SOIL, WATER AND PLANT RELATIONSHIPS UNDER IRRIGATION

REASEARCH IN THE UPPER COLORADO RIVER BASIN

Grand Junction, Colorado
Colorado Agricultural Experiment Station
Colorado State Unviersity
In Cooperation With U. S. Department of Agriculture

July 25, 1957

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FOREWORD

Soil, water, and crop management research in the Upper Colorado River Basin is a joint endeavor involving the following:

1. Colorado State University, Colorado Agricultural Experiment Station.
2. U. S. Department of Agriculture, Agricultural Research Service.
   a. Western Soil and Water Management Section
   b. U. S. Salinity Laboratory

The cooperation and support of the following groups and agencies in planning and executing this research program are gratefully acknowledged:

1. Soil Conservation Service, U. S. Department of Agriculture
2. Colorado Agricultural Extension Service
3. Lower Grand Valley Soil Conservation District
4. Grand Junction Drainage District
5. Mesa County Research Committee
6. Mesa County Board of Commissioners
7. Fertilizer Industry:
   C. D. Smith Company
   U. S. Steel Company
   Western Phosphates, Inc.
   Dow Chemical Company
   Geigy Agricultural Chemicals
8. Holly Sugar Corporation
9. Public Service Company of Colorado

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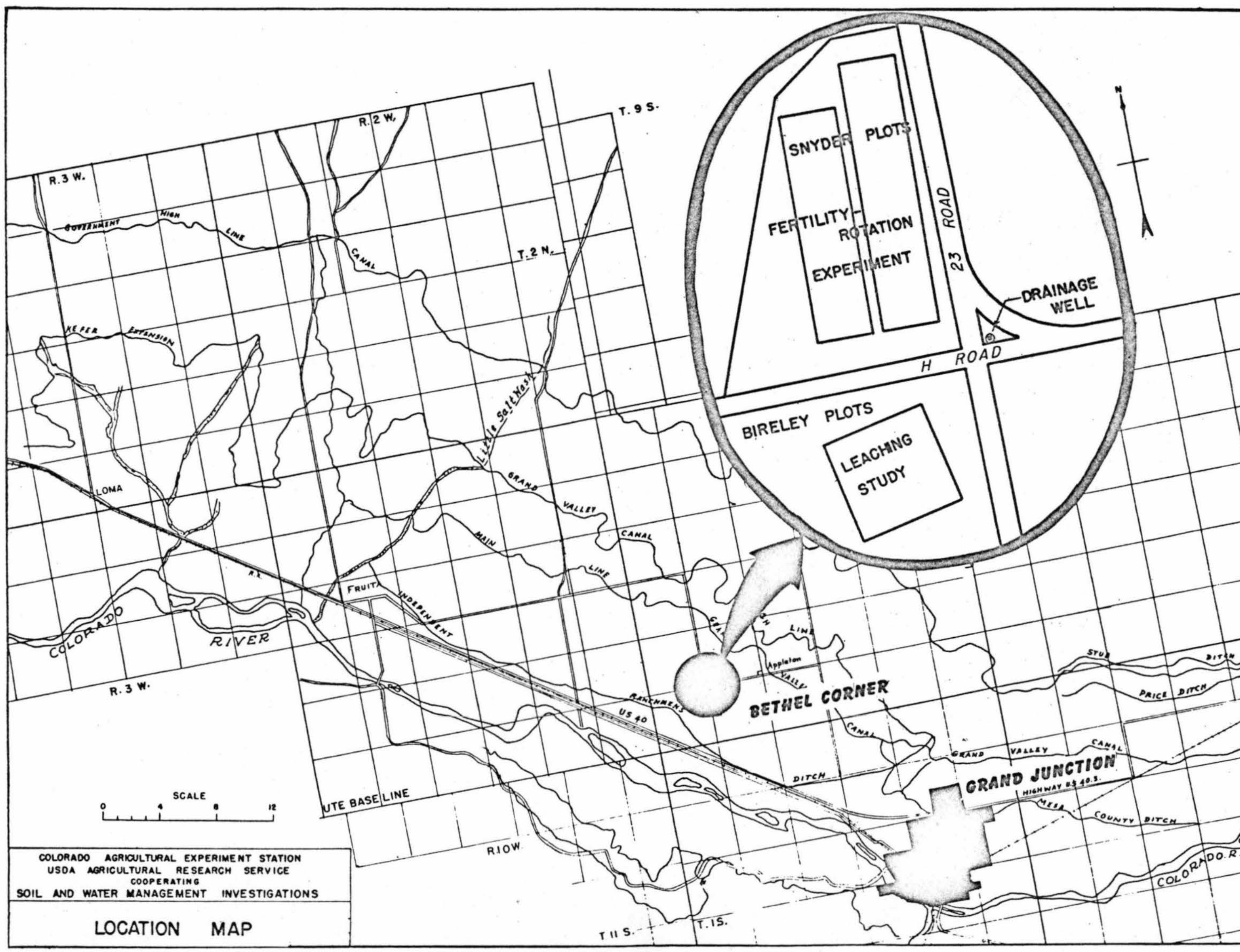
INTRODUCTION

Crop production in portions of the Upper Colorado River Basin is limited by poor drainage, excessive salts and alkali, low fertility and organic matter, and poor physical condition. Without adequate drainage, the alleviation of other factors adversely affecting crop production would not be fruitful. Assuming that drainage can be obtained, the removal of excess soluble salts and sodium would be of next importance. With the removal of salts and sodium, both of which are limiting factors for c rop production, the remaining soil and crop management problems can be considered. These include soil fertility, cropping system, organic matter residue management, irrigation management and other factors influencing soil physical properties.

The current program of soil, water (including drainage and irrigation), and crop management investigations in the Upper Colorado River Basin was undertaken in 1950. At the outset, major emphasis was placed on drainage, and the reclamation of saline and sodium soils. In 1954, the soil and crop management phases began to assume their share of emphasis. In 1955, basic studies relative to soil physical properties were initiated. This sequence of events leading to development of the current program is believed to be logical.

Fig. 1 Geographical Location Map
and
Sketch of Experimental Area



DRAINAGE AND WATER MANAGEMENT

The investigations reported here were undertaken under joint support by the federal, state and local agencies and groups listed under acknowledgements in the front of this report. These are studies covering principally the engineering phases of drainage and irrigation water management. Included are an analysis of drainage by pumping, canal seepage losses, irrigation water use, and a survey of the physical and hydraulic character of the artesian aquifer.

Major Results

Natural Drainage Capacity of the Soils of the Lower Valley.

Field measurements were made to determine the natural drainage rate of the free ground water through the area in which the regional research on W-28, W-29, and W-30 is being conducted. The measurements included hydraulic gradient, stratification, and hydraulic conductivity of individual stratum. An "average" profile was determined for the Bethel Corner area by considering logs at 27 locations within the 80 acres surrounding the well. The hydraulic gradient (slope of the water table) was measured during March and April when no pumping was being done. This gives a condition of natural ground water movement, unaffected by pumping, through the area.

Calculation of the discharge through the profile above the aquifer due to natural ground water movement for a section one mile wide as shown in Figure 2 gives the equivalent of 2.72 acre-inches of water per month. This means that the soil mantle above the aquifer is capable of transmitting only a very small amount of water under natural drainage.

The limit of natural drainage can be interpreted in terms of excess irrigation water application by dividing the number of contributing acres into 2.72. This will give the permissible excess irrigation for each acre which can be handled by natural drainage in a month. Without making a calculation, it is evident that the natural drainage capacity of the soil mantle through this part of the Grand Valley is practically negligible.

Drainage Load Due to Seepage and Irrigation.

Sample-farm studies were made to get an estimate of the

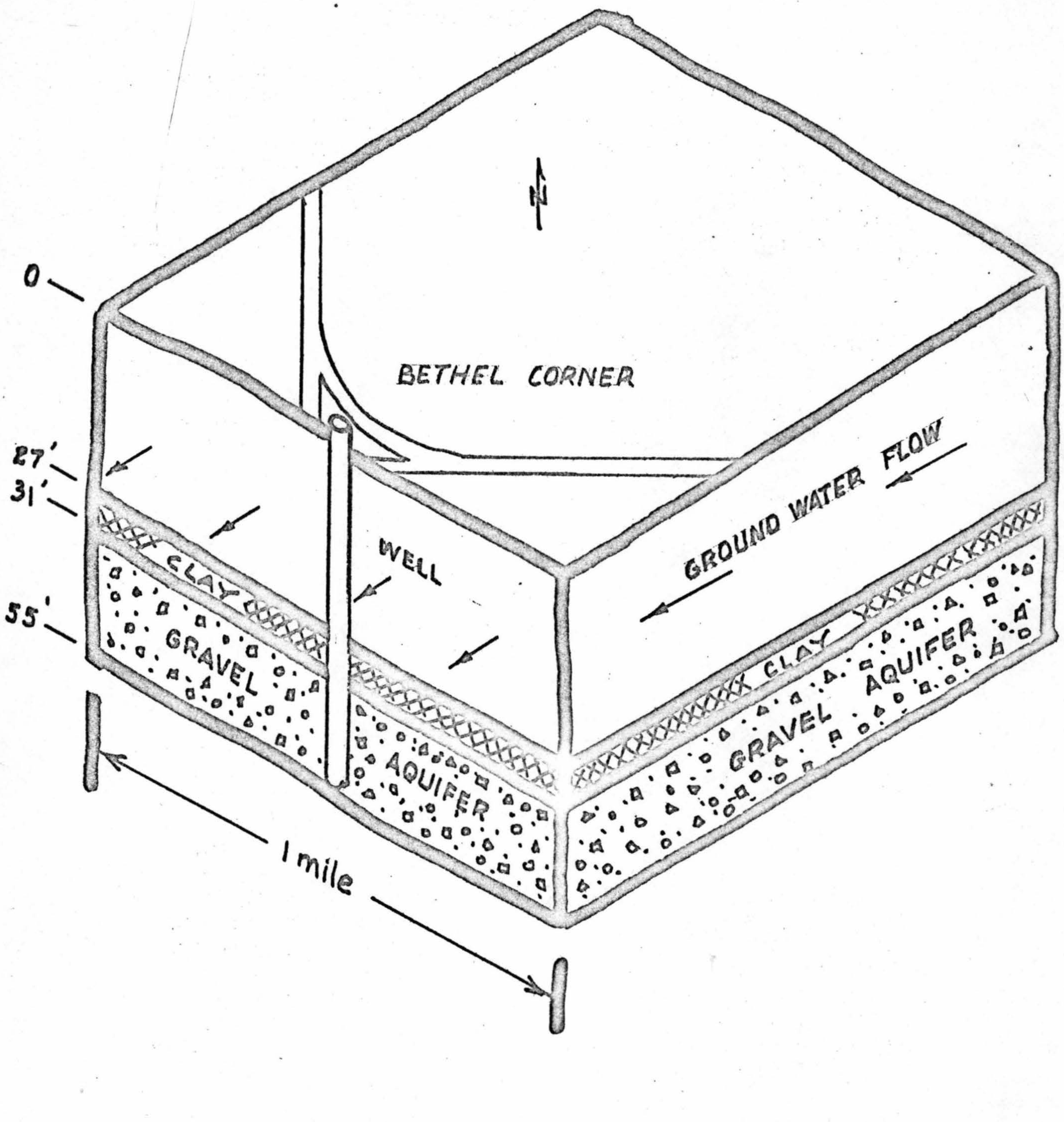


Fig. 2. IDEALIZED SECTION ONE MILE WIDE PERPENDICULAR TO DIRECTION OF GROUND WATER FLOW AT BETHEL CORNER.

amount of water added to the drainage load from excess irrigation. Six farms were selected from different areas of the valley so as to obtain representation of different farming practices and water delivery systems. Both demand and continuous delivery are used in this part of the Valley.

