, awnless glumes which cover only the lower two-fifths of the seeds. It is slightly taller than Lecti Red and averages about 54 inches in height. It matures 3 or 4 days earlier than Lecti Red. Fremont produces a juicy sweet leafy stalk. It was selected at the Akron Station from some local Orange sorgo.

4. **Highland**: A dual-purpose sorghum with a rather large open head on an erect shank. The seeds thresh free from the reddish-brown glumes, which are awnless and which cover about two-fifths of the lower part of the seed. The seeds are chalky white, with small reddish-brown spots scattered sparingly over the seedcoat. The grain will mature at Akron head of average fall frosts when planted before June 10. It has an average height of 56 inches. The rather fine stalks are sturdy at the base. Highland produces a juicy leafy fine-stemmed stalk. The leaves are rather narrow. This variety originated at the Akron Field Station as a head selection from Dawn Kafir in 1920.

5. **Improved Coes**: A white-seeded, dual-purpose sorghum that produces a long, semi-compact, cylindrical head on an erect shank. The heads have in some cases attained a length of 17 inches at Akron, but the average length is about 12 inches. The seeds are completely enclosed in awned glumes, from which they thresh readily. The seeds are white with occasionally a very small red spot. The glumes of this variety are usually straw-colored. In some seasons the glumes are red. The grain matures slightly earlier than Highland. It is slightly taller. It produces a juicy, slightly sweet, leafy very fine-stemmed stalk. The leaves are relatively narrow. Improved Coes originated at the Akron Station as a selection from Hurdoc 241 in 1926.

6. **Negari**: A grain sorghum with a compact, cylindrical, white head on a straight shank. The seeds are partly enclosed in dark glumes and thresh free. The awns on the lemmas are shed at maturity. The chalky-white seeds are about the size of ordinary kafir and blotched with reddish-brown spots. Negari seeds have a brown undercoat. The average plant height at Akron is about 42 inches. It produces a leafy juicy slightly sweet stalk. The leaves are rather wide. Negari is grown widely in southeastern Colorado.

7. **Dwarf Yellow Milo**: A grain sorghum, midseason in maturity. The stems are mid-juicy to dry. The panicles are compact, oval to ellipsoid. The glumes are black to reddish brown while the kernels are exposed and salmon-yellow
in color. The lemmas are long-awned. The plants average about 48 inches in height, being dwarf in general appearance. This variety is grown in southeastern Colorado, being too late for the eastern part of the state.

8. **Standard Blackhull Kafir**: A midseason grain sorghum that averages about 56 inches in height. The stems are mid-juicy, and quite leafy. The panicles are erect, cylindrical. The glumes of this variety are black or brownish. The kernels are exposed. They are white with reddish brown to black spots. This variety matures in the southeastern part of the state but is too late for Akron conditions.

9. **Black Spanish Broomcorn**: A standard variety with dry stalks that average 95 inches tall. The panicles are erect, sometimes effuse and umbelliform but usually appressed forming a brush. The rachis is very short and the rachis branches very long. The glumes are dark-brown to black. This variety is grown in Baca county.

10. **Scarborough**: A dwarf broomcorn variety with reddish seeds. The seeds are produced near the tips of the panicle branches. This variety is grown in southeastern Colorado. It produces a very desirable type of commercial brush.

VI. **Crop Rotations**

Sorghums follow other crops readily, but care must be exercised in the selection of a crop to follow them. Sorghums are very heavy users of soil moisture because they continue growth until late in the fall. An occasional practice in the grain sorghum region is to fallow sorghum land before another crop is planted. Sorghum land in Colorado should generally be reserved for fallow or for late spring-seeded crops such as proso, beans, corn, or sorghum. Sorghum will follow sorghum and yield well, but is a poor crop to precede fall or spring-seeded small grains.

VII. **Seedbed Preparation**

Sorghums are among the most exact crops in seedbed requirements. The seedbed should be weed-free because sorghum seedlings are small, being about the same size as those of weeds which start growth at the same time.

The common method of sorghum production in Colorado is to list and plant in one operation in 42 to 44-inch rows on small grain stubble with or without previous preparation. This method is undesirable because it places the seed in cold soil.

A more satisfactory method, advised by Brandon and associates (1938), is to work the stubble or other land early in the spring about April 1. The next step is to list or cultivate the land in late April or early May, or as soon as a new crop of weeds can be destroyed. The crop is then planted with a lister in the same furrows at a later date after the soil has become warm.

VIII. **Seeding Practices**

Sorghums for hay, silage, or grain on non-irrigated lands usually are planted in rows and cultivated. Grain sorghums should be planted in rows on the drylands regardless of soil type. Akron experiments show that forage sorghum yields are about 25 percent greater from row than from drill seeding.
Some data for 9 years show the average yields to be as follows: (1) sorghums in 42-inch rows, 4387 pounds; and (2) in the 8-inch drilled rows, 3222 pounds per acre. Forage sorghums are often lister-planted on the hard lands in the bottoms of the original furrows.

(a) Dates of Planting

Sorghums require a warm soil for germination. A safe general rule is to plant sorghums at least 2 weeks after corn planting time. The earliest recommended dates in Colorado are from about May 20 in the lower altitudes of the southeast, to about May 25 in the same regions of the northeast. From these early dates, planting should be delayed about 5 days for each increase of 500 feet in elevation up until about June 3, when it should be safe to plant in any soil preparation on the Eastern Slope below 8,000 feet elevation.

Sudan grass, being earlier than the other sorghums, may be seeded later, from June 10 to 20 in the northeast and 10 to 15 days later in the southeast. For pasture, the crop should be planted at the same time as for other sorghums. Broomcorn is usually planted in June in this state, according to Martin and Washburn (1930).

(b) Rates of Seeding

Row-planted sorghums in eastern Colorado require 1 to 10 pounds of seed per acre. The rate depends upon the size and viability of the seed, stand desired, etc. Brandon and others (1938) observed that seed with a laboratory germination of 90 percent or higher, planted at the recommended dates, and treated, will produce about half as many plants as there are viable seeds. Seed with a germination of 90 percent or better will not germinate more than 55 to 60 percent under field conditions, while that with a germination of about 70 percent will give a field germination of only about 2 to 7 percent. This indicates the sensitiveness of the sorghums to cold soil.

Sorghums for grain should have a plant spacing between 3 and 12 inches. This will require from 2 to 3 pounds of seed per acre. Fallow land can stand a thicker rate of seeding than grain stubble land. For fine-stemmed forage the plants should be spaced 1 to 3 inches apart in the row, or a seed requirement of 6 to 10 pounds. Drill-sown forage sorghums on non-irrigated lands will require from 30 to 40 pounds of seed per acre.

Sudan grass drilled for hay or pasture on the drylands will require from 20 to 30 pounds of seed per acre. The rate for irrigated lands should be from about 40 to 50 pounds per acre on irrigated lands to prevent excessively coarse growth. Sudan grass seeded in rows for pasture will require from 4 to 6 pounds per acre.

Broomcorn plants should be 7 to 10 inches apart in the row under semi-arid conditions. Generally 3 to 4 pounds of seed per acre will produce a stand where the rows are 3 to 4 feet apart.

IX. Methods of Harvest

The method of harvest of sorghums depends upon the use to be made of the crop, i.e., whether for grain, forage, or brooms. Different methods are described by Brandon and others (1938).
(a) **Grain Sorghums**

Sorghums cut with a binder are ready to harvest when the seeds are fully colored. For hand-heading, the grain should be well hardened. When the crop is harvested with a combine, the grain must be hard and dry.

In Colorado the grain crop is usually bound and shocked to save the stover for feed. The heads are best removed from the bound grain, after it has dried in the shock, by means of a "cheese" knife attached to the side of the barge. The whole bundle may be run thru the ordinary small grain separator when the stalks are dry and not too coarse. Highland Kafir and Improved Coes may be threshed in this manner, provided the cylinder speed is reduced.

Often the heads are removed from the standing stalks in the field, placed in small piles, and later ricked for final drying. There is a special knife for this purpose. Some use the header for the straight-shanked grain sorghums and follow the same procedure in drying the grain. A basket attached to the header might well drop the heads in small piles.

In Colorado, the heads may be placed directly into ricks where field heading is not done until after a hard freeze. They can usually be placed in ricks after a week of drying where the header has been used. The grain should be left in the field only long enough to drive out the excess moisture because of the danger of rabbit and bird damage.

Ordinary grain sorghum varieties will not stand in the field until the grain is dry enough to keep in the bin. Special combine-type varieties should be planted by growers who expect to combine the crop. Unfortunately these are milos which are susceptible to a recently discovered weak-neck disease.

(b) **Forage Sorghums**

Row-planted forage sorghums are usually harvested with the row binder and cured in shocks in the field. Sorghums should be harvested for forage when the seeds are in the soft dough stage. When harvested much earlier, the feed is too laxative. The shocks should be set wide at the base to aid aeration as well as to give them a firm base on which to settle and shrink. The header is sometimes used, the headed forage being steady enough to dry well in small piles.

Forage sorghums intended for the silo should be left until the grain is mature. They make excellent silage under such conditions. Immature or green sorghums should not be ensiled alone because many troubles with sorghum silage have been traced to the use of an immature crop. Immature sorghum should not be harvested and cured for hay unless it can be mixed with corn or other mature sorghum when ensiled.

(c) **Sudan Grass**

Sudan grass may be mowed, or harvested with a grain binder. Where a side-delivery rake is available, the former method is to be preferred. There is danger of molds when the binder is used to tie green bundles.

Sudan grass may be mowed repeatedly in the pre-heading stage with a total yield as great or greater than when it is allowed to mature. For the 4-year period from 1933 to 1936, Brandon and others (1938) obtained an average yield of 1807 pounds of hay per acre, with an average of 2 cuttings per year. The average protein content was well above 12 percent. To secure this high percentage, it was necessary to harvest not later than the boot stage and to cure without much bleaching.
Sudan grass is an important midsummer and fall pasture on the Colorado plains. There is evidence that even pure Sudan grass may contain prussic acid poison. As a result, caution must be exercised, even when pure seed is planted. Pasture is available at Akron soon after July 1 when the crop is seeded between June 1 and 5. One acre of Sudan grass pasture is reported by some farmers to support as much livestock as 2 to 3 acres of native grasses.

(d) **Broomcorn**

Broomcorn should be harvested when the entire brush is green from the tip clear down to the knuckle. The fiber will be floppy when harvested while the lower ends are still yellow. Martin and Washburn (1930) state that the seeds are about in the milk stage when the brush is ready to harvest. In about 4 or 5 days after this stage the brush begins to get overripe. The method of harvest depends upon whether standard or dwarf varieties are grown.

Standard varieties are almost always cut. The crop is first "tabled" where the plants are 9 feet tall or over. To table broomcorn, a man walks backwards between 2 rows and breaks or bends the stalks diagonally across each other with the heads extended cut beyond the rows. The table is formed at a height of 2.5 to 3.0 feet. The heads are then cut with a special broomcorn knife and placed on the table in small piles. The brush is left on the table 24 hours or less before it is hauled to the curing shed. It takes 10 to 20 days for the brush to cure. After curing, the brush is threshed and placed in 300 to 350-pound bales. A good yield of baled brush is 200 to 300 pounds per acre under semi-arid conditions.

Dwarf broomcorn is pulled or jerked from the standing stalks instead of being cut. The brush stem breaks at the upper joint (node) of the stem. In Colorado, the brush often remains in the field for several days before it is hauled. It is generally cured in ricks, being threshed and baled afterwards. Shed curing is not practiced in this state.

X. **Prussic Acid in Sorghums**

A serious disadvantage in the use of sorghum for pasture is the danger of cyanide or prussic acid poisoning. Small amounts of sorghum eaten by cattle before it is mature may cause death within a few minutes. Martin and Stephens (1940) state that several points have been well established in regard to prussic acid. (1) The prussic acid content of sorghum decreases as the plant approaches maturity. Small plants (includes those retarded by drought) and early second growth are high in prussic acid. Most of the poison is found in the younger leaves. (2) Well-cured sorghum fodder has lost much of the prussic acid and ordinarily is safe to feed to animals. (3) Sorghum silage can be fed with safety. (4) Loss usually occurs when hungry cattle stray into a field of sorghum. The ordinary grain and forage sorghums are never safe as pasture or soiling crops in Colorado.

Some losses have been reported where cattle have been pastured on Sudan grass. Coleman and Robertson (1938) state that the amount of prussic acid (HCN) in Sudan grass may be influenced by: (1) A mechanical mixture of Sudan grass with the forage sorghums that are high in HCN, (2) the presence of sorghum x sudan hybrids, and (3) the ability of sudan grass to produce extremely high concentration of HCN. There is considerable variability in
commercial sudan grass due to cross-pollination. These workers found that
inbred lines of sudan grass have differential ability to produce HCF. Soil
and seasonal differences seem to influence the production of HCF in inbred
lines of Sudan grass.

While Sudan grass is widely used for pasture purposes, the grower is cau-
tioned to use pure seed, free from sorghum mixtures or hybrids. A further
precaution is to avoid the pasturing of second growth, stunted, or frosted
Sudan grass.

XI. Sorghum Diseases

The most prevalent sorghum diseases in the state are the kernel smuts
and weak neck.

(a) The Kernel Smuts

All varieties in Colorado, except Feterita, Hegari, and Milo, are very
susceptible. In kernel smut the individual grains in the head are at-
tacked and changed into a mass of dark-colored spores. The head itself re-
tains its shape, and these spore masses look somewhat like elongated seeds.
There are two distinct species, namely, covered kernel smut (Sphacelothea
sorghii), and loose kernel smut (S. cruenta). The covered kernel smut is
probably the most prevalent in the state. Kernel smut can be controlled by
dust fungicides such as Improved Ceresan. It is applied at the rate of one-
half ounce per bushel. In Colorado, this treatment will not insure stands
when sorghums are planted too early, but it may protect seed during periods
unfavorable for germination. Present milo hybrids, such as Sooner, Day,
Colby, and Pygmy may not have the resistance to this disease that is pos-
sessed by the old-line milos.

(b) Weak Neck

Weak Neck is a comparatively new disease in Colorado that affects cer-
tain varieties. The symptoms are similar to those caused by drought. The
panicle dies from the top towards the bottom about the time the grain reach-
es the soft dough stage. The result is shrivelled grain. Fortunately, the
Highland and Improved Ceres varieties show high resistance to the disease.
The sorgos and their derivatives are also highly resistant. Colby milo ap-
ppears to be highly susceptible. The only control at the present time is
the use of resistant varieties.

XII. Insect Pests

The midge, a small aphid-like insect, sometimes attacks the panicles of
grain sorghums. Mold sometimes develops with off-colored grain as a conse-
quency. The damage from this insect appears to be less in the open-panicled
varieties. The midge is not troublesome in most seasons in Colorado.

Grasshoppers may cause damage when present at the time sorghums emerge.
Damage from this insect is generally negligible after the plants have at-
tained a height of 3 or 4 inches.

References

Questions for Discussion

1. Why has the sorghum acreage increased in Colorado in recent years?
2. About what acreage is devoted to grain sorghums in Colorado? Sweet sorghums? Broomcorn?
3. Describe the sorghum plant botanically.
4. In a general way, distinguish between 4 agronomic groups of sorghums.
5. To what conditions are sorghums adapted?
6. Name recommended sorghum varieties for Akron conditions for grain, fodder, and for dual-purpose.
7. What results were obtained with broomcorn at Akron?
8. Briefly describe these sorghum varieties: Lecti Red, Tremont, Highland, and Improved Coes.
9. Name and describe any 5 sorghum varieties grown in the state.
10. Name and describe 2 broomcorn varieties adapted to Colorado.
11. Give some general suggestions for crop sequences with sorghums.
12. What seedbed conditions are necessary for sorghums? Why?
13. Briefly explain how stubble land may be prepared as a seedbed for sorghums.
14. Under what conditions should sorghums be planted in rows in Colorado? in drills?
15. How are sorghums ordinarily planted?
16. What general recommendations can be made on time of planting sorghums in Colorado?
17. When is Sudan grass planted? Broomcorn?
18. Explain why high germination is desirable in sorghum seed.
19. What general spacing is desirable between plants for grain sorghums? Forage sorghums? Broomcorn?
20. Explain how sorghums are usually harvested for grain in this state.
21. How are sorghums harvested for forage? At what stages?
22. How can Sudan grass be harvested to increase the protein content?
23. Explain 2 methods for the harvest of broomcorn.
24. What 4 general points have been established in regard to prussic acid in sorghums?
25. Under what conditions may sudan grass be high in prussic acid?
26. Describe kernel smut of sorghum and how it may be controlled.
FIELD CROPS IN COLORADO

Chapter 11. Wheat

I. Economic Importance

Wheat is one of the important Colorado field crops, about 20 percent of the harvested crop acreage being devoted to it. The average annual harvested acreage of all wheat for the 10-year period from 1928 to 1937 was 1,063,200 acres on which the average annual production was 13,119,600 bushels. The average yield per acre for this period was 12.0 bushels. The 1938 crop of 19,068,000 bushels was the largest since 1930.

In the 10-year period from 1928 to 1937 an average of 64 percent of the acreage of the crop was winter wheat. An average of 754,900 acres was harvested during this period on which the mean production was 9,034,000 bushels. The comparable spring wheat acreage was 308,300 acres with a production of 4,085,400 bushels.

About 70 percent of the wheat produced in the state is grown under non-irrigated conditions. Most of the dryland wheat is winter wheat since it outyields spring wheat by about 25 percent.

I. Botanical Description

Wheat is an annual grass with a spike-like inflorescence. The spike consists of 2 rows of sessile spikelets placed at each notch of the zig-zag rachis. There is a single spikelet at a rachis joint which consists usually of 2 or 3 fertile florets. The glumes are broad, and usually have a short awn or blunt apex. Each floret consists of a lemma, caryopsis and palea. The lemmas may be awnless or awned. The "seed" is a caryopsis which threshes free from the floral bracts in the varieties most widely grown in Colorado. The caryopsis has a deep suture. The color of the kernel is generally red, white or yellow. There is very little natural cross pollination in wheat.

I. Species or Races

The wheats most widely grown in Colorado are varieties of common or durum wheats. Spelt and emmer are of minor importance. These species are briefly described by Clark and Bayles (1935).

(a) Common Wheat (Triticum vulgare)

The spike or head of common wheat is usually dorsally compressed and is thus wide when seen in face view of the spikelet. The spikelets are 2 to 5-flowered, and pressed close to the rachis. The glumes are keeled only in the upper half. They are shorter than the lemmas and either glabrous or pubescent. The kernels may be soft or hard, and red or white. Both winter and spring varieties are grown in Colorado. Common wheat is a bread wheat.

(b) Durum Wheat (T. durum)

The plants of durum wheat are spring habit and tall. The peduncle is pithy, at least in the upper portion. The spikes, like those of common
wheat, are laterally compressed. The glumes are sharply keeled. All
durum varieties in Colorado are awned. The kernels are white or red and
usually rather long and pointed. They are very hard and translucent, mak-
ing the white-kernelled forms appear amber-colored. The kernels are the
hardest of all known wheats. Durum wheat is used in the manufacture of
semolina, macaroni, and spaghetti.

(c) Other Wheat Species

Spelt may be either winter or spring habit and awnless or awned. It
has a long, narrow, lax spike and a brittle rachis. The spikelets are
2 kernelled. The kernels remain enclosed in the glumes after threshing.
They are pale red, long, and laterally compressed.

Emmer may be of either spring or winter habit, and usually awned.
The rachis is brittle. The spikes are very dense and laterally compressed.
There are usually 2 florets per spikelet. The kernels, which remain en-
closed in the glumes after threshing are red, long, and slender, with both
ends acute.

Emmer is distinguished from spelt by the shorter, denser spikes which
are laterally compressed. The kernel is darker red than that of spelt.

IV. Quality of the Wheat Kernel

The best quality bread wheats with hard, flinty kernels high in protein,
are produced in continental climates. In general, a prolonged ripening
period after wheat has headed, results in a plump kernel with a low protein
percentage. Hot, dry ripening periods cause wheat to ripen rapidly. The
kernels are often shrivelled, low in bushel weight, but high in protein.

Soil conditions may influence quality. Hard wheats produced under irriga-
tion may be comparatively starchy. A condition known as "yellowberry" is
often found in Colorado wheats, especially in those grown under irrigation.
Yellowberry kernels are mealy, soft, starchy in texture, and low in protein,
even in a normal hard red wheat variety. Headden (1918) studied hardness
and softness of wheats of the same variety grown on different soils and
found them to vary greatly. Soils that produced yellowberry kernels were
made to produce hard flinty kernels by the application of 250 pounds of
sodium nitrate per acre. An equal application of potassium produced the
opposite effect. He concluded that yellowberry was caused by an unfavor-
able ratio of potassium to nitrogen in the soil. Apparently, the nitrates
tended to be leached from the soil by the irrigation water. Such a condi-
tion can be corrected by fertilizer applications to maintain soil nitrogen.
Yellowberry is seldom serious under dryland conditions.

Recently Robertson and others (1939) made a study of the relation between
length of grain storage and quality. Kenred and Marquis wheats stored in
a dry room for 9 to 17 years were milled and baked in comparison with grain
from more recent crops. There was a definite increase in fat acidity with
storage, which indicated a certain amount of progressive deterioration from
age in storage. All of the samples produced satisfactory bread. There
were no indications of deterioration in baking quality in any of the
samples.
V. Germination Studies of Wheat

Vitality of wheat after storage for several years under arid conditions was studied by Robertson and Lute (1933, 1937). It was concluded that wheat stored in a dry unheated room under climatic conditions at Fort Collins may still have a high percentage of viable seed when 10 years old. The germination percentage decreased about 7.0 percent in this period. The test was extended to seed stored for 15 years. The average germination percentages for wheat 1, 5, 10 and 15 years after harvest were 100.0, 97.2, 95.0 and 80.5 respectively. There was a gradual decline in germination for the first 10 years, but a sharp break in germination between the tenth and fifteenth years. All varieties tested were similar in behavior. In a more fundamental study, Robertson and associates (1939) found that the length of life of both treated and untreated seeds in storage increased as the humidity decreased. Serious injury occurred in wheat at 100-percent saturation within 30 days. The injury decreased with decreased humidity. Only a slight loss in viability was found in some wheat samples after 1032 days (about 3 years) in storage in an atmosphere of 57.6 percent saturation.

Dormancy in wheat kernels planted at various intervals after harvest was studied by Deming and Robertson (1933). Some of their data appear in Table 1.

Table 1. Germination of Wheat Varieties Grown at Fort Collins in 1929.

<table>
<thead>
<tr>
<th>Planted Days after Harvest</th>
<th>Marquis</th>
<th>Kenred</th>
<th>Federation</th>
<th>Kubanka</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3</td>
<td>4</td>
<td>58</td>
<td>38</td>
<td>93</td>
</tr>
<tr>
<td>4-7</td>
<td>22</td>
<td>77</td>
<td>98</td>
<td>90</td>
</tr>
<tr>
<td>8-11</td>
<td>41</td>
<td>76</td>
<td>97</td>
<td>91</td>
</tr>
<tr>
<td>12-15</td>
<td>72</td>
<td>82</td>
<td>79</td>
<td>96</td>
</tr>
<tr>
<td>16-19</td>
<td>86</td>
<td>86</td>
<td>99</td>
<td>97</td>
</tr>
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<td>95</td>
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<td>24-27</td>
<td>99</td>
<td>84</td>
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<td>28-31</td>
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<td>32-35</td>
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<td>98</td>
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<td>97</td>
</tr>
<tr>
<td>36-39</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>--</td>
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<td>Normal</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>97</td>
</tr>
</tbody>
</table>

¹Germination percentage after storage for over 100 days after harvest.

Marquis showed dormancy for a 10-day period after harvest. Kanred, Federation, and Kubanka show a high germination immediately after harvest. These data agree with field observations in 1930 for Marquis and Kanred. Kanred sprouted badly in the field while Marquis showed little sprouting in the shock and none in the standing grain. Rows of Federation also sprouted badly in the field. It is thus apparent that varieties differ in their dormancy period after harvest. There is also some indication that there is a relationship between the length of the dormancy period and resistance to sprouting in the shock under unfavorable conditions (wet harvest weather).

VI. Adaptation

Wheat has a very wide range of adaptation to both climatic and soil conditions. Winter wheat varieties must be winter-hardy in Colorado. The best adapted spring wheat varieties under dryland conditions are generally those
that mature early enough to escape some of the hot summer drought. Durum
wheat is well adapted to drouthy conditions. In the non-irrigated regions, 
wheat is about equally productive on the "hard land" soils.

In the wheat production areas of Colorado the rainfall varies from 10 to 20 
inches, and the altitude from 4000 to 7000 feet. Most of the crop is pro-
duced on the eastern slope.

II. Varieties

Both winter and spring varieties are grown in the state. The Crimean types 
of winter wheat are the best adapted, while some of the Marquis hybrids are 
the most widely grown spring wheats.

(a) Variety Trials

For northern Colorado irrigated conditions, Robertson and associates 
(1933) recommended Kanred as a winter wheat. Komar has given the highest 
yields among the hard red spring wheats. Kanred produced an average yield 
of 64.4 bushels per acre for the 6-year period from 1926 to 1932. Some of 
the important spring wheat yields are given in Table 2.

Table 2. Yields of Spring Wheats in Northern Colorado, 1926-32.

<table>
<thead>
<tr>
<th>Variety</th>
<th>No. years Grown</th>
<th>Av. yield Bu. per A.</th>
<th>Ceres Percentage</th>
<th>Date Nature</th>
<th>Straw Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceres</td>
<td>7</td>
<td>44.9</td>
<td>100.0</td>
<td>7/31</td>
<td>Stiff</td>
</tr>
<tr>
<td>Komar</td>
<td>6</td>
<td>48.7</td>
<td>113.6</td>
<td>7/29</td>
<td>Medium</td>
</tr>
<tr>
<td>Marquis (no.1)</td>
<td>7</td>
<td>43.4</td>
<td>99.8</td>
<td>7/30</td>
<td>Stiff</td>
</tr>
<tr>
<td>Mindum</td>
<td>7</td>
<td>52.0</td>
<td>115.8</td>
<td>8/1</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Komar has a weaker straw than Marquis and may lodge under irrigation. It 
is also susceptible to loose smut. Mindum is a durum wheat. A comparative 
yield test of winter and spring wheats for the same period gave average 
results as follows: Kanred 61.4 and Komar 48.7 bushels per acre. Recent 
data indicates that Thatcher has yielded higher than Komar and will probably 
replace it as a hard red spring wheat under irrigation.

Winter wheat variety tests have been conducted under dryland conditions 
since 1909. Comparative yields of several winter wheat varieties grown at 
Akron are given in Table 3.

Table 3. Yields of Hard Red winter wheat at Akron, 1926-32.

<table>
<thead>
<tr>
<th>Variety</th>
<th>No. years Grown</th>
<th>Av. yield Bu. per A.</th>
<th>Kharkov Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenmarq</td>
<td>7</td>
<td>15.2</td>
<td>104.9</td>
</tr>
<tr>
<td>Kharkov</td>
<td>7</td>
<td>14.5</td>
<td>100.0</td>
</tr>
<tr>
<td>Blackbull</td>
<td>7</td>
<td>14.5</td>
<td>100.0</td>
</tr>
<tr>
<td>Kanred</td>
<td>7</td>
<td>14.3</td>
<td>98.5</td>
</tr>
</tbody>
</table>

For the period from 1926 to 1932, Kanred and Tenmarq yielded slightly 
higher than the Kharkov check. Blackbull yielded 1.5 percent more than Kan-
red over this 7-year period. This yield difference is too small to be 
significant. While Tenmarq yields well, it lacks winter hardiness of the
Crimean types at Akron. Killing and baking tests show that Blackhall has a type of protein unable to withstand the rough usage encountered in high-speed mechanical dough mixers. The quality of loaf, as compared with Kanred, is low. Some variety comparisons for spring wheat are given in Table 4.

Table 4. Yields of Spring Wheats at Akron, 1926-32.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Species</th>
<th>No. years Grown</th>
<th>Av. yield Bu per A.</th>
<th>Peliss percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akron</td>
<td>Durum</td>
<td>6</td>
<td>10.2</td>
<td>105.6</td>
</tr>
<tr>
<td>Kubanka</td>
<td>Durum</td>
<td>6</td>
<td>9.5</td>
<td>99.0</td>
</tr>
<tr>
<td>Quality</td>
<td>Common</td>
<td>6</td>
<td>11.4</td>
<td>118.0</td>
</tr>
<tr>
<td>Komar</td>
<td>Common</td>
<td>5</td>
<td>15.3</td>
<td>151.6</td>
</tr>
<tr>
<td>Ceres</td>
<td>Common</td>
<td>5</td>
<td>12.9</td>
<td>112.0</td>
</tr>
</tbody>
</table>

Komar, a hard red spring wheat, outyielded all other varieties. Recent data indicates that Reward has outyielded Komar at Akron. Akron yielded highest among the durums while Quality appeared to be the best common white wheat. Winter wheat sown as late as October 15 usually will outyield spring wheat at Akron.

Emmer was tested for yield at the Akron Station by both McMurdo (1916) and Coffman (1925). Black winter emmer produced very low yields, lacked winter hardiness, and was dropped from the variety test in 1914. Vernal spring emmer, which was often seriously injured by drought at Akron, was found to yield much less than the better varieties of barley and oats. Spelt was found to be inferior to emmer at Akron.

Under high altitude conditions at Fort Lewis, Kanred was the best winter wheat tested. Dicklow proved to be the highest yielder among the soft white spring wheats, while Komar led the hard red spring wheats in yield. Winter wheat outyielded spring wheat at Fort Lewis by about 10 percent.

(b) Description of Varieties

A total of 36 named varieties were reported by Clark and Quisenberry (1937) as grown in the state in 1934. The percentage of acreage of the most widely grown varieties was as follows: Turkey 33.5, Kanred 14.4, Marquis 12.7, Blackhall 5.8, Ceres 3.0, and Defiance 1.8. Descriptions of the important Colorado varieties are given by Kezer and others (1928), and by Robertson and others (1933).

1. **Kanred**: A hard red winter wheat. The lemmas are awned and white. The straw is rather weak. Kernels of Kanred are dark red, medium long, and hard. This wheat can be distinguished from Turkey when in head. The beaks of the glumes are from 3 to 25 mm. long, while those of Turkey are from 3 to 8 mm. long. This variety is resistant to some forms of both leaf and stem rusts.

2. **Turkey**: A hard red winter wheat that is similar to Kanred, but distinguished from it by the shorter beaks on the glumes. Turkey is slightly less winter hardy and a little later in maturity than Kanred.

3. **Marquis**: A hard red spring wheat of hybrid origin. It matures fairly early and has a stiff white straw. The glumes are white in color and have short beaks. The kernels of this variety are short, deeply creased, and dark red in color. The checks are angular. When planted late, Marquis often becomes badly infected with stem rust.
4. Komar: A hard red spring wheat of hybrid origin. This variety is awned white glumated, and with awns on the glumes 2 to 3 mm. long. The kernels are mid-long and red in color. The straw is slightly weak under irrigated conditions. The milling and baking qualities of this variety are good, but the millers object to it on account of the tendency for the kernels to crack. It is susceptible to both loose and covered smuts. Komar was produced from a hybrid between Marquis and Kota.

5. Ceres: A hard red spring wheat of hybrid origin. This variety is awned, white glumated, and has hard, red, mid-long kernels. It is distinguished from Komar by the longer awns, which are 2 to 10 mm. long. This variety originated from a Marquis x Kota cross.

6. Thatcher: A hard red spring wheat. This variety closely resembles Marquis in appearance, but the head is slightly shorter and more compact and sometimes slightly crooked. Thatcher matures 1 or 2 days earlier and is moderately resistant to stem rust. The plant has mid-tall strong stems, awnless spikes, and white glabrous glumes. The kernels are red, short, hard, and ovate. The kernels are slightly smaller than those of Marquis.

7. Defiance: A soft white spring wheat. The head is awnless with short awns on the glumes. The straw and glumes are white. The head is open, the spikelets being far apart on the rachis. This variety makes a ranker growth under favorable conditions than Marquis. It is from 10 to 14 days later in maturity than Marquis. Defiance is susceptible to both stem rust and covered smut. The kernels are similar in shape to those of Marquis, white in color.

8. Dicklow: A soft white spring wheat. The head has short awns and a clavate (club-shaped) tip. The grain is white, and the straw stiff. This variety matures late, i.e., about the same time as Defiance.

9. Akrona: A white durum wheat of spring growth habit. The stems are tall, midstrong, and white. The spike is awned, fusiform. The glumes are yellowish, while the kernels are white, long, hard, and elliptical. This variety is an early selection of Arnautka made at the Akron Field Station.

I. Crop Rotations

Winter wheat after wheat may be grown in the non-irrigated areas where rain- fall conditions are favorable, and diseases not serious. In the vicinity of Akron, wheat is often grown on the more sandy soils in alternate years with corn. In the drier regions as well as on the "hard lands", alternate wheat and fallow is necessary to insure a crop. Robertson and associates (1933) have observed that wheat, either fall or spring sown, produce poorly after sorghums. Wheat is inadvisable after beans because of the danger of wind erosion. Brandon (1925-1941) obtained a 30-year average yield of 16.3 bushels per acre for winter wheat on fallow, while it averaged 10.1 bushels on disked corn land. Spring wheat for the same period averaged 10.2 bushels on fallow, and 7.1 bushels on spring-plowed corn land.

