T H E S I S

FIELD SEEDING VERSUS TRANSPLANTING OF TOMATOES

Submitted by
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In partial fulfillment of the requirements
for the Degree of Master of Science
Colorado
Agricultural and Mechanical College
Fort Collins, Colorado

May, 1952

COLORADO AGRICULTURAL AND MECHANICAL COLLEGE

May 23 1952

WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY JAMES A. URANO

ENTITLED FIELD SEEDING VERSUS TRANSPLANTING OF TOMATOES

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ACKNOWLEDGMENT

The author wishes to express his appreciation to Professor A. M. Binkley, Head of Horticulture Department, and A. C. Ferguson, Associate Professor, Horticulture Department, for their valuable assistance in bringing this work to completion.

He also wishes to thank Dr. W. D. Thomas, Professor, Botany and Plant Pathology, and Mr. L. B. Daniels, Head of Entomology Department, for constructive criticisims on the problems conducted.

Many thanks to my wife, Mable, for the encouragement and the many personal sacrifices given up during the years I spent in college.

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Chapter I

INTRODUCTION

The tomato (Lycopersicum esculentum) ranks third in importance as a major vegetable crop in the United States and is one of the important agricultural crops in Colorado.

According to Colorado Crops and Livestock Reporting Service (17) December, 1951, tomatoes were grown on 4,500 acres in 1950, of which 1,500 acres were harvested for fresh market and 3,000 acres for canning. The total crop was valued at $1,160,000 in 1948 and $476,000 in 1939. Colorado's average yield over the ten-year period from 1939 to 1948 was 6.9 tons per acre as compared to 9.2 tons per acre in Utah. The United States average for the same period was 5.4 tons per acre. The price per ton for the commercial crop in Colorado in 1949 was $21.70 and $20.90 a ton in 1950, as compared to a high for the United States of $30.00 per ton paid in Delaware. The United States average was $23.51 per ton. The Colorado market crop value per bushel was $1.60 in 1949, and $1.75 in 1950, with a ten-year average of $1.30 per bushel.

Ninety-four per cent of the processing tomatoes in Colorado are grown in Adams, Weld, Crowley, Otero, Delta and Mesa Counties. Eighty-four per cent of the market tomatoes in Colorado are grown in Adams, Weld, Crowley, Otero, Delta, Mesa and Pueblo Counties. Each of these counties harvested more than 250 acres in 1949. The three counties in Colorado with the largest acreage are Mesa County with 1,050 acres, Otero County with 880 acres, and Weld County with 830 acres. These three counties on the average produce 60 per cent of the Colorado tomato crop. Each of the counties listed above are in different sections of the state, Mesa County on the Western Slope, Otero County in the Arkansas Valley in southeastern Colorado and Weld County in the northeastern section of the state.

These statistics indicate the economic importance of the tomato crop in the irrigated areas of Colorado. Growers and processors are faced with increased labor costs and decreased yields per acre. Tomatoes cannot be harvested mechanically at present, therefore, the cost of the most expensive single item in production cannot be reduced. The use of mechanical handling methods with certain other competitive cash crops may result in growers changing to these crops, since they offer possibilities of greater net returns.

One of the factors which has made the production of canning tomatoes in northern Colorado a marginal crop in some years is the short cool growing season. Growers must adapt their cultural practices to meet the climatic conditions under which the crop is grown. Some of the conditions which limit tomato production are: (1) the difficulty in establishing plants in the field due to variability in the quality of plants, (2) diseases and insects carried by the plants, (3) improper handling of plants in shipment, and (4) field labor problems.

Processors and growers are anxious to find ways and means of producing higher yields, higher quality fruit, with a higher net return per acre by any improved cultural practice. Field seeding is being used successfully in certain parts of the state, where length of growing season and soil types are favorable to the practice.

In most parts of Colorado, field seeding has not been attempted because of the short growing season. If, by field seeding, tomato production costs can be reduced and yield and quality are equal to or better than the crop grown by the field transplanting methods, then the practice should be used.

Some of the transplanting problems which have been voiced by growers and processors are as follows;

1. Variability in quality of plants from various sources.

2. Virus disease content in plants.

3. The presence of insects on plants at transplanting time.

4. Locally grown plants are produced under crowded conditions resulting in soft, tall and spindly plants with poorly developed root systems.