Averaging all the farms together resulted in an estimate of net excess application of 19 acre inches per acre. However two of the farms accounted for 90% of the excess. These two farms represented both systems of delivery.

No positive conclusions can be drawn from an observation of this kind, although it appears that the average net excess water application of 19 acre inches per acre is an adequate estimate of the drainage load imposed by irrigation practice. An estimate of this factor is necessarily poor due to the dependency upon management. As this study showed, the system of water delivery or the cropping practices did not necessarily affect the efficiency of water application.

On the basis of these findings alone it is clear why a high ground water condition should have developed in the lower Valley. With an inflow to ground water from irrigation of over 1 acre inch per acre per month and an out-flow of only a fraction of that amount in natural drainage, a "credit" to ground water must necessarily follow.

Irrigation system conveyance losses to ground water have also been considered. Direct seepage loss measurements on main canals were made. These proved to be neither extremely high nor low. The estimated total annual contribution to ground water from main canal seepage is 1.9 acre feet per day per mile on the Grand Valley Irrigation Company ditch (lower system) and 3.5 acre feet per day per mile on the Grand Valley Water Users Association canal (Gov't Hiline). Combined, these losses total 5.4 acre feet per day per mile. This is equivalent to 162 acre ft. per mile per month. Comparison of this value with the calculated natural drainage rate of 2.72 acre inches per month per mile indicates also the inevitability of an accumulation of ground water under the regime of natural drainage processes.

The Artesian Aquifer.

Study of the Colorado River records compared with aquifer pressure records discloses that the aquifer pressure is not related to the river discharge, stage, or sediment load. The pressure is, however, directly related to the use of the main canals. Pressure rises occur simultaneously with dates on which water is turned into the canal system.

Continued use of the stratum survey techniques employing jetting equipment and electrical resistivity equipment have shown this to be a valuable and practical method of getting important stratum data. Furthermore, the technique is highly economical. Figure 3 shows results of the survey completed during the summer, 1956. The aquifer areal extent and thickness was mapped for the entire lower Grand Valley.

This survey shows that the aquifer extends only under the lower, or first terrace, lands although this comprises about one-third the total area of the lower Valley west of Grand Junction. The aquifer ranges in thickness from a maximum of about 35 feet in the vicinity of Bethel Corner (drainage well) to about 10 feet near the river.

Effectiveness of Pumping

Effect on water table -- During 1955 and 1956, water table observations were taken at a number of points distributed within the square mile. Water table trends at these points were computed for three separate periods. One was for June 23 to August 20, 1956--a period of two months of pumping following 6 months of non-pumping. The same period -- June 23 to August 20 -- during 1955 was also used. During that time there was no pumping nor had there been any pumping for the previous six months. The third period used was August 22 to December 12, 1955--a 4 month pumping period following 5 months of non-pumping.

The pump discharges during the two pumping periods were not the same. During 1955 the discharge was only slightly over 200 gpm, while in 1956 this had been increased to about 285 gpm.

Analysis of the trend data shows that during the 1956 pumping period, the water table dropped at the rate of 0.10 inch per day in a small area west of the well, and at smaller rates outward from this area in an oblong pattern. The sketch of Figure 4 shows two lines of equal water table recession rate for this pumping period.

During the same period in 1955, when the pump was not

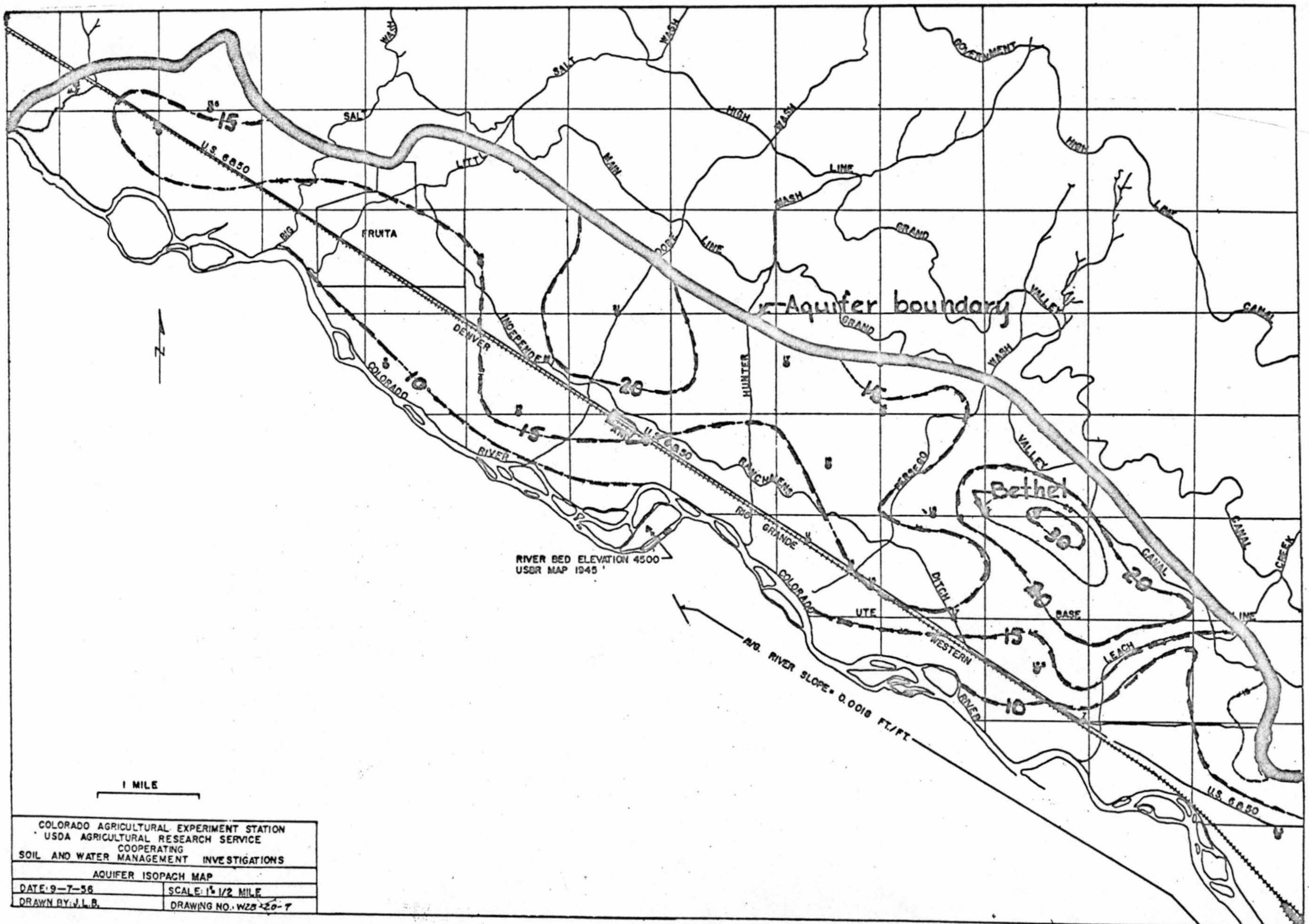


Fig. 3. EXTENT AND THICKNESS OF AQUIFER (WATER BEARING GRAVEL)

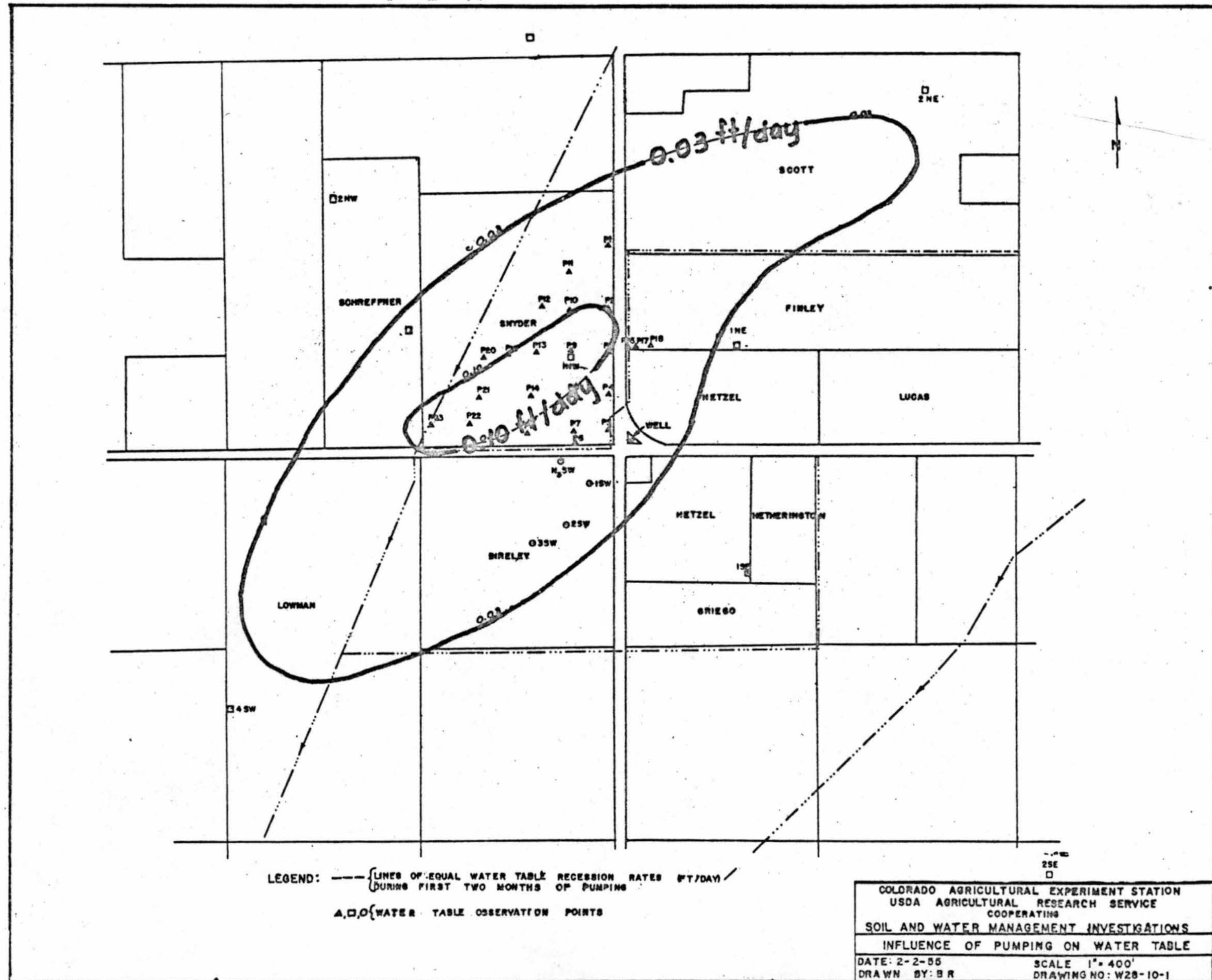


Fig. 4. WATER TABLE RECESSION.

operated, the water table trend in this area was upward, which indicates that the lowering water table observed in 1956 was due to the pumping.

The area outlined on Figure 4 within the outer line of equal recession rate is approximately 200 acres. We conclude that about 200 acres receives benefit from the well within the first two months of pumping at this particular location. Or we might say that the water table within the 200 acres outlined declined by at least 1.8 ft. in the first two months of pumping. This decline is progressively greater toward the center of the area outlined.

<u>Effect on pressure in aquifer</u> -- Pumping lowers the pressure in the aquifer as shown on Figure 5. The pressure reduction is greatest near the well and only slight at a radius of one half mile. No noticeable effect on pressure was observed at one mile radius.