Spring wheat is more generally grown under irrigation than winter wheat. It can be grown in rotations of alfalfa, cultivated crops, and small-grain crops. Spring wheat sometimes follows sugar beets.
IX. Seedbed Preparation

Several methods of seedbed preparation may be followed under dryland conditions. Where wheat follows corn, it may be planted with a small drill between the corn rows, or the corn cut for forage and the wheat drilled on corn stubble. Spring wheat may be planted on corn stubble that has been duck-foot or spring-tooth cultivated in the early spring. Where wheat alternates with fallow, it is essential to keep a small cloddy surface on the fallow land. The ground may be lister immediately after the crop has been removed, or in the spring about June 1. When the weeds commence growth in the spring the lister is used to break the ridges. The ridges may be broken down with the duckfoot cultivator. This implement leaves the surface soil slightly ridged and in a cloddy condition.

Under irrigation, land for spring wheat should be fall-plowed where soil moisture conditions are good. The land should be spring-plowed when the soil is dry in the fall, according to Robertson and others (1933). The spring-plowed land should be followed immediately with the disk and harrow. It should also be leveled before the crop is planted to facilitate the distribution of irrigation water.

X. Seeding Practices

The seeding practices for wheat depend upon whether the crop is irrigated or non-irrigated, and whether it is winter or spring wheat.

(a) Method of Seeding

Dryland winter wheat is often planted with a furrow drill which places the seed in shallow furrows 10 to 14 inches apart. Zezer and others (1933) state that the drier the conditions and the colder the winters the greater the advantage of the furrow drill over the common drill for planting wheat. This drill ridges the soil and plants the seed deeper than the common drill. These ridges catch more snow than a smooth surface and aid in the prevention of wind erosion on most soil types. Winter wheat planted with the furrow drill usually suffers less from alternate freezing and thawing in the spring. Wheat grown under irrigation is almost always surface-planted with the common drill which spaces the rows 6 to 8 inches apart.

(b) Seeding Dates

Winter wheat has given the highest yields at Akron when seeded between September 6 and 21. Good yields have been obtained when it was planted as late as October 11. Winter wheat seed as late as October 15 usually will outyield spring wheat on the drylands. When grown under irrigation, winter wheat should be seeded in September in northern Colorado. For high altitude conditions at Fort Lewis, September 15 to 20 has been a satisfactory seeding period.

Spring wheat should be seeded in the non-irrigated areas as soon in the spring as practicable. Conditions are usually favorable for planting at Akron sometime between March 20 and 31. In the irrigated regions of Northern Colorado, spring wheat should be planted before April 20. Wheat sown later than this at Fort Collins may give a good yield but the danger of rust attack increases as the ripening period is delayed. The average date for spring seeding under high altitude conditions at Fort Lewis is about April 20.
(c) Rates of Seeding

 Akron data show little difference between the 2 and 8-peck rates for seeding winter wheat. In all years, the better yields have been obtained from rates heavier than 2 pecks. A common rate for dryland conditions is 2 or 3 pecks for winter wheat, and 4 pecks for spring wheat. Two pecks appears to be sufficient where the furrow drill is used for timely seedings on fallow land. The usual rate for wheat under irrigation is 4 pecks (60 pounds) per acre for winter, and 6 pecks (90 pounds) for spring wheat.

XI. Irrigation

Wheat requires a comparatively small amount of water for high yields. The amount of water consumed per pound of dry matter was estimated by Robertson and associates (1934) in their wheat irrigation studies. The plots to which one 6-inch irrigation was applied at the jointing stage made the most efficient use of water for a single irrigation, i.e., 338 lbs. of water per pound of dry matter.

(a) Irrigation for Germination

In northeastern Colorado it is seldom necessary to "irrigate up" wheat. This practice is common in the Arkansas Valley, San Luis Valley, and in some western slope localities. To "irrigate up" wheat on the heavier soils, it is advisable to irrigate, disk, level, plant the seed, and harrow the land. On sandy soils it is better to plant the crop and irrigate afterwards because sandy soils dry out on the surface rapidly.

A tendency of spring wheat to turn pale when irrigated immediately after germination, or when heavy rains occur soon after the crop emerged, has been observed by Robertson and Gardner (1937). The pale green color may last 3 to 6 weeks before the plants recover their normal appearance. These workers found that the addition of nitrogen fertilizers to the crop immediately after germination prevents the chlorotic condition and increased the grain yield. The irrigation water was shown to wash the soluble nitrate nitrogen below the 3-foot level, or below the root zone.

(b) Critical Period

An elaborate experiment on the critical period of irrigation of wheat has been reported by Kezer and Robertson (1927), and by Robertson and others (1934). Six growth stages were arbitrarily chosen at which one 6-inch irrigation was applied. These stages were as follows: germination, tillering, jointing, heading, blossoming, and filling. In addition, four checks were included, viz., distributed with one inch applied at each of the above 6 stages, one without irrigation, another with sufficient to maintain plant growth, and one with one-inch applied at germination. The plots were covered with canvas whenever rain threatened. The 9-year average results are given in table 5.
Table 5. Average Yields of Wheat Irrigated at Different Stages, 1921 to 1929.

<table>
<thead>
<tr>
<th>Growth Stage</th>
<th>Grain Yield (lbs.)</th>
<th>Straw Yield (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germination</td>
<td>685</td>
<td>1457</td>
</tr>
<tr>
<td>Tillering</td>
<td>794</td>
<td>1785</td>
</tr>
<tr>
<td>Jointing</td>
<td>900</td>
<td>1908</td>
</tr>
<tr>
<td>Heading</td>
<td>833</td>
<td>1664</td>
</tr>
<tr>
<td>Blossoming</td>
<td>762</td>
<td>1486</td>
</tr>
<tr>
<td>Filling</td>
<td>657</td>
<td>1357</td>
</tr>
<tr>
<td>Distributed</td>
<td>1135</td>
<td>2249</td>
</tr>
</tbody>
</table>

It is obvious that the highest yield from a single irrigation was obtained at the jointing stage. The earlier irrigations increased the straw yields to a greater extent than later ones.

(c) Effect on Crop Quality

The bushel weight and weight per 1000 kernels were used by Robertson and associates (1934) as a measure of grain quality. As shown by the weights per 1000 kernels, the single irrigation at the heading stage gave the heaviest kernels. The 9-year average results were as follows: Heading 26.14 gm., blossoming 25.62 gm., jointing 23.84 gm., filling 23.71 gm., tillering 22.95 gm., and germination 22.57 gm. Kezer (1928) found that irrigation at the tillering and jointing stages gave the highest protein production. Late irrigations have a tendency to cause wheat to lodge and to prolong ripening.

(d) Number of Irrigations

Excessive irrigation may cause an actual decrease in yield. Kezer and others (1928) state that it is seldom necessary to irrigate wheat in northern Colorado until it commences to head, when there is sufficient moisture in the soil to maintain plant growth up to that time. However, the crop should never be allowed to suffer for lack of water even tho it is necessary to irrigate before that time. One irrigation on heavy soil and two on sandy soil are generally sufficient to mature the crop. At least one more irrigation per season would be required for such soils under conditions where the crop is "irrigated up".

I. Methods of Harvest

Wheat is harvested in Colorado by 3 different methods, namely, binder, header, and combined harvester-thresher.

(a) Binder Harvest

Wheat grown under irrigation is usually harvested with a binder. It is the general practice to shock the bundles in the field for several days to cure. Robertson and others (1933) suggests that the bundles be placed in small round shocks of about 8 bundles and capped. This enables the straw to cure and produces a better quality of grain. Grain in uncapped shocks will bleach under the weather conditions that usually prevail in northern Colorado at harvest time. Shocked grain may be stacked where a considerable time lapses before it is threshed. The grain is usually threshed after the moisture content is below 15 percent.
(b) **Header-Barge**

The header barge method is used on large dryland acreages where the straw is short and erect. The header merely removes the heads which are collected in barges. The heads are stacked to be threshed later. Wheat is ready to cut by the header at the same stage as for binder harvest, that is, the hard dough stage. The crop should be relatively free from tall green weeds for header harvest because green weeds in the stack may cause spoilage.

(c) **Combined Harvester-Thresher**

The combined harvester-thresher has been widely used for the harvest of wheat on the drylands of eastern Colorado since the World War. The wheat must stand in the field until it is dead ripe, or until the grain has dried to below 15 percent moisture. This is usually 10 to 14 days later than the stage for binder or header harvest. The field must be comparatively free of green weeds for satisfactory harvest by this method. The weather must be dry also.

The swather pickup method is a modification useful in fields badly infested with weeds, or which ripen unevenly. The wheat is windrowed to dry. Later it is picked up from the windrow by a combine with a special attachment to the cutter bar and threshed.

XIII. **Wheat Diseases**

The principal diseases of wheat in Colorado are covered smut, loose smut, black stem rust, and the foot-rot diseases.

(a) **Covered Smut**

Covered smut (*Tilletia Laevis*) is a serious wheat disease in Colorado. It causes large yearly losses, both in yields and in dockage at the elevator. Durrell (1931) describes the disease as follows. The organism produces its spores in the wheat kernels at the time the plant heads. Masses of spores are contained in the smutted heads and show as a dark powder when the diseased grains are crushed. The heads are frequently smaller than normal, and the smutted kernels show under the chaff. The diseased kernels are filled with dark brown smut spores. These spread to normal grains when the wheat is threshed. When the seed is planted, the spores germinate and infect the young seedling. Lungren and Durrell (1928) found that smut infection in winter wheat is affected by temperature at seeding time, being greatest in field tests in Colorado when about 56°F. This has a special significance to date of planting untreated seed. It has been observed that early planted winter wheat often has little smut, while later plantings are severely attacked. For example, wheat planted September 11 when the temperatures were relatively high averaged 25.3 percent smut, while that planted October 9 averaged 35.1 percent infection.

Covered smut can be controlled by seed treatment. **Organic mercury** dusts such as Improved Ceresan, are effective when applied in an air-tight barrel mixer. The usual application is one-half ounce per bushel of seed. This treatment is practically 100 percent effective for the control of the disease and should be applied to all wheat planted.
(b) **Loose Smut**

Loose smut of wheat (*Ustilago tritici*) is frequently found in wheat fields in the state, though it is less common than covered smut. The disease may be identified by the naked rachis which remains after the floral parts are consumed. The spores are spread at the blossom stage to healthy heads. The smut sporangia grow on the open flower and grow down into the ovary of the new seed being formed. There it remains dormant until next season.

Since the mycelium of the fungus is within the kernel, the hot-water treatment is the only effective control measure. The recommended seed treatment is as follows: (1) The seed is dipped in warm water at 68 to 80°F. for 4 to 6 hours. (2) Immerse in a vat for one minute at 120°F. (3) Lastly dip the seed for 10 minutes in water kept at a temperature between 123°F and 129°F. (4) Spread the seed out in a thin layer to dry. This treatment is difficult for the farmer to apply because he seldom controls the temperature accurately with the equipment usually at his disposal. Too high a temperature may injure the seed germination, while too low a temperature may fail to kill the fungus.

(c) **Black Stem Rust**

Black Stem rust (*Puccinia graminis tritici*) is one of the most destructive grain diseases found in Colorado. The disease appears on the wheat plant as long reddish-brown granular pustules which may break thru the epidermis. These pustules are more abundant on the stems and on the leaf sheaths, altho occasionally they occur on the leaves and on the floral bracts. As the season advances, the reddish pustules turn black. The black spores live over winter in a dormant condition on the stubble and straw. These spores germinate in the spring and are carried by the wind to the barberry bush, the alternate host. Spores from the barberry reinfect wheat. Two susceptible barberry species are found in Colorado, according to Durell and Lungren (1927) and Lungren and Durrell (1938). These are the common barberry (*Berberis vulgaris*), and wild mountain barberry (*B. fendleri*), a native species. Rust spores may also over-winter in the South and be blown into the state. Durrell and Lungren (1927) found the first appearance of these spores in the state was about June 24 on the eastern boundary. These infestations are 12 to 17 days later than those caused by spores from local barberry bushes.

The principal control measures for stem rust are given by Lungren and Durrell as follows:

1. Rust-spreading barberry bushes should be destroyed as soon as possible. In addition to being responsible for early spring outbreaks of black stem rust, barberries serve as the breeding ground for new parasitic races of the stem rust fungus. A total of 4,847,000 barberry bushes have been destroyed in Colorado since 1918.

2. Select wheat varieties that are resistant or immune to the more prevalent forms of stem rust. Thresher wheat, recently introduced, is resistant to a large number of forms. Reward, being very early, often will escape rust epidemics.
3. Spring-wheat should be planted as early in the spring as possible to promote early maturity. This enables the crop to largely escape rust epidemics blown into the state.

(d) Foot-Rot Diseases

This is a general term which includes any disease that attacks the basal portion of the plant. Among them are Take-all, Helminthosporium, and Fusarium. The disease was widespread in Colorado in 1928 with large losses as a consequence. The Helminthosporium foot-rot appears to be the most prevalent form in the state. It attacks all parts of the wheat plant, but appears to cause the most serious damage to the roots and lower parts of the stem. The diseases often occur in wheat planted early in the fall when the temperatures are rather high. Destruction occurs when growth starts the next spring.

The foot-rot diseases are on the increase in abundance and destructiveness. They seem to be accumulative and appear in periodic outbreaks. The only controls known at the present time are as follows: (1) Good summer fallow, (2) late-fall seeding after September 10, and (3) crop rotations without barley in the sequence.

IV. Insect Pests

Insect pests of wheat are of minor importance. Army cutworms occasionally damage winter wheat in April, as in 1925. Aphids sometimes appear on the leaves at the pre-jointing stage. False wireworms have been known to eat the kernels in the fall, especially when the seed is in dry ground.

References

Questions for Discussion

1. Why is winter wheat more widely grown than spring wheat on drylands?
2. Describe the wheat plant botanically.
3. Describe 4 species of wheat grown in Colorado.
4. How can Durum be distinguished from common wheat? Emmer from spelt?
5. What kernel qualities are found in the best bread wheats?
   How influenced by climate?
6. Explain how soil conditions may affect kernel quality.
7. What is yellowberry? How caused?
8. What is the effect of long-time storage on kernel quality for milling and baking?
9. How long will wheat kernels maintain their vitality in dry storage? At 100 percent humidity?
10. Do wheat kernels have a dormant period after harvest?
11. To what conditions is wheat adapted?
12. What wheat varieties have proved best adapted to northern Colorado irrigated conditions? On the drylands? At high altitudes?
15. What crop rotations have been most satisfactory for wheat on the drylands? Why?
16. Briefly describe seedbed preparation for dryland winter wheat. Irrigated spring wheat.
17. What are the advantages of the furrow drill under dryland conditions?
18. Give seeding dates for wheat in Colorado.
19. What rates of seeding are recommended for wheat under dryland conditions? Under irrigation.
20. How should wheat be "irrigated up" on heavy soil? On sandy soil?
21. Account for the pale foliage color of some wheat in the irrigated regions soon after emergence.
22. What is the critical period of irrigation of wheat? Explain how the experiment was conducted.
23. What is the effect of irrigation on quality?
24. Briefly state the recommendations for the irrigation of wheat.
25. Explain the header-barge method of wheat harvest.
26. What precautions are necessary in the use of the combine?
27. Explain the swather-pickup method and the conditions where used.
28. Describe covered smut and give control measures.
29. Describe loose smut and tell how it can be controlled.
30. What are the symptoms of black stem rust? Control measures?
31. What are the foot-rot diseases? How controlled?
FIELD CROPS IN COLORADO

Chapter 12. Rye

I. Economic Importance

Rye is a cereal of lesser importance. It is grown in Colorado principally for grain, pasture, or hay. Rye is sometimes used as a green manure crop under irrigation. The 10-year average acreage of rye for the period 1928 to 1937 was 45,800 acres with an average production of 329,900 bushels. The average yield per acre for this period was 7.4 bushels. In 1938 there were 52,360 acres harvested for grain in the state, the total production being 449,200 bushels. The five counties that led in production were: Weld, Logan, Phillips, Elbert, and Yuma.

II. Botanical Description

The rye inflorescence is a spike that resembles wheat in general structure. The rachis bears 2 opposite rows of sessile spikelets. There is one spikelet at each rachis joint which consists of 3 florets, 2 fertile and the other abortive. The glumes are very narrow. The lemma is broad, keeled, and bears a long terminal awn. The keel of the lemma is fringed with stiff hairs. Rye cross-pollinates readily, being classified as a cross-fertilized crop. The caryopsis threshes free from the lemma and palea. The rye kernel is narrower than that of wheat, and usually brownish-olive, greenish-brown, or bluish-green in color. It has a dull appearance. One species, common rye (Secale cereale), is cultivated.

Rye is sometimes said to be "hard on the land" in the dryland areas because crops that come after it are often depressed in yield. The explanation is undoubtedly in the root system. Weaver (1926) found rye to have more lateral branches on the roots than either oats or barley grown under the same conditions. The roots may branch profusely at the tips. This root system enables the plant to remove the available moisture in the soil more thoroughly than is possible by other cereals.

III. Adaptation

Rye is the hardiest of all cereals, being able to withstand severe winter climates. (Martin and Smith, 1923). It is rarely grown in warm climates. Under semi-arid conditions, rye is only fairly drought resistant. It grows well upon almost all light soils - at least better than other cereals - especially on the sandier soils. Coffman (1925) observed that rye generally outyields wheat on the sandier dryland soils, while wheat outyields rye on the so-called "hard lands."

IV. Varieties

Very few rye varieties exist due to the ease of cross pollination. Petkus and Rosen rye have produced the highest yields under irrigation in Colorado. The 2 varieties yield about the same, according to Kezer and Robertson (1925). The yields at Fort Collins (1931-34) were as follows: Petkus 60.6, Rosen 59.5, Dwarf 50.9, and 20th Century 43.5 bushels per acre. Under irrigation, rye is grown principally as a temporary pasture or as a grain crop on poor land.
Winter rye appears to be one of the better dryland cash crops where winter wheat cannot be grown. Coffman (1925) reported the yields of rye at Akron as follows for 1920 to 1922: Winter rye (Rosen) 19.6 bushels, and spring rye (Vance) 13.7 bushels per acre. It was found to yield less than winter wheat but more than spring wheat.

The principal varieties grown in the state are described as follows:

1. **Common**: This rye variety is characterized by small brown kernels. The yields are low.

2. **Rosen**: A winter rye with large bluish-green kernels. The presence of dark brown or smut-colored kernels indicates an admixture of common rye. Rosen and Petkus are indistinguishable.

V. **General Cultural Methods**

The cultural methods for rye are very similar to those for wheat, except that it is never planted on fallow. Under irrigation, winter rye is planted about September 15 at the rate of 4 pecks or 60 pounds per acre. For dryland conditions, 2 or 3 pecks per acre is a common rate, being seeded from September 1 to 15.

Winter rye is a recommended grass for annual pastures for the plains region. Rosen rye may be seeded as early as August 1 at the rate of 3 or 4 pecks per acre. This will furnish some fall, and considerable spring pasture up to about June 1. In an adjacent field sudan grass may be drilled at the rate of 10 to 15 pounds per acre about May 15. It will furnish pasture from about July 1 until frost. Native pasture or spring-sown winter rye may be used to furnish pasture during June.

VI. **Rye Diseases**

Ergot (Claviceps purpurea) is the most serious and destructive disease of rye. The fungus attacks the ovary while the flowers are in bloom. The ovary is consumed and replaced by ergot, a black purplish body several times larger than the seed. The sclerotia germinate in the spring, and the spores infect susceptible plants that are in bloom. Stock is poisoned when they eat ergot in large quantities. It will often cause abortion in pregnant animals, and even death in extreme cases. The principal control measures are: (1) Avoid rye after rye on the same land, and (2) plant disease-free seed. The sclerotia may be floated off by immersion of the seed in a 20 percent brine solution.
References


Questions for Discussion

1. Describe rye botanically.
2. Distinguish between rye and wheat.
3. What is the probable explanation for rye being "hard on the land"?
4. To what conditions is rye adapted?
5. Describe 2 rye varieties.
6. Explain how rye is used in a pasture combination for the drylands. Give details.
7. Describe ergot and give control measures for the disease.
I. Economic Importance

Barley has increased in acreage in Colorado during the past few years because it is a safer crop than corn where the season is short and the mean summer temperatures moderate. As a 10-year average for the period 1928 to 1937, barley was grown on 427,200 acres each year with an average production of 8,075,300 bushels. The average yield for this period was 19.9 bushels per acre. The 1938 crop was 11,985,000 bushels produced on 510,000 acres, being the largest total production recorded in the state. About 215,410 acres, or 42 percent of the crop, was grown on the drylands. The estimated yield per acre was 38.4 bushels for irrigated, and 12.6 bushels for dryland barleys. Most of the crop is produced in the northeastern one-fourth of the state. The counties which led in the production in 1938 were: Weld, Logan, Larimer, Washington, and Morgan.

II. Botanical Description

Barley is an annual grass that is classified in the Tribe Hordeae, characterized by a zig-zag rachis. The inflorescence is a spike in which there are 3 spikelets borne at a rachis joint. Each spikelet consists of 2 awl-like glumes and one floret. A fertile floret is composed of the lemma, palea, and Caryopsis or Kernel. Except in the hull-less sorts, the lemma and palea grow to the Caryopsis. The barley grain is actually a fertile floret. The awn in barley, which is a flat extension of the lemma, may be rough or smooth. The hood is a trifurcate appendage on the lemma that replaces the awn. The vegetative portion of the barley plant is similar to that of other cereals, except that the auricles on the barley leaf are conspicuous.

Barley is generally self-fertilized due to the fact that pollination occurs in many varieties while the head is still in the boot. In studies of natural cross pollination, Robertson and Dening (1931) observed a low number of natural hybrids in commercial varieties, i.e., less than 0.15 percent. The variety Trebi had one and Colseiss two hybrid plants in 10,000. For practical purposes, natural crossing may be disregarded in commercial varieties.

Some barley varieties have a dormancy period immediately after harvest. Dening and Robertson (1933) found most 6-rowed, hulled varieties to have dormant periods of about 20 days after harvest. Among the varieties tested were Trebi and Colseiss. Nepal, a hull-less variety, had a high germination immediately after harvest. The 3-rowed hulled varieties, Hanna and Vance Smyrna, showed a slight dormancy up to 7 days after harvest. In longevity studies, Robertson and Lute (1937) report a gradual decline in germination for the first 12 years, with a sharp decline between the 12th and 15th years. As an average for all varieties, there was a drop of 5.9 percent in germination for the first 5 years, 4.7 percent for the second 5-year period, and 9.8 percent for the third. The hulled varieties declined at a less rapid rate than the hull-less ones.

III. Barley Classification

All commercial varieties of barley grown in the state are classified in two species on the basis of the fertility of the lateral spikelets. Common
6-rowed barley, Hordeum vulgare, has 3 fertile spikelets per rachis joint. The lemmas are uniformly awned or hooded. Two-rowed barley, H. distichon, has one fertile spikelet per rachis joint. The lateral spikelets are sterile, but consist of glumes, lemma, palea, rachilla, and usually rudiments of sexual organs. Two other species, H. intermedium and H. deficiens, are unimportant commercially (Harlan, 1918).

Barley varieties within each species may also be classified into covered or naked, awned or hooded, blue or white kernels, and rough or smooth awns. These distinctions are important in variety identification.

IV. Quality of the Barley Kernel

The main factors in kernel quality for malting purposes are determined by variety, cultural practices, disease, and climatic conditions. The maltsters desire a plump, mellow, small-kerneled barley with tight hulls (Harlan and Wiebe, 1940). Such barley should be all of the same type, sound, and free from either weather or disease damage. Six-rowed barleys that are starchy, mellow, and of high germinative capacity are in demand. The kind and solubility of the proteins are also factors. Flinty or "glassy" kernels, a condition brought about by interrupted growth, or other factors, are objectionable. Broken kernels will not malt. Skinned or peeled kernels fail to germinate properly in the malting process. Wisconsin Barbless and Velvet are satisfactory malting barleys. Trebi is objectionable.

V. Adaptation

Barley thrives in a cool, humid climate. It will stand more heat under semi-arid than under humid conditions. The best barley soils are well-drained loams. Light sandy soils are poor for the crop because growth often fails to occur at a uniform rate. Moreover, it is more apt to be prematurely ripened on such soils. Barley is the most dependable cereal under extreme conditions of alkali, frost, or drought. (Harlan and Wiebe, 1940). Both 2-row and 6-row varieties are adapted to conditions in Colorado.

The climate of Colorado is suitable for the production of barley in most agricultural areas. High quality barley is produced under irrigation. On the eastern slope, the high protein barley produced is suitable for feed, but is not in demand for malting purposes. At the higher altitudes, where the season is cooler, it may be possible to produce a barley which lacks the hard "steely" kernel typical of the high protein barleys common east of the mountains. This is still to be determined. (Robertson and others, 1936).  

VI. Barley Varieties

The 6-rowed, awned, hulled barleys are most widely produced in the state. For years, Coast or California Feed was the principal variety. The work of Robertson and others (1930) indicated that Trebi outyielded Coast by 23 percent as a 6-year average under irrigation. The most widely grown varieties at the present time are Trebi for irrigated conditions and Club Karicut on the drylands. Beecher, an Atlas x Vaughn cross, may soon become popular in the non-irrigated regions.

(a) Varietal Trials

Results of barley variety tests for 8 years under irrigation at Fort Collins are given by Robertson and others (1936). Trebi was the highest
yielder during this period. Lico, a coast x lion hybrid, has yielded about the same as Trebi, but has the advantage of a stiffer straw and smooth awns. Wisconsin Barbless and Velvet, which yield about 15 percent less than Trebi, are suitable malting varieties. Colsees, is recommended as a companion crop for alfalfa or red clover. Yields of several varieties are given in table 1.

Table 1. Yields of Barley Varieties under Irrigation at Fort Collins, 1928-35.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Years Grown</th>
<th>Av. Yield Bu./A.</th>
<th>Percent of Trebi</th>
<th>Days to Maturity</th>
<th>Straw Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trebi</td>
<td>8</td>
<td>81.4</td>
<td>100.00</td>
<td>105</td>
<td>Medium</td>
</tr>
<tr>
<td>Hannechen</td>
<td>8</td>
<td>74.6</td>
<td>91.69</td>
<td>107</td>
<td>Medium</td>
</tr>
<tr>
<td>Colsees</td>
<td>8</td>
<td>68.7</td>
<td>84.43</td>
<td>103</td>
<td>Strong</td>
</tr>
<tr>
<td>Velvet</td>
<td>8</td>
<td>67.2</td>
<td>82.54</td>
<td>106</td>
<td>Strong</td>
</tr>
<tr>
<td>Nepal</td>
<td>8</td>
<td>50.3</td>
<td>61.85</td>
<td>104</td>
<td>Weak</td>
</tr>
<tr>
<td>Lico (F.C.1110)</td>
<td>4</td>
<td>73.9</td>
<td>100.48</td>
<td>102</td>
<td>Strong</td>
</tr>
<tr>
<td>Wisconsin Barbless</td>
<td>3</td>
<td>65.7</td>
<td>84.63</td>
<td>105</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Nepal is the highest yielder among the hulless barleys, but it yields too low to encourage the production of barley of this type. It yields about 35 percent less than Trebi. Hannechen, the best of the 2-rowed varieties, shatters more than the other recommended 6-rowed varieties.

Many of the same varieties yielded well under high altitude conditions at Fort Lewis. The average results for the period 1928 to 1935 are given in table 2.

Table 2. Yield of Barley Varieties under High Altitude Conditions (1928-1935).

<table>
<thead>
<tr>
<th>Variety</th>
<th>Years Grown</th>
<th>Av. Yield Bu./A.</th>
<th>Percent of Trebi</th>
<th>Days to Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trebi</td>
<td>7</td>
<td>77.2</td>
<td>100.00</td>
<td>105</td>
</tr>
<tr>
<td>Colsees</td>
<td>7</td>
<td>63.6</td>
<td>82.38</td>
<td>104</td>
</tr>
<tr>
<td>Velvet</td>
<td>7</td>
<td>64.8</td>
<td>83.83</td>
<td>105</td>
</tr>
<tr>
<td>Wisconsin Barbless</td>
<td>3</td>
<td>60.5</td>
<td>86.53</td>
<td>103</td>
</tr>
<tr>
<td>Lico (F.C. 1110)</td>
<td>4</td>
<td>72.9</td>
<td>93.28</td>
<td>101</td>
</tr>
</tbody>
</table>

Trebi gave the highest yield for the 7-year period. Colsees is recommended as a companion crop for alfalfa or red clover.

Barley varieties have been tested under dryland conditions at Akron during the 8-year period, 1928 to 1935. The yields of several varieties are given in table 3.
Table 3. Average Yield of Barley Varieties at the Akron Field Station, 1928 to 1935.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Years Grown</th>
<th>Av. Yield Bu./A.</th>
<th>Percent Yield of Club Mariout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Club Mariout</td>
<td>8</td>
<td>20.6</td>
<td>100.0</td>
</tr>
<tr>
<td>Flynn</td>
<td>8</td>
<td>20.5</td>
<td>99.5</td>
</tr>
<tr>
<td>Vaughn</td>
<td>5</td>
<td>16.9</td>
<td>107.0</td>
</tr>
<tr>
<td>Vance Smyrna</td>
<td>8</td>
<td>20.0</td>
<td>97.1</td>
</tr>
<tr>
<td>Coast</td>
<td>8</td>
<td>18.5</td>
<td>89.8</td>
</tr>
</tbody>
</table>

Early varieties are the best adapted to the drylands. Club Mariout and Flynn have given the best yields in this test. Vaughn shows promise under dryland conditions, but is slightly later than Club Mariout. Vance Smyrna, a 2-row barley of high yield, is smut resistant. Coast has been practically replaced by some of these newer varieties on the drylands. Trebi is unadapted to these conditions, being too late. Spartan, a new 2-row variety with a taller and stiffer straw than Vance Smyrna, has replaced some of the Club Mariout. Recently (unpublished data), a new variety has been released which outyields Club Mariout by about 20 percent. This variety is Beecher. The comparative average yields of these varieties for a 6-year period (1934-39) in nursery tests are as follows: Club Mariout 30.5 bushels, and Beecher 38.0 bushels per acre.

A general observation of the growth habit of the various strains which survive under dryland conditions indicates that barleys with a narrow blue-green foliage are more likely to be adapted than barleys with a yellow-green foliage such as found in trebi and Oderbrucker.

(b) Variety Descriptions.

Descriptions of some of the more important Colorado barley varieties are given by Robertson and associates (1925, 1930, 1936).

1. Trebi: A 6-rowed, bearded, hulled barley with heads similar to those of Coast. Under Colorado conditions the kernels are large and bluish in color. The straw is weak, a factor that causes it to lodge badly on fertile soils. The awns break more readily than those of Coast in threshing.

2. Col�ess: A 6-rowed, hooded, hulled barley produced from a cross between Coast and Success (Robertson and Kezer, 1925). The grain is a bluish-green color. The straw and glume color is light yellow. The heads are more compact and darker in color than those of Success. The rachis is tough and the head does not shatter readily. Col�ess has a short-haired rachilla. It is stiff-strawed and stands up well under irrigation.

3. Club Mariout: A 6-rowed, awned, hulled variety with a dense or compact head. The grain is light in color, i.e., white. The awns are stiff and rough. The straw of this variety is short. It matures very early under Colorado conditions. The rachilla hairs are long.

4. Flynn: A 6-rowed, smooth awned, hulled hybrid variety. It originated from a Club Mariout x Lion cross. The smooth-awn character makes it a desirable barley where the straw is wanted for roughage.
5. **Velvet:** A 6-rowed, smooth-awned, hulled variety. The kernels are rather short and plump under Colorado conditions.

6. **Wisconsin Earless:** A 6-rowed, smooth-awned, hulled variety produced from an Oderbrucker x Lelorrhynchum cross. It is resistant to the barley stripe disease. This variety resembles Oderbrucker in malted quality. The hybrid has a somewhat looser hull which makes threshing without peeling difficult. (Wisconsin Pedigree No. 28)

7. **Nepal:** A 6-rowed, hooded, hull-less variety with a light-colored grain that threshes free from the hull. This barley is weak-strawed and frequently lodges. It is grown as a hay crop in the higher altitudes.

8. **Vance Sayre:** A 2-rowed, awned, hulled variety. The straw is very short and the head seldom fully emerges but usually remains about half enclosed in the boot. The awn is partly rough.

9. **Beecher:** A 6-rowed, semi-smooth awned, hulled hybrid variety that originated from an Atlas x Vaughn cross. The head is compact and the grain light-colored, i.e., white aleurone.

**VII. Crop Rotations**

In general, barley makes its best growth after a cultivated crop such as corn, sugar beets, or potatoes. Barley is often used in irrigated rotations as a companion crop for alfalfa. A typical rotation is: Alfalfa 3 years, corn, sugar beets, and barley seeded to alfalfa.

Fallow and cornland for barley production have been compared under dryland conditions at Akron for several years. Robertson and associates (1936) report that the 6-year average yields of 7 varieties was higher on fallow than on cornland. In the case of Club barley, the yield on fallow was 27.5 bushels while that on cornland was 13.7 bushels. This difference of 13.8 bushels suggests that fallow may be a desirable preparation for barley. The chances of failure are greater on cornland in extremely dry seasons. Barley has very largely replaced winter wheat as a crop for non-irrigated cornlands during the last 15 years.

**VIII. Seedbed Preparation**

Methods of seedbed preparation depend on whether the crop is grown under irrigated or non-irrigated conditions, as well as on the previous crop on the land.

(a) **Seedbed under Irrigation**

Heavier soils should be plowed in the fall and left in a roughened condition over winter. Fall plowing is necessarily late where barley follows sugar beets or potatoes. When land is plowed in the spring, it should be done early. The land should be disked, harrowed, and leveled prior to seeding. The object of leveling is to produce a uniform surface for the even distribution of irrigation water.