5. Unsatisfactory handling and shipping of the plants which are imported from other states.

6. High mortality rate of plants when set out in the fields.

7. Improper cultural practices such as seeding and pruning which result in the delaying of maturity, and cause the peak of production to be too near the first killing frost in the fall.

8. High cost of labor and labor shortage.

After considering the many cultural practices which affect the economic production of tomatoes it was believed that methods of growing plants might be improved and that direct seeding offered possibilities of reducing costs as well as improving yields and quality of the tomato crop.

Chapter II

REVIEW OF LITERATURE

Field seeding

Direct seeding is slowly becoming a new cultural practice in the tomato industry; this is especially true in the midwest, far west, and some eastern areas of the United States. However, only a limited amount of literature has been published about the comparative performance of field seeded and transplanted tomatoes.

Evidence of the practicability of field seeding was noted by Fraser (10) in 1943. Fraser listed some of the advantages of field seeding as: (a) generally lower cost per acre to produce, (b) less trouble with diseases, (c) deeper taproot systems, and (d) generally a better stand throughout the field.

Decker and Amstein (9) stated that a selected variety may be seeded three to four seeds per hill and later thinned to a single plant. As a general rule direct seeded plants were late producers, but indications were that such plants produced stronger and deeper root systems than transplanted plants of the same variety and, therefore, would be able to withstand adverse conditions. Should transplants encounter adverse conditions before becoming established, their development and production was delayed so that direct seeded plants produced fruit as soon as the transplanted plants of the same variety.

Huelsen (13) stated that in Ohio and Illinois, in 1938, there was a widespread interest in growing tomatoes directly seeded in the field. There was considerable acreage that was directly seeded and growers were well satisfied with the results. The general practice consisted of sowing the seed in the field in rows four to five feet apart with a group of four hand-seeders. The seed was sown at a rate of about 20 ounces per acre as soon after April 15 as was possible. The plants were allowed to grow until they were four to six inches high, at which time they were cross-cultivated. Hand thinning was required wherever more than one plant remained. Plants grown by direct seeding appeared to have more tolerance to frost than transplanted plants. Reports showed that a heavy May frost in Ohio and Illinois killed the transplanted tomatoes, but injured none of the direct seeded plants.

Haber (11) and Bushnell (7) both found that the yield of direct seeded tomatoes was almost equal to or larger than that of the transplants. But Haber (11), in summarizing his second year's work on "direct seeding versus Southern grown plants", stated that all direct seeded tomato plants yielded significantly less tomatoes than Southern grown plants. The later the seeding date, the smaller was the yield. His results in 1940 were not consistent with those of 1939. Direct seeding in 1939 with a single variety, was equal to Southern grown plants; whereas, in 1940 none of the seedings of the same variety, irrespective of planting date, produced as much as the Southern grown plants. It was stated that weather conditions were quite variable between the two years. From these results Haber (11) concluded that the canners should not expect any more consistent yields by direct seeding, year after year, than by the use of Southern grown plants if the latter were well grown and fairly disease free.

Brasher (3) in a randomized block experiment with three replications, compared the yielding ability of plants produced from direct seeding and those produced in a greenhouse. The greenhouse grown plants were transplanted to the field on May 7; the direct seeding in the field occurred on April 4. About eight to ten seeds were planted per hill and not until April 20, did plants from this seeding begin to appear above the ground. When the plants were about four inches high, they were thinned to one plant per hill. The plants which were started in the greenhouse gave a significant increase in yield over the field seeded tomatoes. This report was based on one year's work.

Burlingame and Underhill (6) found that field seeding was less costly than transplanting in establishing a field stand of tomatoes. However, they pointed out that other factors such as yields, date of first picking, risk with respect to weather conditions, and other factors had to be considered in weighing the advantages of one method over the other. There was no significant difference in yields between the two methods for the single year's results.

<u>Transplants</u>

There has been much published about the care and growing of transplants in greenhouses, hotbeds, and coldframes, with cultural practices modified to meet growing conditions in different districts.