The importance of this observation is that water might be drawn into the aquifer anywhere within a radius of one half mile because the pressure is reduced significantly within that area. <u>However, the water table was shown to have lowered only in an oblong shaped area, the center of which does not even correspond with the well location.</u>

The reason for this behavior is a most important observation that a tight clay layer on top of the aquifer prevents the upper ground water from going down into the aquifer freely. This clay has thin spots, however, which do permit water to pass. Thus when pressure is reduced in the aquifer, water passes downward into the aquifer through such spots. Such a spot was located about 800 feet west of the well which accounts for the odd shape and location of the water table drawdown.

<u>Power and Maintenance</u> -- Operation costs have been mainly power which has cost approximately $70.00 per month.

Deterioration of the pump discharge column made repairs necessary during the past season. It was discovered that holes had been created in the steel column pipe at the same elevation as the top of the brass screen. The cause was evidently a cell created by the lead packing used at the top of the screen. The reversible cell potential between lead and iron is 0.3146 volts which apparently caused the iron from the pipe to be oxidized to ferrous iron and carried

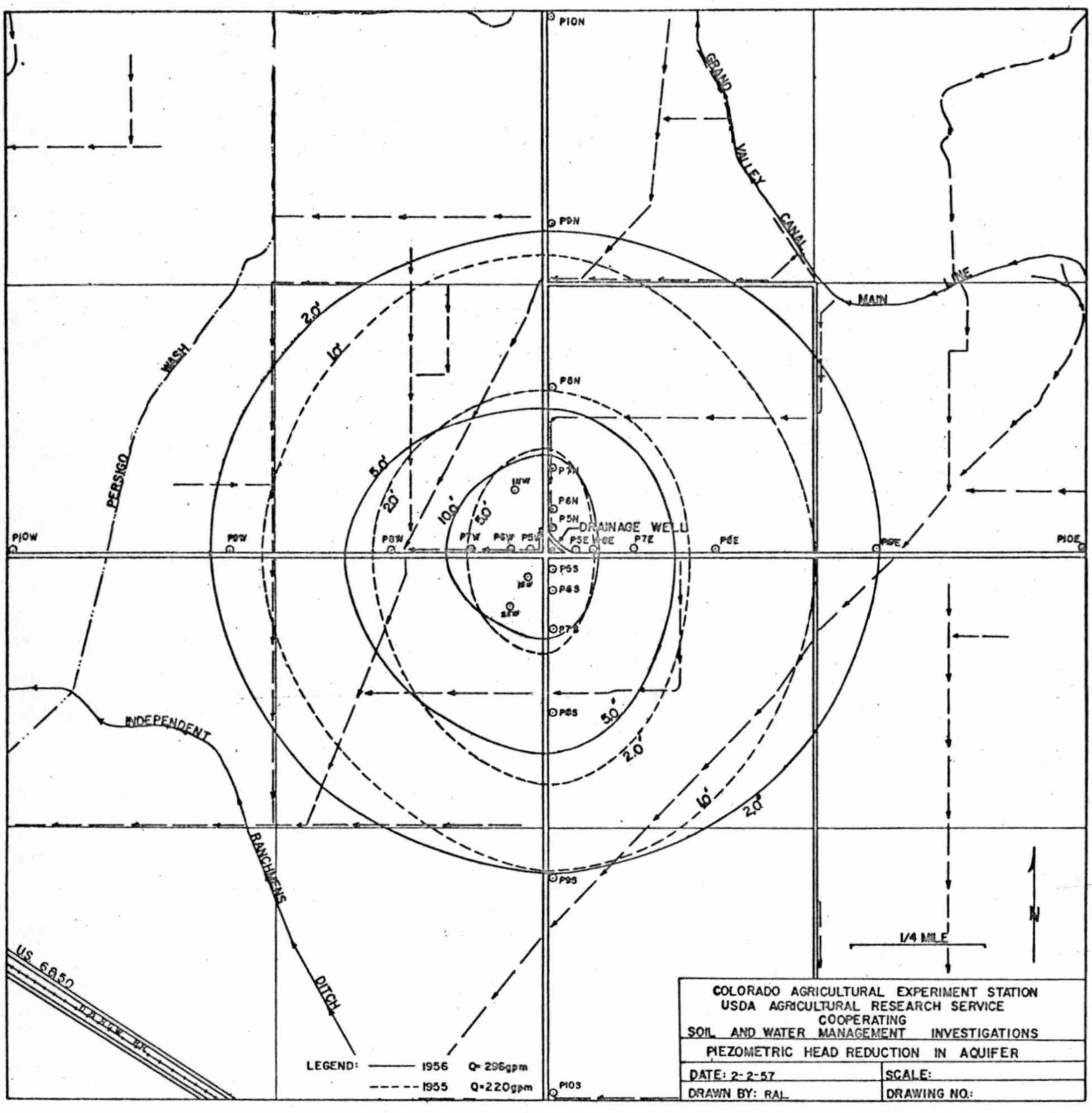


Fig. 5. PRESSURE REDUCTION IN AQUIFER.

away in the water.

A 10-foot replacement section for the damaged column pipe was coated with a porcelain coating to prevent recurrence of the deterioration.

The shaft was also badly coated with tubercles at the lower end where it was constantly submerged. Although it could have been used for sometime longer, a 4-foot replacement section of stainless steel was added.

Following these repairs the plant efficiency increased to 46%. It was previously as low as 21%.

Conclusion

The experimental drainage well has been effective in controlling the water table in an area of at least 200 acres in its vicinity. This success has been due to the fact that an opening in the clay layer exists in this vicinity. A drainage well in any part of the lower valley can be successful only if such an opening exists in its proximity. Therefore it is essential that investigation of the clay layer overlying the aquifer be made prior to installing any such well.

In the experimental area, the well has been operated intermittently over the past two years. The water table has been adequately controlled by pumping only during the irrigation season. The rise of the water table during the non-irrigation season is comparatively slow, so that the lower water level can be maintained on a year-around basis by pumping only part of the year.

RECLAMATION OF SALINE AND SODIUM SOILS

The reclamation of saline and alkali soil involves 1) the removal of excess soluble salts and/or 2) the removal of excess adsorbed sodium. The first is accomplished by leaching and washing the salts out of the soil. The second is accomplished by substituting calcium (inherent in the soil or added as an amendment) for exchangeable sodium and removing the latter by leaching.

An experiment was initiated in the summer of 1952, on the Bireley tract west of Grand Junction, to determine the feasibility of reclaiming a saline-alkali soil of the Billings series.

Four leaching treatments consisting of two rates of water (2 and 6 feet) in combination with two rates of gypsum application (0 and 4 tons/acre) were studied.

Results at the conclusion of the leaching phase of the experiment indicated decreases in soluble salts and adsorbed sodium when compared with pre-leaching values. These decreases were related to the amount of water used to leach. Leaching with 2 feet of water resulted in a decrease in the salt and sodium content to a depth of 24 to 30 inches. Where six feet of water were used to leach, the soil was reclaimed to a depth of 50 inches. No significant benefits attributable to gypsum were obtained with either leaching rate since the soil already contained gypsum in such quantity as to produce adequate soluble calcium to replace the exchangeable sodium.

In the fall of 1953 all plots were seeded to Ranger alfalfa. In 1954, 1955 and 1956 three cuttings of hay were obtained. Hay yields (Figure 6) were related to soil salinity and sodium which were in turn a function of the amount of water used to leach. There were some indications that incorporation of gypsum may be beneficial with the 2-foot leaching, but no benefits due to gypsum were apparent with the 6-foot leaching treatment.

Studies of some of the soil properties believed to be associated with soil-air-water relationships were initiated in 1955. Investigations of infiltration rate, hydraulic conductivity, osmotic pressure, and modulus of rupture all showed that these properties were related to the amount of salt and sodium left in the soil. The latter were influenced

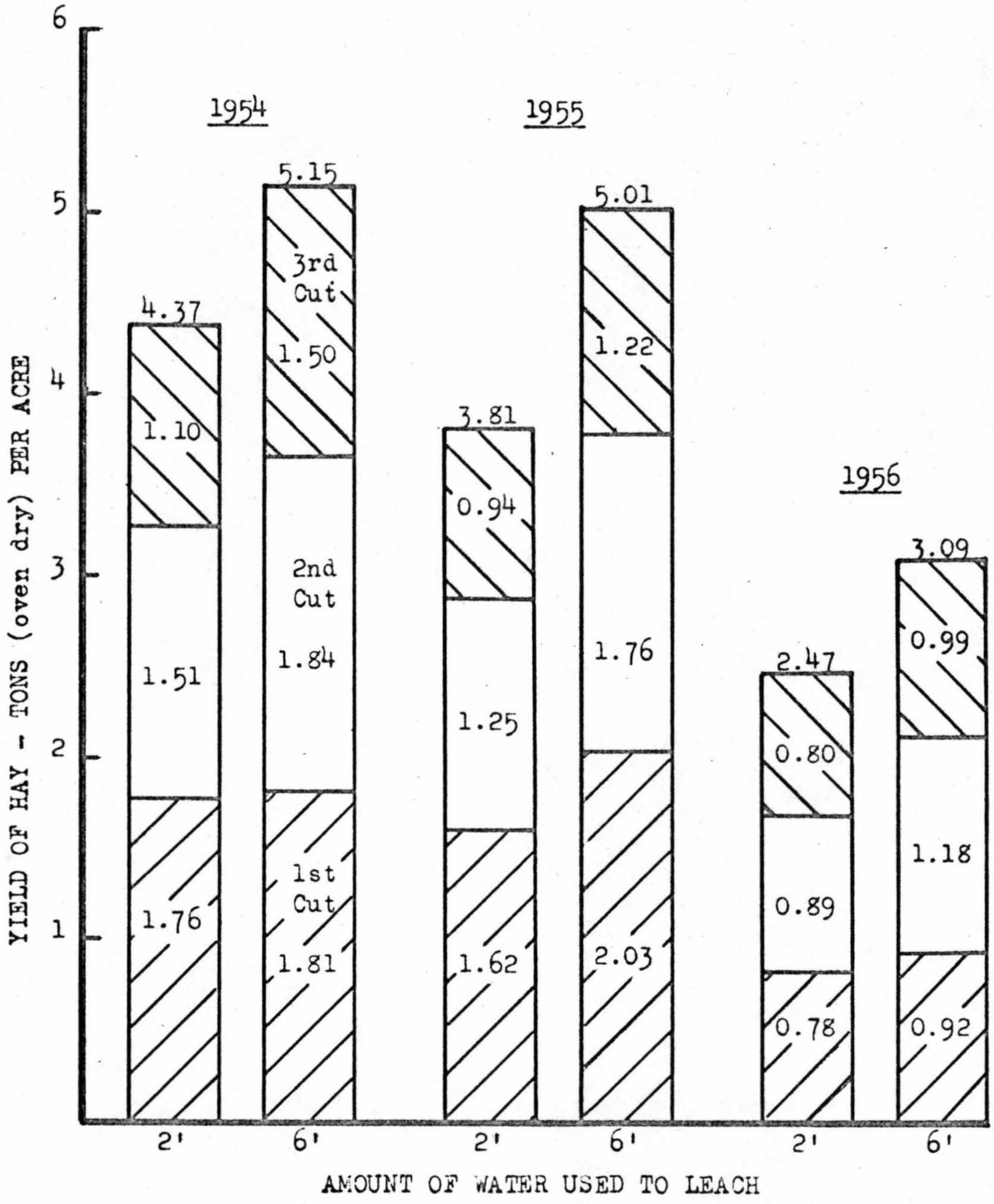


Figure 6. Yield of hay as influenced by leaching prior to seeding, Grand Junction, Colorado

by the amount of water used initially to leach this soil.