(b) **Dryland Seedbed**

Where the previous crop will permit such treatment, fall listing has been found cheaper than fall plowing as a preparation for barley. Some fall treatment for weed destruction appears to be desirable, especially in areas
where precipitation is low. Lands likely to blow should not be fall-worked when covered with a good stubble. Cornland may be disked in the spring to incorporate the stalks in the soil. Where the stalks were removed the previous fall, a spring tooth harrow will usually loosen the surface soil sufficient to prepare the seedbed for barley. The duckfoot cultivator is used on fallow.

IX. Seeding Practices

Barley is usually planted under northern Colorado irrigated conditions sometime between April 1 and 20, according to Robertson and others (1936). Earlier seedings may be injured by frost. The usual rate is 8 pecks or 2 bushels per acre for hulled varieties. It is sometimes given as 95 pounds for hulled and 90 pounds for hullless varieties. For high altitude conditions, the Fort Lewis results indicate that the highest yields are obtained when barley is seeded before May 15, although the crop will mature when planted as late as June 15. Some data on time of seeding for high altitude conditions are given in Table 4.

Table 4. Average Yields of Trebi Barley Planted at Different Dates at Fort Lewis, 1931-35.

<table>
<thead>
<tr>
<th>Date Planted</th>
<th>Average yield Bu. per A.</th>
<th>Date Ripened</th>
<th>Days to Mature</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 15</td>
<td>83.1</td>
<td>August 2</td>
<td>106</td>
</tr>
<tr>
<td>May 1</td>
<td>81.6</td>
<td>7</td>
<td>98</td>
</tr>
<tr>
<td>May 15</td>
<td>75.9</td>
<td>19</td>
<td>95</td>
</tr>
<tr>
<td>June 1</td>
<td>69.6</td>
<td>September 4</td>
<td>95</td>
</tr>
<tr>
<td>June 15</td>
<td>47.9</td>
<td>16</td>
<td>95</td>
</tr>
</tbody>
</table>

The same rate of seeding is used for irrigated high altitude conditions as for the plains irrigated areas.

Climatic conditions are generally favorable for seeding barley in the dryland region sometime between March 1 and April 10. Delay in seeding beyond April 10 causes the crop to mature under unfavorable weather conditions. The rate of seeding in general farm practice is 4 pecks per acre.

X. Irrigation

In northern Colorado, it is seldom necessary to "irrigate up" the crop as often practiced in the Arkansas Valley and San Luis Valley. The heavier soils should be irrigated, disked, leveled, harrowed, and planted as soon as possible. The better practice on light sandy soils is to plant before irrigation because such soils dry at the surface rapidly. Where furrow irrigation is practiced, the crop is planted, furrowed, and irrigated.

On the heavier northern Colorado soils, one irrigation applied at the heading stage is generally sufficient where the crop has grown vigorously up to this stage. Two irrigations are generally necessary in regions where the crop is "irrigated up." Irrigation applied after the milk stage often causes late maturity and lodging.

XI. Methods of Harvest

Barley is mature when a dent will remain in the kernel for some time. The crop is usually harvested with a binder under irrigation, and with a header
under dryland conditions. The combine is used to some extent for dryland barley.

Barley may be harvested with a binder when the grain has turned a golden color, altho the straw is still slightly green. There is little loss from shattered grain or broken heads when shocked properly. The crop is generally threshed from the shocks after bundles are dry. Great care should be exercised in threshing to reduce the number of peeled and broken kernels.

The header-barge method is still widely used on large dryland acreages. The crop is harvested with a header, the heads stacked, and threshed later. Headed barley is more apt to heat in the stack than wheat. There is little danger of spoilage when the crop is harvested ripe and piled in long narrow ricks.

The combine is used to some extent on the drylands. The crop must stand until it is thoroly ripe and dry. Considerable loss from broken heads may have occurred by that time. Wet weather will delay harvest with the combine. Sometimes the swather-pickup attachment on the combine is used.

XII. Barley Diseases

The principal barley diseases that occur in the state are covered smut (Ustilago hordei), brown loose smut (U. nuda), black loose smut (U. nigra), stripe (Helminosporium gramineum), and stem rust (Puccinia graminis).

(a) Covered Smut
Covered smut appears on affected plants about 7 days after they have headed. Frequently the heads are borne on short stalks and fail to emerge from the boot. The smut mass is hard, and remains intact until broken in threshing. All Colorado varieties should be treated for covered smut with one of the dust treatments. Formaldehyde dust is usually applied at the rate of 3 ounces per bushel in a rotary seed treater or by the shoval method. The grain should be stored in sacks or in a covered pile for 1 to 5 days before it is planted. New Improved Ceresan may be applied in a similar manner but at the rate of one-half ounce per bushel.

(b) Black Loose Smut
This disease is observed at the time the plants head. The smut mass is powdery and easily rubbed off, being soon blown away. The bare rachis is left. The smut mass is almost black in color. The control is the same as for covered smut.

(c) Brown Loose Smut
This smut has symptoms similar to black loose smut except that the spore mass is brown. The two smuts are very similar in appearance, being difficult to distinguish. This is the most destructive smut in Colorado. The hot water treatment is the principal control.

(d) Stripe
Shortly after barley heads, yellow-to-brown stripes appear in the leaves. Later the leaves shred or split along these stripes. Affected plants are usually stunted. The head usually fails to emerge fully from the boot; it is usually shrunk, discolored, and rarely produces sound kernels. Diseased plants are generally dead by harvest time. Several Colorado varieties are susceptible to this disease, particularly Colsess, Coast, and Club
Mariout. Stripe is rather destructive in some seasons. It can be controlled by organic mercury dusts, such as New Improved Ceresan.

(e) **Stem Rust**

Stem rust is of minor importance, the symptoms being similar for the same disease on wheat. The disease spreads in this state from local barberry bushes. It is sometimes found on barley planted after May 1.

References


Questions for Discussion

1. Why has the barley acreage increased in Colorado in recent years?
2. Describe the barley plant botanically.
3. What is the extent of natural crossing in barley? Seed dormancy? Give the practical importance of each.
4. Distinguish between Hordeum vulgare and H. distichon.
5. Describe the qualities desired in the barley kernel for malting purposes. Name 2 suitable varieties for the state.
6. To what conditions is barley adapted.
7. Name and describe 2 barley varieties for northern Colorado irrigated conditions.
8. Name and describe 2 dryland varieties of barley.
9. What relation seems to exist between plant color and adaptation to dryland conditions.
10. Give a rotation for barley, under irrigation. Discuss dryland barley sequence.
11. Tell how to prepare a seedbed for barley under irrigated conditions. For non-irrigated conditions.
12. Give rates and dates for seeding barley under irrigated, high altitude, and dryland conditions.
13. Give directions for the irrigation of barley for different parts of the state.
14. Explain the different methods of harvesting barley.
15. Describe covered smut of barley and the control measure.
16. Describe and distinguish between black and brown loose smuts. Give control measures for each.
17. Describe the barley stripe disease and a method of control.
FIELD CROPS IN COLORADO

Chapter 14. Oats

I. Economic Importance

Oats are grown largely as a grain crop in Colorado, although a considerable acreage is cut for hay in the mountain valleys each year. For the 10-year period, 1928 to 1937, the average annual acreage was 161,300 acres on which an average of 4,503,900 bushels were produced. The average yield per acre for irrigated conditions was 38.4 bushels for this period, while that for the dry lands was 13.7 bushels per acre. Most of the oats in the state are produced under irrigated conditions. In 1938, oats were harvested on 94,690 acres under irrigation, the production being 3,857,140 bushels. There were 63,250 acres harvested in the non-irrigated areas with a production of 1,324,010 bushels. The total state production was 5,181,150 bushels harvested from 162,940 acres. The five counties that led in production were: Weld, Larimer, Routt, Montrose, and Rio Grande.

II. Botanical Description

The oat plant belongs to the grass tribe Aveneae. Under average conditions it produces from 3 to 5 culms and reaches a height of 2 to 5 feet. The panicles are either equilateral (spreading) or unilateral (one-sided). The grain is produced on small branches in spikelets that vary from 20 to 150 per panicle. The spikelet, surrounded by 2 glumes, generally has 2 or 3 florets (oat grains). Each floret consists of a lemma, caryopsis, and palea. The lemma or hull varies in color from white, yellow, gray, and red to black. The lemma may also be awned or awnless. The kernel or caryopsis constitutes about 65 to 75 percent of the total weight of the whole grain. (Stanton, 1936).

Oats are normally self-pollinated, but the work of Stanton and Coffman (1924) at Akron indicates that cross-pollination may occur. Black and white oats grown in adjacent rows crossed naturally to the extent of 0.39 percent. Natural crossing may account for some of the variability observed in supposedly pure lines.

III. Species or Groups of Oats

Three oat species are common in Colorado, the common oat (Avena sativa), the cultivated red oat (A. byzantina), and the common wild oat (A. fatua). The side oats are now grouped with the common oats. The common oats have solidified spikelet attachments and weak awns. The grain color may be either white or black. Cultivated red oats have their upper grains persistent to their rachillas, and vary in grain color from red to black.

Common wild oats (A. fatua) differ from cultivated oats by their taller plants and their strongly twisted, geniculate awns. They can also be differentiated by the pronounced oval-pitted callous ("sucker mouth") at the base of each floret, and usually by the hairiness of the lemma. Wild oats are difficult to eradicate because of the ability of the seeds to lie dormant in a dry soil for years, and then to germinate and grow when moisture and temperature conditions become favorable. The wild oat is a noxious weed in this state, being particularly troublesome on irrigated lands.
IV. Kernel or "Seed" Characteristics

Oat "seeds" retain their viability for many years in arid climates. Robertson and Lute (1937) found that oats stored in a dry room for 15 years retained over 80 percent of their original ability to germinate.

Some dormancy in the grains of freshly harvested oats is an advantage, especially when wet weather occurs after harvest. Some varieties sprout in the shock under such conditions. Several oat varieties were tested for dormancy by Deming and Robertson (1933). Seeds were planted at successive days after harvest. The common oat species (A. sativa), represented by Colorado 37 and Nebraska 21, showed little or no dormancy. Both these varieties sprouted badly in the shock in 1930. Kanota, a red oat (A. byzantina), showed considerable dormancy. It failed to germinate readily for a period of over 40 days. Kanota also showed very little sprouting in shocked grain. Both Colorado 37 and Nebraska 21 should be reshocked after heavy rains to aid in drying and to prevent sprouting of the grain.

V. Adaptation

Two general oat regions are represented in Colorado, the Great Plains area in the eastern and the Rocky Mountain area in the western parts of the state. Oat production is more or less hazardous on the Great Plains due to the rigorous climate. Oats use water freely and often fail because of drought. This is often made critical by hot winds. In the mountain valleys, oats are usually grown under irrigation. The quality of these oats is unsurpassed.

Stanton and Coffman(1929) state that common oats (A. sativa) are better adapted to the cooler regions, while some varieties of red oats (A. byzantina) grow more favorably in the warmer regions. Robertson and associates (1930, 1936) found common oats to give better yields in areas where the mean summer temperature ranges between 60 and 70 degrees F. Where it is well over 70 degrees F. in the southern or eastern part of the state, at the lower altitudes, red oat varieties are better adapted. At altitudes below 7,000 feet, with the mean summer temperature below 70 degrees F. and above 60 degrees F., the midseason or Victory type of common oat is best adapted, provided there is sufficient water either as rainfall or irrigation. In the drier localities of the area, the Kherson type is better adapted and will outyield the later oats in dry years. Above 3,000 feet in elevation, where the frost-free season is short, early varieties are better adapted for grain production, but the Victory type will give the highest hay yields.

VI. Oat Varieties

Oat varieties have been tested for yield in irrigated, dryland, and high altitude variety trials over a period of years. (See Robertson and others, 1930, 1936).

(a) Results of Variety Trials

As an average for 8 years (1928-35), Morkton yielded 99.4 bushels per acre in Fort Collins irrigated tests, while Colorado 37 yielded 95.6 bushels. This difference is significant. Morkton, although smut resistant, has a weaker straw than Colorado 37. Early varieties, such as Kherson and Kanota yielded less than the midseason sorts in this test. The early varieties -
matured about 10 days before than the mid-season ones. Some yields are given in Table 1.

Table 1. Oat Yields under Irrigation at Fort Collins, 1928-1935.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Markton</td>
<td>8</td>
<td>110</td>
<td>99.4</td>
<td>103.94</td>
</tr>
<tr>
<td>Great Dakota</td>
<td>8</td>
<td>108</td>
<td>96.7</td>
<td>101.12</td>
</tr>
<tr>
<td>Colorado 37</td>
<td>8</td>
<td>109</td>
<td>95.6</td>
<td>100.00</td>
</tr>
<tr>
<td>Kherson</td>
<td>8</td>
<td>105</td>
<td>88.3</td>
<td>92.33</td>
</tr>
<tr>
<td>Kanota</td>
<td>7</td>
<td>100</td>
<td>74.3</td>
<td>83.41</td>
</tr>
</tbody>
</table>

In earlier tests, Robertson and others (1930) found side oats too late, yielding only 83 percent as much as Colorado 37. Liberty Full-less yielded 75.45 percent as much.

The yields of oats over a 7-year period (1928-1935) at Fort Lewis are representative for some of the irrigated higher altitude regions. They are given in Table 2.

Table 2. Yields of Oats under High Altitude Conditions, 1928-1935.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Yield Bu./A.</th>
<th>Pct. Colorado 37</th>
<th>Days to Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Markton</td>
<td>99.3</td>
<td>103.25</td>
<td>113</td>
</tr>
<tr>
<td>Great Dakota (F.C. 1063)</td>
<td>99.2</td>
<td>106.19</td>
<td>114</td>
</tr>
<tr>
<td>Colorado 37</td>
<td>91.7</td>
<td>100.00</td>
<td>115</td>
</tr>
<tr>
<td>Nebraska 21</td>
<td>82.3</td>
<td>89.69</td>
<td>104</td>
</tr>
</tbody>
</table>

Markton or Colorado 37 are well adapted to high altitude irrigated conditions at Fort Lewis. The early short-season oats are too low in yield.

Under dryland conditions, early sorts have given the highest yields at Akron. Brunker, a highly smut resistant red oat, has outyielded all other varieties under test. Kanota, a smut-susceptible red oat, has been a close second. Kherson, an early common oat, has yielded about 76 percent of Brunker. Red or hot-climate oats are well adapted to eastern Colorado dryland conditions, Brunker or Kanota being recommended. Kanota oats must be treated for smut before planting. The 10-year average yield of these three varieties is given in Table 3.

Table 3. Average Yields of Oats under Dryland Conditions at Akron, 1923-35.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Oat Species</th>
<th>Lemma Color</th>
<th>Maturity</th>
<th>Av. Yield Bu./A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kherson</td>
<td>A. sativa</td>
<td>yellow</td>
<td>early</td>
<td>20.5</td>
</tr>
<tr>
<td>Kanota</td>
<td>A. byzantina</td>
<td>red</td>
<td>early</td>
<td>24.8</td>
</tr>
<tr>
<td>Brunker</td>
<td>A. byzantina</td>
<td>red</td>
<td>early</td>
<td>26.0</td>
</tr>
</tbody>
</table>
Midseason oats have failed more often than the early ones. They have yielded less even under favorable conditions.

(b) Varietal Description

Important Colorado oat varieties have been described by Robertson and others (1930, 1936).

1. **Colorado 37**: A midseason white common oat similar to Swedish Select, except that it has decidedly fewer awns and a little shorter culm. The superior characteristics are high yield, stiff straw, and awnless kernels. It was selected in the San Luis Valley in 1900.

2. **Brunker**: A very early variety of the red oat group, maturing even earlier than Fulghum. The straw is rather short and slender with a typical reddish tinge. The panicles are small and equaliteral with short branches. The spikelets are usually 2-flowered. The lemmas are reddish, with an occasional slender awn on the lower floret of the spikelet; basal hairs are usually present, while the nerves are somewhat prominent. It has considerable resistance to some strains of loose smut (Ustilago avenae) which infect other red oats. The strain was selected from Surt by F. A. Coffman at the Akron Field Station in 1919.

3. **Markton**: A midseason, midstalk common oat with culms, hairy near the nodes, large drooping panicles, and rather long, slender-to-mid-plump, yellowish-white kernels. The lower floret of the spikelet is usually awned. This variety is practically immune to the oat smuts. It was selected in Oregon in 1911.

4. **Kanota**: An early red oat of the Fulghum type. The superior characteristics of Kanota are high yield, high test weight, and earliness. It was released by the Kansas Station in 1919.

VII. Crop Rotations

On irrigated land, the general practice is to sow oats after a row crop such as sugar beets, potatoes, or corn. Oats are not recommended as a companion crop for alfalfa.

Under dryland conditions oats, like other small grains, are most productive on fallow. A widely used rotation in the central Great Plains is alternate corn and oats. At the Akron Station, Brunker yielded 33.1 bushels per acre on fallow for an 3-year period (1928-1935), and 19.3 bushels on cornland for the same years. Fallow insures a yield each year, but even with adapted varieties, Robertson and others (1936) point out that the difference in yield may be insufficient to make up for the loss of a crop in the fallow year. Adapted varieties yield well on cornland, there being only one crop failure in eight years. Oats produce less than barley under dryland conditions.

VIII. Seedbed Preparation

Seedbed preparation for oats depends largely on the previous crop as well as moisture conditions.
(a) **Irrigated Conditions**

Where a row crop was on the land the previous year, the ground may be disked, harrowed, and leveled to prepare a satisfactory seedbed for oats. The land is often plowed after corn to bury the stalks. A good seedbed can be prepared by fall plowing, the land being left rough all winter. The ground is harrowed and leveled in the spring to complete the soil preparation.

(b) **Dryland Conditions**

Corn or sorghum leaves the soil in a comparatively good condition for oats. The stalks can be broken down during the winter with a heavy pole or iron rail while the ground is frozen. The land is then worked in the spring with either a duckfoot or a spring-tooth cultivator to break up the soil held by the corn or sorghum roots.

**IX. Seeding Practices**

Oats are drilled almost entirely in Colorado due to the importance of a uniform depth of planting.

(a) **Irrigated Conditions**

Oats have given the best yields on northern Colorado irrigated lands when planted between April 1 and 20. Oats seeded in late March may suffer from frost damage. They are usually retarded in germination due to low soil temperatures at that time. At Fort Lewis, the optimum time is between April 15 and 30. Early oats showed little difference in yield until the planting date was later than June 1. The usual rate of seeding oats on irrigated land is 30 pounds or 10 pecks.

(b) **On the Drylands**

Oats should be seeded as early in the spring as practicable. Injury from late freezes after the seed is sown causes less damage than the loss in yield from late seeding. Oats seeded after April 15 at Akron are very often injured by dry weather before maturity. The usual rate of seeding is 4 pecks. (Hickurdo, 1916; Robertson, et al., 1936)

**X. Irrigation**

Under normal conditions in northeastern Colorado, Robertson and associates (1936) advise a single irrigation for oats at the jointing stage. On the lighter soils several irrigations may be necessary. When two applications are made, one is recommended at tillering and the other at the late jointing stage. Irrigation after the crop is headed out may cause lodging on rich soils.

**XI. Methods of Harvest**

Oats are harvested in the state for both grain and hay.

(a) **Oats for Grain**

Oats are harvested with the binder, header, or combine. The method of harvest determines the stage at which to cut the crop. Stutton and Coffman (1929) advise that oats be cut with the binder at the stiff-dough stage, header at the late dough stage, and the combine when ripe and dry enough to store. Combined oats are sometimes spread to dry before storage. Nearly all oats grown under irrigation are cut with a binder, while considerable
of the dryland acreage is harvested with a header or combine. Oats cut with a binder are usually shocked immediately to reduce shattering. Due to the immature straw in oats produced under irrigation, the experiences of Robertson and others (1936) indicate long shocks made with two sheaves in a row are better for curing oats than round shocks. It is unnecessary to cap oat shocks in Colorado. The crop is usually threshed directly from the shock after they are thoroughly dried.

(b) Oats for Hay

Oats are generally cut for hay when the grain is in the milk stage. Oat hay is the most valuable hay made from any of the cereals. In the last few years, there have been several reports of cattle being poisoned when fed oat hay. Newsom and associates (1937) report a loss of 67 head of cattle near Franktown after being fed on oat hay mixed with some pigweed. The hay was dampened by snow at the time it was fed. Further studies by Thorpe (1938) indicate other cases. Tests for hydrocyanic acid were generally negative. It appears that oats grown along the foothills on poor soils under drouthy conditions are likely to cause trouble, especially when cut immature. More recent work indicates that the nitrates accumulate in the immature growth arrested by drouth. Nitrates, as potassium nitrate, have been isolated in oat hay that caused the deaths. When eaten, the nitrates appear to be changed in the stomachs of cattle to nitrites. The nitrites appear to poison animals, the symptoms being similar to hydrocyanic acid poisoning. Gardner (1940) reports as high as 5 percent \( \text{KNO}_3 \) in oat hays grown under very drouthy conditions, especially where the soils are low in phosphates. Poisoning from oat hay is not believed to be a problem when yields are good.

XII. Oat Diseases

The principal oat diseases in Colorado are the smuts and rusts. Smuts are troublesome under all conditions. Rusts are of minor importance in this state.

(a) Smuts

Both loose smut (Ustilago avenae) and covered smut (U. levis) attack oats. The grain is displaced by masses of black spores that are readily shattered out by wind or rain and carried to healthy plants, (Durrell, 1931) It is almost impossible to distinguish between the two smuts in the field. Markton, a midseason common oat, is extremely resistant to both smuts. Brunner, a red oat, is also highly resistant to smut. The oat smuts can be controlled by seed treatment with New Improved Ceresan applied at the rate of one-half ounce per bushel. After treatment the seed should be stored in an uncovered pile or in sacks for 24 hours. After that, the seed should be planted as soon as possible, but not later than two or three months after treatment. The formaldehyde spray method is also used.

(b) Rusts

The oat rusts are seldom serious enough in Colorado to reduce yields materially. Both crown rust (Fuccinia coronata) and stem rust (P. graminis avenae) have been found in the state. All Colorado varieties are susceptible to crown rust. Resistant varieties is the most satisfactory control where these rusts are serious.
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   Bul 370. 1930.
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11. __________ Superior Germ Plasm in Oats. Yearbook of Agriculture,

Questions for Discussion

1. Describe the oat plant botanically.
2. What is the significance of natural crossing in oats from a practical
   standpoint? How detected? How prevented?
3. Distinguish between two cultivated oat species found in Colorado.
4. How can wild oats be distinguished from cultivated oats?
5. Why do oats retain their viability so long under Colorado conditions?
   What is the practical significance of dormancy in oats?
6. What general conditions are found for oats in Colorado? What oat types
   are adapted to each?
7. Name and describe two varieties adapted to irrigated conditions.
8. Name and describe two adapted dry-land oat varieties.
9. Give cultural methods (rotations, seedbed preparation, seeding practices,
   harvest methods) for dryland oats.
11. Describe the different methods for harvesting oats for grain.
12. Under what conditions may cattle be poisoned by oat hay? What are probably
    the causes?
13. Name the oat smuts, give their symptoms, and describe control measures.
14. What oat rusts are found in the state? Account for their minor impor-
    tance.

(7727-40)
FIELD CROPS IN COLORADO

Chapter 15. Millets

I. Economic Importance

The millets are minor crops in Colorado, being grown almost entirely in the non-irrigated region of eastern Colorado. The two millets grown are: (1) proso, a grain millet; and (2) foxtail millet, primarily a forage crop.

Foxtail millet has proved to be the best yielding, fine-stemmed hay crop that can be grown on the drylands. It has been exceeded only by sorghum. In experiments at Akron from 1925 to 1934, the 10-year average yield of foxtail millet hay was 1.70 tons, or about 70 percent as much as Leoti Red sorgo. The seed yields at Akron averaged 6.6 bushels per acre from 1931 to 1938 as compared with 8.1 bushels for the highest yielding proso variety. Curtis and associates (1940) state that the straw is of rather poor quality when seed is produced. Foxtail millet is not recommended for irrigated lands because alfalfa and other crops produce more and better forage.

Proso, locally called "Hershey", is one of the more important feed grain crops on the non-irrigated lands of eastern Colorado. Curtis and others (1937) state that it yields well on the hard lands in comparison with corn and barley, the other common feed grain crops of the region. It may be fed to the same classes of livestock with equally good results. Proso has been especially popular as a feed for hogs. Proso was recommended as a catch crop both by Hicurdo (1916) and Coffman (1925).

II. The Millet Genera

The millets grown in Colorado are classified in two different genera of the grass tribe Paniceae.

A. Inflorescence spicate (spike-like), with an involucre of bristles below each spikelet; "head" usually 1-3 cm. thick.................. Setaria italica (foxtail millet)

AA. Inflorescence paniculate, with no involucre of bristles below the individual spikelets; glumes not awned...Panicum miliaceum (Proso)

A -- Foxtail Millet¹

III. Botanical Description

Foxtail millet is described by Vinall (1924) and by Curtis and associates (1940) as an annual grass with slender, erect, leafy stems. The plants vary in height from 12 to 40 inches, depending upon variety and season. The seeds are small, convex in shape and are borne in dense, cylindrical, bristly spike-like (compressed) panicles. The spikelet is subtended by an involucre of bristles. The two glumes are unequal, the sterile lemma being the same size as the second glume. The single fertile floret consists of the lemma, Caryopsis and palea. These bracts constitute the hull which

¹The material in this section is taken almost entirely from "Foxtail Millet in Colorado" by J. J. Curtis, J. F. Brandon, and R. K. Weihing.
surrounds the carpusis, and which remain with the threshed "seed". The
hulls of different varieties vary in color, and may be creamy white, yellow,
orange, reddish-orange, green, dark purple, or a mixture of various colors
in the same panicle.

IV. Adaptation

Foxtail millet is a hot-weather crop with about the same general climatic
requirements as sorghum, but is a shorter season crop. This millet requires
from 75 to 90 days to mature seed, but only 55 to 70 days to reach a stage
suitable for hay at Akron (Curtis and associates, 1940). As it requires
only a part of the average growing season of 139 days in this vicinity, it
can be used as a catch crop. For this purpose it may be seeded as late as
July 1.

Millet is one of the first crops to show the effect of drought mainly because
of its shallow root system. It lacks the ability to recover rapidly after
being injured by a period of drought, according to Finall (1924). Millets
have succeeded in dry localities almost entirely through their ability to
escape periods of acute drought on account of their short growing season.

V. Foxtail Millet Varieties

Foxtail millets are primarily grown for hay. Trials at Akron with lambs
show that foxtail millet hay is slightly superior to sorgo fodder when cut
early, but slightly inferior when cut after the seed is ripe. When ripe,
it is sometimes injurious to horses when fed as the sole roughage. The seed
is slightly less palatable than proso and only about 83 percent as valuable
as shown by Akron feeding tests (Curtis and others 1940).

(a) Varietal Yield Trials

The varieties which yielded the most hay at Akron during the period
from 1931 to 1939 were Siberian, German, and Goldmine. The yields are
given in table 1 for this period.

Table 1. Hay Yields of Foxtail Millet Varieties at Akron, 1931-39.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Fallow Land</th>
<th>Sudan Grass</th>
<th>Stubble Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dakota Kursk</td>
<td>2736</td>
<td>100</td>
<td>730</td>
</tr>
<tr>
<td>White Wonder</td>
<td>2805</td>
<td>101</td>
<td>759</td>
</tr>
<tr>
<td>Siberian</td>
<td>3308</td>
<td>119</td>
<td>814</td>
</tr>
<tr>
<td>Goldmine</td>
<td>3169</td>
<td>114</td>
<td>806</td>
</tr>
<tr>
<td>Hungarian</td>
<td>2601</td>
<td>93</td>
<td>747</td>
</tr>
<tr>
<td>German</td>
<td>3318</td>
<td>114</td>
<td>983</td>
</tr>
<tr>
<td>Av. all varieties</td>
<td>3027</td>
<td>---</td>
<td>852</td>
</tr>
</tbody>
</table>

All varieties grown averaged more than a ton of hay per acre on fallowed
land despite the many crop failures in the region during this period.

The highest seed yields were obtained from Dakota Kursk and White Wonder
shown in table 2.
Table 2. Average Seed Yields of Foxtail Millet at Akron, 1931-39.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Fallow Land Bu./A.</th>
<th>Pct. Dakota Kursk</th>
<th>Sudan Grass Bu./A.</th>
<th>Pct. Dakota Kursk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dakota Kursk</td>
<td>11.8</td>
<td>100</td>
<td>1.8</td>
<td>100</td>
</tr>
<tr>
<td>White Wonder</td>
<td>11.8</td>
<td>100</td>
<td>2.0</td>
<td>111</td>
</tr>
<tr>
<td>Siberian</td>
<td>10.3</td>
<td>87</td>
<td>1.3</td>
<td>72</td>
</tr>
<tr>
<td>Goldmine</td>
<td>10.2</td>
<td>86</td>
<td>1.1</td>
<td>61</td>
</tr>
<tr>
<td>Hungarian</td>
<td>10.0</td>
<td>85</td>
<td>1.5</td>
<td>83</td>
</tr>
<tr>
<td>German</td>
<td>8.1</td>
<td>75</td>
<td>1.4</td>
<td>70</td>
</tr>
</tbody>
</table>

There were 4 failures to produce seed, i.e., in 1931, 1934, 1938, and 1939.

Siberian millet is recommended by Curtis and associates (1940) for both hay and seed, but White Wonder, Dakota Kursk, Goldmine and others are nearly equal to Siberian. Their data indicate that failures of foxtail millet on fallowed land are to be expected only 3 or 4 percent of the time.

(b) Variety Descriptions

The principal foxtail millet varieties are described by Curtis and others (1940) as follows:

1. Siberian: A medium-early variety that requires an average of 84 days to mature at Akron. It has medium-sized stems, 12 to 36 inches in height, and bears a medium-sized head that is not lobed. The head has purple bristles. The seed is oval to elliptical in shape and pale orange in color.

2. Dakota Kursk: An early variety that matures in an average of 77 days at Akron. It has slender stems 12 to 34 inches in height. The head is small, has long purple bristles, and usually is not lobed. It develops lobes in exceptionally good years. The seed is oval to elliptical in shape and a little darker orange in color than Siberian.

3. Goldmine: A medium-early variety that requires an average of 86 days to mature. It is about the same as Siberian in height. It has medium-sized stems, while the heads are medium-large and not lobed. The bristles are pale yellow. The seed is elliptical in shape and pale yellow in color.

4. Hungarian: A variety of medium-early maturity, i.e., it requires an average of 85 days to mature at Akron. It grows to a height of 11 to 35 inches. The head is small, not lobed, and has long purple bristles. The seeds are oval to elliptical and vary from pale yellow to purple or black. The seeds in the individual heads are mixed in color.

5. White Wonder: An early variety that requires 79 days to mature. It has stout stems which attain a height of 14 to 33 inches at Akron. The head is lobed, except in the more unfavorable years. It has yellow seeds. The hay is coarser than that of Siberian in years of good yields. This variety is probably an early selection of German.

6. German: This is a medium to late variety in maturity which requires an average of 80 days to ripen. The stems are stout, and vary from 12 to 40 inches in height. The heads are large, lobed, and with long green to purple bristles. The seed is round and pale yellow in color.
VI. Crop Rotations

While foxtail millet is usually grown as a catch crop, it may be used as a regular forage crop in a rotation. Some crops yield poorly after millet. Curtis and associates (1940) report that winter wheat averaged 12.4 bushels per acre after corn and only 9.0 bushels after foxtail millet over an 11-year period. Fallow, or late-planted spring crops such as corn or sorghum, will follow foxtail millet in the rotation much better than fall or early spring-sown small grains. Late spring planting or fallow after foxtail millet will eliminate the depressing effects on the next crop to a large extent. In tests at Akron, the highest yields of foxtail millet were obtained on fallow, intermediate yields on winter wheat or spring seeded small grain stubble land, and the lowest yields on Sudan grass stubble. Fallow land probably can be used to better advantage for small grains or grain sorghums. It is advised that foxtail millet be grown on small-grain or corn stubble land. It should be used largely as a catch crop when seeding conditions for an earlier-planted crop are unfavorable.

VII. Seedbed Preparation

In the spring, stubble land (corn or small grains) should be worked with shovel-type implements, such as the duckfoot cultivator or spring-tooth harrow, as soon as weeds emerge. This cultivation will leave the surface soil rough to reduce wind erosion, and receptive to spring rains. The disk-harrow is advisable only when there is excessive weed growth or crop residues. In parts of southeastern Colorado, where the small-grain crop is harvested early, the land may be fall-listed to roughen the surface and destroy weeds. In general, fall tillage is not beneficial to the next spring-seeded crop in northeastern Colorado, unless done prior to about August 15. In the spring, the land should be kept free of weeds until seeding time.

Land with little or no crop residue should be fall-worked with an ordinary lister or with a basin lister or duckfoot cultivator to check run-off and to prevent wind erosion.

Foxtail millet requires a firm seedbed, which makes it necessary to level listed fields 3 or 4 weeks before seeding time. This cultivation, as well as later ones to control weeds, should be done with shovel-type implements.

VIII. Seeding Practices

A grain drill is nearly always used to seed foxtail millet. The 5 to 8-inch drills are preferable to the wider-spaced furrow drills because the closer-spaced rows aid the crop to compete with weeds. As the seed is small, it should be planted shallow. It may be sown about one inch deep, or a little deeper, when necessary to place it in moist soil.