Binkley (2) reported that in Colorado, transplants were grown either by the grower or by the canning companies which contracted with the growers. Many methods have been followed in growing plants, but they were all essentially alike. The variation has been in the adaptation of certain methods to the area's prevailing climatic conditions. Usually seed was sown in specially prepared seedbeds in greenhouses, hotbeds, and coldframes, eight to 12 weeks in advance of field setting. The time of sowing the tomato seeds largely depended on the time that the plants could be safely set in the field, as determined by the date of the last killing frost. Many growers seeded too far in advance of field setting because they thought that a slow growth was desirable. Research (2), (4), and

(8), indicated that sowing the seed too early and too thick, resulted in plants becoming soft, tall, or woody before they were ready for field setting.

Talbert and Hibbard (19) reported that the planting time for tomatoes varied with the location within a state. According to the United States Weather Bureau, approximately 175 days between the latest and earliest killing frost was the mean for all sections of the country which grew a large acreage of tomatoes. Tomatoes required from 150 to 170 days to mature a crop from seed. This, however, was dependent on the variety being used. The average number of frost free growing days for the Grand Junction area was 189 days; Rocky Ford area, 163 days; and Greeley and Longmont area was 149 days. In the Greeley-Longmont area the 43 year average date of last frost in spring was on May 4 and the first fall frost was on October 3. This period falls short of the 150-170 days required to produce high yields of tomatoes.

Apple (1) stated that when the plants were not to be transplanted before setting in the field, the rows should be at least five to six inches apart and the seed sown thinly so that the plants would be one and one-half to two inches apart in the row. Where it is followed the seeding should be delayed until five to six weeks before the plants would be moved to the field. The author also stated that this method did not give as desirable a plant as did transplanting prior to field setting.

Pollard (15) and his co-workers found that seed sown in shallow flats six to seven weeks before the plants were needed for the field and then transplanted into deep flats or benches or floor beds with three and one-half to five inches of soil, produced better plants. The seedlings were placed one and one-half or two by two inches in the flats.

Loomis (13) showed that tomato plants grown in paper pots gave consistently earlier and larger total yields than plants grown in flats because, in the former instance, roots were disturbed considerably less when the plants were set in the field. It was also demonstrated by Loomis (13) that plants grown from seed sown directly in the pots were just as good as those transplanted once or twice. Raleigh (16) found that it did not matter whether plants were transplanted from pots, from flats, or from the seed bed; it was important that the soil in which the plants were grown contained a good supply of water before they were moved. This assured an adequate amount of water in the plant tissues and caused the soil to adhere to the roots better than would be the case if the soil were dry.

Decker and Amstein (9) stated that sufficient space was required to grow and develop strong plants, and recommended four square inches per plant. These authors, also, found it important to regulate the temperature, soil moisture, and light. A night temperature of 60°F and a day temperature of 70°F was found to be ideal for tomato plant growth. A high moisture content in the soil and air had a tendency to cause a rapid, soft plant growth and was favorable to the development of damping off, a seedling disease. Such plants had to have their growth checked and be somewhat hardened before they were suitable for planting into the field where they were exposed to fluctuating temperatures, winds, and the direct sun.

Brown (4) stated, as early as 1924, that maximum yields were secured from stocky, disease free plants, which were beginning to bloom at the time they were set out in the field. Decker and Amstein (9) in 1943, found that plants were best transplanted before flower buds had set as the shock of transplanting was most injurious to the development of fruit buds and would have prevented a subsequent set of fruit.

Observations made by Watts (20) indicated that the highest yields were usually secured on plants which were vigorous but not too succulent. On plants which were both very vigorous and very succulent, the formation of deformed fruit frequently occurred in high percentages. On non-vigorous plants there was a tendency for the blossoms to drop without forming fruit. When lack of vegetative vigor was extreme, the buds frequently dropped without opening. Burk and Roberts (5) found that the ability of plants to set fruit varied with vegetative vigor. These workers had stated that plants having very thick stems and those having slender stems were less capable of fruit production than those with stems of moderate width in diameter.

Brasher (3) found in his work with yield data that in comparing stem size, the large stem size of five-sixteenths gave significantly earlier and higher total yields. The small stem size of three-sixteenths or less gave the next highest early yield, but was considerably lower in total yield. The medium stem size of three-sixteenths to five-sixteenths gave the lowest early yield and a total yield comparable to the small stem size. A difference of total marketable yield between the small and the large stem sizes amounted to 5.6 tons per acre, with the significance at the five per cent level being 1.87 tons per acre.