Soil data (Figure 7) indicate that after three years of cropping following reclamation, salts and sodium were re-accumulating in the profile. This means that in order to sustain the beneficial effects of reclamation treatments, water in excess of crop requirements must be applied. However, care must be taken such that water is applied at a rate not to exceed the capacity of the soil to handle it. This additional water can be applied in the fall, for example, following the last cutting of alfalfa, or it may be applied during the growing season. On two of the plots in 1956 the crowns were submerged for more than 8 days without apparent damage.

Aeration studies have shown that under flood irrigation conditions the oxygen concentration of the soil atmosphere dropped to as low as 3% without apparent adverse effects on plant growth. If there were any deleterious effects due to low oxygen levels, they were masked by the dominating influence of soil moisture.

Root studies made in 1955 and 1956 indicated that the growth and development of alfalfa roots were closely related to the concentration of salts and sodium in the profile. On a plot initially leached with 6 feet of water actively growing roots were found at depths in excess of 6 feet. On another plot initially leached with only 2 feet of water active root development was observed only to 30".

In the latter instance, decaying roots and old root channels to 5 or 6 feet suggests that immediately following reclamation soil moisture conditions were favorable for root growth at these depths. As the roots developed, however, the rate of moisture removal was greater than the rate of moisture replenishment, resulting in adverse soil moisture conditions inhibiting further growth.

Within most of the individual 30 x 60' plots, marked variation in growth has occurred. Localized plant and soil samplings indicate a close relationship between plant growth and soil salts and sodium which in turn govern soil moisture availability in the profile. After the first cutting of hay in 1957, half of the plots will be chiseled to a depth of 24" to determine whether these variations may be lessened as a result of more uniform distribution of applied water.

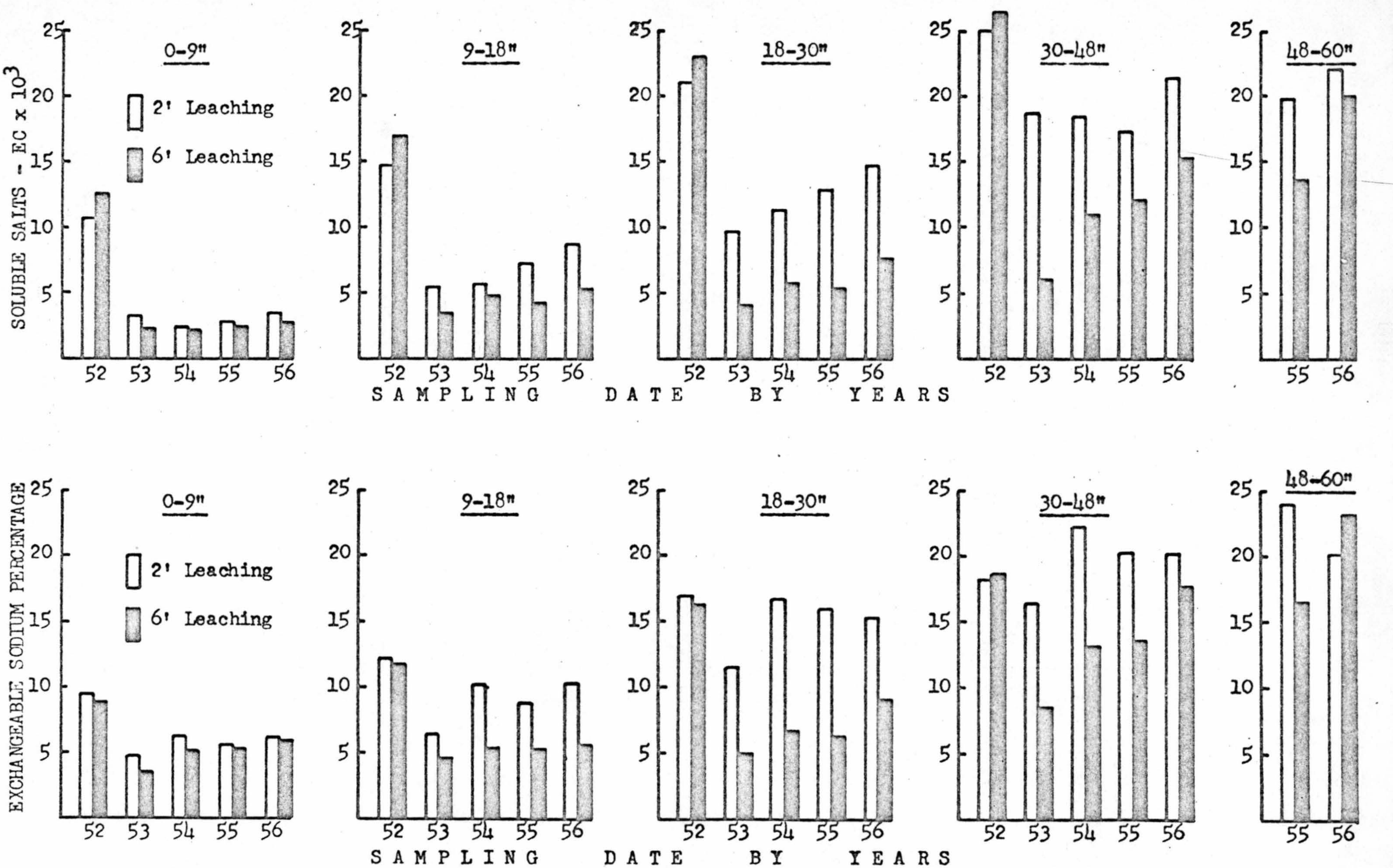


Figure 7 . Soluble salts and exchangeable sodium percentage of Billings soil at various depths as influenced by the amount of water used to leach and subsequent cropping to alfalfa, 1952-56, Grand Junction, Colorado. (Sampling dates: 1952 - Before leaching; 1953 - After leaching; 1954 - After one crop year; 1955 - After two crop years; 1956 - After three crop years.)

Results of these studies have shown a definite relationship between soil properties and plant growth. It appears that the growth of alfalfa is associated primarily with the factors governing the movement and availability of soil moisture.

Practical Application of Experimental Research

With the knowledge that leaching with water alone will accomplish reclamation where drainage occurs at a sufficiently rapid rate, there remains the question of how to accomplish the leaching. Ponding water on the land, as was done in initial experiments, may not be entirely feasible for field application in many cases, since extensive change in the physical land conditions is necessary. The changes would include land leveling and field reorientation.

Many farmers ask the question, "How can I best do this leaching on my farm?"

In 1957 an investigation was initiated to translate results from leaching plots into usable field scale investigations. In the plot study it was concluded that saline-sodium soils of the Billings series, as found in the Grand Junction area, may be satisfactorily reclaimed by leaching the profile with 6 feet of water.

The objective of the new study is to determine by field scale trials acceptable methods of applying and passing 6 feet leaching water through the soil profile.

The following methods of water application will be compared:

1) Level borders
2) Level furrows (20" spacing)
3) Level furrows (30" spacing)
4) Graded border (0.3% slope)
5) Graded furrows (0.3% slope, 20" spacing)
6) Graded furrows (0.3% slope, 30" spacing)

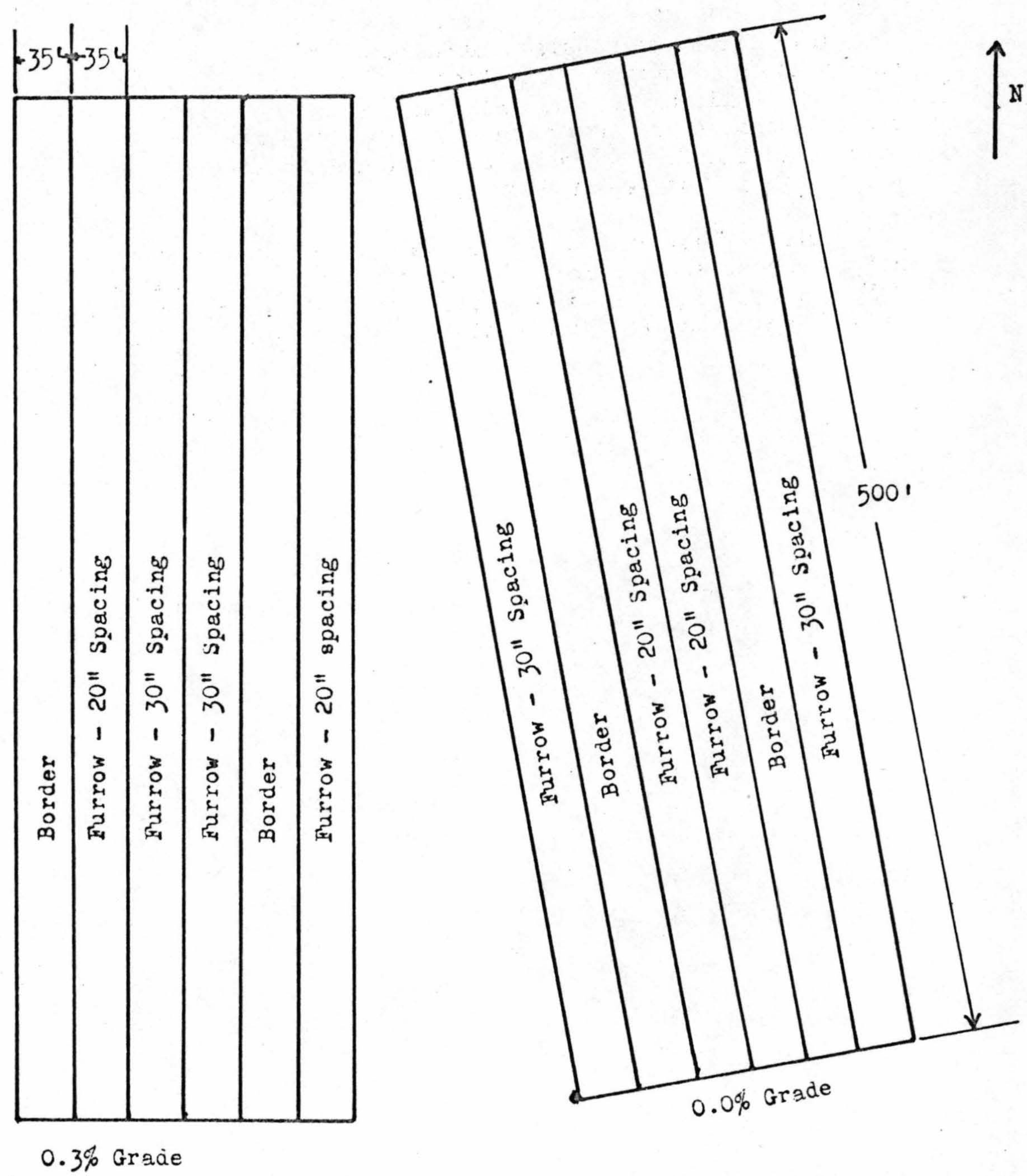
Each of the above "treatments" will be duplicated and established on plots 25'x500', as indicated in Figure 8.

Since it is known that alternate wetting and drying results in quicker application of a large volume of water, the leaching treatments will be cycled. Each plot will be

Fig. 8. SCHEMATIC DIAGRAM OF FIELD SCALE LEACHING PLOTS

Experiment GJ-9

Bireley Place - 1957



irrigated according to its infiltration capacity.

A typical cycle will be as follows:

Irrigation until the infiltration rate declines to a given rate (to be determined during irrigation.) Then the irrigation will be interrupted to allow a period of time for drying. This length of time is flexible and will be established by inspection. Generally, it will last until the surface soil appears cracked sufficiently to permit a high infiltration rate.