Foxtail millet should be planted as soon as possible after May 15 and before July 1 whenever there is sufficient moisture in the surface soil to germinate the seed and support plant growth. Conditions usually are favorable after a rain of 0.75-inch or more. The crop should be planted as soon as possible after such a rain. Average yields for different dates are given in table 3, for the period from 1930 to 1939.
Table 3. Average Yields of Foxtail Millets at Akron for Different Seeding Dates, 1930 to 1939.

<table>
<thead>
<tr>
<th>Seeding Date</th>
<th>Hay Yields</th>
<th>Seed Yields</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pounds / A. Pct. May 15 Yield</td>
<td>Bu./acres Pct. May 15 Yield</td>
</tr>
<tr>
<td>May 15</td>
<td>2352</td>
<td>100</td>
</tr>
<tr>
<td>June 1</td>
<td>2126</td>
<td>90</td>
</tr>
<tr>
<td>15</td>
<td>1985</td>
<td>84</td>
</tr>
<tr>
<td>July 1</td>
<td>1464</td>
<td>62</td>
</tr>
<tr>
<td>15</td>
<td>895</td>
<td>47</td>
</tr>
<tr>
<td>August 1</td>
<td>217</td>
<td>11</td>
</tr>
</tbody>
</table>

Foxtail millet should be sown at the rate of 25 to 30 pounds per acre to provide a thick stand to enable the crop to compete with weeds. A rate of 10 to 15 pounds is ample for weed-free soil.

IX. Methods of Harvest

A mower may be used to cut foxtail millet for hay. It should be cut when the heads first appear. Millet is more palatable and nutritious at the earlier stages of growth than when fully mature. It should be windrowed before fully dry to complete the curing, after which it may be stacked.

When harvested for seed, the crop is usually cut with a binder or header and windrowed. It should be allowed to stand in the field until the seed can be rubbed from the head in the hand. The seed can be threshed with an ordinary separator equipped with the proper screens for small seeds or, when the crop is windrowed, a combine with pick-up attachment may be used.

X. Foxtail Millet Diseases

The smut of millet (Ustilago carameri) is of frequent occurrence in the state. Durrell (1931) states that the disease attacks the millet heads. It resembles covered smut of wheat in appearance, manner of attack, and spread. The diseased plants are stunted while the heads appear yellowed. At maturity, the diseased seeds are filled with masses of dark smut spores. The disease can be controlled by organic mercury dusts as for covered smut of wheat. This disease has never proved serious at Akron.

XI. Botanical Description

Proso is often called hog millet, Hershey, or broomcorn millet. It is distinguished from the foxtail millets by an open-panicked head, similar to that of oats. The seed is larger and not so tightly held in the hull as in the foxtail millets. When threshed, most of the seed remains in the hull (lemmas and paleas). The hulls of different varieties of proso are of various shades and colors: white, cream, yellow, red, brown, gray, or black. The seed coat of all varieties is creamy white. (See Martin, 1924).

Proso has coarse, hollow, hairy stems. At Akron, the crop averages from 22 to 24 inches in height. This varies in different varieties. White Ural, a very early variety, has been as short as 11 inches in a very unfavorable year, while White French, a tall variety, has grown to 52 inches in a favorable year.
Proso flowers may be either cross- or self-fertilized, according to Curtis and others (1937). As a large percentage of the flowers are self-fertilized two varieties may be grown side by side without much cross-pollination.

XII. Adaptation

Proso is sometimes referred to as being very drouth-resistant. Seeded in season, it matures very quickly, that is, in 60 to 65 days. It may produce a fair crop with only one or two consequential rains, that is, 1 inch or more after seeding. Thus, the crop is more truly drouth-evasive than drouth-resistant, even tho it does have the lowest water requirement of any crop tested at Akron. Proso is sometimes a complete failure in seasons when barley has produced good yields. Conversely, it sometimes produces good yields in seasons with delayed summer rains when barley fails or when both barley and corn yield poorly.

Curtis and associates (1957) observed that proso is a relatively shallow-rooted crop, being better adapted to the "hard land" soils than to the sandy soils. Corn will outyield proso on the sandy soils. The shallow-root habit may explain why the crop apparently lacks drouth resistance when moisture is scarce.

Due to its quick maturity, proso is adapted as a catch crop in many regions of Colorado. It is often used for seeding on "hailed-out" wheat land up to July 10 at an altitude of 4600 feet.

Proso is unadapted to irrigated lands, because it lacks the yield capacity of either barley or corn. It has a top limit in yield of about 60 bushels per acre in Colorado, and would probably lodge in attempts to obtain higher productions.

XIII. Proso Varieties

Variety tests with proso were begun at Akron in 1908. Brandon and others (1932) reported 13-year average yields for several varieties during the period from 1908 to 1931. These were as follows: Red Russian 24.6 bushels, Tarshai 24.6, Tambov 23.5, and Black Voronozh 20.2 bushels per acre. Results from 1930 to 1936 at Akron are reported by Curtis and associates (1937).

(a) Varietal Trials

The average yield in bushels per acre for several varieties grown on fallow and Sudan-grass stubble are given in table 4.

Table 4. Average Yields of Proso Varieties at Akron, 1930 to 1936.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Grain Yields</th>
<th>Straw Yields</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bushels per Acre</td>
<td>Pounds per Acre</td>
</tr>
<tr>
<td>White Ural</td>
<td>9.0</td>
<td>370</td>
</tr>
<tr>
<td>Tambov</td>
<td>14.3</td>
<td>1473</td>
</tr>
<tr>
<td>Early Fortune</td>
<td>11.4</td>
<td>1067</td>
</tr>
<tr>
<td>Red Russian</td>
<td>14.3</td>
<td>1611</td>
</tr>
<tr>
<td>White Siberian</td>
<td>13.0</td>
<td>1432</td>
</tr>
<tr>
<td>Tarshai</td>
<td>15.9</td>
<td>1643</td>
</tr>
<tr>
<td>Yellow Manitoba</td>
<td>14.4</td>
<td>1865</td>
</tr>
<tr>
<td>White French</td>
<td>5.1</td>
<td>1724</td>
</tr>
<tr>
<td>Black Voronozh</td>
<td>12.8</td>
<td>1325</td>
</tr>
</tbody>
</table>
The highest grain yield was obtained from Turghai. Red Russian, Tambov, and Yellow Manitoba yielded from 1.0 to 1.5 bushels less. The highest straw yield, 1865 pounds was obtained from Yellow Manitoba. Turghai ranked third in straw yield. Black Voronezh, a black-seeded variety, is discriminated against on the market because most of the proso grain is used in mixed feeds. The black hulls give an undesirable color to these feeds. Neither White French nor White Ural are adapted at Akron. Turghai or Yellow Manitoba are usually grown in Colorado. Coffman (1925) reported that proso was inferior to foxtail millets, such as Siberian, for hay.

(b) Variety Descriptions

Martin (1924) divides proso varieties into 3 main groups based on panicle characteristics, whether, spreading, loose, or compact. Some of the varieties grown in Colorado are described as follows:

1. Turghai: A variety with spreading panicles. The seeds are yellowish-brown in color, while the glumes are reddish-green. It is an early to midseason variety with plants short to mid tall.

2. Yellow Manitoba: A variety with a loose, one-sided panicle. The seeds are yellowish while the glumes or outer chaff are yellowish green. It is a midseason to late variety and mid tall to tall in plant height.

3. Red Russian: A variety with a spreading panicle. The seeds are reddish brown and the glumes reddish green in color. It is an early to midseason variety and short to mid tall in plant height. This variety is very similar to Turghai in appearance.

4. Tambov: A variety with spreading panicles. The seeds are reddish brown and the glumes reddish green in color. This variety is early to midseason in maturity, and short to mid tall in plant height.

5. Early Fortune: A variety with a compact head and large reddish brown seeds. The glumes or outer chaff are yellowish green. It is early to midseason in maturity and the plants are short to mid tall in height.

6. Black Voronezh: A variety with a loose one-sided panicle, brownish black seeds, and yellowish green glumes. It is a midseason to late variety and mid tall to tall in plant height.

XIV. Crop Rotations

Proso is a late-seeded, short-season summer crop well adapted to follow any other crop that may be grown in the rotation. For this reason, it may follow the most severe conditions of crop sequence such as after sorgo. Proso leaves a closely spaced stubble that is ideal to hold the soil in place. Winter wheat can usually be drilled in proso stubble without previous tillage. The average yield of winter wheat on proso stubble for the period from 1931 to 1936 was 10.1 bushels per acre, compared with an average yield from corn land of 7.1 bushels per acre. Rotation studies indicate that proso leaves the best stubble for subsequent crops of any of the cereal small grains adapted at Akron. It differs greatly from foxtail millet in this respect.
XV. Seedbed Preparation

Fallow is a good preparation for proso. However, winter wheat responds well to fallow and generally brings a greater acre return. Small grain stubble land intended for proso should be worked early in the fall or spring and kept free from weeds up to seeding time. Shovel-type implements, such as the spring-tooth harrow, the duckfoot cultivator, or the Peacock lister, should be used where possible. Other considerations of seedbed preparation are the same as for foxtail millets.

(a) Rate of Seeding

Experiments to determine the best rate of seeding have been carried on at Akron since 1930. Yellow Manitoba was seeded late in June each year at rates per acre as follows: 20, 28, 35, 48, and 53 pounds. The highest average yield was obtained from 53 pounds of seed per acre, but the increase in yield over the 35 pound rate was only 0.8 bushel per acre. Under Akron conditions, 35 pounds should be ample to secure a good stand. The light seeding rates were noticeably weedier than the heavier rates in all years.

(b) Date of Seeding

Date of seeding experiments were conducted at Akron from 1930 to 1936 with two varieties, Turghai and Yellow Manitoba. The results are given in table 5.

Table 5. Average Yields of Proso Seeded on Different Dates at Akron, 1930 to 1936.

<table>
<thead>
<tr>
<th>Date Sown</th>
<th>Grain Yields per Acre (Bu.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yellow Manitoba</td>
</tr>
<tr>
<td>May 15</td>
<td>4.1</td>
</tr>
<tr>
<td>June 1</td>
<td>5.7</td>
</tr>
<tr>
<td>15</td>
<td>6.5</td>
</tr>
<tr>
<td>July 1</td>
<td>7.4</td>
</tr>
<tr>
<td>15</td>
<td>6.3</td>
</tr>
<tr>
<td>August 1</td>
<td>5.0</td>
</tr>
</tbody>
</table>

The land used in this experiment was clean-cultivated up to the respective seeding dates.

The highest yields for both varieties were obtained when seeded July 1. The yields of proso seeded June 15 were slightly lower. Three failures out of 7 occurred in the July 15 seedings. The May 15 were comparatively free from weeds. Proso should be seeded between June 15 and July 1 for the best yields.

XVII. Methods of Harvest

Proso heads ripen from the top downward. Curtis and associates (1937) state that harvesting too early results in immature seed on the lower portion of the head. Harvesting too late results in heavy losses from shattering.
Heading the crop with ordinary small-grain machinery when the heads are about two-thirds ripe is one of the best methods of harvest. When headed, the grain may be allowed to become considerably riper than when it is cut with a binder. Some growers arrange to run 2 headers and elevate the double swath into one windrow. Others have improvised boxes to catch the grain from the header and then dump it into sizeable piles. The choice depends upon the ultimate method planned for threshing. When a pick-up attachment for the combine harvester is available, the crop may be threshed readily from the windrow. For the ordinary thresher, the piles are loaded and hauled to the machine after they have field cured. The header and combine harvester are great improvements over the old method of harvesting proso.

Proso is unadapted to direct combine harvest because it shatters and lodges soon after ripening. Furthermore, the seed and straw contain too much moisture at harvest time. The harvested crop should be allowed to dry in piles or windrows before being picked up by the combine harvester and threshed.

Where the binder is used, the crop must be cut just as soon as the top seeds show evidence of shattering. The stems and leaves of the plant will still be green at that stage, but the bundles can be placed in small narrow shocks where they will cure satisfactorily. The shocks must be aired in wet weather to prevent damage to the grain.

References

Questions for Discussion

1. How does foxtail millet compare with other dryland forage crops for hay?
2. How does foxtail millet compare with proso as a grain crop?
3. Distinguish between proso and foxtail millet.
4. Describe foxtail millet botanically.
5. To what conditions is foxtail millet adapted in Colorado?
6. Is foxtail millet drought resistant? Why?
7. Name and describe a variety of foxtail millet recommended for hay production in Colorado.
8. Name and describe 3 foxtail millet varieties grown on the drylands.
9. Discuss crop sequences for foxtail millet.
10. Describe seedbed preparation for foxtail millet.
12. Tell how to harvest foxtail millet for hay. For seed.
13. Describe smut of foxtail millet and control measures.
15. Give the adaptation of proso in Colorado.
16. Why is proso a desirable catch crop on the drylands?
17. Name and describe 2 proso varieties well adapted in the state.
18. What are the objections to Black Voronezh? White Ural?
19. Describe crop sequences for proso.
20. What precautions are necessary in seedbed preparation for proso? Why?
21. How is proso generally seeded? Why?
22. What rates of seeding are the most satisfactory for proso? Dates of seeding?
23. Describe proso harvest with a header.
24. Give the method for harvesting proso with a binder.
Chapter 16. Forage Grasses

I. Economic Importance

Cultivated forage grasses are important in Colorado for hay and pasture. Some of them are adapted to irrigated pasture mixtures while others are sufficiently drought resistant for reseeding abandoned non-irrigated crop lands to grass, particularly in the more favorable locations.

Among the forage grasses adapted to different situations in the state are: Timothy (Phleum pratense), brome grass (Bromus inermis), orchard grass (Dactylis glomerata), crested wheatgrass (Agropyron cristatum), slender wheatgrass (Agropyron pauciflorum), redtop (Agrostis alba), meadow fescue (Festuca elatior), Kentucky bluegrass (Poa pratensis), tall oat grass (Arrhenatherum elatius), roed canary grass (Phalaris arundinacea), and perennial rye grass (Lolium perenne).

II. Grass Tribes

The common cultivated forage grasses grown in Colorado can be classified in 8 tribes. The characteristics that distinguish these tribes are as follows:

1. Spikelets one-flowered.
   a. Glumes none-----------------------------------Oryzaceae.
   b. Glumes two-----------------------------------Poaceae.
   c. Glumes three-----------------------------------Poaceae.
   d. Glumes four-----------------------------------Poaceae.

2. Spikelets in pairs (occasionally 3)
   a. One sessile, one pedicellate. The pedicellate
      flower may be sterile or reduced to a mere
      pedicel-----------------------------------------------Andropogoneae.

3. Spikelets two to several-flowered.
   a. Rachis zig-zag-----------------------------------Poaceae.
   b. Rachis not zig-zag-----------------------------------Poaceae.
   c. Spikelets on one side of rachis---------------------Chlorideae.
   d. Lemma armed, am arising midway between base
      and apex of lemma-----------------------------------Aveneae.

The cultivated forage grasses in Colorado belong to tribes as follows:

1. Agrostideae: Redtop (Agrostis alba), and timothy (Phleum pratense).
2. Phalarideae: Reed canary grass (Phalaris arundinacea).
3. Hordeae: Crested wheatgrass (Agropyron cristatum), slender wheatgrass
   (A. pauciflorum) and perennial ryegrass (Lolium perenne).
4. Festucaceae: Brome grass (Bromus inermis), meadow fescue (Festuca
   elatior), orchard grass (Dactylis glomerata), and Kentucky
   bluegrass (Poa pratensis).
5. Aveneae: Tall oatgrass (Arrhenatherum elatius).
III. General Cultural Methods

To prepare the soil for grass seeding will depend on the site, previous land use, and whether or not irrigation water is available. Abandoned cultivated lands on the Great Plains present problems quite different from those on depleted eroded mountain slopes.

(a) Dryland Cultural Methods

Experiences of the experiment station and farmers indicate that certain precautions are necessary for seeding grasses in dryland fields previously farmed. These are discussed by Stewart (1932), and by Nelson and Shephard (1940). The suggestions of Stewart (1932) are as follows: (1) The field to be seeded should have a firm seedbed and an abundance of stored moisture, such as corn stubble or fallow land that has been kept free of weeds. (2) Wind erosion should be prevented by leaving the stubble on the surface, or by leaving a small clover mulch by the use of shovel-type implements. (3) Early seedings (April) have a better chance to become established before the approach of hot dry weather. (4) Grasses should be planted which have the greatest chance to succeed. These are slender wheatgrass, brome, and crested wheatgrass (in the cooler regions). (5) A rate of 12 to 15 pounds of seed per acre should be sufficient. A mixture has some advantages over a single grass. (6) The common drill has been used successfully for seeding grasses. Corn choppers will help chiefly grass seed to feed down. The drill set to seed 1.5 bushels of oats per acre should drop sufficient seed. (7) Alternate holes in the furrow drill, or 2 or 3 holes in the common drill, may be stopped in order to plant grasses in rows. Rows are desirable for a seed crop or for weed control. (8) Livestock should be kept away from new seedings the first year to allow the plants to become established.

Additional suggestions have been made by Nelson and Shephard (1940). Strips of weeds may be left between seeded strips to control wind erosion. Aggressive species will often fill in the weed strips. A suitable seedbed has been prepared in mountainous areas by the disk or harrow. Where topographic features permit, plowed contour furrows spaced several feet apart, often afford an effective seedbed on slopes. Seed should be drilled rather than broadcast where possible. On most soils, a depth of 0.75 to 1.00 inch will bring about emergence so long as the seed is planted in moist soil. A satisfactory rate for large-seeded grasses, such as brome, is 5 to 10 pounds per acre; while for small-seeded grasses, like crested wheatgrass, a rate of 5 to 6 pounds will suffice on cultivated fields. Dependent on moisture supply, grasses may be seeded in the early fall, late fall, or early spring. Fall plantings should be early enough to allow the seedlings to become established before frost. Late fall seedings, which are more certain in the mountainous regions, should be delayed enough to prevent germination before spring. Companion crops are inadvisable for grass seedings in the semi-arid regions.

(b) Irrigated Conditions

A seedbed for grasses under irrigated conditions should be firm, especially for the establishment of pastures. Stewart and others (1932) advise seeding on a field that was clean-cultivated the previous year in order to reduce the competition with weeds. Such fields can be prepared as a seedbed with a disk, harrow, and float. The seed may be planted when continuous irrigation water is available, either in the fall or spring. The light chaffy seed should be placed in the drill box, while heavy seeds of mixtures should be seeded thru the grass-seeder attachment.
IV. Comparative Grass Yields

Forage yields of various cultivated grasses have been reported for irrigated and high altitude conditions.

(a) Irrigated Conditions
Grass yields under irrigation at Fort Collins are reported by Stewart and associates (1932). Some of their data are given in Table 1.

Table 1. Yields of Hay from Forage Grasses under Irrigation.

<table>
<thead>
<tr>
<th>Grass Species</th>
<th>Rate Seeded (lbs.)</th>
<th>Av. No. Irrigations</th>
<th>Crop Years Grown</th>
<th>Av. Yield Hay in Pounds per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brome</td>
<td>15</td>
<td>4.5</td>
<td>12</td>
<td>2553</td>
</tr>
<tr>
<td>Slender wheat</td>
<td>15</td>
<td>4.5</td>
<td>11</td>
<td>2750</td>
</tr>
<tr>
<td>Orchard</td>
<td>30</td>
<td>4.5</td>
<td>13</td>
<td>2224</td>
</tr>
<tr>
<td>Meadow fescue</td>
<td>25</td>
<td>4.5</td>
<td>8</td>
<td>2156</td>
</tr>
<tr>
<td>Tall oat</td>
<td>40</td>
<td>4.5</td>
<td>13</td>
<td>3263</td>
</tr>
<tr>
<td>Crested wheat</td>
<td>10</td>
<td>4.5</td>
<td>3</td>
<td>1513</td>
</tr>
</tbody>
</table>

(b) High Altitude Tests
Several forage grasses were grown under dryland conditions at Fort Lewis at an elevation of 7600 feet during the 10-year period from 1926 to 1935. The average annual precipitation for this period was 18.56 inches. The hay yields, as well as quadrat counts, in Table 2.

Table 2. Dryland Grass Yields at Ft. Lewis, 1926 to 1935.

<table>
<thead>
<tr>
<th>Grass Species</th>
<th>Rate Seeded</th>
<th>Forage Yields in Pounds per Acre</th>
<th>Plant Counts on Sq. Yd. Quadrats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slender wheat</td>
<td>10</td>
<td>163</td>
<td>8.3</td>
</tr>
<tr>
<td>Orchard</td>
<td>30</td>
<td>270</td>
<td>12.3</td>
</tr>
<tr>
<td>Tall oat</td>
<td>40</td>
<td>458</td>
<td>8.5</td>
</tr>
<tr>
<td>Meadow fescue</td>
<td>15</td>
<td>249</td>
<td>8.5</td>
</tr>
<tr>
<td>Brome</td>
<td>15</td>
<td>416</td>
<td>17.2</td>
</tr>
<tr>
<td>Crested wheat</td>
<td>3</td>
<td>378</td>
<td>18.9</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>326</td>
<td>33.1</td>
</tr>
</tbody>
</table>

The differences between spring and fall seedlings were due purely to moisture and seedbed conditions.

V. Smooth Brome Grass (Bromus inermis)

Brome grass is one of the best cultivated forage grasses in Colorado. It is widely used in Horton's pasture grass mixture under irrigated conditions.

(a) Botanical Description
Smooth Brome is classified in the Tribe Festucceae in which there are many florets per spikelet. The genus Bromus is characterized by a lemma which is 2-toothed at the apex. Brome grass is a long-lived perennial that spreads by underground rootstalks or rhizomes. Hitchcock (1935) describes it as an erect grass with narrow, many-flowered panicles, and smooth, narrow spikelets about one inch long, the lemmas being acute, awnless, or nearly so. The inflorescence assumes a brown color towards seed maturity. In the vegetative stage, smooth brome may be identified by a constriction or demarkation on the leaf blade. Brome produces a dense sod after a few years,
that is, it becomes sod-bound.

(b) Adaptation

Smooth brome has been a widely grown pasture grass in the semi-arid region. It is the best grass in Morton's mixture, being well-adapted to irrigated conditions. It is primarily a pasture grass in Colorado, and can withstand close grazing and trampling. Brome is fairly alkali tolerant. It will grow in some dryland regions, especially in wet sandhill valleys. At Akron and Cheyenne Wells it was found to do well in wet years. However, 2 years of drought were found to kill it out. In recent years it has been replaced largely by western and crested wheatgrasses. Koonce (1937) observed it to be drought resistant under high altitude conditions. It produced a good cover and forage yield in 1935 after the severe drought of 1934. Brome persisted, increased, and became the predominant grass in all Fort Lewis tests. This grass is adapted to a wide altitude range. Stewart and others (1932) report it as grown successfully at 9300 feet in Teller, as well as at lower altitudes in other mountain counties.

(c) Forage Value

This grass compares favorably in nutrients, palatability, and yield with that of any cultivated grass. It has a greater yield capacity than crested wheatgrass. Brome withstands heavy grazing and trampling, being an excellent pasture grass.

VI. Orchard Grass (Dactylis glomerata)

This grass is grown in Colorado almost entirely in irrigated pasture grass mixtures, especially those that contain sod-forming grasses.

(a) Botanical Description

Orchard grass is a deep-rooted, long-lived perennial bunch-grass that will persist 10 or more years after it is established. It is rather coarse and erect. Hitchcock (1935) describes the inflorescence as a panicle in which the spikelets are compressed in dense, one-sided fascicles borne at the ends of a few panicle branches. The glumes are unequal in size, and ciliate on the keels. The lemmae are compressed, keeled, mucronate, and ciliate on the keels also. The leaf blades are folded and the stems flattened.

(b) Adaptation

Orchard grass is adapted to cool moist conditions. It will stand some drouth, but not such as experienced in dry upland farm regions. It is less drought-resistant than Brome, but Koonce (1937) found it to be fairly consistent in stand and yield in dryland tests at Fort Lewis. It survived the drouth of 1934, and withstood competition in mixtures. Orchard grass will stand shade better than other meadow grasses.

(c) Forage Value

Orchard grass is coarse as a hay grass, being less valuable than either brome or timothy. Its bunch habit makes it less desirable for meadows. It is grown in Colorado almost entirely in pasture mixtures where it makes excellent forage when combined with other grasses. It starts growth early in the spring and produces an abundance of leafy growth throughout the summer.

VII. Meadow Fescue (Festuca elatior)

Meadow fescue is used principally as a pasture grass under irrigation in Colorado.
(a) **Botanical Description**

This grass is classified in the Tribe Festucae. Hitchcock (1935) describes it as a smooth perennial 1-4 feet high with flat blades and narrow but loose panicles 4 to 8 inches long. The awnless spikelets are about one-half inch in length. It is a semi-sod-forming grass.

(b) **Adaptation**

Meadow fescue grows best where moisture is plentiful. It has few equals in wet situations. This grass is remarkably long-lived, and noticeably frost resistant. It matures rapidly after seeding, being desirable in mixtures with some of the slower-growing species. It is adapted to most regions in Colorado under irrigation, or regions of moderately heavy rainfall. Koonce (1937) found that meadow fescue did not become established as soon as brome, is short-lived, and is unable to compete satisfactorily in mixtures under dryland conditions at Fort Lewis. Very few plants persisted after 4 years.

(c) **Forage Value**

This grass is grown for pastures rather than for hay and preferably in mixtures. It is slower to start in the spring than brome or orchard grass, but furnishes a fine palatable growth during the summer and late fall. Koonce (1937) reported an average forage yield to compare favorably with that of orchard when grown alone at high altitudes. Meadow fescue is an important grass in Morton’s mixture.

VIII. **Slender Wheatgrass (**Agropyron pauciflorum**)**

Slender wheatgrass is the only native grass to be used to any considerable extent under cultivation, according to Nelson and Shepherd (1940).

(a) **Botanical Description**

Slender wheat is a perennial bunchgrass with erect, slender to stout stems from 6 to 48 inches in height. The spikelets are slender, being from 2 to 8 inches in length. The spikelets are described by Hitchcock (1935) as solitary at a rachis joint, several-flowered, and sessile. The rachilla disarticulates above the glumes. The glumes are broad and nearly as long as the spikelet. The lemmas are awnless. It starts growth in the spring about 2 weeks later than crested wheatgrass. This species is short-lived and usually dies out after 4 or 5 years.

(b) **Adaptation**

Slender wheatgrass has an extremely wide range of adaptation, but Nelson and Shepherd (1940) observe that it is predominantly a grass of mountain areas in Colorado. It makes its maximum growth at 8000 feet elevation in the northern half of the state. It is drought resistant and withstands low temperatures. It has done quite well at Akron, but it is short-lived. Slender wheatgrass makes its best growth on well-drained, light, sandy soils. It possesses a high degree of tolerance to soil salinity, and can be grown in a mixture with sweet clover in such locations.

(c) **Forage Value**

The forage is rated rather high as feed for livestock, particularly for cattle and horses. It is readily grazed by sheep up until the time it flowers. At that time the herbage becomes somewhat harsh. As a hay, it is slightly lower in protein and higher in fiber than Brome grass or crested wheatgrass. It should be cut for hay in the flowering stage. Nelson and Shepherd (1940) observe that delayed cutting results in a coarse hay that may contain harmful amounts of ergot.
IX. Crested Wheatgrass (*Agropyron cristatum*)

Crested wheatgrass is one of the best grass species for range reseeding in the state, especially in the dry cool regions.

(a) Botanical Description

Crested wheatgrass is classified in the Tribe Hordeae. It is a long-lived perennial bunchgrass that tillers profusely. The crowded spikelets tend to stand out from the axis of the spike, which therefore appears rather broad. In some types, the seeds have decided awns, while others are practically awnless. The stems are generally fine and the leaves dark green in color. This grass has been known to be productive for 10 to 15 years. It grows at lower temperatures than most grasses and starts growth in the spring 5 to 14 days earlier than either brome grass or slender wheatgrass. Nelson and Shepherd (1940) observed it to mature seed at Fort Collins from July 15 to 31, after which it remained dormant until early fall. It then makes considerable regrowth.

(b) Adaptation

Crested wheatgrass is especially adapted to conditions of severe winter temperatures and limited moisture. Stewart and associates (1932) report it to be one of the earliest and most drought-resistant of the perennial cultivated grasses. It is believed to be adapted to the cooler regions of the state, being almost a failure under hot dryland conditions at Akron. Some recent observations indicate that this may be due to root-rot organisms. Nelson and Shepherd (1940) found it to be exceptionally good in high mountain plantings, but better adapted to the lower foothills of the eastern slope. It is successfully grown in northern Colorado at elevations of 5000 to 8000 feet. At Fort Lewis, Koone (1937) observed that it would take several years for crested wheatgrass to become established under high altitude dryland conditions. While adapted to this part of the state, neither the cover nor the yield was as good as that of brome grass after the 1934 drought. This grass appears to make its best growth on loam soils, although good results have been obtained on both light sandy and heavy clay loams. It is slightly alkali tolerant.

(c) Forage Value

The forage value is equal to that of most native grasses in Colorado. The herbage is relished by all classes of livestock. It is valuable as a hay crop in the cooler regions of low precipitation.

X. Timothy (*Phleum pratense*)

Timothy is grown in Colorado principally as a hay crop, although it is included in Morton’s pasture grass mixture in the cooler irrigated regions.

(a) Botanical Description

Timothy is classified in the grass tribe Agrostideae. It is a tall bunch grass with the culms arising from a swollen or bulb-like base. The panicle is cylindric, commonly 5 to 10 cm. long. The spikelets are crowded, one-flowered, and laterally compressed. The glumes are equal, membranous, keeled, and abruptly mucronate or awned. Common timothy has ciliate hairs on the keels of the glumes. The only native species is mountain timothy (*P. alpinum*), a perennial with short spikes 2 or 3 times as long as wide. It is considered a valuable late sheep pasture in mountain meadows. (See Hitchcock, 1935).
(b) Adaptation

Timothy is a cool-season plant that requires considerable moisture. It makes a quick growth, but is short-lived when grazed closely. It grows well in mixtures of alsike clover in North, South, and Middle Parks. Under dryland conditions at Fort Lewis, Kooces (1937) observed that the conditions were too dry for the crop, the results obtained being unfavorable. It is not adapted to eastern Colorado dryland conditions.

(c) Forage Value

Timothy is an extremely palatable pasture grass but is usually short-lived under grazing conditions. It does not produce a heavy leaf growth like brone, orchard, or tall oat grass. Therefore, the feed value of timothy alone is not considered to be very high. When mixed with alsike clover in hay meadows, excellent yields of high quality hay are obtained.

XI. Tall Oat Grass (Arrhenatherum elatius)

Tall oat grass is a succulent high-yielding bunch grass that may have a place in Colorado in irrigated pasture mixtures, especially in the cooler parts.

(a) Botanical Description

Tall oat grass belongs to the tribe Aveneae. Hitchcock (1935) describes it as a hardy perennial bunch grass that grows to a height of 30 to 60 inches. The inflorescence is an open panicle somewhat similar to cultivated oats, the seed is much smaller and more carply. The Spikelets are 2-flowered, the lower floret being staminate and the upper one perfect. The lemmas are hairy on the callus. The lower lemma bears a twisted, geniculate, exserted um near the base, while the lemma of the upper floret bears a short, straight, slender um just below the tip. The seed is very low in vitality, it being difficult to secure a stand.

(b) Adaptation

Tall oat grass is described by Stewart and others (1932) as best adapted to irrigated conditions or to areas with rather high rainfall in the state. Kooces (1937) found it to mature early under high altitude dryland conditions at Fort Lewis. When planted alone, it produced the highest average forage yield, the stand and cover being consistent. It was unable to withstand competition in mixtures, being practically eliminated after 6 to 8 years. It seems to require more moisture than is regularly available at Akron.

(c) Forage Value

The results of Colorado indicate tall oat grass to be one of the better hay grasses. Its ability to withstand close grazing has not been determined under Colorado conditions. As a pasture grass, it has a bitter taste to which stock must become accustomed. Piper (1922) states that it is palatable and highly nutritious.

XII. Redtop (Agrostis alba)

Redtop is grown on wet lands in Colorado, there being probably 200 to 300 acres in the San Luis Valley.

(a) Botanical Description

Redtop is classified in the tribe Agrostideae. The panicle has an open, reddish color. This species is erect and produces rhizomes. The blades are flat, and the ligules prominent and somewhat pointed.
(b) Adaptation
Redtop is well adapted to wet swampy lands or meadows where the roots bind the soil firmly and make it very resistant to stock trampling. Stewart and others (1932) have observed that it will grow when kept under water for several days. However, redtop is adapted to a wide range of conditions. It thrives on relatively dry lands and is equal to timothy in cold resistance. Koonce (1937) observed that redtop persisted in dry years, but produced very little forage. It is not adapted to the dryland conditions of the plains region.

(c) Forage Value
Redtop is one of the least palatable of the cultivated grasses. Stewart and associates (1932) advise that it be grown in mixtures with white Dutch clover, ladino clover, or alsike clover to increase its value and palatability in pastures.

XIII. Reed Canary Grass (Phalaris Arundinacea)

This grass has come into prominence in recent years, especially on wet lands. It grows wild from Colorado northward.

(a) Botanical Description
Reed canary grass belongs to the tribe Phalarideae in which there are 4 glumes and one fertile floret per spikelet. There is one terminal perfect floret in reed canary grass. The 2 sterile lemmas (or glumes) are reduced to 2 small bracts. The inflorescence is a rather loose, spike-like panicle 2 to 6 inches long.

(b) Adaptation
This grass is adapted particularly to low, wet, poorly drained land. It is able to thrive where the water table is practically at the soil surface all the time and above part of the time. It may have a place on wet lands in this state.

(c) Forage Value
Reed canary grass is reported to be an excellent grass for pasture or hay. It should be cut for hay as soon as the panicles begin to appear. Otherwise, it is woody and coarse.

XIV. Perennial Ryegrass (Lolium perenne)

This grass is sometimes grown in the warmer regions of the state in irrigated pasture mixtures. It is classified in the tribe Hordeae. The spikelets are several-flowered, solitary, and set edgewise to the rachis. There is only one glume, except in the terminal spikelet. The spikelets contain 8 to 10 florets, the lemmas being awnless. Perennial ryegrass is short-lived, Koonce (1937) found that it persisted for only a few years under high altitude natural rainfall conditions. It was almost a complete failure at Fort Lewis. In the warmer regions of the state, this grass is recommended in Kortens mixture instead of timothy.

XV. Kentucky Bluegrass (Poa pratensis)

Kentucky bluegrass is primarily a pasture grass adapted to areas with a plentiful moisture supply. It is sometimes seeded in irrigated pasture mixtures. Hitchcock (1935) describes it as 15 to 40 inches tall. The sheaths are somewhat keeled. The panicle is pyramidal, and open. The spikelets are small, crowded, and 3 to 5 flowered. The lemmas are cob-webby at
the base. This grass spreads by rhizomes. When planted in mixtures, Stewart and associates (1932) state that it will crowd out all other grasses or crop plants except Dutch white clover where soil moisture is abundant. Unless continuously supplied with moisture, bluegrass will fire or produce very little forage in July and August. Koonce (1937) found it to cause considerable trouble by sodding alfalfa fields.

References


Questions for Discussion

1. Name 8 cultivated forage grasses grown in Colorado, together with their scientific names.
2. Give suggestions for the establishment of perennial grasses on drylands previously cropped.
3. What precautions should be taken on seeding grasses or lands subject to wind erosion?
4. At what seasons of the year may grasses be seeded? Why?
5. Explain how to seed grasses under irrigated conditions.
6. What 3 grasses produced the highest forage yields at Fort Collins? At Fort Lewis?
7. Describe brome grass and give the conditions to which it is adapted.
8. Why is orchard grass primarily a pasture grass? To what conditions is it adapted?
9. Compare meadow fescue with brome under Fort Lewis conditions.
10. Distinguish between slender wheatgrass and crested wheatgrass. To what conditions is each adapted?
11. Describe the timothy plant. Why is it poor in pastures?
12. Name 2 objections to tall-oat grass as a forage plant.
13. Name and describe 2 grass species adapted to wet lands in the state.
14. Describe perennial ryegrass and state the conditions to which it is adapted.
FIELD CROPS IN COLORADO

Part III

Leguminous Crops
I. Economic Importance

Alfalfa (Medicago sativa) long has been an important hay crop in the irrigated regions of Colorado. The area seeded to this crop has increased from a small garden patch in 1863 to some 709,035 acres as an average for the 10-year period from 1928 to 1937. The average annual hay production during this period was 1,337,400 tons, with an average yield of 1.39 tons per acre. The counties that lead in alfalfa acreage are: Weld, Larimer, Garfield, Prowers, and Montrose.

A considerable acreage of alfalfa is grown for seed. Approximately 25,000 bushels are produced annually in Colorado, an amount insufficient to supply the usual demands for seed in the state. Spencer and Stewart (1932) state that the bulk of Colorado alfalfa seed is produced in the irrigated Arkansas and Grand Valleys, and in the non-irrigated areas of both northwestern and southwestern Colorado.

The alfalfa acreage has declined almost steadily for over 15 years. The general prevalence of bacterial wilt has made it necessary to replant the crop every 3 to 5 years to maintain stands that will produce satisfactory tonnages. This has increased the cost of alfalfa production. For example, Colorado had 890,000 acres of alfalfa in 1924. By 1937, this acreage had declined 637,370 acres harvested.

II. Botanical Description

Alfalfa is classified in the legume family. It is an herbaceous perennial that may live several years, but this depends on environmental conditions. The primary root is strongly developed and forms a taproot which may penetrate from 15 to 30 feet in an aerable soil. The alfalfa leaf is pinnately trifoliate, the stipules adnate to the petiole, while the leaflets are commonly dentate. The stems are hollow but partly filled with pith. They branch profusely from the axils of the leaves. The flowers, which vary from purple to yellow, are borne in dense axillary racemes. The calyx of the flower is 5-perted, united at the base, but sharply pointed at the ends. There are 5 petals, viz., 2 that form the keel, 2 wings, and a stamens. The fruit is a pod that is usually coiled 2 or 3 times into a loose spiral. It contains several seeds. The seeds are irregular in form, some being kidney-shaped while others are more or less oval. Both self and cross pollination are possible in alfalfa.

III. Species or Groups

Alfalfa grown in Colorado is classified in the species, Medicago sativa. Another species, M. falcata or Siberian alfalfa, is not grown in the state. There are 3 agronomic groups represented in the state, these being common, variegated, and Turkestian. These are described by Westover (1924)

(a) Common

Common alfalfa is characterized by blue to purple blossoms, upright stems, high crowns, and a preponderance of straight taproots. The seed pods are coiled. The different strains are generally named after the states where they were adapted. Northern-grown common from old stands is the only common alfalfa adapted to Colorado conditions.
(b) Variegated

These alfalfas are hybrids between common and Siberian. The blossom colors vary from light to dark shades of blue and purple with mixtures of white and yellow as well as blends of smoky. The seed pods vary in shape from sickle-like to coiled. As a group, the variegated are harder than the common alfalfas. There are several well-known varieties grown to some extent in Colorado, among them being Grimm, Baltic, and Cossack.

(c) Turkestan

Turkestan alfalfa is indistinguishable from common. Some strains are quite hardy while others are distinctly non-hardy. Russian knapweed was introduced into Colorado in Turkestan alfalfa which may be identified in some instances by the presence of this weed. Turkestan alfalfas have low productivity and short survival as compared with other alfalfas. A strain resistant to bacterial wilt, known as Hardistan, is being grown in the state to a limited extent.

IV. Seed Characteristics

Alfalfa seeds are buff-yellow when fresh, but darken to a yellowish-brown color with age. Some seeds are hard or impermeable. Lute (1928) found that alfalfa seed pricked with a pin would swell and grow. By the use of dyes it was found that water failed to penetrate beyond the cuticle in impermeable seeds, but that these seeds germinated readily when the palisade cells were planed thru. Mature seed tended to have a higher percentage of hard seed than immature seed. It was found also that some scarification was incidental to machine threshing. All impermeable seeds in alfalfa germinated after 11 years of dry storage, while fully 50 percent germinated after 3.5 years. Investigation showed that hard seeds could be made permeable by the application of dry heat at 80°C, for one hour or 60°C for two hours. Scarification of alfalfa seed is seldom advisable under field conditions.

V. Adaptation

Alfalfa is well adapted to the irrigated lands of Colorado, but it has too high a water requirement for the dryland regions.

(a) Soil and Climatic Conditions

Alfalfa will thrive under high temperate conditions so long as the humidity is low. This is a condition general to Colorado. Some strains have been found more winter-hardy than others, some being able to resist winter temperatures of 30 to 40°F, below zero. Snow cover has been found to increase the resistance to low temperatures. Alfalfa is best adapted to a deep, porous, well-drained, calcareous soil. Good drainage is essential to successful alfalfa culture. Water-logged soils are fatal to the roots. In addition to these requirements, specific module bacteria must be present for symbiotic nitrogen fixation.

(b) Winter-hardiness

Winter-hardiness in alfalfa varieties is important in Colorado. As a result of tests at Rocky Ford, Ellin (1911) concluded that northern grown strains were the most desirable for forage production in Colorado. Southern-grown strains winter-killed so badly that they were considered impractical. After the winter of 1907-08, over one-half the plants were dead in the plots seeded to Arabian and North African strains. Plots seeded with strains from Spain, Mexico, and South America had many dead plants, and many partially-killed crowns. This was untrue.
of the native American plants. The variegated varieties, Baltic and Grimm, proved the most desirable for Colorado conditions at that time.

(c) Loss of Stands
Considerable loss in stand has occurred in comparatively young alfalfa in Colorado during the last 10 to 15 years. This may be due to non-hardy varieties, depleted soil fertility, or disease. Stand losses in the first 2 or 3 years after normal winters are likely to be due to southern-grown seed. Kezer (1933) reports a case in Weld County after the winter of 1927-28 where seed from a particular lot killed out badly. It was found to be blended seed in the proportion of 4 hardy to 40 non-hardy. Stands that thin rapidly in the third and fourth years may be due to bacterial wilt. There are other cases where poor production of alfalfa may be due to depleted soil fertility. The application of barnyard manure may be desirable under such conditions.

VI. Varieties

Yield trials of alfalfa varieties grown in Colorado have been given by Robertson and others (1938)

(a) Variety Trials in Colorado

In tests seeded to both variegated and common strains in 1929 and 1933, Meeker Baltic yielded highest. Some Common strains yielded almost as much.

The summary yields for all tests of variegated alfalfa are given in table 1.

Table 1. Yields of Variegated Strains of Alfalfa at Fort Collins.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Average Yield Moisture-free Hay (tons)</th>
<th>Yield in Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 years 1930-32</td>
<td>4 years 1931-34</td>
</tr>
<tr>
<td>Meeker Baltic</td>
<td>5.45</td>
<td>5.41</td>
</tr>
<tr>
<td>Grimm</td>
<td>5.28</td>
<td>5.24</td>
</tr>
<tr>
<td>Hardistan</td>
<td>-----</td>
<td>5.33</td>
</tr>
<tr>
<td>Cossack</td>
<td>4.96</td>
<td>-----</td>
</tr>
<tr>
<td>Ladak</td>
<td>4.87</td>
<td>-----</td>
</tr>
<tr>
<td>Colorado Common</td>
<td>5.32</td>
<td>-----</td>
</tr>
<tr>
<td>Turkestan</td>
<td>4.28</td>
<td>-----</td>
</tr>
</tbody>
</table>

Colorado Common produced 95 percent as much hay as Meeker Baltic. The varieties Hardistan, Grimm, Cossack and Ladak produced 95 to 93 percent as much as Meeker Baltic. Hardistan was found to remain productive one year longer than the other varieties because of its resistance to bacterial wilt. For the 4-year period it was nearly as productive as Meeker Baltic, altho for 3 years the latter averaged 0.65 ton more hay per acre annually. The 4-year average yield gave Meeker Baltic a slight margin of only 0.08 ton.

Hardistan produced two good cuttings the fifth year while the other varieties had to be plowed up because of poor stands.

The yields of common alfalfa varieties tested are given in table 2.
Table 2. Yields of Common Alfalfa Strains at Fort Collins

<table>
<thead>
<tr>
<th>Variety</th>
<th>3-year Average Yields Moisture-free Hay (tons)</th>
<th>Years Grown</th>
<th>Percent of Colo. Common</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1930-32</td>
<td>1931-36</td>
<td></td>
</tr>
<tr>
<td>Colorado</td>
<td>5.04</td>
<td>5.43</td>
<td>6</td>
</tr>
<tr>
<td>Kansas</td>
<td>4.86</td>
<td>5.62</td>
<td>6</td>
</tr>
<tr>
<td>Nebraska</td>
<td>5.64</td>
<td>5.64</td>
<td>3</td>
</tr>
<tr>
<td>Montana</td>
<td>5.21</td>
<td>5.21</td>
<td>3</td>
</tr>
<tr>
<td>Arizona</td>
<td>4.50</td>
<td>5.13</td>
<td>3</td>
</tr>
<tr>
<td>Argentine</td>
<td>4.50</td>
<td>4.50</td>
<td>3</td>
</tr>
<tr>
<td>Chilean</td>
<td>4.33</td>
<td>4.33</td>
<td>3</td>
</tr>
</tbody>
</table>

The Common varieties from Colorado, Kansas, Nebraska, and Montana all produced well. These varieties are winter-hardy in Colorado, with the exception of southern-grown Kansas Common, Arizona Common, Argentine, and Chilean lack winter-hardiness.

The varieties recommended in the state are Heeker Baltic, Grimm, and Hardistan. Where it is desired to keep a stand for more than 3 years, Hardistan should be grown. Northern-grown Common strains may be planted, provided the origin can be traced.

(b) Variety Descriptions

The alfalfa varieties commonly grown in Colorado are described by Robertson and associates (1933).

1. Grimm: Present commercial stocks of Grimm alfalfa are the progeny of the original importation made by Wendelin Grimm into Minnesota in 1857. Grimm has a greater diversity of forms than Common strains. Upright and decumbent individuals often occur side by side. While a large percentage of the flowers are of the same color as Common alfalfa, there are a few that are greenish, apple, or blackish, and occasionally a plant is found with yellow flowers. This diversity indicates definitely that the strain is the result of a cross between the Common and yellow-flowered species.

2. Baltic: This is a variegated variety similar to Grimm. It differs slightly in minor details, but it is seldom possible to distinguish one from the other. Heeker Baltic originated in Northwestern Colorado. Some Baltic seed was sown on non-irrigated land in 1918, and finally thru natural selection the strain known as Heeker Baltic was developed. This variety is susceptible to bacterial wilt.

3. Ladak: The variety Ladak is a variegated type originally from India. Ladak has a greater diversity of forms than any other variety grown commercially in this country. It shows more variegated flowers with a higher proportion of yellow than the other variegated varieties grown in the state. This variety has the ability to make an exceptionally heavy first crop, exceeding all other varieties in this respect. For this reason, it is especially suited to regions where only 1 or 2 cuttings are normally obtained. Ladak recovers slowly after cutting. Under Colorado conditions this variety has shown very little resistance to bacterial wilt.

4. Hardistan: This variety came from an old superior field of alfalfa in Nebraska. It is a Turkestan variety that is resistant to bacterial wilt. In Colorado it has produced a good crop of hay for 5 years after planting.
5. Common: Common alfalfa includes the ordinary purple-flowered non-hardy strains. After alfalfa of this type is grown for several generations in an area, it is designated as, for instance, Colorado Common, Nebraska Common, Kansas Common, Argentine, etc. Adaptation of alfalfa in areas with severe winters for several generations has eliminated the non-hardy plants. For this reason, southern-grown Common is less hardy than northern-grown. Southern-grown Common strains are not winter-hardy in Colorado. Foreign importations are generally inferior to seed produced in Colorado or in the northern regions of this country. None of the Common strains are resistant to bacterial wilt.

VII. Crop Rotations

Alfalfa in a rotation appears to improve the mechanical condition of the soil as well as to bring about some soil sanitation. Readman (1932) concluded that the nitrogen supply was not increased, but that the amount of water-soluble potassium was increased by the production of a large amount of carbon dioxide in the soil air.

Alfalfa is grown in shorter rotations in Colorado than was the case 15 years ago. The field life of alfalfa has been shortened by bacterial wilt. In some cases the entire crop is killed in 3 years. In northern Colorado, this 5-year rotation may be followed: alfalfa seeded alone, alfalfa, alfalfa, potatoes, or corn, and sugar beets. A 7-year rotation sometimes suggested is: small grain seeded to alfalfa, alfalfa, alfalfa, alfalfa, small grain or corn, sugar beets, and sugar beets.

Alfalfa appears in a 6-year rotation under dry-land conditions at Akron. Brandon (1925) states that the crop occupies the land for 3 years followed by oats, corn and wheat. It has been difficult to obtain stands, particularly in dry seasons. After the sod was broken up, the yield of the subsequent crop was below that on land that had not been in sod. Alfalfa has been unsatisfactory as a hay crop on the drylands, except on land that is sub-irrigated or that receives run-off from adjacent fields.

VIII. Fertilizers

Alfalfa makes a heavy draft on the available plant food supply in the soil. After a time, even rich soils show reduction in yield from lowered fertility. Robertson and others (1938) conducted an experiment to determine the effect of different fertilizer treatments on alfalfa. Duplicate plots were treated in 1929 and in 1931 with one of these treatments: 10 tons of manure; 100, 200 or 300 pounds of triple superphosphate; and 100 or 200 pounds of potassium sulfate. The results are given in table 3.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Tons of Moisture</th>
<th>Free Hay</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1930 1931 1932</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treble Superphosphate, 300 lbs.</td>
<td>4.17 5.73 5.94</td>
<td>4.98</td>
<td></td>
</tr>
<tr>
<td>200 lbs.</td>
<td>4.16 5.35 5.09</td>
<td>4.86</td>
<td></td>
</tr>
<tr>
<td>100 lbs.</td>
<td>4.22 5.30 5.79</td>
<td>4.76</td>
<td></td>
</tr>
<tr>
<td>Potassium Sulfate 200 lbs.</td>
<td>4.35 5.26 4.34</td>
<td>4.75</td>
<td></td>
</tr>
<tr>
<td>100 lbs.</td>
<td>4.13 5.28 4.82</td>
<td>4.63</td>
<td></td>
</tr>
<tr>
<td>Manure, 10 tons</td>
<td>4.40 5.18 4.82</td>
<td>4.92</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>4.40 5.34 4.76</td>
<td>4.83</td>
<td></td>
</tr>
</tbody>
</table>
The data indicate that no benefit was gained from any fertilizer treatment. From the results of this experiment, as well as from others, it appears that little is to be gained from the application of either manure or fertilizer to highly productive soils in northeastern Colorado. On soils known to be deficient in plant food, considerable increase in yield has been obtained from the application of treble superphosphate or manure.

IX. **Seedbed Preparation**

In Colorado, most alfalfa is grown under irrigation. It is important that the field be smooth and of uniform grade to permit irrigation water to be applied readily. The seedbed should be leveled before the crop is planted because the crop is usually left on the land for 3 years or more. In addition, a smooth, firmly packed, moist seedbed free from weeds is necessary for the germination and development of the small alfalfa seedlings. (See Robertson and others, 1938)

The land should be fall-plowed where possible in order to allow the seedbed to become firm. It is difficult to compact spring-plowed land in time for spring planting. (See Kezer, 1933)

X. **Seeding Practices**

The time and rate of seeding alfalfa varies in different parts of the state.

(a) **Seeding Time**

Spring seeding is the most common practice under irrigated conditions in Colorado. Good stands have been obtained by fall seeding where a dependable supply of irrigation water is available. To succeed, fall plantings must be made early enough to permit plant establishment before winter. In most seasons, Robertson and associates (1938) believe September 1 to be about the latest safe date. August seeding has been found satisfactory where there is a reliable supply of fall irrigation water. Kezer (1933) observed this practice to be necessary in northern Colorado in 1932 because of webworm damage to spring-planted alfalfa.

(b) **Rate of Seeding**

From 8 to 10 pounds of good seed of high germination has given excellent stands at the Colorado Station on well-prepared seedbeds. It may be desirable to seed 15 pounds per acre where either seedbed or weather conditions are severe. The seed is usually drilled 1.0 to 1.5 inches deep in loam soils, while a depth of 2.0 inches may be necessary in sandy soils to place the seed down to moisture. After seeding, the land should be harrowed or packed to properly contact the seed with moist soil.

(c) **Companion Crops**

A companion crop is often seeded with alfalfa in order to produce a crop on the land while the alfalfa is being established. Tests conducted by Robertson and others (1938) indicate good stands of alfalfa may be secured when seeded alone or with companion crops of either field peas or flax. A companion crop of barley decreased the yield of the subsequent alfalfa crop when it was compared with alfalfa seeded alone, alfalfa sown with field peas, or alfalfa sown with flax. Some of their data for a 1931 seeding are given in table 4.
Table IV. Effects of Various Companion Crops on Alfalfa Yields

<table>
<thead>
<tr>
<th>Companion Crop</th>
<th>Tons Moisture-free Hay per acre</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>6.35</td>
<td>5.30</td>
</tr>
<tr>
<td>Flax</td>
<td>6.13</td>
<td>5.26</td>
</tr>
<tr>
<td>Peas</td>
<td>6.15</td>
<td>5.19</td>
</tr>
<tr>
<td>Barley</td>
<td>5.64</td>
<td>5.14</td>
</tr>
</tbody>
</table>

Small grains used as companion crops should be seeded at about one-half the usual rates, that is, barley 40 pounds, oats 50 pounds, and wheat 50 pounds.

I. Irrigation

In Colorado irrigation is required for maximum yields. Mezer (1933) reports that young alfalfa plants have been killed by irrigation at the 2-to-4 leaf stage, but that the application of water is safe after the 6-to-8 leaf stage.

Alfalfa is generally irrigated by the flooding, border, or furrow irrigation methods. The flooding method is used almost entirely in northeastern Colorado. The general practice is to flood between field laterals. In the Brush-Fort Morgan area, the border method is sometimes used. In either of these methods, the laterals or borders should be from 50 to 150 feet apart, and the length should not exceed 500 or 500 feet. Longer laterals over-irrigate the upper end of the field before sufficient water is applied to the lower end. The furrow or furrow method of irrigation is much better for alfalfa where silty waters prevail. To flood with silty water causes the soil to become hard between irrigations.

An experiment was conducted at Fort Collins to determine the effect of long and short runs of irrigation water on alfalfa. One set of plots was irrigated for an 8-hour period at each irrigation, while another set was given a normal irrigation that required less than an hour. An average of 12.38 acre-feet of water remained on the long-run plots per season. An average of 1.68 acre-feet was applied to the short-run plots. The yields of dry hay show a slight but insignificant difference in favor of the short-run plots. The 8-year average yields, for the period 1934 to 1937, were as follows: long run 4.91 tons per acre, and short run 5.07 tons. The results show nothing to be gained from flood irrigation for an 8-hour period.

The number of irrigations per season is governed by the water supply and soil type. One irrigation to each cutting is sufficient on the more retentive soils, but more frequent irrigations may be necessary on the lighter soils.

II. Methods of Harvest

Alfalfa should be cut for hay when in one-tenth to one-fourth bloom stage. When blossoms are scarce, the crop should be cut just before the new shoots will be clipped by the mower. Later cutting results in hay with coarse stems, fewer leaves, and lower digestibility.
(a) Curing Process
In order to have a good quality hay, the stand should be thick and free from weeds. The cured hay should be green in color, leafy, and the stalks fine. As early as 1889, Blount and others (1889) stated that alfalfa "when slightly wilted should be raked into windrows and then put into cocks to be cured." This statement made 50 years ago is still sound today. The hay should be allowed to partially cure in the windrow, and while still a little damp, either bunched or cocked and allowed to cure. The hay should be thoroly cured before it is stacked. Large well-topped stacks should be built to reduce the amount of loss from weathering.

(b) Losses in Weathered Hay
The effects of weathering on the vitamin content of alfalfa hay was studied by Douglass and others (1933). They found that alfalfa may lose as much as 80 percent of its vitamin A, and 50 percent of its vitamin B when rained on after it is cut. Vitamin A seems to be highest in the early bloom stage while vitamin B appears to be highest at mid-bloom. Vitamin C was high in green fresh cut hay, but is practically all lost in cured hay. Vail and associates (1936) found that vitamin A tends to become more inactive the longer the hay is stored.

XIII Alfalfa Seed Production
Most of the alfalfa seed is produced in the irrigated Arkansas and Grand valleys and in the non-irrigated regions of northwest and southwest Colorado. Spencer and Stewart (1932) state that alfalfa sets seed most readily in climates where the weather is dry at blossom time. A period of damp cool weather at this stage results in a poor seed set. The soil fertility and moisture content should be low enough to cause a slightly stunted growth. Otherwise, the plants make vegetative growth at the expense of seed set.

(a) Cultural Methods
Planting alfalfa in rows is advocated for seed production by Spencer and Stewart (1932). Good results have been obtained with 28-inch rows with the plants spaced 14 to 49 inches apart in the row. From 2 to 5 pounds of seed per acre is sufficient. Cultivation is necessary for weed control. It is sometimes necessary to thin the stand after the third year in order to increase seed production. This can be accomplished by a plow, with the moldboard removed, run across the drill rows. Alfalfa is often cut for seed when two-thirds to three-fourths of the pods are brown or black. The self-rake reaper is the best implement to harvest alfalfa seed, although a mower with a buncher attachment will serve the purpose. A clover huller or an ordinary separator with some of the concaves removed, should be used to thresh the crop.

(b) Factors that Influence Seed Set
Several causes for the failure of seed set in alfalfa have been recognized by Blinn (1920), and by Spencer and Stewart (1932). Among these are: Too thick a stand, over-irrigation, drought, cold weather at blossom time, late sprin; frost, and insect pests. The moisture supply in the early period should be sufficient for normal plant development. As the summer advances, moisture should be restricted to induce seed setting. Blinn (1920) found that pasturing the first crop late in the spring stimulated good seed yields. Recently, the Lygus bug has been found to reduce seed setting.
IV. Alfalfa Diseases and Other Pests

The most serious diseases of alfalfa in Colorado are bacterial wilt and bacterial stem blight.

(a) Bacterial Wilt (Phytophthora insidiosa)

The organism that causes the bacterial wilt disease of alfalfa is probably present in most of the irrigated soils of Colorado. Due to this disease, all plants of some varieties of alfalfa are dead after 3 or 4 years of harvesting, while the plants of other varieties may survive for longer periods.

Dead crowns are conspicuous in a severely infected field early in the spring. Many plants are noticeably stunted, from severely dwarfed to nearly normal. The leaves on diseased plants are also smaller than normal, yellowish in color, and rolled upward. The new shoots wilt in hot weather. Wilt is a more prominent symptom in late summer than earlier in the season. Some time after a crop is cut, diseased plants are dwarfish and often have a yellowish cast. When the bark of the taproot is peeled back, the woody cylinder of healthy plants is white, while that of diseased plant is yellow or light brown in color. Occasionally, reddish streaks are conspicuous. These differences are even more apparent when the taproot is cut crosswise. The wood in severely diseased plants is conspicuously discolored and contains deposits of brown material. This is a gum which, together with the bacterial masses, clogs the water vessels and causes the characteristic stunting, wilting, and eventually death. The symptoms are described by Lo Clerc and Durrell (1928), although they failed to determine the cause of the disease.

The disease is caused by a bacterium, Phytophthora insidiosa. The bacteria are found in abundance in the large tracheal vessels, particularly at the bases of shoots affected by winter injury. The bacteria over-winter in the diseased crowns. They are released by injuries which expose the infected tissues, particularly frost action. The bacteria are then carried in rain or irrigation water. They enter the plant thru wounds caused by any mechanical means. From these outer tissues, they work their way into the water vessels. The plant responds by the production of a yellow gum that clogs the vessels.

Bacterial wilt is rarely observed before the alfalfa plant is 2 years old. It may appear at any time afterwards. New seedings may escape for several years when away from diseased fields. Irrigation water favors the spread of the disease. Plants usually die the second year after infection. Weihing and associates (1933), from a study of 10 alfalfa variety trials, observed that the strains of most varieties were too thin for hay production at or near Fort Collins after the third or fourth year of harvest.

Different varieties vary in resistance to bacterial wilt. Weihing and associates (1933) concluded that there was little difference in the average survival of variegated and common strains of alfalfa grown on wilt-infested land. Some of the Turkestian strains show resistance. Hardistain survived and remained productive one and possibly two or more additional years in northern Colorado tests. A commercial strain of Turkestian (No. 2674) ranked next to Hardistain in survival.
After a stand has become too thin for profitable production, which is usually less than 20 plants per square meter, it should be plowed under. This means short rotations with alfalfa left for 3 or 4 years. Seed of hardy varieties should be used to reduce injury. Hardistia offers promise as a resistant variety, but yields less than Grimm until the latter becomes thinned out.

(b) Bacterial Stem Blight

A disease known as bacterial stem blight (Pseudomonas medicaginis) was described by Sackett in 1910. It seems to be caused by late frosts intermingled with warm weather. It was very severe in the Gypsum Valley where 80 percent of the first crop was destroyed in 1906. A late spring frost caused a recurrence of the disease in northern Colorado in 1931. It is primarily a stem infection. In the early stages the stem has a watery, semi-transparent, yellowish to olive-green color. A thick, clear, viscid liquid oozes from the stem where it dries with a glistening finish. Such stems are very brittle and easily broken. One-year-old plants may exhibit blackened areas in the crown together with black streaks that run down into the taproot. As the plants grow older, this blackening increases until the whole crown becomes involved, and finally the plant dies. The disease seems to run its course with the first cutting. The recommended control is to clip the frosted growth at once and allow a new crop to grow. Otherwise, the frosted stems will make only retarded growth.

V. Alfalfa Dodder

Dodder or "love-vine" is one of the worst pests of alfalfa in the state. It reduces the yield of hay and contaminates the seed crop. Robbins and Egginton (1918) report dodder in all alfalfa-growing regions of Colorado, in a greater or lesser degree.

Dodder plants have slender thread-like stems of a yellowish or orange color which twine and coil about the alfalfa plants. They are parasitic flowering plants that produce seeds that resemble those of alfalfa. Dodder seeds germinate in the soil, but as soon as the parasite has become attached to alfalfa so as to obtain nourishment from its tissues, it loses connection with the soil. Dodder is spread in impure seed, irrigation water, hay, and manure. The species that attack alfalfa in Colorado are: (1) Small-seeded dodder (Cuscuta planiflora), (2) field dodder (C. arvensis), and (3) large-seeded dodder (C. indecora).

When the areas of infection are small, the infested plants should be cut close to the ground. The plants should be burned when dry. The area should be hoed to a depth of 2 or 3 inches every few days for several weeks. When the areas of infection are extensive, the alfalfa crop may be cut for hay when cut before the dodder plants form seed. The area should then be plowed and planted to a cultivated crop. Where the seeds have been allowed to mature over a large heavily infested area, the entire crop should be moved, dried, and burned. The land should be plowed and kept in cultivated crops for several seasons. Dodder-free seed will avoid introduction of the pest in later years.

VI. Insect Pests

The principal alfalfa insect pests in Colorado are the alfalfa weevil and the alfalfa webworm.
(a) Alfalfa Weevil (Hypera postica)

The alfalfa weevil first appeared in Colorado on the western slope in 1917. There have been sporadic occurrences of alfalfa weevil damage in several western-slope counties, and now it occurs in northeastern Colorado. The primary host is alfalfa, although the weevil is known to attack both sweet clover and red clover.

The weevil is described by Newton (1933) as a brown-colored snout beetle, three-sixteenths of an inch long. The adult emerges in July and August and enters hibernation in the late fall. It remains in and about alfalfa crowns and in debris. The eggs are laid in the spring. The larva is marked by a black head shield and a white dorso-medial line that extends the length of the body. The larvae crawl into the new leaves and perforate them. They pupate when they reach full size. About 10 days later the adult emerges. The damage to the alfalfa crop is done by the larvae. The alfalfa leaves may be completely consumed, except for the midribs. The epidermis may be stripped from the stems in severe cases. Alfalfa in this condition is a total loss as a hay crop. Dissemination to new areas is confined to the adults. They crawl from one plant to another. Hay is considered the most important carrier, being made the basis of interstate quarantines.

Spring cultivation, to stir the soil and stimulate rapid plant growth, will often give the crop such a vigorous start that injury may never be apparent. Improper irrigation and frost are often responsible for spotted injury. The plant may be sprayed with zinc arsenite at the rate of 1 pound to 50 gallons of water, 100 gallons being applied per acre. Thorough application to the tips of the plants is important. The usual practice is to spray during the last 2 weeks growth of the first crop. The spray should be applied when the injury first becomes apparent in order to poison the larvae. (See Newton and McCampbell, 1940).

(b) Alfalfa Weevil (Loxostege cornixalis)

The alfalfa weevil caused serious losses in Colorado in 1914, 1920, and 1932. Thousands of acres of young alfalfa seedlings were lost in northern Colorado in 1932. Each outbreak was preceded by a very dry year.

The adult moth, according to Hoerner (1933) appears early in the spring. This insect is rather small, buff-colored withgradations of light and dark shades of gray. It is closely allied to the sugar-beet weevil which has a dark line on the underside of the hind wing. The alfalfa weevil has a row of spots in this area. The adults lay eggs soon after they appear. The larvae are about one-sixteenth inch in length, being pale yellow or greenish-yellow in color. They first feed on the underside of the leaf to which the young worms attach themselves with a flimsy web. Small worms skeletonize the leaves. They eat the entire plant when they become larval. It takes 4 to 5 weeks for the moth to become full-grown. The worm enters the ground when it is ready to pupate. Three broods usually occur in Colorado, the first brood early in the spring until late June, the second in the middle of July, and the third about September 1. The first brood causes the most damage.

Badly infested alfalfa should be cut and harvested early. A compressed roller run over the field will kill many of the worms. The crop may be sprayed with calcium arsenate at the rate of 1 pound to 50 gallons of water. Calcium arsenate is not an accumulative poison, being eliminated by livestock when taken in small quantities. Irrigation of alfalfa -
may force the crop and reduce the amount of injury. Spring-seeding of alfalfa is a questionable practice in areas where injury occurred the previous year. Late seeding, such as in August, will usually escape injury.