This procedure requires measurement of infiltration rate constantly during irrigation. This will be done by means of small Parshall flumes equipped with stage recorders. Instantaneous inflow and outflow rates will be used to calculate infiltration rate. Evaporation will be subtracted from measured infiltration.

Total soluble salts will be determined in each plot before and after leaching. Based on salt removal from the soil, the various methods of water application will be classified as to effectiveness.

SOIL AND CROP MANAGEMENT

In 1953 an experiment titled, "Irrigation, Drainage, and Cropping Studies, including Fertilization of Representative Crop Rotations for the Maintenance of High Crop Yields and Soil Fertility Levels in the Upper Colorado River Basin," was started on the Snyder farm, located 3½ miles northwest of Grand Junction.

Although preliminary studies were made in 1953, it was not until 1954 that the cropping aspects of this experiment were initiated. The 1953 studies were made with particular reference to fluctuations in the ground water table. The experimental area had been a pasture having a water table ranging from ½ to 2 feet below the surface during the growing season, apparently due to excessive applications of water. Water table measurements made in 1953 and subsequent years indicate that with the drainage well in operation, it is possible to maintain the water table at a level satisfactory for crop production, especially when application of excessive irrigation water is avoided.

The experiment was designed to study under controlled moisture conditions, and under four different cropping systems, the effects of the following variables on crop yield, nutrient uptake, and soil physical properties: (a) rate of application of fertilizer, (b) place in a rotation (crop) to apply fertilizer, and (c) handling of crop residues.

The following cropping systems are being studied:

a. 6-year rotation: corn-sugar beets-barley-3 years alfalfa.

b. 3-year rotation: corn-sugar beets-barley

c. Continuous corn.

d. Continuous sugar beets.

Sixteen fertilizer treatments including nitrogen, phosphorus, potash, trace elements, manure, and crop residues at various rates and combinations are under investigation (see Table 1). All fertilizer applications are made in the spring of each year prior to planting. Fertilizer is broadcast and disked into a depth of 5-6 inches.

Table 1. Fertilizer treatments showing rate and time of application by cropping systems and crops. (GJ-4)

Tmt. No.	CROPPING SYSTEM: Six Year Rotation[1/]			Three Year Rotation			Continuous			Tmt. No.
	Corn	Beets	Barley	Corn	Beets	Barley	Corn	Beets 1954-6	Beets 1957-	
1	0	0	0	0	0	0	N	0	2M	1
2	P	P	4P	P	P	P	N+Rs	$\frac{1}{2}$P	2P	2
3	P	NP	4P	P	NP	P	P	P	P	3
4	P	2NP	4P	P	2NP	P	P+Rs	$\frac{1}{2}$N	NPKT	4
5	NP	P	4P	NP	P	P	$\frac{1}{2}$NP	$\frac{1}{2}$N$\frac{1}{2}$P	2NP	5
6	NP	NP	4P	NP	NP	P	$\frac{1}{2}$NP+Rs	$\frac{1}{2}$NP	$\frac{1}{2}$NP	6
7	NP+Rs	NP+Rs	4P	NP+Rs	NP+Rs	P	NP	N	$\frac{1}{2}$N2P	7
8	NP	2NP	4P	NP	2NP	P	NP+Rs	N$\frac{1}{2}$P	N2P	8
9	2NP	P	4P	2NP	P	P	2NP	NP	NP	9
10	2NP	NP	4P	2NP	NP	P	2NP+Rs	NPK	NPK	10
11	2N	N	6P	2N	N	6P[2/]	4NP	NP2K	NP2K	11
12	2N	N	0	2N	N	0	4NP+Rs	M	M	12
13	2NP	2NP	4P	2NP	2NP	P	M	---	2N2P	13
14	2NP+Rs	2NP+Rs	4P	2NP+Rs	2NP+Rs	P	M+Rs	---	2N2PK	14
15	M	M	4P	M	M	P	NPK	---	2N2P2K	15
16	NPK	NPK	4P	NPK	NPK	P	NPK+Rs	---	2N2P2KT	16

1/ Six year rotation consisting of corn, beets, barley, 3 yrs. alfalfa
2/ 6P rate to be applied once every six years.

LEGEND:

0 = No treatment

$\frac{1}{2}$N = 50 lbs. Nitrogen per acre)
N = 100 lbs. Nitrogen per acre)
2N = 200 lbs. Nitrogen per acre)
4N = 400 lbs. Nitrogen per acre) $(NH_4)_2SO_4$

$\frac{1}{2}$P = $37\frac{1}{2}$ lbs. P_2O_5 per acre)
P = 75 lbs. P_2O_5 per acre)
2P = 150 lbs. P_2O_5 per acre) Treble Superphosphate
4P = 300 lbs. P_2O_5 per acre)
6P = 450 lbs. P_2O_5 per acre)

M = Manure: Based on its nitrogen content, a sufficient quantity will be used so that the amount of nitrogen applied will be equal to the N rate (100# per acre); to be fortified with treble superphosphate to bring its P_2O_5 level equivalent to the P rate (75# P_2O_5 per acre).

2M = Manure, applied at two times the M rate.

K = K_2O: Rate equivalent to K_2O content of manure (M) used.
2K = K_2O: Applied at two times the K rate.

T = Trace element mixture: 10# Fe per acre (chelate); 10 lbs. Mn per acre (manganese sulfate); 10# Zn per acre (zinc sulfate); 5 lbs. B per acre (Sodium tetraborate).

Rs = All residue to be turned under.

The experiment is replicated three times. Each replication consists of eleven main crop plots (60'x160') to accommodate each crop in the 6 and 3 year rotations, as well as the continuous corn and sugar beet cropping systems. These crops are randomized within each replication. Randomization of crop plots and crop sequence by plots and years are given in Figure 9. Each crop plot is subdivided into sixteen subplots (15'x40') upon which the several fertilizer and residue management treatments are randomized.

All crops are surface irrigated by furrow or corrugation methods. Water is delivered to each plot by means of a portable gated-pipe system. Time of irrigation is based on periodic soil sampling as well as observed crop need.

Crop yields are being recorded, and information relative to the nutritional status of the several crops as affected by cropping system, soil fertility and cultural treatments are being obtained by means of plant analysis. Changes in the physical condition of the soil as a result of the various treatments are being measured through analysis of soil samples obtained periodically.

Fluctuations in the water table are being determined by means of piezometers installed in the experimental field as well as in adjacent areas.

Experimental Results and Observations

Crop data for the 1955 and 1956 growing seasons are summarized in Figures 10, 11, 12, 13, 14 and 15. Values shown in these figures are two year averages.

Rotation Corn. Alfalfa in a rotation was beneficial to corn production. (Fig. 10). Corn following alfalfa yielded approximately 121 bushels of shelled grain (15.5% moisture) and 7.3 tons of total dry matter per acre, while corn following barley yielded approximately 100 bushels of shelled corn and 5.9 tons of total dry matter.

Responses to fertilization with nitrogen and phosphorus were obtained. On corn following alfalfa the benefits of nitrogen were apparent only when 200 pounds of nitrogen per acre were applied. On corn following barley, there was a significant response to an application of 100 pounds of nitrogen per acre indicating that alfalfa was contributing to the nitrogen economy of the soil. This was substantiated by plant analysis which showed a higher uptake of nitrogen in corn following alfalfa than in corn following barley.

WEST

	REPLICATION III							REPLICATION II						REPLICATION I						
CROP	A	L	F	D	B	H		K	C	B	A	G		L	C	D	J			
Plot No.	33	32	31	30	29	28		27	26	25	24	23		22	21	20	19			
CROP	C	J	E	G	K		J	F	H	E	D	L		B	G	F	K	E	A	H
Plot No.	18	17	16	15	14		13	12	11	10	9	8		7	6	5	4	3	2	1

Alley 5'

30'

160'

EAST

60'

YEAR	CROP PLOT										
	A	B	C	D	E	F	G	H	J	K	L
1954	CORN	BEETS	BARLEY	CORN	BEETS	BARLEY	ALF-1	ALF-2	ALF-3	CORN	BEETS
1955	BEETS	BARLEY	CORN	BEETS	BARLEY	ALF-1	ALF-2	ALF-3	CORN	CORN	BEETS
1956	BARLEY	CORN	BEETS	BARLEY	ALF-1	ALF-2	ALF-3	CORN	BEETS	CORN	BEETS
1957	CORN	BEETS	BARLEY	ALF-1	ALF-2	ALF-3	CORN	BEETS	BARLEY	CORN	BEETS
1958	BEETS	BARLEY	CORN	ALF-2	ALF-3	CORN	BEETS	BARLEY	ALF-1	CORN	BEETS
1959	BARLEY	CORN	BEETS	ALF-3	CORN	BEETS	BARLEY	ALF-1	ALF-2	CORN	BEETS
Crop Seq.	THREE YEAR ROTATION			SIX YEAR ROTATION						CONTINUOUS	

Figure 9. Schematic diagram of field layout -- Crop plot randomization and crop sequence by plots and years. (GJ-4)

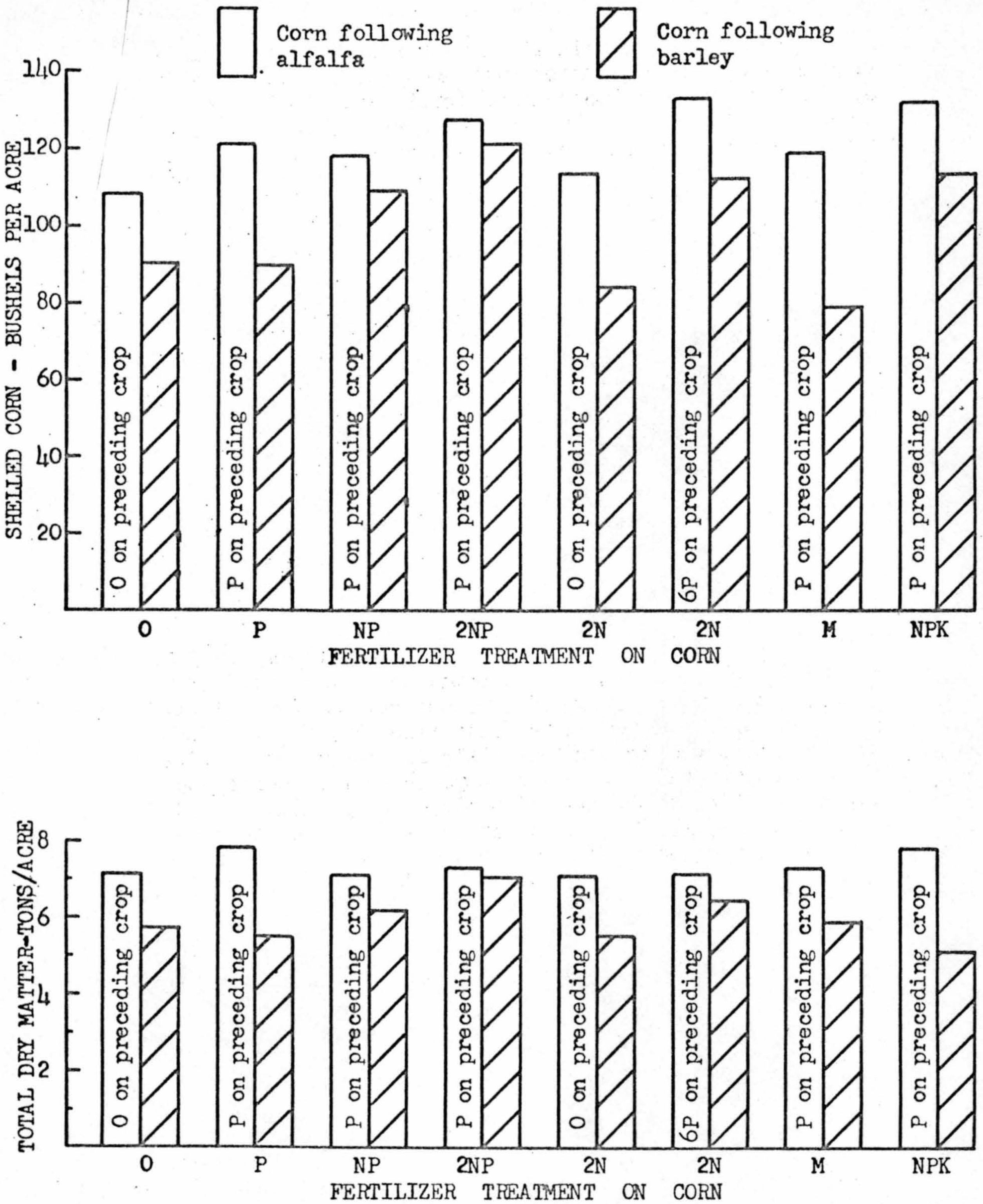


Figure 10 . Yield of grain and total dry matter of rotation corn as influenced by fertilization and crop sequence, 1955-56, Grand Junction, Colorado. (Key: O=No treatment; N = 100# N/acre; 2N = 200# N/acre; P = 75# P_2O_5/acre; 6P = 450# P_2O_5/acre; M = Manure; K = Potash)