References

Questions for Discussion

1. Discuss alfalfa as a hay and seed crop in Colorado.
2. Where is most of the alfalfa seed produced in the state?
3. Describe the alfalfa plant botanically.
4. Name and describe 3 agronomic groups of alfalfa found in the state.
5. What causes the alfalfa seed to be impermeable? How made to germinate.
6. To what conditions is alfalfa adapted?
7. What is the relation of strain to winter-hardiness?
8. Describe the conditions that have brought about losses of stands.
9. What alfalfa varieties are recommended in Colorado? Under what conditions?
10. Describe any 3 of these varieties: Griffin, Baltic, Ludak, Hardistan, and common.
11. What is the value of alfalfa in a crop rotation?
12. Under what conditions may alfalfa be grown on the drylands successfully?
13. What fertilizers will prove beneficial to alfalfa? Under what conditions?
15. When should alfalfa be planted in Colorado? Why?
17. Should companion crops be used with alfalfa? Why?
18. Describe the methods of irrigation used for alfalfa in Colorado.
19. What are the effects of long and short runs of irrigation water in Colorado?
20. How many irrigations are commonly applied to alfalfa in Colorado? Why?
21. When should alfalfa be cut for hay? Why?
22. Describe a curing process for alfalfa in this state.
23. What are the influences of stages of cutting and weathering on the different vitamins in alfalfa hay?
24. Describe the cultural methods for successful seed-setting of alfalfa in this state.
25. What factors influence seed setting in alfalfa?
26. Describe the symptoms, manner of dissemination and control measures for the bacterial wilt disease.
27. Describe the bacterial stem blight disease of alfalfa and give the control measures.
28. Describe alfalfa dodder and explain how to control it.
29. Give a description of the alfalfa weevil, explain the life cycle, and explain the damage it causes to alfalfa.
30. Give control measures for the alfalfa weevil.
31. Describe the alfalfa webworm, its life cycle, and control measures.
FIELD CROPS IN COLORADO

Chapter 18. Sweet Clover

Economic Importance

Sweet clover has become a popular field crop in Colorado under certain conditions. It is used most extensively as a pasture crop, although a limited acreage is harvested for hay. Sweet clover is also grown as a green manure crop to some extent. Its use as a cultivated crop has been rather recent, due possibly to a bitter taste caused by a substance known as cuminin. However, animals soon become accustomed to the taste. The feed value is about the same as for alfalfa.

Sweet clover was harvested on an average of 13,667 acres during the 10-year period from 1923 to 1937. The crop was grown for seed on an estimated 3,000 acres with an average yield of 4.0 bushels per acre in 1938. A large percentage of the seed crop is grown in the San Luis Valley.

Botanical Description

The sweet clovers are annual or biennial herbs with a fragrant odor given off when the leaf is rubbed. The leaves are pinnately 3-foliolate, petioled, possess large stipules, and have dentate leaflets. The yellow or white flowers are borne in slender, spike-like racemes, while those of the Medicago are borne in heads or short spikes. The pods are globose, small, indehiscent or finally 2-valved, and usually one-seeded. They are usually green until maturity. The cuminin is usually low in young plants, but increases as the plants approach maturity.

I. Species

Sweet clover is classified in the genus Medicago which contains two species commonly grown in Colorado. These species are white sweet clover (M. alba), and yellow sweet clover (M. officinalis).

(a) White Sweet Clover (M. alba)

White sweet clover is a coarse plant of rank growth habit which becomes woody at maturity. It is an erect, smooth-stemmed plant. The type commonly grown is a biennial. Occasionally the annual white sweet clover or Hubam (M. alba annus) is grown in the state. Hubam is an annual that makes its full growth, blooms, sets seed, and dies the year it is planted. The biennial makes a strong root-growth the first year, but produces its main vegetative growth in the second season.

(b) Yellow Sweet Clover (M. officinalis)

Yellow sweet clover does not grow as tall as the white species, and matures 10 to 14 days earlier. The stems are finer and more leafy. It has a tendency to be procumbent, a fact which makes it more popular with some growers as a pasture crop because of the greater amount of re-seeding.

V. Adaptation

Sweet clover will grow on almost any soil so long as it is not acid nor deficient in phosphorus. Stewart and associates (1932) observed it to be quite alkali-resistant in Colorado. Brandon (1926) reported the plant as better adapted to dry-land conditions than alfalfa. While it has considerable drought resistance, sweet clover is not a dependable dryland crop unless conditions are very favorable. Stewart (1932) estimates
that dryland farmers in eastern Colorado obtain a stand only about 50 per-
cent of the time. It is grown successfully in the more favored dryland
areas from the standpoint of rainfall. It does better there on the sandy than
on the loam soils. Yellow sweet clover appears to be better adapted to the
cooler mountain regions than the white species.

### Varietal Trials

Yellow sweet clover is reported by Stewart and others (1932) to produce
less hay than white blossom sweet clover under comparable conditions. Some
observations in Colorado indicate that the difference in yield in favor
of the white sweet clover becomes greater as the climatic conditions become
warmer. The yellow species is popular in the higher altitudes.

The two sweet clover species were grown under irrigation at Fort Collins
under comparable conditions, the hay yields being presented in Table 1.

#### Table 1. Sweet Clover Hay Yields in Northern Colorado

<table>
<thead>
<tr>
<th>Crop</th>
<th>Rate Seeded (lbs.)</th>
<th>Av. No. Irrigations</th>
<th>Total Grown Years</th>
<th>Av. Yield lbs. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow sweet clover</td>
<td>10</td>
<td>1</td>
<td>4</td>
<td>3761</td>
</tr>
<tr>
<td>White sweet clover</td>
<td>10</td>
<td>1</td>
<td>4</td>
<td>890</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>10</td>
<td>-</td>
<td>16</td>
<td>3546</td>
</tr>
</tbody>
</table>

The results indicate white blossom sweet clover yields more air-dry hay
per acre than the yellow blossom species, but the quality is inferior
because of coarse stems.

Koonce (1937) determined the yields of sweet clover, both alone and in
mixtures, under high altitude dryland conditions at Fort Lewis. Some of
the data are given in Table 2.

#### Table 2. Sweet Clover Yields under Dryland High Altitude Conditions,
1926 to 1935.

<table>
<thead>
<tr>
<th>Mixture: Species and Rate per Acre.</th>
<th>Air-Dry Forage per Acre (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slender wheat 8, Bromus 8, Yellow sweet clover 4</td>
<td>731</td>
</tr>
<tr>
<td>Slender wheat 8, M. fiske 4, Yellow sweet clover 4</td>
<td>700</td>
</tr>
<tr>
<td>Bromus 12, M. fiske 8, yellow sweet clover 4</td>
<td>770</td>
</tr>
<tr>
<td>Yellow sweet clover 15</td>
<td>447</td>
</tr>
<tr>
<td>White sweet clover 15</td>
<td>465</td>
</tr>
</tbody>
</table>

All plots with high forage yields contained yellow sweet clover. Most of
the forage produced during the first part of the test was from the clover.
The yellow species showed the most promise of all the clovers in this
test. Sweet clover was less prevalent in mixtures that contained brome
grass. This was probably due to the competitive effects of the brome.
Yellow sweet clover persisted in the test longer than the white species,
the latter having practically disappeared by 1928.

### Cultural Methods

The cultural practices for sweet clover depend largely on whether the crop
is grown under irrigated or dryland conditions.
(a) **Crop Rotations**

Some sweet clover rotations have been suggested for irrigated lands in the state. A 4-year San Luis Valley rotation is as follows: Potatoes; small grain; field peas seeded to sweet clover; and sweet clover for pasture, hay, or green manure. In northern Colorado a successful 5-year rotation has been: canning peas seeded to sweet clover; sweet clover pasture, corn or potatoes, sugar beets, and small grain.

Sweet clover was grown at Akron in 2 rotations as a green manure crop. In one rotation the sweet clover was sown with oats and in the other it was seeded with spring wheat. In both it was sown on disked corn ground that had been spring-tooth harrowed. Brandon (1925) reported that a good stand was generally obtained, but that the sweet clover survived the grain crop in only about 4 years out of 10. The companion crop was seeded at the normal rate per acre.

(b) **Seedbed Preparation**

A firm seedbed is essential for sweet clover. Under dryland conditions the seedbed should also be weed-free. Stored moisture is necessary for plant establishment. In eastern Colorado, Stewart (1932) advises that sweet clover be planted on corn land, bean land, or on fallow. A light cultivation with shovel implements is sometimes necessary to kill weeds before the crop is seeded, although it is considered a better practice to attempt the control of weed growth with the drill at the time of seeding.

(c) **Seeding Practices**

Three kinds of sweet clover seed are on the market, namely, hulled, unhulled, and scarified. Each gives satisfactory stands when seeded at the proper time of year. Both hulled and unhulled seed contain considerable impermeable seed, but either kind will germinate in the spring when fall or winter seeded. For spring seeding, either unhulled or scarified seed is satisfactory.

Ordinarily, sweet clover should be planted early in the spring at about the same time as for alfalfa or small grains. This allows the crop to become established ahead of the weeds. Stewart (1932) advised that sweet clover be seeded in April on the drylands. Brandon (1925) recommends April 1 to 10 for scarified seed. Seeding in small-grain stubble late in the fall is considered a better practice for unscarified seed. A rate of 6 to 10 pounds is usually sufficient for dryland conditions while 10 to 12 pounds is a common rate used on irrigated lands.

It is generally agreed that sweet clover should be seeded alone where moisture is a limiting factor. Sweet clover has often failed on the drylands where a companion crop has been used. Brandon (1925) observed that many sweet clover seedlings died immediately after the harvest of the companion crop in a majority of the years. The companion crop exhausted the available soil moisture. Under irrigation, barley or field peas are often seeded with sweet clover.

VII. **Sweet Clover Pasture**

In the Great Plains area, Crosby (1933) estimated that 82 percent of the sweet clover grown was pastured. One acre of sweet clover supported as much livestock as 4 to 15 acres of native grasses. It sometimes requires
several days for animals to become accustomed to the bitter taste, but they soon eat sweet clover as readily as other plants. The danger of bloat is much less from sweet clover than from either alfalfa or red clover. However, some dry roughage should be fed to animals while on sweet clover pasture. The plants may be pastured when 8 to 10 inches high. It is seldom pastured much during the first season when grown under dryland conditions. Yellow sweet clover is preferred to the white as a pasture crop by many because of its greater ability to re-seed itself.

Stewart and associates (1932) observed that sweet clover would provide some pasture from August until late in the fall when seeded in April or May without a companion crop. Close grazing of this spring-seeded sweet clover will cause a reduced growth in the early spring of the second year. Sweet clover plants will live only two years. Should a longer pasture period be desired, it should be allowed to produce seed for re-seeding. An alternative is to drill in additional seed in the early spring of the second year. Sheep are especially fond of the young growing tips of sweet clover and often prevent re-seeding of sweet clover when closely grazed. Koonce (1937) found that the percentage of sweet clover under high altitude dryland conditions gradually declined in grass mixtures after the second year when left to natural re-seeding.

VIII. Sweet Clover Hay

Sweet clover hay is difficult to cure, has a more or less bitter taste, and has a tendency to steminess and woodiness in the second season. Kidder (1925) advised that it be cut for hay before it becomes woody, preferably just before it starts to bloom. This would be the bud stage. The large amount of cumarin in mature growth tends to make the hay unpalatable. Sweet clover should be cut with a stubble 4 or 5 inches high so that buds will be left on the stems to produce the new growth. However, Stewart and others (1932) observed that thick-planted sweet clover cut in this manner for hay failed to produce a satisfactory second crop under irrigation at Fort Collins.

Sweet clover is difficult to cure into high quality hay. Kidder (1925) advised that it be raked into windrows as soon as it has wilted slightly. The remainder of the curing process should take place in the windrow or in bunches. This precaution is necessary because the stems are heavy and full of moisture. The leaves become brittle and break off when the hay is allowed to dry thoroughly in the shock.

Sweet clover hay should not be stacked with external moisture on it (damp from showers) because of the danger of molding. Moldy or spoiled sweet clover hay is dangerous as a feed. It contains a substance that prevents the clotting of the blood, with the result that animals fed on moldy sweet clover hay may bleed to death when dehorned or even scratched. Crosby (1933) states that 5.7 percent of the farmers who have fed sweet clover hay to have had losses. They can be avoided by alternation of this hay with other kinds of roughage.
References


Questions for Discussion

1. What are the uses of sweet clover as a crop?
2. Describe sweet clover botanically.
3. Distinguish between the yellow and white sweet clover species. What are the scientific names?
4. To what conditions is sweet clover adapted?
5. What general results have been obtained in variety trials with yellow and white sweet clover?
6. What is the general behavior of sweet clover in pasture mixtures?
7. Give a sweet clover rotation for irrigated lands.
8. What seedbed conditions are most satisfactory for sweet clover?
9. When should sweet clover be planted? Why?
10. Would you use a companion crop for sweet clover under dryland conditions? Why?
11. Describe sweet clover as a pasture crop.
12. What sweet clover species is generally seeded in pastures? Why?
13. Explain in detail how sweet clover should be harvested and cured as a hay crop.
14. Why is it dangerous to feed moldy sweet clover hay? What precautions are recommended?
FIELD CROPS IN COLORADO

Chapter 19. Red and other True Clovers

I. Economic Importance

The true clovers are grown in Colorado for pasture and hay crops. Most of them are grown under irrigation. There was an average of 160,000 acres of all clover and timothy hay grown in the state during the 10-year period from 1928 to 1937.

II. Description of the True Clovers

The true clovers are classified in the genus Trifolium in which the plants are herbs with palmately trifoliate leaves. The inflorescence is a dense spike or head while the flowers vary in color from white to shades of pink and red. The pods are small, membranous, mostly one-seeded, and indehiscent or opening circularly. The seeds are small and kidney-shaped.

The principal species grown in the state are: Red clover (T. pratense), alsike clover (T. hybridum), Dutch white clover (T. repens), Ladino clover (T. repens var. latum), and strawberry clover (T. fragiferum).

III. Comparative Clover Yields

The yields of various clover species grown under irrigation at Fort Collins are reported by Stewart and associates (1932). Some of their data appears in table 1.

Table 1. Yields of Clovers as Over-Dry Hay per Acre at Fort Collins.

<table>
<thead>
<tr>
<th>Species</th>
<th>Rate seeded (lbs.)</th>
<th>Av. No. Irrigations</th>
<th>Total Crop Years grown</th>
<th>No. Cuttings</th>
<th>Av. yield lbs. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ladino</td>
<td>4</td>
<td>.5</td>
<td>2</td>
<td>2</td>
<td>5488</td>
</tr>
<tr>
<td>Alsike</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4736</td>
</tr>
<tr>
<td>Red</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>8345</td>
</tr>
<tr>
<td>Alalfa (check)</td>
<td>10</td>
<td>—</td>
<td>16</td>
<td>3</td>
<td>8546</td>
</tr>
</tbody>
</table>

It is noted that alfalfa outyielded all the true clovers as a hay crop under irrigation. The stands of red clover remained good for 3 years. Ladino, which is not a hay clover, required frequent irrigations.

Several of the clovers have been grown in clover-grass mixtures. These mixtures were cut with a mover when about 6 inches high, 5 or 6 cuttings being made each year. The yields in pounds of air-dry forage for several mixtures are given in table 2.

Table 2. Yields of Several Clover-Grass Mixtures, 1924-30.

<table>
<thead>
<tr>
<th>Mixture with Species and Rate Seeded</th>
<th>Av. Yield Forage Dry in lbs. per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bromo 10, Orchard 6, Tall Oatgrass 6</td>
<td>4704</td>
</tr>
<tr>
<td>Alsike clover 2, Red Clover 4</td>
<td></td>
</tr>
<tr>
<td>Kentucky bluegrass 5, Orchard 6, Tall Oatgrass 6</td>
<td>4591</td>
</tr>
<tr>
<td>Redtop 5, Red Clover 4, White Dutch Clover 1</td>
<td></td>
</tr>
<tr>
<td>Timothy 8, Redtop 8, Red Clover 4, Alsike clover 4, Dutch white clover 3</td>
<td>4150</td>
</tr>
</tbody>
</table>
IV. Botanical Description

Red clover is an herbaceous plant, being composed of leafy stems that arise from a thick crown. It usually lives 2 years, but some plants may survive longer. Stewart and associates (1932) report that single plants have been known to live for 7 years. The rose-pink flowers are borne in compact heads at the tips of the branches. The pods are small, short, and break open transversely. The seeds are kidney-shaped, about one-twelfth of an inch long, and vary in color from yellow to deep violet. Each leaf is composed of three leaflets, usually with a pale spot in the center of each.

Medium red clover is the most widely grown variety in Colorado. Two crops can be obtained in a season. Mammoth red clover is seldom grown in the state because it yields less than medium red clover.

V. Adaptation

Under irrigation in Colorado, red clover as a hay crop has been replaced almost altogether by alfalfa, except in some mountain valleys where the season is too short to produce 3 cuttings of alfalfa. Recently, it has been grown in Colorado to a limited extent for seed because of favorable climatic conditions. A good irrigation right is necessary for seed production.

Red clover makes its best growth on well-drained soils which are abundant in lime. The crop should be inoculated with the proper legume bacteria when grown on land for the first time in this state. Alsike clover is preferred on low poorly drained lands. Seed produced under less severe climatic conditions than where it is to be planted is inadvisable. Unhardy regional strains are apt to winter-kill. Red clover has a wide range of adaptation throughout Colorado at all altitudes. Koonce (1937) found that the crop lacked drought resistance under dryland conditions at high altitudes. It was practically eliminated in mixtures in the first dry years at Fort Lewis. It also lacks drought resistance on the eastern Colorado plains.

VI. Cultural Methods

Red clover must have a firm seedbed because of the small seeds. Fall-plowed land is preferable, although spring-plowed land is satisfactory when worked several times with soil packers or a rain has intervened to pack the soil.

Red clover is usually drilled at the rate of 6 to 8 pounds per acre by a grain drill with a grass seed attachment. The seed should be planted about one-half inch deep on heavy soils, and slightly deeper on very light soils. In Colorado, red clover may be seeded as early as February in the Arkansas Valley, but the usual practice is to plant in March. Some growers have been successful with August seeding without a companion crop.

Red clover is generally cut for hay when just past full bloom. The maximum amount of protein and dry matter is present at this stage. The hay is cured in much the same way as alfalfa.
VII. Red Clover Seed Production

Red clover produces high seed yields in this state under favorable conditions. Some seed has been produced in the Arkansas Valley and on the Western Slope. The average yield ranges from 500 to 800 pounds per acre. However, some difficulty has been experienced recently due to aphid damage. Some trouble has also been caused by weeds, particularly bindweed, dock, and foxtail. In some cases, volunteer alfalfa and sweet clover have resulted in seed of low quality.

(a) Pollination

Cross-pollination by insects appears to be necessary for a satisfactory seed set. Richmond (1932) proved that honey bees were a major factor in the pollination of red clover in Colorado. He found that red clover set an average of 61.54 seeds per head when caged with bees. The set was 0.19 seeds per head when bees were excluded from the cages. It is likely that the decline in seed yields in Colorado during the past few years has been due to the scarcity of honey bees.

(b) Factors that Influence Seed Yield

The factors that influence red clover seed yields are not well understood. Pieters (1925) gives the ideal conditions for seed production as follows: (1) Strong, vigorous recovery after the hay crop is removed; (2) Clear, warm, but not extremely hot weather when the crop is in bloom; (3) an abundance of pollenization insects; (4) absence of injurious insects like the chalcis fly; (5) good harvesting and curing weather.

(c) Harvest for Seed

The best time to cut red clover for seed is when the heads have turned brown and the stalks deep yellow. Then the harvest is delayed until the heads turn black, the loss of seed from broken heads is heavy. The most common machinery for seed harvest is a mower with a windrow attachment, or bunching attachment. The bunching attachment is the best equipment to use when the clover is cut dry. The hay must be thoroughly dry at the time it is stacked. It should be handled as little as possible to reduce the amount of shattering. Hulling is commonly done with special clover hullers, or with attachments on small grain separators. The clover huller is an ordinary separator equipped with an auxiliary cylinder and concave with rasps or other devices to rub off the hulls.

VIII. Crop Pests

The most serious pests of red clover in Colorado are two insects, the chalcis fly and the clover aphid. There are no serious fungus diseases in the state.

(a) Chalcis Fly

The chalcis fly is a small, black, wasp-like insect about the size of a red clover seed. It may be seen emerging from recently threshed seed. It is one of the worst pests of the crop. The chalcis fly has been observed in the Arkansas Valley. The insect spends the winter to a large extent in deformed, hollow seed capsules of clover and alfalfa plants. All screenings and debris from threshing these two crops should be destroyed as soon as possible. Light early pasturing or clipping the first spring growth will materially reduce the danger from this pest.
(b) Clover Aphis

A very material reduction in yield of red clover seed has been attributed to the clover aphis. Many fields in the Arkansas Valley have had such heavy infestations that a white excrecence covered the clover heads. As soon as the clover blooms, the aphid's crawl deep down among the florets. They feed on the bases of the florets and secrete a so-called "honey dew". This causes the seed to become sticky when threshed. Moreover, the aphid causes a serious reduction in yield. Late harvest of the hay crop and "burning" the stubble are effective practices in the control of aphids. Cutting the first hay crop 10 days later than usual tends to delay blossoming of the seed crop until after the aphids are largely exterminated by their natural enemies. "Burning" is merely to withhold irrigation water for 1 or 2 weeks to expose the stubble and crowns to the direct rays of the sun. Ladybird beetles are a natural enemy that destroy large numbers of aphids.

B---Alsike Clover

IX. Botanical Description

Alsike clover is a perennial, although usually it is treated agriculturally as a biennial. It will live for 4 to 6 years. Pieters (1920) describes the plant as one that produces many smooth stalks from the crown. The leaves are smooth, and consist of 3 leaflets. The flowers, borne in heads, are partly pink and partly white. As the flowers fade, they bend back and hang down. Alsike differs from red clover in its growth habit. In red clover the main axis terminates in a flower and thus limits the growth. Branches arise from the leaf axils, these in turn being terminated by flowers. In Alsike clover the main axis keeps growing. Single flower-bearing branches, each with one or more flower heads, arise successively from each leaf axil. The leafy branches in turn may keep on growing with flower heads or branches in the axils of each leaf. The terminal flower is the first formed in red clover, but the last formed in Alsike clover. The Alsike clover stem may bear flower heads along its entire length. This allows it to be cut for hay over a longer period of time than in the case of red clover.

The seeds of Alsike clover are small, there being more than twice as many in a pound than in red clover. The seed has various shades of green color mixed with yellow. It becomes greenish-brown with age. There is less hard seed than in red clover.

X. Adaptation

Alsike clover grows well in the mountainous areas of Colorado, especially on the higher irrigated mesas.

Stewart and others (1932) observed that it prefers a cool, moist climate with an abundance of soil moisture. It grows well on seepy areas or fields that receive excessive amounts of irrigation water. Alsike withstands severe winters better than red clover, and rare winter kills. It is as drought resistant as red clover, although drought reduces it greatly.

Konske (1937) observed that Alsike clover was a complete failure under dryland high-altitude conditions at Fort Lewis.

Alsike clover is best adapted to heavy silt or clay soils. The plant grows well on many wet, cold, and "sour" soils. It should be inoculated with the proper bacteria when planted in Colorado. Alsike has been used successfully in pasture mixtures for wet lands in this state.
XI. Cultural Methods

Alsike clover is generally planted in either hay or pasture mixtures in Colorado.

(a) Seeding Practices

Alsike clover is planted at the rate of 4 to 6 pounds per acre when grown alone. It is usually drilled at a depth of 0.5 to 1.0 inch. Alsike is generally planted in the early spring to permit plant establishment before the advent of hot dry weather. The common practice is to seed it with timothy, with red clover, or with both. A common formula is one part of alsike, one or two parts of red clover, to two or three parts of timothy.

(b) Hay Production

Alsike makes a better quality hay than red clover, although the latter generally outyields it. The hay is less dusty because the leaves are smooth. Alsike is generally planted with timothy or red clover because these plants hold the weak, slender alsike stems upright. Alsike clover cures more readily and will endure more wet weather at harvest time. This clover should be cut for hay when in full bloom. Yields of 4 tons have been observed in North Park in Colorado where it is grown alone or with timothy. It produces only one crop in a season.

(c) Use as a Pasture Plant

Alsike clover is especially suited for use in pastures. It is valuable in permanent pastures on wet, sour land, and will withstand more trampling than red clover. Stewart and associates (1932) observe that it will withstand fairly close grazing. Alsike is often sown on natural meadows that are wet. Sometimes the seed is broadcast, harrowed, and the meadow irrigated. It often volunteers in wet high altitude meadows. Alsike is a very good crop for over-flow lands because it will endure submergence for several weeks without being killed. It will cause bloat when stock are allowed to eat the green plants freely, especially early in the season.

C—Other True Clovers

XII. Dutch White Clover

Dutch white clover (T. repens) is the little white-flowered clover commonly grown in bluegrass lawns. It is a long-lived, low-growing plant with creeping stems that grow along the surface of the ground. These stems root to form new plants. Dutch white clover requires a great deal of moisture, being suitable for pasture where abundant water for irrigation is available. Koence (1937) observed it to be a complete failure in dryland pasture mixtures at high altitudes in southwestern Colorado.

Dutch white clover has the ability to withstand close grazing, being able to maintain itself in a pasture mixture by its rooting habit and by its ability to produce seed.

XIII. Ladino Clover

Ladino, or giant Dutch white clover (T. repens latum) is a variety of white clover that grows two to four times as large. As a pasture crop it has a greater yield capacity than white clover, although considerably less cold-resistance.
Ladino makes its best growth where the summers are cool and the winters comparatively mild. This limits it to the foothill area in Colorado. Moreover, it is adapted to heavy soils where irrigation can be applied at 10 to 14-day intervals. It requires too much water for most Colorado conditions. Stewart and others (1932) observe that ladino will probably find its greatest usefulness in Colorado along rivers or creek bottoms in shady places or in heavily irrigated or seeped areas.

Since it will not survive the competition of other plants, ladino clover must be seeded only on relatively weed-free land. The usual rate of seeding is 4 pounds per acre when seeded alone. Success in the establishment of a ladino clover pasture depends largely upon the preparation of a firm seedbed, shallow covering of the seed, and liberal moisture at the surface of the ground for several weeks.

XIV. Strawberry Clover

Strawberry clover (T. fragiferum) has attracted a great deal of attention in Colorado in recent years because of its adaptability to wet alkali soil conditions. A small patch is located north of Fort Collins where it has grown for 10 to 15 years.

(a) Plant Description

The plant is described by Pieters (1932) as similar to Dutch white clover in growth habit. The leaves are smaller and pointed. The small pink flowers are borne in a head which, at maturity, enlarges to somewhat the size and shape, tho not the color, of a strawberry. The seeds are borne singly in an inflated pod. The plant spreads both by seed, and by the stems rooting at the nodes.

(b) Adaptation

Strawberry clover has been found to thrive on somewhat alkali soils sub-irrigated by seepage from canals or reservoirs. It has promise on poorly-drained soils. Probably no plant will turn such areas into more profitable grazing lands. The plant seems to be winter-hardy in this state.

(c) Utilization

This clover is primarily a pasture plant, being entirely too short for hay. As pasturage it is one of the best plants for the conditions under which it thrives. Strawberry clover is said to not cause bloat in cattle or sheep. This plant has promise in Colorado on wet seepy areas where the water table is too high for the growth of ordinary forage plants.

References

Questions for Discussion

1. Briefly describe the true clovers botanically.
2. Give the common and scientific names of the true clovers grown in Colorado.
3. How do the true clovers compare with alfalfa in hay yields? Why?
4. Describe the red clover plant botanically. The seed.
5. Why is medium red clover more widely grown in Colorado than Mammoth Red?
6. To what conditions is red clover adapted?
7. Why has alfalfa largely replaced red clover as a hay crop in the state?
8. Describe seedbed preparation, seeding practices, and harvesting of red clover.
9. Describe pollination of red clover.
10. Name the factors that influence seed-set in red clover.
11. Explain the harvest and curing of red clover as a seed crop.
12. Describe the chalcis fly and the control measures.
13. What damage is caused by the clover aphids? How controlled?
15. Tell how alsike clover differs from red clover.
16. To what climatic and soil conditions is alsike clover adapted?
17. Describe the seeding practices for Alsike clover.
18. Describe the use of alsike clover as a hay crop.
19. Explain how alsike clover is used as a pasture crop.
20. Give a general description of Dutch white clover, its adaptation, and uses.
21. To what conditions is ladino clover adapted?
22. Explain how to grow ladino clover as a pasture crop.
23. Describe strawberry clover botanically.
24. To what conditions is strawberry clover adapted.
25. What is the value of strawberry clover as a pasture crop?
FIELD CROPS IN COLORADO

Chapter 20. Soybeans

I. Economic Importance

The soybean is a minor crop in Colorado. It has been grown in the state to a limited extent since 1923. Soybeans are unable to compete with alfalfa as a protein forage crop under irrigation because of the lower hay yields per acre. As a seed crop, field beans are more profitable at present prices. Soybeans are unsatisfactory as a dryland crop because of jackrabbit damage. They are also very susceptible to hail damage. Stewart (1932) believes they may have possibilities in areas where the jackrabbits are controlled. Brandon (unpublished data, 1941) states that over a series of years soybeans produce no more than pinto beans which the market favors as a seed crop.

II. Botanical Description

The soybean (Soja max) is an erect, rather leafy annual that attains a height of several feet under favorable conditions. In general, the growth habit is determinate. The leaves are compound, trifoliate, and the leaflets ovate-lanceolate in shape. The leaves and stems are finely pubescent. The flowers are borne in axillary racemes at the nodes. The flowers appear first at the base of the main stem, then progressively toward the tip. The pods are small, containing one to four seeds. The pods are straight or slightly curved. The seeds are round to elliptical in shape. They vary in color, but may be cream, white, yellow, green, brown, or black. The soybean is normally self-pollinated, but natural cross pollination occurs occasionally.

Viability of the Wisconsin Black variety of soybeans was studied by Robertson and Lute (1937) under dry storage conditions at Fort Collins over a 13-year period. The seed germinated 100 per cent at the start of the experiment. The germination dropped 10 per cent during the first 5-year period, followed by a drop of 42.9 per cent in the second 5-year period. The drop in germination in the final 3-year period was very marked, the final germination being only 5.3 per cent of the original.

III. Adaptation

Soybeans are adapted to about the same conditions as corn. After they are well-started, soybeans will withstand considerable drought. The soybean is less susceptible to frost than corn, either when the plants are young or nearly mature. Robertson and others (1932) found that the large, so-called hay types are not adapted to Colorado conditions where the average elevation is high and the season cool as well as comparatively short. The midseason varieties were found to be adapted at Fort Collins. While the early varieties will grow under these climatic conditions, they fail to make full use of the available frost-free season.

Soybeans prefer well-drained soils such as those suitable for corn or alfalfa. Inoculation of the seed is necessary when soybeans are grown on the land for the first time. The bacteria that live on soybean roots are not found on the roots of any other legumes. Robertson and associates (1932) advise that the soybean seed be sprinkled with a water mixture of the bacteria. The seed can be planted immediately without drying. Inoculation is usually necessary in this state.
V. Soybean Varieties

The midseason soybean varieties will mature in northern Colorado. These include both yellow and dark-seeded types.

(a) Variety Tests

A total of 22 soybean varieties and strains were tested for yield under irrigation at Fort Collins from 1923 to 1926 by Robertson and others (1932). The soybeans were planted about May 25 in 30-inch rows. The seed yields, as well as days to maturity, are given in table 1 for several recommended varieties.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Seed Color</th>
<th>Days to Maturity</th>
<th>Seed Yield Bu. per Acre</th>
<th>Percentage of Minsoy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wes</td>
<td>yellow</td>
<td>123</td>
<td>25.3</td>
<td>111.5</td>
</tr>
<tr>
<td>Minsoy (check)</td>
<td>&quot;</td>
<td>111</td>
<td>22.7</td>
<td>100.0</td>
</tr>
<tr>
<td>Saskatoon</td>
<td>&quot;</td>
<td>125</td>
<td>22.1</td>
<td>97.9</td>
</tr>
<tr>
<td>Hanchu</td>
<td>&quot;</td>
<td>123</td>
<td>21.0</td>
<td>92.5</td>
</tr>
<tr>
<td>Soysota</td>
<td>Dark</td>
<td>123</td>
<td>28.6</td>
<td>126.0</td>
</tr>
<tr>
<td>Black Eyebrow</td>
<td>&quot;</td>
<td>120</td>
<td>21.3</td>
<td>93.8</td>
</tr>
</tbody>
</table>

Due to the discrimination against colored beans, the varieties are classified into (1) yellow or green-colored beans, and (2) the colored beans. Two varieties, Wes and Soysota, outyielded Minsoy. These other varieties yielded more than 90 percent of the check variety. These were Saskatoon, Hanchu, and Black Eyebrow. Hanchu and Saskatoon both froze in 1926 before harvest. Black Eyebrow ripened only 10 days later than Minsoy.

(b) Variety Descriptions

Several varieties of soybeans that are early enough for Colorado are described by Robertson and associates (1932)

1. Minsoy: This variety is fairly early under Colorado conditions. The plants are small and bushy. The pods are medium in size and straw-colored. The seed is medium in size and yellow, the hilum being olive-brown.
2. Wes: This variety matures later than Minsoy in this state. The plants are small, bushy, and the pods medium in size. The seeds are yellow, the hilums being olive-gray.
3. Saskatoon: Saskatoon matures in about the same number of days as Wes. The plants are medium in size and bushy. The medium-sized beans are yellow while the hilum is brown.
4. Soysota: This variety matures a little later than Minsoy under Colorado conditions. The plants are medium in size, while the beans are brown in color.
5. Black Eyebrow: The plants of Black Eyebrow are medium in height and bushy. They mature about as early as Minsoy. The seed is yellow-brown with a black saddle.
V. Cultural Methods

Soybeans may be grown either for hay or for grain. Robertson and others (1932) obtained the most satisfactory seed yields when the beans were grown in rows. Soybeans for hay may be drilled under irrigated conditions. The seedbed should be well worked and firm in either case.

(a) Seeding Practices

Soybeans are usually planted in rows 24 to 36 inches apart under western conditions. However, Robertson and associates (1932) obtained the highest grain yields under irrigated conditions from narrow rows, 18 to 20 inches apart. They used a beet planter for these narrow rows. A corn planter with bean plates, or an ordinary grain drill with several spouts closed, can be used for planting 30 or 36-inch rows. However, lower yields were obtained with the wider rows. A grain drill can be used to broadcast soybeans for hay. Some data are given in table 2.