Responses to fertilization with nitrogen were greater when applied in conjunction with phosphorus. There was an apparent response to phosphorus fertilization alone by corn following alfalfa, but not on corn following barley. There were indications that a response to potash fertilization was being obtained. Plant analysis showed that this response was related to increased uptake to nitrogen. There was no response to manure, compared with commercial fertilizer, applied at equivalent rates of N, P, and K.

Continuous corn. Average yields for a second and third year continuous corn were approximately 92 bushels of shelled grain (15.5% moisture) and 5.4 tons of total dry matter (Table 11). With 75 pounds P_2O_5 per acre, grain yields were increased approximately 20 bushels by the addition of nitrogen at rates up to 200 pounds of N per acre. Yields of total dry matter were increased approximately 1.5 tons by nitrogen at rates up to 100 pounds per acre. Although potash fertilization did not result in yield response, plant analysis indicates that K apparently increased the uptake of N. It appears that under continuous cropping to corn, factors other than those of soil fertility were limiting the growth of corn.

Rotation Sugar Beets. Significant increases in yield of beets, sugar and tops, were obtained as a result of fertilization with phosphorus, either current or residual, at all levels of nitrogen fertilization (Fig. 12). Non-treated plots yielded approximately 14 tons of beets, 2.2 tons of sugar, and 1.3 tons of tops per acre. Corresponding values for the phosphated plots were in excess of 20 tons of beets, 2.9 tons of sugar and 1.6 tons of tops. Responses to nitrogen, both current and residual, were obtained. There were trends towards a decreased sugar content of beets as a result of high rates of fertilization with nitrogen. Potash fertilization depressed yields of tops but increased the sugar content of beets when compared with N and P treatments. Increases in sugar content were associated with decreases in nitrogen uptake as indicated by petiole analysis. Manure, compared with commercial fertilizer at equivalent N, P, and K rates, had a depressing effect on yields of beets, sugar and tops, but it caused a slight increase in the sugar content of beets.

Continuous beets. Average yields ranged from approximately 6 tons of roots, 1 ton of sugar, and 0.8 tons of tops per acre on the unfertilized plots to almost 17 tons of

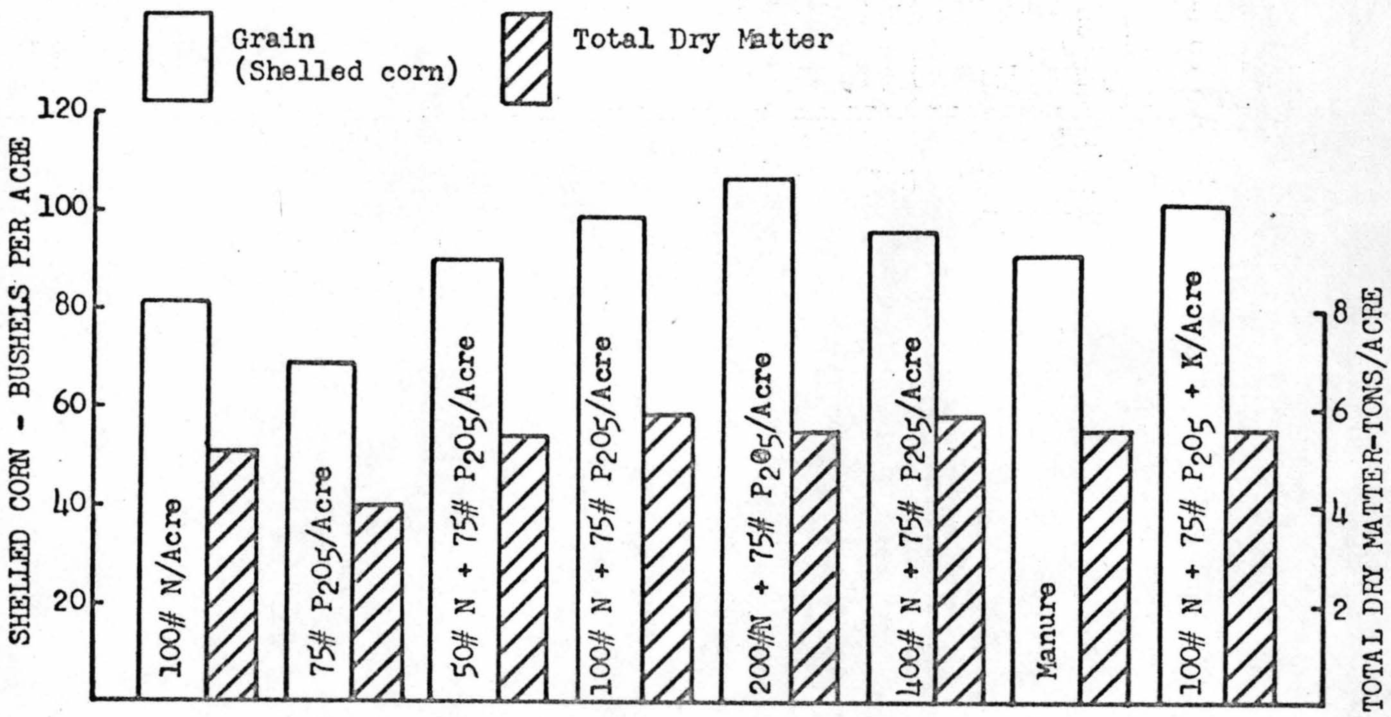


Figure 11 . Yield of grain and total dry matter of corn following corn as influenced by fertilization, 1955-56, Grand Junction, Colorado

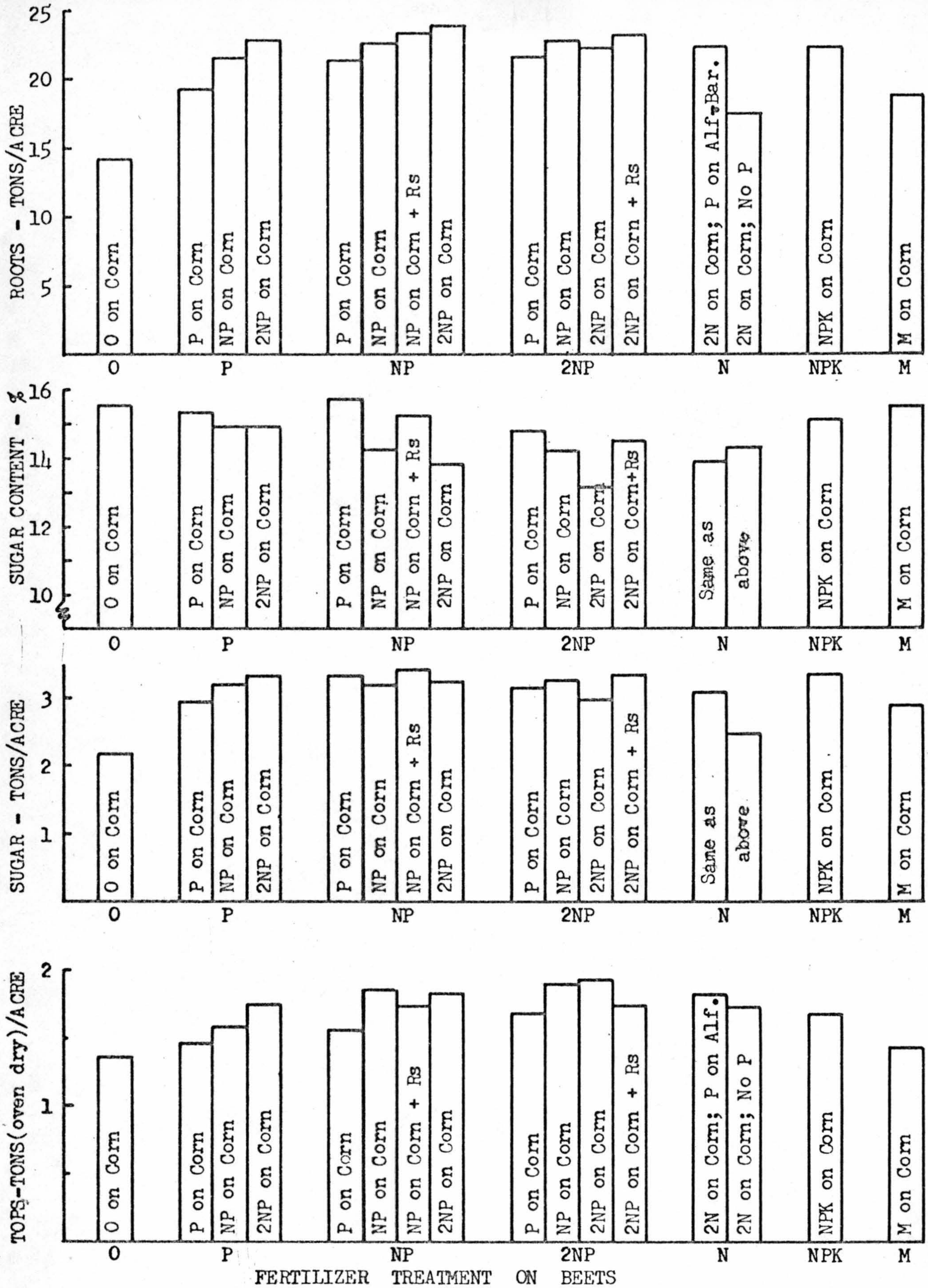


Figure 12 . Yield of roots, sugar content, yield of sugar and yield of tops of sugar beets in a rotation as influenced by fertilization, 1955-56, Grand Junction, Colorado. (Key: O = No treatment; N = 100# N/acre; 2N = 200# N/acre; P = 75# P_2O_5/acre; M = Manure; K = Potash)

roots, 2.5 tons of sugar and 1.5 tons of tops on plots fertilized with 100 pounds of N and 75 pounds of P_2O_5 (Fig. 13).

As was the case with the rotation beets, a highly significant increase in yields of roots, sugar and tops were obtained as a result of fertilization with phosphorus. Application of treble-superphosphate at the rate of 37 pounds of P_2O_5 per acre resulted in an 80% increase in root yields (from 6 to 11 tons). Sugar yields were at least doubled and top yields were increased about 1/3 by this treatment. Responses to nitrogen, however, were apparent only when used in combination with 75 pounds of P_2O_5 per acre. Potash and manure had an apparent depressing effect on yield of roots, sugar and tops.

The sugar content of beets was decreased at the higher levels of fertilizer application. With 75 pounds of P_2O_5 there were successive decreases in sugar content with increasing rate of nitrogen used. Both potash and manure resulted in lower sugar percentages. Petiole analysis indicated a negative correlation between nitrogen uptake and sugar content.

During the past several seasons, the continuous beet plots experienced a very serious weed infestation. Beet plants, especially on the low fertility treatments, were slow in making early growth, and the weeds took over the plots. With the thought that a higher fertility level would promote more rapid, early growth of beets, the fertilizer treatments were revised in 1957, as indicated in the treatment schedule, Table 1. In addition to higher levels of N (200#/acre) and P_2O_5 (150#/acre), a trace element mixture consisting of iron, zinc, manganese and boron is now being applied.

<u>Barley</u>. Grain and straw yields of barley were significantly increased by fertilization with phosphorus (Fig. 14). Barley fertilized with phosphorus yielded approximately 4000 pounds of grain and 4300 pounds of straw as compared to 2600 pounds of grain and 3000 pounds of straw obtained from the non-phosphated plots. Only at low fertility levels were any yield differences obtained between methods of seeding. Yield responses to the residual effects of nitrogen applied to beets in the preceding years were apparent.

<u>Alfalfa</u>. Application of 300 pounds of P_2O_5 per acre

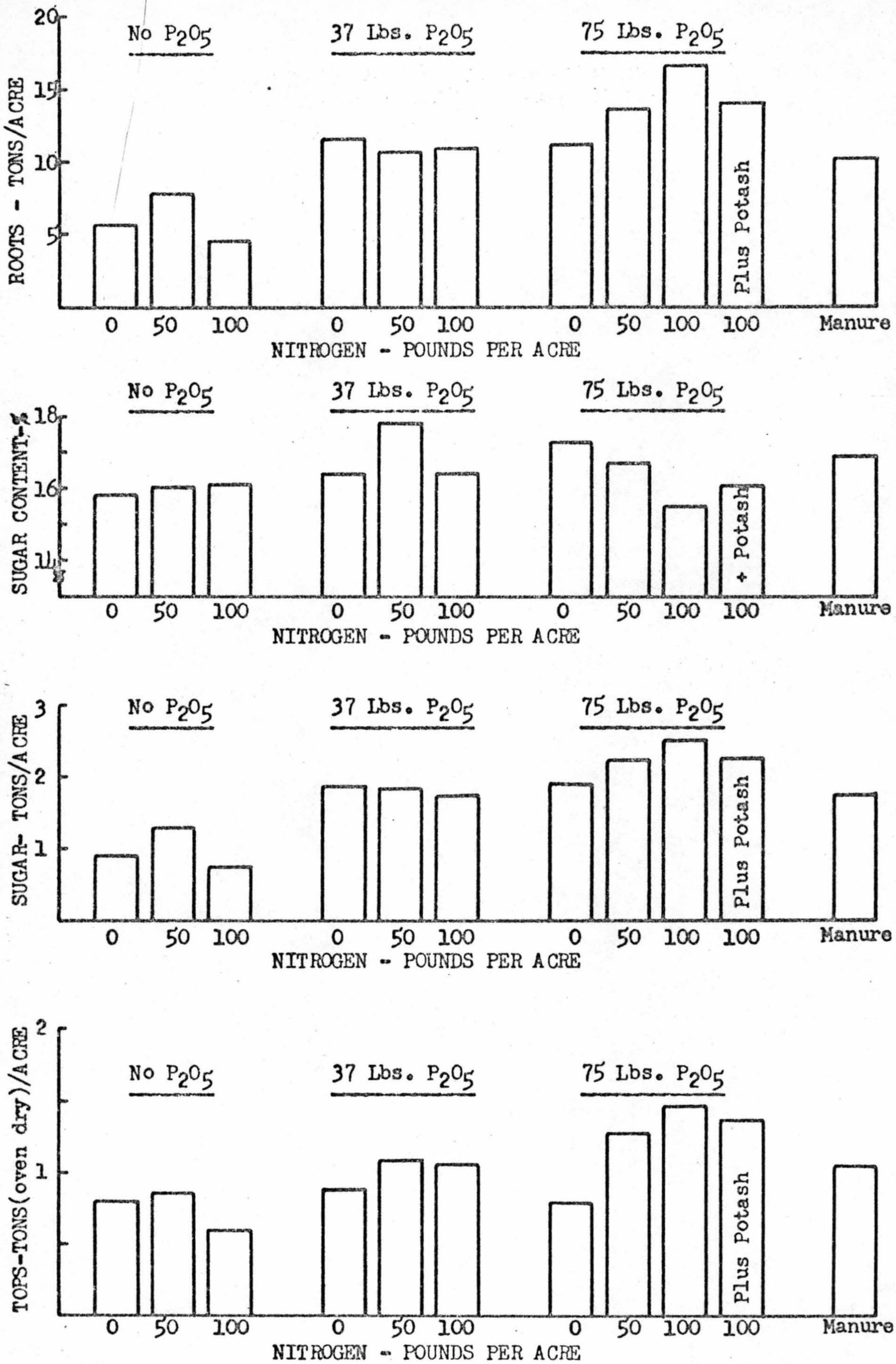


Figure 13 . Yield of roots, sugar content, yield of sugar and yield of tops of continuous sugar beets as influenced by fertilization, 1955-56, Grand Junction, Colorado

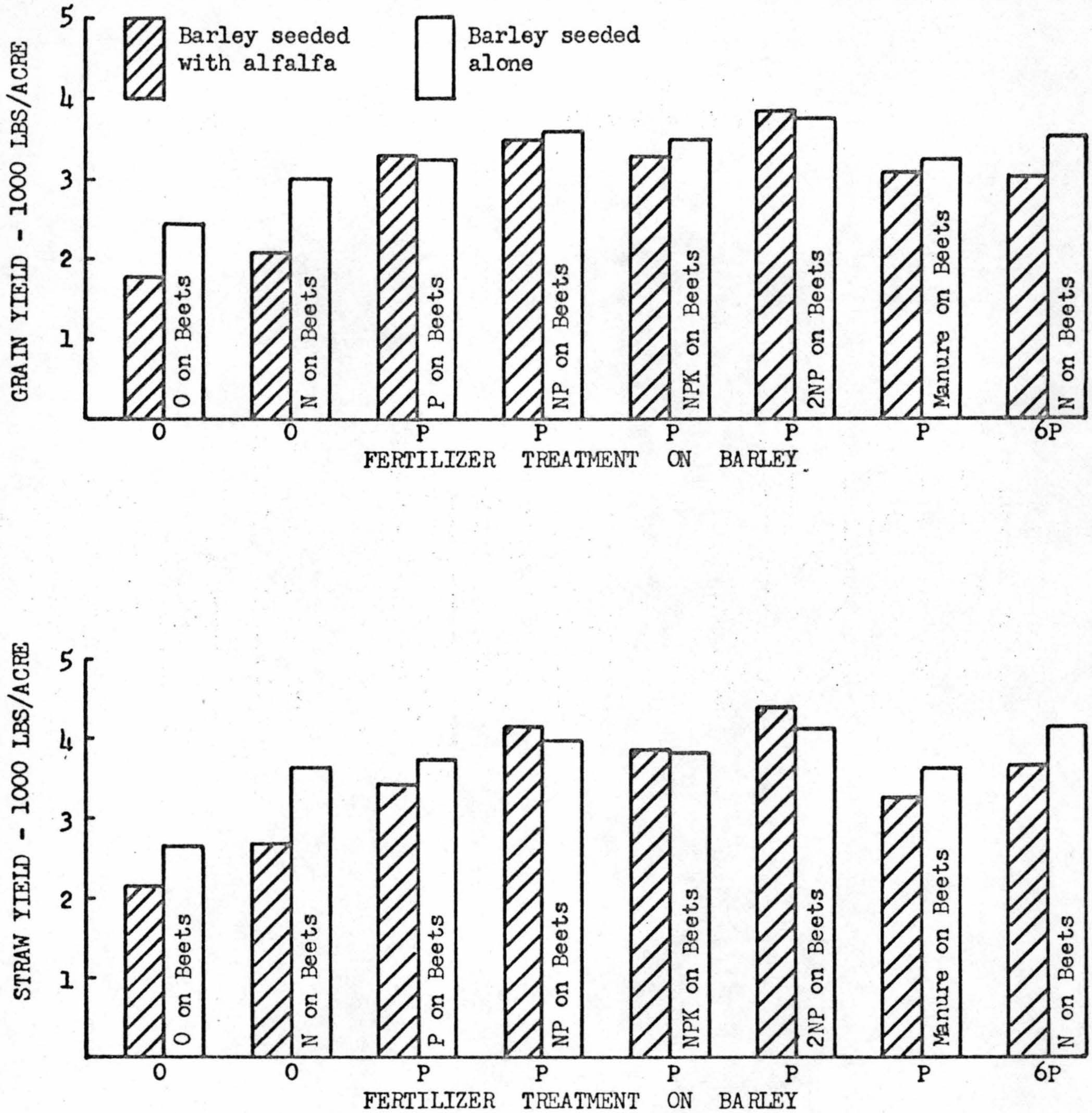


Figure 14 . Yield of grain and straw of barley as influenced by fertilization and method of seeding, 1955-56, Grand Junction, Colorado. (Key: O = No treatment; N = 100# N/acre; 2N = 200# N/acre; P = 75# P_2O_5/acre; 6P = 450# P_2O_5/acre; K = Potash)

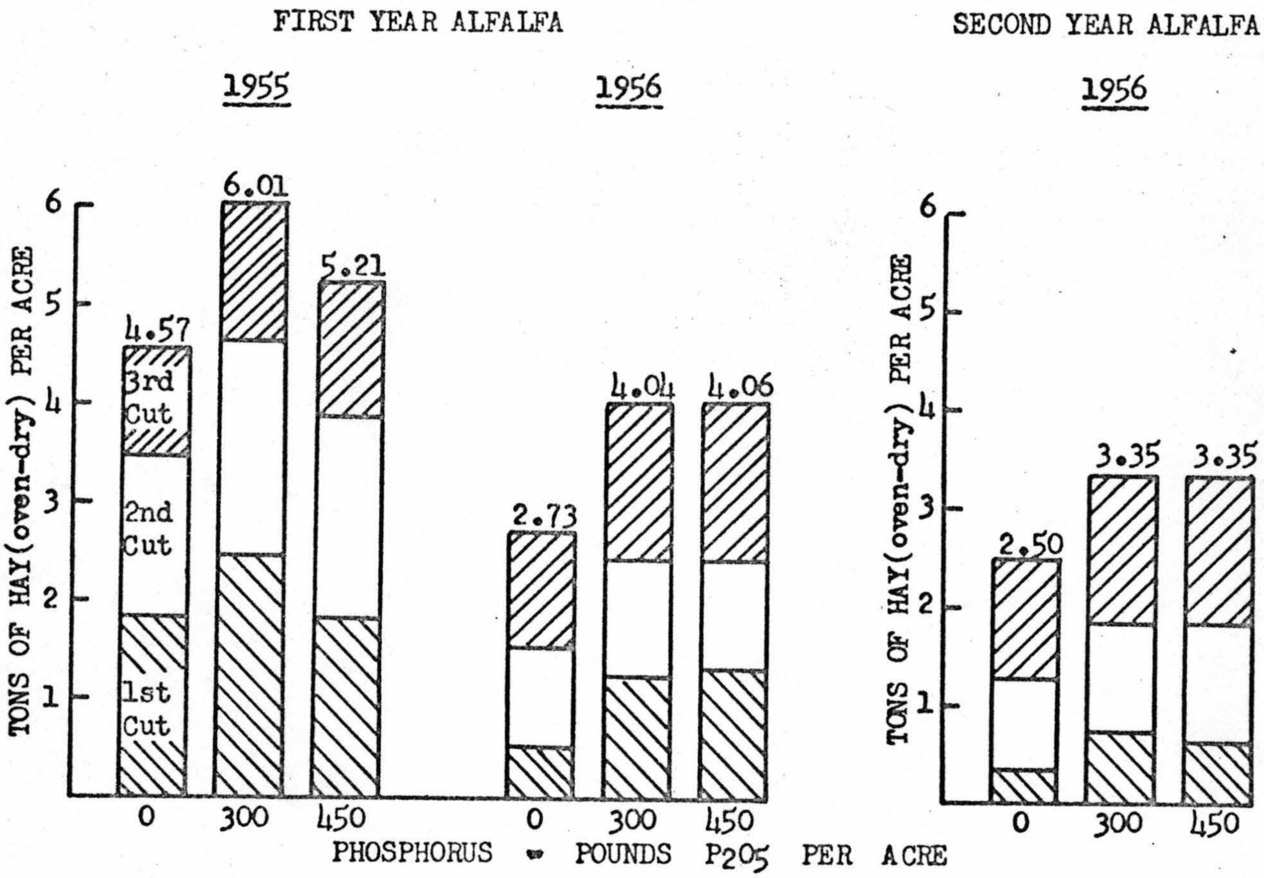


Figure 15 . Yield of first and second year alfalfa as influenced by phosphorus fertilization, 1955-56, Grand Junction, Colorado.