Table 2. Methods of Planting Soybeans at Fort Collins.

<table>
<thead>
<tr>
<th>Method of Planting</th>
<th>Distance between Rows (Inches)</th>
<th>Yield of Seed Bu. per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beet Drill</td>
<td>18</td>
<td>17.3</td>
</tr>
<tr>
<td>Beet Drill</td>
<td>20</td>
<td>16.5</td>
</tr>
<tr>
<td>Grain Drill</td>
<td>30</td>
<td>14.3</td>
</tr>
<tr>
<td>Corn Planter</td>
<td>30</td>
<td>12.7</td>
</tr>
</tbody>
</table>

The rate of seeding varies both with the method and with the variety, i.e., seed size. When sown in rows, 20 to 40 pounds of beans per acre are necessary. About 100 to 150 pounds of seed are used when soybeans are drilled broadcast for hay.

A date-of-planting test was conducted under irrigated conditions at Fort Collins to determine the best time to plant soybeans in northern Colorado. The Ito San variety was used in all tests from 1924 to 1927. Yields for 1927 were low because of a dry season. The data of Robertson and others (1932) are given in table 3.

Table 3. Average Yields of Soybeans Planted at Different Dates, 1924, 1926, and 1927.

<table>
<thead>
<tr>
<th>Date Planted</th>
<th>Yield of Grain Bu. per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 20</td>
<td>23.3</td>
</tr>
<tr>
<td>30</td>
<td></td>
</tr>
<tr>
<td>May 10</td>
<td>17.4</td>
</tr>
<tr>
<td>20</td>
<td>16.5</td>
</tr>
<tr>
<td>30</td>
<td>14.2</td>
</tr>
<tr>
<td>June 9</td>
<td>9.7</td>
</tr>
</tbody>
</table>

Under the conditions found at the experiment station, the earlier seeding (April 20 to 30) gave the highest yields. Soybeans should not be planted until the danger of hard frosts is over. The yields of beans decreased materially when the crop was planted after May 15. While some varieties are able to mature in a short time, the best yielding ones use the entire growing season.
(b) **Irrigation**

Data for two years indicate that two irrigations, one when the plants were 6 inches high and the other at the blossom stage, gave the highest yields under Colorado conditions. Soybeans were found to be sensitive to over-irrigation.

(c) **Harvest**

Under Colorado conditions, the highest yields were obtained when the majority of the leaves had turned yellow and dropped. The pods at this stage had nearly all turned brown. Beans harvested after maturity often shatter badly, the yield being decreased as a result.

When soybeans are harvested for grain under Colorado conditions, the mower or binder can be used. When cut with a binder with side-delivery attachment, the beans can be cocked from the bunches and later hauled in bulk to the thresher. Soybeans may be cut with the binder where the plants are not too short. Care should be taken, where the binder is used, to keep the twine tension loose so that bundles will not mold under the band. When the soybeans are lodged, they can be harvested with a binder using lodged-grain guards. Long shocks, rather than round ones, should be used in curing soybeans. The soybeans can be threshed with the usual type of bean thresher.

Soybeans should be cut for hay before the leaves begin to turn yellow and drop. The crop should be cut with a mower and raked into windrows soon afterwards. They are allowed to cure in the windrow before being cocked. The hay should be handled as little as possible after it is dry to avoid shattering of the leaves.

### Sorbean-Corn Mixtures

Several methods of planting sorbeans and corn were tried at the experiment station from 1923 to 1925 by Robertson and others (1932). The methods used were as follows: (1) Corn and soybeans planted in the same hill by hand; (2) corn planted in hills with soybeans in hills between the corn hills; (3) Soybeans and corn planted in alternate rows with a corn planter; and (4) soybeans planted in alternate hills by hand. The 3-year average yields for these methods are presented in table 4.

<table>
<thead>
<tr>
<th>Method</th>
<th>Av. Yield per Acre (Bu)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Corn</td>
</tr>
<tr>
<td>Corn and Soybeans in hills</td>
<td>50.4</td>
</tr>
<tr>
<td>Soybeans planted between hills</td>
<td>50.5</td>
</tr>
<tr>
<td>Soybeans and corn in alternate rows (hills)</td>
<td>37.9</td>
</tr>
<tr>
<td>Soybeans and corn in alternate hills</td>
<td>54.1</td>
</tr>
<tr>
<td>Soybeans alone</td>
<td>---</td>
</tr>
<tr>
<td>Corn alone1</td>
<td>74.0</td>
</tr>
</tbody>
</table>

1. 2-year average only.

The corn retards the growth of the soybeans, since only small yields are obtained, especially when they are planted in the same row or hill. There appears to be no benefit to the corn because it produced the highest yield when planted alone. The yields were lower when the number of hills per acre of corn were reduced. Soybeans grown alone far outyielded soybeans grown with corn.
Where soybeans and corn are grown in the same field to be hogged down, Stewart and others (1932) advise that separate rows of each crop be planted. A group of 4 to 6 rows of soybeans to 20 rows of corn was the recommended portion.

References


Questions for Discussion

1. What is the economic importance of soybeans in Colorado? Why?
2. Describe the soybean plant botanically.
3. Discuss viability of soybean seed in dry storage.
4. To what conditions are soybeans adapted?
5. Why is inoculation of soybeans necessary in Colorado? How accomplished?
6. Name and briefly describe 3 soybean varieties adapted to northern Colorado.
7. Describe methods of seeding soybeans.
8. What rates and dates are recommended for soybeans in Colorado? Why?
9. What irrigation practices should be followed for soybeans?
10. Describe the stages for soybean harvest for grain. For hay.
11. Explain how to cut and handle soybeans as a grain crop.
12. Give a procedure for harvesting soybeans as a hay crop.
13. What statements can be made about soybean-corn mixtures?
FIELD CROPS IN COLORADO

Chapter 21. Field Peas

I. Economic Importance

Conditions are suitable for field peas in most of the mountain valleys of Colorado, altho 90 percent of the present production is found in the San Luis Valley. The average acreage of field peas for the 10-year period from 1922 to 1931 was 61,000 acres with an average production of 754,000 bushels. The average yield per acre during this period was 12.6 bushels. There was 22,000 acres in the state in 1938 with a total production of 192,000 bushels. Field peas are grown for the threshed seed, pasture, and hay.

II. Botanical Description

The field pea is an annual herbaceous plant with stems 2 to 12 feet long. Koonce (1935) describes the herbage as pale green with a whitish bloom on the surface. Each leaf bears 3 pairs of leaflets and is terminated by a slender tendril. The blossoms are either purple or white. The fruit is a pod about 3 inches in length which contains from 4 to 9 seeds. The seeds may be round, angular, wrinkled, or round with flat sides. They may be white, yellow, green, blue, brown, purple, black, or mottled in color. Altho field peas are considered as self-fertilized, Koonce (1935) observed that there is considerable natural cross pollination when white and colored blossom varieties are grown in alternate rows. The field pea belongs to the genus Pisum and to the species arvense. It differs from the garden pea (p. sativum only in the use of the crop.

III. Adaptation

A cool growing season is essential for the successful culture of field peas. High temperatures are more injurious to the crop than light frosts, except at blossom time. The moisture requirements are less important than those of temperature, altho the crop makes its best growth where moisture is fairly abundant, especially early in the growth period.

Field peas are most productive on loams or clay loams rich in lime. The crop is apt to be a failure on poorly drained soils, or those high in alkali salts. Inoculation is advisable when field peas are planted in newly-developed areas. It is seldom necessary to inoculate where the crop has been grown in Colorado.

IV. Agricultural Varieties.

Field pea varieties differ widely in the time required for maturity, height of plant, blossom color, size of pods, and in size, color, and shape of seed. There are over 100 named varieties, 91 of which were tested by Koonce (1935) under high altitude conditions in southwestern Colorado at Fort Lewis.

(a) Varietal Trials

In general, Koonce (1935) found that the medium early to medium late varieties produced the highest grain yields. The yields of several important varieties are given in table 1.
Table 1. Average Grain Yields of Field Peas at Fort Lewis, 1922-33.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Years Grown</th>
<th>Grain Yields Bu. per A.</th>
<th>Percentage of French Gray</th>
</tr>
</thead>
<tbody>
<tr>
<td>French Gray</td>
<td>11</td>
<td>33.5</td>
<td>100.00</td>
</tr>
<tr>
<td>Golden Marrow</td>
<td>11</td>
<td>32.9</td>
<td>98.02</td>
</tr>
<tr>
<td>Clamart</td>
<td>11</td>
<td>32.7</td>
<td>97.45</td>
</tr>
<tr>
<td>New Canadian Beauty</td>
<td>11</td>
<td>32.1</td>
<td>95.77</td>
</tr>
<tr>
<td>Lima</td>
<td>11</td>
<td>31.5</td>
<td>93.85</td>
</tr>
<tr>
<td>Agnes</td>
<td>11</td>
<td>30.6</td>
<td>91.33</td>
</tr>
<tr>
<td>Austrian Winter</td>
<td>4</td>
<td>16.5</td>
<td>59.76</td>
</tr>
</tbody>
</table>

The average date of maturity for these varieties at Fort Lewis ranged from August 26 to September 5. The varieties that matured very late were generally low in grain but high in forage yield, while the extremely early ones were low in both grain and forage yields.

Forage yields were taken over a 10-year period, from 1924 to 1933. Some of the late varieties have given the highest forage yields (See table 2).

Table 2. Average air-dry Forage Yields of Field Peas at Fort Lewis, 1924-33.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Years Grown</th>
<th>Forage Yields Tons per A.</th>
<th>Percentage of French Gray</th>
</tr>
</thead>
<tbody>
<tr>
<td>French Gray</td>
<td>10</td>
<td>2.79</td>
<td>100.00</td>
</tr>
<tr>
<td>Golden Marrow</td>
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<td>3.29</td>
<td>117.78</td>
</tr>
<tr>
<td>Clamart</td>
<td>10</td>
<td>2.96</td>
<td>106.09</td>
</tr>
<tr>
<td>New Canadian Beauty</td>
<td>10</td>
<td>3.49</td>
<td>124.98</td>
</tr>
<tr>
<td>Lima</td>
<td>10</td>
<td>2.93</td>
<td>105.05</td>
</tr>
<tr>
<td>Agnes</td>
<td>10</td>
<td>3.48</td>
<td>124.70</td>
</tr>
<tr>
<td>Austrian Winter</td>
<td>4</td>
<td>1.92</td>
<td>84.45</td>
</tr>
</tbody>
</table>

New Canadian Beauty, Agnes, and Golden Marrow have given good yields of both forage and grain. The 7 varieties did not differ over 10 days in maturity.

(b) Varieties in the San Luis Valley

There is a conglomerate mixture of 8 to 10 varieties grown in the San Luis Valley under the name of "native field peas". Warshauer and White Australian are selections from the native peas, but they are more or less mixed. Recently, two garden pea varieties have been grown as field peas because they have given higher yields. These are New Perfection and Yellow Admiral, the latter being 8 to 10 days later in maturity. French Gray has been introduced as an improved field pea variety, but the color of the seed has been found objectionable. The seed is the color of gravel, with the result that many seeds are missed when this variety is pastured. French Gray matures earlier and yields higher than Warshauer.

(c) Variety Descriptions

A few of the more important Colorado varieties are briefly described as follows by Koonce (1935):

1. **French Gray**: A medium late variety with colored flowers. The vines have a purplish tinge. The seeds are medium in size, angular and dented, gray in color (speckled with purple), and with brown hilums. The pods are medium in length and contain 4 to 8 seeds. This variety has given the highest grain yield at Fort Lewis.
2. **Golden Marrow**: This variety belongs to the Marrowfat group. It has white blossoms, large vines, and is rather late in maturity. The seeds are medium large, round, and cream-colored with hilums of the same color. The pods are rather large, long, and contain 4 to 8 seeds. Golden Marrow has produced almost as much grain and more forage than French Gray.

3. **Clamart**: This is a medium-late variety with white blossoms, and medium-length vines. The seeds are medium in size, cream colored, nearly round with flat sides, and brown hilums. The color of the seeds is not uniform, many having a greenish hue. The pods are medium in size and contain 4 to 6 seeds. Clamart produces nearly as much grain as French Gray and more forage. The two varieties mature at about the same time (121 days).

4. **New Canadian Beauty**: This variety, which belongs to the Marrowfat group, is very similar to Golden Marrow. It has large seeds and a very heavy vine growth. It matures about 7 days later than French Gray.

5. **Lima**: Lima is a medium-late variety (125 days) with colored flowers and a medium vine growth. The seeds are medium in size, green, with flat sides. The pods are medium long and contain 5 to 7 seeds. Lima produces less grain, but a little more forage than French Gray. It matures a few days later.

6. **Agnes**: This is a late variety (130 days) which produces a heavy vine growth as well as a fair yield of grain. The blossoms are white. The seeds are rather small, round, and cream-colored. The hilum is of the same color. The medium-long pods contain from 4 to 9 seeds. This variety produces more forage than French Gray.

7. **Austrian Winter**: This is a hardy variety that has survived the winter when fall-planted. It has colored flowers, and small gray speckled (with either brown or purple) seeds. The seeds are nearly round with flat sides. Small plantings at Fort Lewis have survived 2 winters, possibly due to snow cover.

V. **Seedbed Preparation**

Field peas follow other crops in a rotation provided the land is comparatively weed-free. It is advisable to fall-plow the land and disk it early in the spring. This makes early seeding possible. A well-prepared seedbed, while less essential for field peas than for small grains, is an aid to good stands. In the San Luis Valley, many growers plant field peas for grain on small-grain stubble because plantings on fall-plowed land tends to produce more foliage and less grain.

VI. **Seeding Practices**

Seeding practices for field peas depend upon the size of seed, as well as upon width of rows.

(a) **Method of Seeding**

It is preferable to plant field peas with a disk drill. A type that regulates the amount of seed planted by the size of the opening will materially reduce the amount of cracked peas. Koonce (1935) studied the effect of space between drill rows upon yield. There was little difference in yield in 8 and 18-inch rows, altho a 20 percent reduction resulted when the crop was planted in 36-inch rows. The 3-year average yields for 4 varieties for the
8, 18, and 36-inch rows was 27.1, 28.3, and 21.8 bushels per acre, respectively. Field peas are often grown in mixtures with either oats or barley for hay.

(b) **Time of Planting**

Early planting is essential for field pea production. They may be planted as early or even earlier than small grains. They are not damaged by light frosts. Larger yields may be expected from early than from late seedings. The average date of planting at Fort Lewis was April 16. Koons (1935) states that the time of planting in Colorado varies from March until May. In the lower areas of the Grand Valley, field peas may be planted as early as February with very little danger of frost injury. In the mountain valleys, the planting should seldom be delayed much later than May 1.

(c) **Seeding Rate**

The rate at which field peas are planted depends upon the size of the seed, character of the soil, and moisture available. The larger the seed, the more pounds per acre required to produce the same number of plants per acre. Probably 4 or 5 plants per square foot will produce the highest yield, regardless of variety. Koons (1935) advised that field peas be seeded at the rate of 1.5 bushels per acre for medium-sized peas like French Gray or Clamart.

VII. **Methods of Harvest**

Field peas are harvested for grain, forage or as pasture.

(a) **Grain**

Field peas should be cut for grain when the pods are mature and before there is danger of loss from shattering. As the peas seldom ripen evenly, it is necessary to harvest them before all the seeds have hardened. They are difficult to cut with a mower unless equipped with special guards to lift the peas from the ground. The mower should also be equipped with a windrow attachment. The peas may be allowed to cure in the windrow, or they may be bunched with forks. They should be handled as little as possible until threshered. The ordinary grain separator or a special pea thresher may be used to thresh field peas. In a few cases, field peas have been successfully harvested with a combine with a pick-up attachment.

(b) **Hay**

Field peas are often sown in mixtures with small grains to hold the vines off the ground and to facilitate harvesting. The oat-pea mixture is recommended for hay. Field peas should be cut for hay when the pods are well-formed. The presence of oats or barley in the hay makes a better quality of feed than peas alone.

(c) **Pasture**

Field peas are sometimes pastured with hogs, cattle, and sheep. This method of harvest is applicable only where the fall and early winter months have very little precipitation, such as is the case in the San Luis Valley. The animals are turned in when the peas in the lower pods begin to harden. This is a wasteful practice, even under favorable conditions. Field peas are generally sown alone when intended for pasture.
Tests conducted in the San Luis Valley by Osland and Norton (1911) indicated that hogs on pea fields alone made unsatisfactory gains. The rate of gain was increased when supplemental feeds, such as barley were used.

VIII. Insect Enemies

The two most prevalent insect enemies of field peas in Colorado are the pea weevil and pea aphis.

(a) Pea Weevil (Bruchus pisorum)

The pea weevil is the most serious insect enemy. The adult pea weevil is a small grayish or brownish-gray beetle about one-fifth of an inch long, marked with black and white spots. There are 4 distinct stages in the life cycle: egg, larva, pupa, and adult. The adult female lays its eggs in the young pod. This egg hatches and produces a larva which bores thru the wall of the pod and enters the young pea where it feeds on the embryo. Later it pupates. The pupa may remain in the seed until next spring. The damage is done by the larva which eats most of the food material in the pea.

The insect may be controlled by the fumigation of the seed with carbon bisulfide. The seed should be placed in a tight receptacle and exposed to the fumes of the liquid for 30 to 48 hours. The liquid may be poured over the peas or exposed on top of them in a shallow dish since the vapor is heavier than air. One pound is generally recommended for each 100 bushels of seed. Carbon disulfide is a fire hazard. Recently, ethylene dichloride mixed with carbon tetrachloride in the ratio of 3:1 has been found to be a satisfactory control. A dosage of 6 pounds per 1000 cubic feet is effective. Growers should use extreme care to avoid the introduction of the weevil into weevil-free areas. The seed should be treated as a precaution.

(b) Pea Aphid (Macrosiphum pisii)

The pea aphid occasionally does considerable damage to the field pea crop. This insect does not stay with the crop year after year like the weevil, but has appeared at intervals when it practically destroyed the crop. The aphids increase rapidly during a period of warm dry weather, but a heavy rain will almost entirely destroy the pest. The growth habit of the field pea plant makes the use of sprays difficult. Unless weather conditions are such as to destroy the pest, the only hope is for parasites to increase sufficiently to control the aphid.

IX. Diseases

The two most important diseases are powdery mildew (Erysiphe polygoni), and bacterial blight (Pseudomonas pisii).

Powdery mildew is common on beans, peas, clover, and other members of the legume family. It is recognized by a whitish or grayish coat on all parts of the pea plant. It is most destructive on late varieties, the yields being reduced considerably in some cases. Crop rotation is the most practical remedy.
A bacterial blight of field peas was reported by Sackett (1916) as destructive in the San Luis Valley in some years. A severe outbreak was found to reduce the stand one-third in some instances. The diseased plants were found to have waxy, olive-green to brown discoloration on the stems while the leaflets and stipules appeared yellowish, bruised, and water-soaked. The bacteria enter the tissue through the stomata and wounds produced by mechanical injury. The amount of injury may be reduced when the peas are planted late, but the breeding of resistant varieties is the only satisfactory remedy.

References


Questions for Discussion

1. Describe the field pea plant botanically.
2. To what conditions are field peas adapted?
3. What types of varieties are best adapted to high altitude conditions? Name 5 for Colorado.
4. What varieties are grown in the San Luis Valley? Discuss them.
5. Describe 3 varieties from this list: French Gray, Golden Marrow, Clunart, New Canadian Beauty, Lima, Agnes, and Austrian Winter.
6. Discuss seedbed preparation for field peas.
7. What type of planter should be used for field peas? What row width?
8. When should field peas be planted in Colorado? Why?
9. What rate of seeding gives the highest yields?
10. Explain how to harvest and thresh field peas for grain.
11. How should field peas be handled as a hay crop? Why?
12. Discuss field peas as a pasture crop.
13. Describe the pea weevil and give control measures.
14. Discuss the aphis as a field-pea pest.
15. What is the appearance of plants infected with powdery mildew? Control?
FIELD CROPS IN COLORADO

Chapter 22. Field Beans

I. Economic Importance

The common field bean is one of the most important plants used for human food. A considerable acreage is grown in Colorado each year, especially on the drylands. Field Beans are an excellent cash crop with a well-established market. There were 293,000 acres devoted to dry beans in 1938, on which the average yield was 480 pounds per acre. The total state production for that year was 1,406,000 pounds. Kezer and Sackett (1918) observed that yields as high as 2000 pounds per acre have been produced on the drylands while as high as 3200 pounds per acre have been reported on irrigated lands.

II. Botanical Description

Practically all the dry edible beans belong to the genus Phaseolus. The plants may be bush or vine-like with pinnaately 3-foliate leaves, and a coiled keel on the flower. The common bean, P. vulgaris, bears flowers in small racemes from a peduncle that arises in the axils of the leaves. The fruit is a several-seeded pod, the seeds being more or less flat. Most of the dry-shell beans are the green-podded bush type. The medium type of bean is the most widely grown in Colorado, i.e., seeds 1.0 to 1.2 cm. in length.

III. Adaptation

Beans are well adapted to the plains region of eastern Colorado. Because beans are a hot weather crop, they must be produced in the frost-free period. Kezer and Sackett (1918) state that the season should be at least 90 days in length to produce the bean crop successfully. A season of this length is seldom found below 6,000 feet in elevation. Cool cloudy weather may extend the growing season, especially when accompanied by rains. In such cases the season required for maturity may be as long as 110 days and too long for many areas even below 6,000 feet in altitude.

Beans will grow on almost all soils, from adobes to light sandy loams. They make their best growth on sandy loam soils.

IV. Agricultural Varieties

The principal market variety in Colorado is the Pinto, altho Great Northern are important in some areas.

The Pinto variety is a medium-sized plant that is semi-trailing. The foliage is medium to dark green in color. The flowers are white, while the seed is grayish-streaked and blotched with greenish to pink colors, medium to large in size, and somewhat flattened. Kezer and Sackett (1918) characterize the seed as buff-colored, and speckled with tan to brown spots and splashes. This variety, medium in maturity is susceptible to bean rust.

The Great Northern variety has a vegetative type similar to the Pinto, but has large, white seeds.
V. Seedbed Preparation

Non-irrigated land should be worked early in the fall or spring as a preparation for field beans. The soil should be kept free from weeds with due regard for the control of soil blowing. Fall-listed land may be worked into a seedbed in the spring, or planted in mosed-out lister furrows. Beans respond to a well-prepared seedbed similar to that for corn. Sometimes it is unnecessary to plow the land for beans, especially after a clean cultivated crop. After a clean cultivated crop such as corn the land may be duckfoot cultivated or spring-tooth harrowed to prepare a seedbed. Beans may be surface-planted or listed in stubble land that has been kept free of weeds.

VI. Seeding Practices

The grower should avoid the use of beans for seed that have been frosted because of reduced viability.

(a) Seeding Time

Beans planted in a cold wet soil may rot. Due to the fact that beans will not stand frost, they should be planted after the soil is warm. In most regions in this state, this will be from May 25 to June 15. At Akron, the best time to plant field beans is between June 10 and 20. Plantings after July 1 are apt to be frosted in the fall before the beans have matured.

(b) Seeding Rates

Beans should be planted either with a regular bean planter or with a corn planter with bean plates. The grain drill may be used when the proper number of holes are stopped. The type of grain drill with a revolving cup feed is adapted to this kind of planting.

Under irrigated conditions the rows should be about 28 inches apart with one plant every 4 to 6 inches in the row. This will require from 30 to 35 pounds of seed per acre for Ploto beans. For dryland conditions beans should ordinarily be planted in 42-inch rows with plants spaced 18 to 24 inches apart. Generally, about 5 to 8 pounds of seed per acre will be necessary.

VII. Irrigation

A study on bean irrigation in 8 Colorado counties has been reported by Kezor and Sackett (1918). This study shows that it is fully as easy to over-irrigate as to under-irrigate beans. As an average of all results obtained, 2 irrigations gave higher yields than 3 or more irrigations. Sandy soils require more water than silt and clay loams. It is essential that they have soil moisture available when they commence to bloom.

In irrigated regions, beans should be given water when the plants show a dark green color, and commence to wilt during the day. The last irrigation should seldom be given after the blossom period. Late irrigations delay maturity of the crop.
VIII. Methods of Harvest

The proper time to harvest beans is probably when the pods are turning yellow but before they have dried. At this stage there will usually be about half the pods yellow ripe while a few will still show some green. Nearly ripe green pods of the Pinto variety will show brown stripes. When cut at the yellow-ripe stage, the beans will ripen up during the curing process. Beans shatter badly when allowed to become completely ripe on the vine. The Great Northern variety shatters more readily than the Pinto.

The most satisfactory implements for the harvest of the bean crop are regular bean harvesters. These machines cut or pull the plants just below the surface of the ground and, by means of "fingers" push 2 rows together into one harvested row. The most up-to-date machines have bunchers which place the vines into small piles. Bunching is done by hand when the harvester lacks a buncher attachment.

Beans cure more readily in small flat shocks than in large ones. The crop should be stacked when it is impossible to thresh them as soon as cured. This prevents loss by blowing, discoloration from weather conditions, and also leaves the land free for cultural operations. There will be very little loss from shattering where the beans have been properly shocked.

Beans split readily unless care is used in threshing. A regular bean huller is the most satisfactory thresher, but a grain separator with special attachments may be used as a second choice. Usually all concave teeth with the exception of one row are removed. The cylinder is run at a very slow speed. The threshed beans should be cleaned and graded before placed on the market.

IX. Use of Bean Straw

Bean straw and hulls, after the beans have been threshed, will yield from 600 to 800 pounds per acre on drylands and somewhat more on irrigated lands. Experience on the drylands indicates that bean straw fed with silage will return a feed value nearly as great as alfalfa. When fed with other dry feeds, it is about one-half as valuable as alfalfa. The utilization of bean straw constitutes a material addition to the dryland feed supply. (See Kezer and Sackett, 1918)

X. Insect Pests

The Mexican or spotted bean-beetle (Epilachna corrupta) is a serious pest in the infested areas of Colorado. Studies by List (1921) indicate that its attacks are confined almost entirely to the true beans. The insect winters as an adult, and appears from hibernation from June 15 to 30. A few individuals pass thru a second complete life cycle and emerge as beetles late in the fall. The adults lay eggs which hatch into larvae. The larvae are responsible for a large part of the damage.

The most satisfactory means of control is spraying with arsenite of zinc. It should be applied at the rate of one pound of the powder to 40 or 50 gallons of water. The spray should be applied to the under surface of the leaves. As many as 3 applications may be necessary to effect control. Early plantings of an early variety are most easily protected in badly infested areas.
XI. Diseases

The most prevalent bean diseases in Colorado are bacterial blight, bean rust, and sometimes anthracnose or pod spot. These are described by Kezer and Sackett (1918).

(a) Bacterial Blight (Pseudomonas phaseoli)
This disease causes great damage to the bean crop in some seasons. The first evidence of the disease is the appearance of small, irregular, amber-colored, water-soaked spots. These spots may become rapidly larger and produce a great deal of dead tissue. Pod lesions are usually reddish in color, water-soaked, and very irregular in outline. Badly diseased plants lose their leaves and fail to mature their seeds. The principal control measure is to plant seed from fields that are blight-free.

(b) Bean Rust
Bean rust (Uromyces appendiculatus) appears on the leaves as rusty-colored pustules about the size of pin-heads. They also appear on the stems and pods to a less extent. The pustules turn black for the winter stage. Bean rust, while common, is rarely of economic importance in the state. The use of resistant varieties and the burning of old bean trash are recommended control measures.

(c) Bean Anthracnose or Pod Spot
Pod Spot (Colletotrichum lindemuthianum) is characterized by large round dark-colored lesions on the pod. There is an orange-colored border around the larger of these pod lesions. Areas along the veins on the underside of the leaves turn black. The disease is concentrated on the leaves until the pods appear. It over-winters in the seed. The disease is most serious in wet seasons, but seldom of importance in Colorado. The most satisfactory control measure is the planting of disease-free seed.

References


Questions For Discussion

1. Describe beans botanically.
2. To what climatic and soil conditions are beans adapted?
3. Describe 2 agricultural varieties of dry-shelled beans grown widely in Colorado.
4. Describe seedbed preparation for beans.
5. What is the best time to plant beans? Why?
6. What seeding rates are recommended for beans in Colorado?
7. Discuss irrigation of beans.
8. At what plant stage should beans be harvested? Why?
9. Describe implements for the harvest of beans.
10. Tell how to cure beans.
11. What precautions are necessary in threshing beans? Why?
12. What is the value of bean straw?
13. Explain how to control the Mexican bean-beetle.
14. Describe the symptoms and control measures for bacterial blight of beans.
15. Describe bean rust. How controlled?
16. Give the symptoms and control measures for Pod Spot.
FIELD CROPS IN COLORADO

Part IV

Crops of other Plant Families
FIELD CROPS IN COLORADO

Chapter 23. Sugar Beets

I. Economic Importance

The sugar beet (Beta vulgaris) has filled the need for an intensively cultivated row crop for Colorado. An average of 185,096 acres of sugar beets have been grown in the state for the 10-year period from 1928 to 1937. The annual production for this period has averaged 2,287,300 tons. The yield per acre has averaged 12.3 tons.

The first sugar beets were grown in Colorado during the 1860s, but the first factory was built at Grand Junction in 1899. Factories at Rocky Ford and Sugar City were built in 1900, while the first plant in northern Colorado started operation at Loveland in 1901. At the present time, there are 18 factories in operation in the state.

II. Botanical Description

The sugar beet is a biennial which stores food in the crown and taproot during the first year, from which seed stalks arise the second year.

(a) First Year Plant

The so-called beet is an enlarged taproot, while the crown is developed from the hypocotyl or stem. The root may be distinguished from the hypocotyl by two opposite longitudinal rows of secondary roots. The taproot extends almost straight downward, the lower portion being small and threadlike. It commonly reaches a depth of 4 feet, but often 6 to 7 feet. Lateral roots may extend horizontally 2 to 3 feet. A cluster of large leaves develop from the crown during the first season, the older leaves being on the outside and the younger leaves towards the center. The leaf has a long petiole which broadens out at the base. The blade is large and roughly triangular in shape, being longer than broad.

(b) Second-year Growth

The seed is developed during the second season. The mother beets first produce a rosette of leaves like those of the first year, but after about 6 weeks of growth the newly formed leaves become progressively smaller and finally the apical portion begins to elongate. The elongated stems bear small, widely-spaced leaves. The mature inflorescence or "seed bush", is composed of large, paniculate, more or less open spikes which bear the flowers, and later the seed. The flowers on the seed stalks are arranged along the axis singly or in dense sessile clusters. While the flowers are perfect, cross pollination generally occurs. Wind is the principal agent in pollen dissemination. The beet "seed", frequently called a "seed ball", is really an aggregate fruit. It usually contains a number of germs. Parts of several flowers grow together to form a several-seeded mass, or "seed ball". Attempts to produce single-germ seed balls have been unsuccessful.

III. Types and Varieties

There are two well-known types of sugar beets, the Kleinwanzlebener and the Vilmorin. These are tonnage and sugar types, respectively. The Vilmorin is more circular in cross-section, smaller, lighter in skin color, and with smaller top leaves than the Kleinwanzlebener. The tonnage type is commonly grown in Colorado. Some data by Skuderna and associates (1936) for northern
Colorado indicate that there is little choice between the \textit{tunnae-type} and the intermediate-type groups, both of which significantly outyielded the sugar-type group in variety tests. In pounds of gross sugar per acre the small differences in tonnage yield obtained among the 3 groups was offset by differences in sucrose percentages. The intermediate or sugar types appeared to be the most efficient in sugar production in the Arkansas Valley.

Several varieties resistant to the curly top disease are found to some extent in western Colorado. Owen and others (1939) found U. S. 12 and U. S. 33 to have high curly top resistance, being adapted to areas where this disease occurs. A variety known as Great Western, developed by the Great Western Sugar Company, has been superior in yield and sugar percentage to the German commercial brands. However, it is susceptible to leaf spot.

IV. Adaptation

Sugar beets of the most desirable quality are produced where the average summer temperature is about 70° F., according to Townsend (1928). The beet is a cool weather plant, excessively high summer temperatures being detrimental to growth. It also has unusual ability to recover from hail damage which may destroy other crops.

Sugar beets are adapted to a wide range of soil types, but Tucker and Stewart (1940) observe the fine sandy loam or clay loam soils are preferable. Kezer (1927) states that very sandy soils are apt to be too low in moisture retentiveness and in fertility to produce high tonnages. Sugar beets grow poorly where the water table is near the surface. They will tolerate large quantities of soluble salts in the soil, but low yields generally result. The crop responds to highly fertile soils better than almost any other crop.

7. Crop Rotations

Alfalfa is the basis for most crop rotations on irrigated lands in Colorado. Sugar beets are a desirable crop in the rotation because they leave the soil in good physical condition for subsequent crops. It is difficult but not impossible to grow sugar beets after alfalfa. To prepare a satisfactory seedbed, the alfalfa should be crowed early in the fall. Later, preferably in the fall, the alfalfa land should be deep-plowed to cover the crowns deeply in moist soil. Sugar beets follow cultivated crops like beans, potatoes, peas, or other vegetable crops better than other crops. Tucker and Stewart (1940) state that satisfactory sugar beet crops may also be produced after corn. Fall seedbed preparation is urged where sugar beets follow small grains or corn harvested for silage. The stubble should be disked soon after harvest to control volunteer growth, and plowed later. Sugar beets may follow sugar beets for two years, except in areas infested with sugar beet nematode.

I. Seedbed Preparation

A firm, moist, well-aerated seedbed free from large clods is essential for the production of high sugar beet yields.

Disking stubble or other land just before it is plowed is one of the operations that contributes to good seedbeds. This operation pulverizes the surface soil, cuts and mixes the stubble, trash, and manure into the soil. The land should be plowed deeply, 7 to 8 inches. This should be done in the fall, provided the soil is neither too wet nor too dry. In the spring, the plowed
field should be prepared as a seedbed by use of the harrow, disk, and leveler. Compactors may be used to firm the seedbed, especially where the land has been early-spring plowed.

VII. Seeding Practices

Sugar beets are usually planted with the ordinary shoe or disk-type drills, but the trend is toward single-seed planting. The single-seed planter reduces the quantity of seed required for a satisfactory stand and may eliminate some of the labor in thinning. With the single-seed planter, the seeds are spaced mechanically as planted. This permits the elimination of unnecessary plants without "stop" labor. All planters should be checked for accuracy before they are used in the field.

Planters should be adjusted to plant the sugar beet seed from 1.0 to 1.5 inches deep. The seed is almost always planted in 20-inch rows in Colorado. The drill should be equipped with ditches to furrow the land for irrigation. This practice is desirable even where beets are not commonly irrigated up, so that water may be applied when necessary to bring about good germination.

The dates of seeding varies in different areas of Colorado. For northern Colorado, Tucker and Stewart (1940) recommend planting on April 10 or earlier. For the Arkansas Valley and the lower regions of the Western Slope, sugar beets should be planted on or before April 1. The crop is generally planted on or before May 1 in the San Luis Valley. In tests conducted in northern Colorado, planting on April 10 resulted in 0.50 to 0.66 tons more beets per acre than with April 25 plantings, and 4.0 tons over May 25 plantings.

The amount of seed planted with the ordinary beet drill is 20 pounds per acre, but the amount may be reduced to 10 to 15 pounds where single-seed-planting plates are used. In a well-prepared seedbed, 20 pounds of seed will result in many more plants than are necessary for a perfect stand, but wide experience has shown the fallacy of attempted economies in seed at the possible expense of a poor stand.

Poor stands may be caused by soil crusts formed by heavy rains before the seedlings emerge. Sometimes the press wheels on the planter leave a crust in moist soil. These soil crusts should be broken immediately to facilitate seedling emergence. Surface crusts may be broken by a harrow or a corrugated roller.

VII. Thinning Operations

When sugar beet seed is drilled by the usual method, the seedlings emerge in a more or less continuous row. When the young plants reach the 6 to 8-leaf stage, it is necessary to reduce the stand to one plant in 10 to 12 inches of row. Because of competition, decreased yields usually result when the plants are thinned later than the 8-leaf stage.

(a) Blocking

Blocking is an operation where a portion of the plants are cut out so as to leave small bunches at the proper intervals to produce the desired stand. For years, this has been a hand operation with a hoe. It is now possible to block a field with machinery with about 30 percent less labor. Equipment for mechanical blocking has been worked out by Mervine and McInirney (1938), while various comparisons of hand and machine blocking have been made by Skuderna and others (1934). The ordinary beet cultivator, with knife
weeders or disks set so that blocks of the desired size and spacing are left, may be used for mechanical blocking. Larger blocks should be left when the stands are poor. The cultivator is used across the row for blocking. Implements that travel with the row have certain advantages of easy adjustment to spacing, less trouble with trash, etc.

(b) Thinning

The sugar beet grower desires a uniform stand. When the plants are spaced 10 to 12 inches apart in the row, the losses of individual plants between thinning and harvest affect yields far less than where they are spaced wider apart. Brewbaker and Deming (1935) state that this is due to the fact that beets adjacent to small skips tend to utilize the additional space fully, while those adjacent to large skips do not. After thinning there should be at least 100 beets per 100 feet of row.

Thinning is one of the critical operations in the production of a sugar beet crop. The largest plant should be left when the plants are thinned, i.e., singled, because increased tonnage often results from this practice. Skuderna (1928) selectively thinned beets and found at the end of a 7-year period that the large plants had outyielded the small ones by an average of 2.05 tons and 705 pounds of sugar per acre. Thinning may be done with a short-handled hoe, but the use of the fingers is necessary to remove some plants. The crowns should be completely removed or the plants may grow again. As much soil as possible should be left around the plants that are left to grow. Exposure of the young roots usually causes some plants to be whipped off by the wind and others to be scalded by the sun.

(c) Influence of Stand on Yield

The stand of sugar beets is known to have an influence on the ultimate yield. Skuderna (1928) reported that an average stand of 84.2 percent after thinning was reduced to a 71.9 percent stand at harvest time. The 12.3 percent loss in stand was accounted for as follows: disease 5.4 percent, hoeing 2.0 percent, cultivation 3.0 percent, and the balance due to insect pests. Yields emphasize the importance of uniform stands. For stands that averaged 50 percent or better (12 inches between plants), Brewbaker and Deming (1935) found a close relationship between stand and yield. For each increase of 10 percent in stand within this range, there was an increase in yield that ranged from 0.76 to 210 tons of beets per acre.

IX. Cultivation

The principal function of cultivation is the destruction of weeds. Experiments by the U. S. Department of Agriculture in northern Colorado indicate that the average yield of beets was just as high where the weeds were merely scraped off with a hoe as where the land was cultivated 3, 5, or 7 times during the season. Cultivation should be frequent enough to control weeds.

The depth of cultivation should only be deep enough to destroy the weeds. The cultivator equipment generally used for this purpose are duckfoot, bull tongs, and weeder knives. Disks are useful where the soil contains trash, such as undecomposed organic matter. The first cultivation is generally performed just before the plants are thinned.

X. Irrigation

Most of the irrigation water for a sugar beet crop is required during the last half of the season. Sugar beets make their best growth when the plants are
supplied with ample moisture throughout the season. Light or moderate irrigations as frequent as necessary to keep the plants growing vigorously, are more effective than heavy irrigations at long intervals. Heavy irrigations early in the season are wasteful of water. In addition, soluble plant nutrients, particularly nitrogen, may be carried beyond the reach of the roots.

In a study of frequency of irrigation, Brewbaker (1934) has shown that the yields of sugar beets may be increased by a first application of water as early as June 15 in northern Colorado. A 5-ton increase in yield was obtained when the first application was made on June 15 rather than July 19, even tho the total amount of water for the season was the same in both cases. Irrigation as late as September 23 proved to be beneficial. The old idea that water should be withheld until the plants begin to suffer has been proved false. The yield is reduced when the plant suffers for lack of water either early or late in the season.

Sugar beets are irrigated by the furrow method. For economical use of irrigation water, the length of rows between head ditches should be between 20 and 30 rods.

XI. Methods of Harvest

The returns from a sugar beet crop are based on the yield of sugar per acre. For this reason, yield and sugar content are important factors. Sugar content of beets increases more rapidly than weight in the cool late fall season. The crop should be harvested as late as possible, but before danger of severe cold weather. Harvest is generally completed in October and November in Colorado.

The mechanical harvest of sugar beets is still in the experimental stage. There is every reason to believe that machines will be developed within a few years which will reduce the expense in harvesting sugar beets.

The sugar beet plants are usually pulled or lifted with horses or tractor-drawn pullers. The plants are pulled out by hand, several rows being thrown together in regularly-spaced piles. The beets are topped immediately. The top should be removed at the base of the crown. Topped beets should be either hauled to the dump immediately or covered with tops to prevent loss in weight from evaporation. Beets should be hauled within a day of the time they are pulled.

II. Seed Production

The production of sugar beet seed has been carried on almost entirely in Europe until recently, due to the high labor cost involved in the stockling method. The stockling method has been described by Tracy (1920).

It has been found that sugar beets will over-winter in the field in some parts of Colorado. In the over-wintering method the beet seed may be planted exactly as one would for ordinary root production. The beets are left unthinned and given sufficient irrigation water to keep them alive over winter. The next summer, seed is produced on the over-wintered plants. Cultural operations are performed by machinery except where the fields are weedy. These fields may also require hand-hoeing. The seed crop may be harvested with a mower, reaper, or by hand. The seed stalks are shocked in shocks to dry. The seed is later threshed from the field or from stacks with standard threshing equipment adapted to this purpose.
Diseases

The principal sugar beet diseases found in Colorado are leaf spot, curly top, seed rot, seeding blight, and blackheart.

(a) Leaf Spot

Leaf Spot (Cercospora beticola) is one of the most serious diseases of sugar beets in eastern Colorado. It is characterized by brown dead spots with ash-gray centers in the leaf tissue. Often the spots become so numerous that the infected leaves die. A pyramidal effect on the root-crown is manifested in instances where infected plants produce new leaves. The disease is encouraged by a hot dry period followed by moisture and high temperatures. When the proper environmental conditions exist, the disease develops rapidly and causes severe losses in yield.

Leaf spot may be prevented by the application of copper fungicides to the foliage prior to infection either in the form of dust or spray. Because of cost, this method is impractical. Strains of sugar beets have been produced recently that are highly resistant to infection by the leaf spot organism. These strains will be distributed in the near future.

(b) Curly Top

Curly top, a virus disease, occurs principally on the Western Slope in Colorado. The virus of this disease is transmitted by the beet leaf hopper (Entettix tenellus) or so-called "white fly". At present, the disease is limited largely to the intermountain region where it has been so serious as to threaten the beet sugar industry. It feeds during a large part of the year on native vegetation. It migrates to sugar beet plants in the spring at about the time they are ready to thin. The leaves of infected plants show a typical curling upward, usually followed by more or less roughened and distorted leaf veins. As the disease progresses there is a general retardation of growth of the entire plant followed by a discoloration of the vascular bundles. Resistant strains have given satisfactory control of the disease in areas where it is likely to occur.

(c) Other Diseases

Seed-rot and damping-off diseases of sugar beets cause considerable loss of stands and yields in many regions of Colorado, according to Tucker and Stewart (1940). The causal organisms of these diseases are seed borne as well as soil borne to some extent. There is some evidence that seed treatment with New Improved Ceresan, at the rate of 4 to 5 ounces per 100 pounds of seed, will effect at least partial control of these diseases.

Black-root or seedling blight, a disease caused by soil-borne organisms, often causes severe losses of sugar beet stands throughout Colorado. Long crop rotations, as well as improved cultural practices, will greatly reduce the incidence of the disease.

Black-heart is a physiological disease caused by a deficiency of phosphorus. This disease can be readily controlled by the application of commercial fertilizers high in available phosphorus. The disease is detected by the characteristic blackened leaves which also curl to some extent.

IV. Insect Pests

The most serious pests of sugar beets in Colorado are the nematode, webworm, and occasionally other insects.
(a) Nematode

The sugar beet nematode, one of the most serious pests, has caused heavy losses in areas where it has been prevalent. It imbeds itself in the roots where it consumes the plant juices. Maxon (1920) states that the plants send out many roots in an attempt to overcome the effects. The foliage of infested plants turns light yellowish green or dull gray-green in color. The leaves wilt and finally lie flat on the ground. Many leaves die while others fail to attain normal sizes. The plant dies in severe cases. The yield, as well as the sugar content, is greatly reduced as the result of nematode attack. Crop rotation is the most practical means of control. The growth of sugar beets on the same land but once in 5 years will control the nematode, except when the infestation is severe. Sugar beets should never be grown two consecutive years on the same field when nematodes are present in the soil.

(b) Webworms

Sugar beet webworms are common insect pests of the crop. The larvae of these small moths may be present in such numbers as to almost defoliate the plant. The control for webworms is to use poisonous sprays. Paris green or arsenate of lead, applied at the rate of 4 or 5 pounds per 100 gallons of water, constitutes the accepted control. Pyrethrum dusts will also control this pest.

(c) Other Insects

Grasshoppers or cutworms may be controlled by poison mash. Flea beetles, blister beetles, and wireworms frequently are troublesome in sugar beets. Wireworms are more apt to be prevalent in grasses. Fall plowing aids in their control. Flea beetles may damage young sugar beet plants. Pyrethrum dusts are effective controls, as well as sufficient moisture so that the crop can "grow away" from the pests.

References

Questions for Discussion

1. Why are sugar beets such an important crop in Colorado?
2. Describe the sugar beet plant botanically.
3. Describe two general types of sugar beets.
4. To what conditions are sugar beets adapted?
5. How are sugar beets placed in crop rotations? Why?
7. What types of sugar beet seed drills are in use? How used?
8. What general recommendations can be made for dates of planting sugar beets in different parts of Colorado?
9. How much seed per acre is generally planted for sugar beets? Why?
10. Why is it necessary to thin sugar beets? When should it be done?
11. Explain the blocking operation in sugar beet culture.
12. What precautions should be taken in thinning sugar beets? Why?
13. What losses may occur in stands between thinning and harvest time?
14. Briefly state the practices in sugar beet cultivation.
15. When should sugar beets be irrigated? Why?
16. When should sugar beets be harvested? Describe the operation.
17. Describe sugar beet seed production by the over-wintering method.
18. Describe the leaf spot disease. How can it be controlled?
19. Give the symptoms and control measures for curly top.
20. Describe and give control measures for the seed-rot, black-root, and black-heart diseases.
21. Give the symptoms and control measures for the sugar beet nematode.
22. What injury is caused by the sugar beet webworm? How controlled?
23. How can these insect pests be controlled: grasshoppers, wireworms, and flea beetles?
FIELD CROPS IN COLORADO

Chapter 24. Minor Crops

I. Economic Importance

There are several crops that are grown in Colorado occasionally. The most important of these are flax, buckwheat, sunflowers, and Jerusalem artichokes.

II. Flax (Linum usitatissimum)

Flax is seldom grown in Colorado at the present time. A considerable acreage was grown east of the mountains up until the time of the World War, especially on land being broken out of sod.

(a) Botanical Description

Flax is an annual with a single stem and a taproot. The leaves are narrow, entire, and blunt at the apex. The flax inflorescence is cymose. The flowers are perfect, being normally self-pollinated. The flowers have 5 petals, blue in color, and 5 sepals. The flax boll has 5 chambers, each with 2 seeds. The seeds are one-seventh to one-fifth inch in length, and usually light brown in color. Bison, a wilt-resistant variety, has been grown to a limited extent in recent years.

(b) Cultural Methods

Flax is essentially a "clean land" crop. Weeds cause more failures on old land than any other cause. For this reason, flax is often planted on newly broken sod land. Large-seeded varieties like Bison, when drilled, are planted at the rate of 25 to 45 pounds per acre. It is possible that flax may be successfully grown in 28-inch rows and cultivated for weed control. Kezer (1915) states that flax may be seeded in this state from April 10 to May 15. Flax will stand a considerable amount of frost without injury. The proper time to harvest flax for seed is when the straw is brown in color and the seed balls ripe. The crop is usually harvested with a binder and shocked, although a header has been used on large acreages. The straw should be stacked in rather narrow stacks.

Flax has been grown under dryland conditions at the Akron Field Station over a long period of years. The results have been reported by McMurdie (1916) and by Coffman (1925). Flax was grown 9 years during the period from 1908 to 1922. The crop failed in 1911, 1914, and 1915. The highest recorded yield was 13.1 bushels per acre in 1912. The Russian variety produced the highest yields, an 8-year average production being 4.14 bushels per acre. Most of the flax seedings were discontinued after 1916. Mixed plantings of flax and wheat were started in 1928 but the results have been negative.

III. Buckwheat (Fagopyrum vulgare)

Buckwheat grows best in cool moist climates, being unadapted for dryland conditions in this state. It may be fairly productive on irrigated lands near the foothills, but the grower must be assured of a local market.
(a) Botanical Description

Buckwheat belongs to the smart-weed family, Polygonaceae. The plant is an herbaceous annual with a taproot. Branches arise from a single main stem. The leaves are triangular, heart-shaped, are alternate on the stem. The leaves are borne on a pedicel that varies from nearly sessile to 4 inches in length. White or pink flowers are borne in racemes at the end of the stems or on short pedicels that arise from the axils of the leaves. The calyx is composed of 5 nearly equal sepals that resemble petals, the latter being absent. Blossoming begins when the plant is immature and continues until frost. The buckwheat fruit is an achene which is usually triangular in shape.

(b) Cultural Results

Buckwheat requires 10 to 12 weeks to grow and mature before the first fall frost. In the 10 years it was grown at Akron, Coffman (1925) reports that buckwheat failed completely in 4 years, produced a light crop 2 other years, and a fair crop in 4 years. Dry hot weather between flowering and seed formation is disastrous to the crop. The highest yielding variety was Mountain, which produced a yield of 1712 pounds per acre in 1912. Buckwheat has very little promise as a dryland crop in Colorado.

IV. Sunflowers (Helianthus annus)

Sunflowers have attracted some attention in Colorado as a silage crop, particularly in the mountainous regions where the climate is too cool for corn.

(a) Botanical Description

The sunflower is a coarse annual which grows from 3 to 12 feet high. The leaves are long-petioled, ovate, acute or acuminate. The flowers are borne in heads surrounded by involucral bracts. The ray flowers are neutral and yellow. The Mammoth Russian variety is the only one grown extensively in Colorado. It is single-stalked with solitary heads 12 to 20 inches in diameter. The "seeds" are striped gray and white. Sunflowers are largely cross-fertilized.

(b) Adaptation

Sunflowers are adapted to a wide range of soil and climatic conditions, but they require more soil moisture than is normally available in the dry-land areas. While they will endure cooler temperatures than corn, sunflowers make their best yields in a long warm season. The crop is uninjured by light frosts at any time. Sunflowers should not be grown in regions where the season is favorable for corn. They have been grown successfully in the San Luis Valley and other high mountain valleys in Colorado where the season is too short and too cool for corn. The cooler the climate, the greater the yield advantage of sunflowers over corn.

(c) Cultural Methods

Seedbed preparation for sunflowers should be about the same as for corn.

Sunflowers may be seeded slightly earlier than corn because they are not injured by light frosts. Ray (1919) observed that they could be planted as late as July 15 as an emergency crop and still produce a satisfactory yield.
Sunflowers may be planted with a corn planter or with a grain drill with part of the holes stopped. For Colorado conditions, Ray (1919) recommended that the plants be spaced 3 to 4 inches apart in the row under irrigation to avoid the production of coarse woody stalks that result from wider spacings. He advised 36 or 42-inch rows.

(d) Methods of Harvest

Sunflowers are harvested in Colorado for silage. Ray (1919) advises harvesting when one-half to three-fourths of the seeds are in the late milk stage. Sunflowers are generally cut with a corn binder.

Analysis show that sunflowers have about the same feed value as corn. As sunflower silage is slightly less palatable than that made from corn, animals generally have to become accustomed to it.

The yields of sunflowers are higher than those for corn in cool regions. Ray (1919) observed in those parts of Colorado that sunflowers would often produce 20 tons per acre where corn produced 15 tons under the same conditions.

V. Jerusalem Artichokes (Helianthus tuberosus)

The Jerusalem artichoke is a hardy perennial which reaches a height of 6 to 8 feet. It closely resembles the wild sunflower. The tubers are pear-shaped and somewhat flattened. All American varieties are probably wild. The tubers are used for hog feed.

Artichokes thrive best in light soils. The tubers may be planted in rows 24 to 30 inches wide and spaced 20 inches apart in the row. The crop is usually allowed to grow until frost. At this time, hogs are turned in to harvest the tubers. The tubers remain alive in the ground all winter with usually enough left by the hogs to grow a new crop. Thus, the crop is apt to become a weed. Eradication is often difficult. Artichokes require more soil moisture than is normally available in the eastern Colorado drylands.

References


Questions for Discussion

1. Describe flax botanically.
2. Describe seeding practices and methods of harvesting flax.
3. What results have been obtained with flax under dryland conditions?
4. To what conditions is buckwheat adapted?
5. Describe buckwheat botanically.
6. What results have been obtained with buckwheat under dryland conditions in Colorado?
7. Describe the sunflower plants botanically.
8. To what conditions are sunflowers adapted? When should they be grown in preference to corn?
9. Give recommendations on rates and dates of planting for sunflowers.
10. Discuss the harvest of sunflowers as a silage crop.
11. How are Jerusalem artichokes grown and used as a crop.

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FIELD CROPS IN COLORADO

Appendix

1. Estimated Tonnage of Silage at the Time Filling is Completed (Table I).

2. Estimated Weights of Settled Silage (Table II).

3. Rates and Dates of Seeding Colorado Crops.
**Table I. Estimated Tonnage of Silage at the Time Filling Is Complete.**

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*Adapted from Nebraska Circular 1.*
### TABLE II.—Estimated Weights of Settled Silage*

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<th>Depth of Silage (Feet)</th>
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<th>Weight of Settled Silage (Tons)</th>
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<td>5.19</td>
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<td>9.37</td>
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<td>10.80</td>
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<td>9</td>
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<td>10</td>
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<tr>
<td>15</td>
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<td>16</td>
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</tr>
<tr>
<td>40</td>
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<td>62.84</td>
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</tbody>
</table>

*Kansas Bulletin 222.*
Table III. — Standard Crop Varieties for Colorado
(Revised September, 1933)

Compiled by Agronomy Staff, Colorado State College

IRRIGATED LANDS

<table>
<thead>
<tr>
<th>Crop</th>
<th>Recommended Varieties</th>
<th>Rates per Acre (lbs)</th>
<th>Dates to Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter Wheat</td>
<td>Kenred, Turkey Red</td>
<td>60</td>
<td>Sept. 10-15</td>
</tr>
<tr>
<td>Spring Wheat</td>
<td>Marqu's</td>
<td>90</td>
<td>March 10-15</td>
</tr>
<tr>
<td>Oats</td>
<td>Colorado 37, Swedish Victory</td>
<td>60</td>
<td>Up to April 20</td>
</tr>
<tr>
<td>Barley</td>
<td>Trebi, Comfort, Bolsens, Coast, (Velvet for brewing)</td>
<td>95</td>
<td>Up to April 20</td>
</tr>
<tr>
<td>Rye</td>
<td>Rosen</td>
<td>60</td>
<td>Sept. 15</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>Grimm, Baltic, Ledak, Northern Grown Common (1)</td>
<td>10-15</td>
<td>April 15-May 1</td>
</tr>
<tr>
<td>Sugar Beets</td>
<td>Minnesota 13 or local adapted Yellow Dents</td>
<td>20-25</td>
<td>April 10-20</td>
</tr>
<tr>
<td>Corn</td>
<td></td>
<td>6-8</td>
<td>May 1-10</td>
</tr>
<tr>
<td>Sweet Clover</td>
<td>(a) Biennial Yellow Blossom for pastures, (b) Biennial White Blossom for green manures</td>
<td>10</td>
<td>April 1-20</td>
</tr>
<tr>
<td>Sorgo</td>
<td>Black Amber or Coes Drilled</td>
<td>40-60</td>
<td>May 10-20</td>
</tr>
<tr>
<td>Potatoes</td>
<td>Russet Rural, Rural New Yorker #2, Triumph, Cobbler</td>
<td>1000-2000</td>
<td>Early Potatoes: April 1 Late Potatoes June 1-15</td>
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<tr>
<td>Mangels</td>
<td>Golden Tankard, Giant Long Red, Half Sugar</td>
<td>6-15</td>
<td>April 10-20</td>
</tr>
<tr>
<td>Field Peas</td>
<td>French Gray or Austrian Winter</td>
<td>100-120</td>
<td>April</td>
</tr>
<tr>
<td>Field Peas and Oats</td>
<td>French Gray Peas and Colo. 37 Oats</td>
<td>50 each</td>
<td>April</td>
</tr>
<tr>
<td>Pasture Grass Mixture</td>
<td>(a) Normal lands</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brome Grass</td>
<td>8</td>
<td>April 15</td>
</tr>
<tr>
<td></td>
<td>Meadow Fescue</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Orchard Grass</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Timothy or Slender Wheat grass</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yellow blossom sweet</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>clover or medium red clover</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) Wet lands</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rodep</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Timothy</td>
<td>6</td>
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<tr>
<td></td>
<td>Alsike Clover</td>
<td>4</td>
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<tr>
<td></td>
<td>Total</td>
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(1) Note: From old-established fields at least four years old.
<table>
<thead>
<tr>
<th>Crop</th>
<th>Recommended Varieties</th>
<th>Rates per acre (lbs)</th>
<th>Date to Plant</th>
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<tbody>
<tr>
<td><strong>B---Arkansas Valley</strong></td>
<td></td>
<td></td>
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<tr>
<td>Corn</td>
<td>Reid yellow dent, Iowa Silvermine and Minnesota 13</td>
<td>6-8</td>
<td>May 1</td>
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<tr>
<td>Winter Wheat</td>
<td>Kanred, Turkey Red</td>
<td>60</td>
<td>Sept. 10-15</td>
</tr>
<tr>
<td>Spring Wheat</td>
<td>Marquis</td>
<td>90</td>
<td>March</td>
</tr>
<tr>
<td>Oats</td>
<td>Kanota, Markton</td>
<td>90</td>
<td>March</td>
</tr>
<tr>
<td>Barley</td>
<td>Trebi, Colossus (Nurse Crop)</td>
<td>90</td>
<td>March</td>
</tr>
<tr>
<td>Winter Rye</td>
<td>Rosen</td>
<td>60</td>
<td>March or August</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>Grimm (1) Northern-grown common (1) or Ladak</td>
<td>10-12</td>
<td>March or August</td>
</tr>
<tr>
<td>Sugar Beets</td>
<td>(a) Biennial Yellow blossom for pastures, (b) Biennial white blossom for green manures</td>
<td>10</td>
<td>March</td>
</tr>
<tr>
<td>Red Clover</td>
<td>Medium Red</td>
<td>8-10</td>
<td>March or August</td>
</tr>
<tr>
<td>Field Peas</td>
<td>Austrian Winter for green manure</td>
<td>60-80</td>
<td>Feb. or August</td>
</tr>
<tr>
<td>Field Peas and Cattle</td>
<td>French Gray Peas and Markton Oats</td>
<td>60-80</td>
<td>Feb. or August</td>
</tr>
<tr>
<td>Pasture Grass Mixtures</td>
<td>(a) Normal lands</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brome Grass</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Orchard &quot;</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Meadow fescue</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yellow blossom sweet clover</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>26</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) Wet lands</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Red top</td>
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</tr>
<tr>
<td></td>
<td>Brome</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yellow blossom sweet clover</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>22</strong></td>
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</tr>
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<td><strong>C---San Luis Valley</strong></td>
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<tr>
<td>Spring Wheat</td>
<td>(a) White: Dainanco, Dicklow, Early Baart</td>
<td>90</td>
<td>April 1-May 15</td>
</tr>
<tr>
<td></td>
<td>(b) Hard red: Marquis</td>
<td>90</td>
<td>April 1-May 15</td>
</tr>
<tr>
<td>Potatoes</td>
<td>Brown Beauties, Peach Blows, Russet Burbanks, Triumphs</td>
<td>1000-1200</td>
<td>April 20-May 15</td>
</tr>
<tr>
<td>Oats</td>
<td>Colorado 37, Nebraska 21 (for high altitudes or late-planted seepage land.)</td>
<td>90</td>
<td>April 1-May 15</td>
</tr>
<tr>
<td>Barley</td>
<td>Trebi, Coloss, Comfort,(Velvet for brewing)</td>
<td>90</td>
<td>April 1-May 15</td>
</tr>
<tr>
<td>Sunflowers</td>
<td>Mammoth Russian</td>
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<td>April 20-May 10</td>
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<td>Sugar Beets</td>
<td></td>
<td>20</td>
<td>April 20-May 10</td>
</tr>
<tr>
<td>Field Peas</td>
<td>(a) Canning peas (grown for field peas), Perfection, Admiral</td>
<td>120</td>
<td>April 15-May 15</td>
</tr>
<tr>
<td></td>
<td>(b) True Field Peas; Clamart, French Gray, Agness, White</td>
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</tr>
<tr>
<td></td>
<td>Australian</td>
<td>100</td>
<td>April 1-May 15</td>
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<tr>
<td>Alfalfa</td>
<td>Grima, or Baltic</td>
<td>10-15</td>
<td>May 20-June 1</td>
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*(1) Note: from old-established stands at least four years old.*
<table>
<thead>
<tr>
<th>Crop</th>
<th>Recommended Varieties</th>
<th>Rate per acre (lbs.)</th>
<th>Date to Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet Clover</td>
<td>Biennial Yellow blossom</td>
<td>10-20</td>
<td>May 20-June 1</td>
</tr>
<tr>
<td>Pasture Grass Mixture</td>
<td>Bromo grass</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Orchard grass</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Meadow fescue</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Timothy</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yellow blossom sweet clover</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>30</strong></td>
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</table>

**D - Western Slope**

(Same as for Northern Colorado and Arkansas Valley except for potatoes and sugar beets.)

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<th>Crop</th>
<th>Varieties</th>
<th>Rate</th>
<th>Date to Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potatoes</td>
<td>(a) People's Russets (river bottoms)</td>
<td>1000-2000</td>
<td>May 1</td>
</tr>
<tr>
<td></td>
<td>(b) Irish Cobbler (early)</td>
<td></td>
<td>March 20-May 1</td>
</tr>
<tr>
<td>Sugar Beets</td>
<td>U.S. No. 1</td>
<td>20</td>
<td>April 1-10</td>
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</table>

**HIGH ALTITUDES, MOUNTAIN PARKS, ETC.**

<table>
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<th>Crop</th>
<th>Varieties</th>
<th>Rate</th>
<th>Date to Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter Wheat</td>
<td>Kanred</td>
<td>60</td>
<td>August 15</td>
</tr>
<tr>
<td>Spring Wheat</td>
<td>Marquis, Defiance</td>
<td>90</td>
<td>April 1-May 15</td>
</tr>
<tr>
<td>Field Peas</td>
<td>Agnes, Clamart, French Gray</td>
<td>100-120</td>
<td>April 1-15</td>
</tr>
<tr>
<td>(Timothy)</td>
<td>(Alsike Clover)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Usually sown in mixture of</td>
<td></td>
<td>Early Spring</td>
</tr>
<tr>
<td></td>
<td>(Timothy)</td>
<td>10</td>
<td>Winter or</td>
</tr>
<tr>
<td></td>
<td>(Alsike)</td>
<td>4-6</td>
<td>early spring</td>
</tr>
<tr>
<td>Barley</td>
<td>Trebi, Collare, Comfort, (Velvet for brewing)</td>
<td>90</td>
<td>April 1-May 15</td>
</tr>
<tr>
<td>Oats</td>
<td>Colo. 37, Nebraska 21 at</td>
<td>80</td>
<td>April 1-May 15</td>
</tr>
<tr>
<td></td>
<td>extremely high altitudes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potatoes</td>
<td>Russet Burbanks (at 5000 feet and above) Rural New Yorker</td>
<td>1000-2000</td>
<td>May 1</td>
</tr>
<tr>
<td></td>
<td><strong>#2</strong></td>
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</tbody>
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**DRYLANDS**

Eastern Colorado Plains

<table>
<thead>
<tr>
<th>Crop</th>
<th>Varieties</th>
<th>Rate</th>
<th>Date to Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>Local adapted strains</td>
<td>4-6</td>
<td>May 1-10</td>
</tr>
<tr>
<td>Winter Wheat</td>
<td>Kanrod, Turkey Red</td>
<td>45</td>
<td>Sept. 1-15</td>
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<tr>
<td></td>
<td>(3 PK.)</td>
<td>60</td>
<td>Up to April 1</td>
</tr>
<tr>
<td>Spring Wheat</td>
<td>Konmar, Ceres</td>
<td>40</td>
<td>April 1-15</td>
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<tr>
<td>Durum Wheat</td>
<td>Akrona, Kubanka, Peliss</td>
<td>60</td>
<td>April 1-15</td>
</tr>
<tr>
<td></td>
<td>4PK.</td>
<td>40</td>
<td>April 1-15</td>
</tr>
<tr>
<td>Oats</td>
<td>Brunker, Kanota, Nebr. 21</td>
<td>60</td>
<td>April 1-15</td>
</tr>
<tr>
<td>Rye</td>
<td>Rosen</td>
<td>30-45</td>
<td>Sept. 1-15</td>
</tr>
<tr>
<td>Proso or Hog Mill</td>
<td>Red Turghai, Early</td>
<td>6-20</td>
<td>May 20-June 1</td>
</tr>
<tr>
<td>Foxtail Milllet</td>
<td>Fortune, Yellow Manitoba</td>
<td>6-20</td>
<td>May 20-June 1</td>
</tr>
<tr>
<td>Siberian</td>
<td>Dakota Kursk, Goldmine</td>
<td>6-20</td>
<td>May 20-June 1</td>
</tr>
<tr>
<td>Sorgos</td>
<td>Black Amber, Red Amber, Drilled</td>
<td>15-30</td>
<td>May 10-20</td>
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<td>In Rows</td>
<td>4-6</td>
<td>May 10-20</td>
</tr>
<tr>
<td>Grain Sorghums</td>
<td>Goes or Greeley</td>
<td>15-20</td>
<td>May 20-June 1</td>
</tr>
<tr>
<td>Pinto Beans</td>
<td>Triumph, Cobblers, Early Ohio</td>
<td>800</td>
<td>June 1-10</td>
</tr>
</tbody>
</table>

South of Divide Country Only

<table>
<thead>
<tr>
<th>Crop</th>
<th>Varieties</th>
<th>Rate</th>
<th>Date to Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Sorghums</td>
<td>Milo, Feterita, Kafir and Hegari</td>
<td>4-6</td>
<td>May 10</td>
</tr>
<tr>
<td></td>
<td>(Extremo southeast part)</td>
<td></td>
<td>(7962-40)</td>
</tr>
<tr>
<td>Broom Corn</td>
<td>Dwarf, Standard</td>
<td>4-6</td>
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