at the time of seeding increased the yield of first and second year hay by at least 30% (Fig. 15). Moreover the average phosphorus content of phosphorus treated alfalfa was in excess of 0.25% as compared with 0.190% in the untreated hay. Phosphorus fertilization had no effect on the nitrogen content of the hay.

Soil Studies. The effects of different cropping systems and fertilizer treatments have been apparent, not only with reference to crop response, but also in terms of soil structural indices.

Alfalfa was found to decrease the stability of soil aggregates when they are wet and increase the ability of the soil to crust until it is plowed under. The aggregate stability of soil in plots in which alfalfa had been plowed under four weeks prior to sampling was almost three times that in those plots still producing alfalfa. Results on plots in which alfalfa was plowed under in 1955, indicate that this structure was still present nine months later.

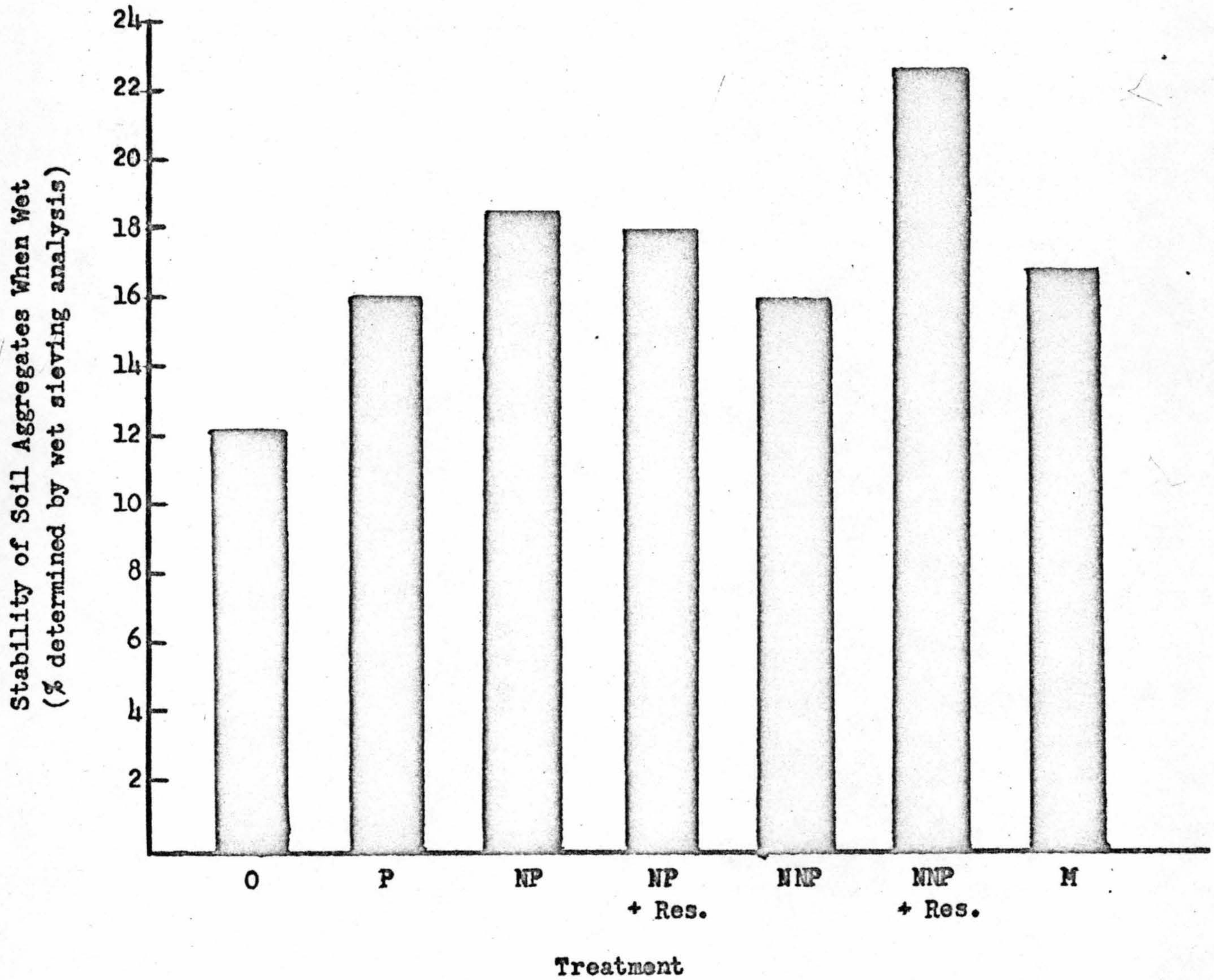
Trends showing increased structure as a result of fertilizer and organic residue treatments are appearing after two cropping years. Figure 16 shows a measure of the stability of the soil aggregates against slaking in water for seven of the fertilizer and fertilizer-plus-residue treatments. Differences between all of these treatments are not statistically significant. The difference between no fertilizer and the average of the other fertilizer treatments is significant, however.

The manure and residue treatments were expected to build soil structure, but the nitrogen and phosphorus treatments were also effective in accomplishing this purpose. Laboratory tests showed that these elements do not act to stabilize the soil themselves.

Therefore, the conclusion has been reached that these elements build structure by increasing root and top growth of plants, which provides more readily decomposable organic material from which structure building organic compounds are formed. This points out another of the long-term benefits of good fertility practices.

Figure 16. Effect of Fertilizer, Residue, and Manure Treatments on Soil Structure.

(Stability of Aggregates When Wet)



Legend:

N = 100 lbs. Nitrogen/Acre
P = 75 lbs. P_2O_5/Acre (Treble Superphosphate)
Res. = All crop residue turned under
M = Manure equivalent to 100 lbs. Nitrogen/Acre and fortified to bring its P_2O_5 level to 75 lbs./Acre

Discussion

During the first three years of this experiment, it has become apparent that the different crop sequences and fertilizer and cultural treatments are affecting the yield of the several crops under investigation. One of the primary objectives of this study is to determine why these responses exist.

Crop yields represent an integration of the various factors contributing to plant growth. Through plant tissue analysis, it is possible to gain a better understanding of the relative uptake of N, P, and K by plants as affected by different treatments.

Investigations of soil physical properties will lead to solutions to problems dealing with soil-air-water relationship. The efficiency of moisture utilization is another important aspect of crop growth that will be pursued during the 1957 season.

This investigation, is by design, a long term study. It will require at least another year or two before definite conclusions can be drawn with respect to the objectives of the experiment.

COST STUDY OF PUMP DRAINAGE EXPERIMENT[1/]

I. F. Davis and R. H. Mason[2/]

Engineers have demonstrated the physical feasibility of a pumping operation to effectively lower the water table in a highly saline affected area. It was not known whether such a pump system could be operated on a sound financial basis.

Economists undertook to compare the value of the added returns from pumping against the cost of such a system. The economic findings should be of interest to all farmers in the area who face problems of high water table, severe salinity and poor drainage.

Tests of pump drawdown have shown that the experimental pump has drained effectively 185 acres of crop land. To be conservative, the economists chose to use a net of 160 acres upon which to base increased productivity estimates.

The value of pump drainage has been estimated on the basis of probable yield increases in corn, barley and sugar beets attributable solely to pumping. Current market prices have been used for budget estimates. Costs involved in obtaining the added production include pump operating expenses, depreciation, interest and taxes. On the basis of these estimates the annual net income on 160 acres of crop land directly attributable to the pump amounts to nearly $800.

Summary of Annual Operating Budget Based on Experimental Pump Data

Gross income attributable to Pumping		
Income from increased yields*		
Corn	$1155.00	
Barley	311.00	
Sugar Beets	546.00	
Gross annual income		$2012.00
Annual Expense of Pumping		
Operating expenses		
Electric power for 4800-hour season @ 8.95 cents per hour	$ 430.00	
Repairs	40.00	
Labor (1 hr. per day @ $1.50 per hour for 200 days)	300.00	
Total operating expense		$ 770.00

1/ Findings are based on the study at the experimental area near Grand Junction. Figures might vary at other locations where different conditions may exist.

2/ Assistant Economist and Research Assistant in Economics, Colorado State University Agricultural Experiment Station.

Depreciation Expense		
Depreciation on well ammortized over a 20 year period	$ 135.00	
Depreciation on pump ammortized over a 10 year period	126.00	
Total depreciation expense		$ 261.00

Interest and Taxes		
Interest on investment @ 5%	$ 100.00	
Taxes @ 35 mils	84.00	
Total interest and taxes		$ 184.00
Grand Total of All Expenses		$1215.00

Profit and Loss Statement

Gross Income	$2012.00
Less total costs	- 1215.00
Net Income	$ 797.00

The initial capital investment in the experimental pump, well and installation amounted to $3963 as follows:

Well materials	$1398.00
Well construction	1300.00
Pump	765.00
Electric power installation	500.00
	$3963.00

It is assumed that the initial cost of reclamation necessary to bring the yields of the area up to those of the experimental plots would be reflected in the added value of the property. It is assumed that 2 years would be required to carry out the initial reclamation program. After this, it is estimated that the permanent increase in returns would be the difference between average yields in the general area and those obtained in the experimental plots using current market prices. The increase in returns is the basis for computing the gross income attributable to the pumping system.

*Alfalfa is omitted since no significant increase in yield was obtained. Acreage used for crops is proportionate to that in the general area. A six year rotation is used in these calculations: ½ alfalfa, 1/6 corn, 1/6 barley and 1/6 sugar beets.

The operating return to the investment in the pump, well and installation after the initial reclamation is computed, is estimated to be 20 percent (\$797/3963 = 20 percent). Within limits, the use of a large scale pumping operation for drainage purposes would prove financially sound based upon existing experimental evidence.

There are possibilities for improving the adaptation of pumping systems for drainage purposes: (1) pumps now are on the market which are superior to the experimental installation, (2) well construction might be improved so as to reduce installation costs, and (3) knowledge gained from the pumping experiment should make possible more efficient future pumping operations.