Loomis (13) compared, in the greenhouse, the root development of plants after transplanting with those seeded directly. In setting up the experiment, Loomis used as a check, a treatment very comparable to field seeding practices in which the seed was sown directly into the benches and thinned. Other treatments included; transplanting once prior to field setting; transplanting twice prior to field setting; and no transplanting prior to field setting. All treatments were seeded on the same day. Loomis found that the check gave the highest average weight in tops of plants, and that the twice transplanting prior to field setting and transplanting directly to the field, gave the highest weight of roots. In early fruit produced, the treatment of once transplanting prior to field setting gave the highest yield and the highest total yield, but was not significantly different from the check. Both check and transplanting once prior to field setting gave from 1.44 to 2.28 tons per acre increase over treatments of twice transplanting prior to field setting and transplanting directly to the field. Thus, Loomis (13) concluded that transplanting in itself was not beneficial, and that transplanting in very early seedling stages did not injure the plants particularly, but that later transplantings was more injurious.

Weaver and Brunner (31) conducted an experiment in Wisconsin which showed that plants which were not transplanted prior to field setting yielded more than those transplanted once prior to field setting, while those transplanted twice prior to field setting, yielded the least.

According to Decker and Amstein (9) the process of preparing plants for adverse conditions, was spoken of as "hardening off", and was accomplished either by gradually withholding water until growth was checked without seriously wilting the plants, or by gradually reducing the temperature to harden the growth. Pollard (15) stated that plants should be well hardened before being set in the field. They should not have been pulled from the bed, but instead, the soil should have been loosened with a trowel or spade before they are lifted. Pollard recommended that the best time to set the plants out in the field would be when the plants are six to eight inches tall. Binkley (2) reported that any treatment which checked growth, hardened a plant and increased its resistence to cold weather and that plants that were hardy, like cabbage and cauliflower, could be toughened by checking growth prior to field setting. However, tender species of plants like tomatoes could be hardened to such a degree that there would be only a slight difference in resistence to cold between hardened and unhardened plants. Recent research (1), (12), showed that hardening of tomato plants reduced early yields and often made the early fruit rough.

Brasher (3) found that any treatment that lessened the effect of the shock of transplanting and accelerated early plant growth, probably increased yields. Starter solutions were used for this purpose and were prepared by dissolving plant food in water. In experiments conducted by Brasher (3), yield increases resulting from the use of a starter solution ranged up to three tons per acre with an average increase of 0.75 tons per acre.

Because Southern grown plants were usually available to growers at low prices, there was a temptation to use them rather than to buy good plants locally grown or to grow the seeded plants. This of course, in recent years, has been eliminated by the very strict Federal, State, and local inspection of out-going plants. Talbert and Hibbard (19) stated that locally grown plants sold by a reliable producer were much more likely to give good results than the so-called shipped-in Southern plants. Raleigh (16) found that it was generally not profitable to use plants grown in other sections. Such plants were severely hardened or they would not ship well and arrived in a partially rotted condition. If they had been severely hardened, they made slow growth and matured fruit later than do well grown plants produced locally. Another factor considered was that Southern grown plants were often of mixed varieties and may have been affected with serious diseases.

In view of what had been published on the cultural practices in direct seeding of tomatoes and the production of tomato transplants, it was obvious that there were many unsolved problems particularly in the tomato production areas of Colorado.

Chapter III

METHODS AND MATERIAL

This experiment was carried out, in Colorado, in cooperation with the Kuner Empson Company of Brighton, and the Matsushima Brothers of Platteville. The Kuner Empson Company's farm located near Longmont, and the Matsushima Brothers' farm were used for the experimental plots.

Seed

The seed used in this experiment was the "K" Stone variety obtained from the Kuner Empson Company. The major portion of the commercial canning acreage in north-central Colorado was planted to this variety in 1951.

Culture

Plants that were grown in the Colorado A & M College greenhouse were called the A & M grown plants. The seed was sown in flats on April 3, 1951. The flats were three inches deep, 14 inches wide and 18 inches long, and were filled with sterilized sandy loam soil. At planting, two seeds were placed in holes spaced at 1.5 inches by 1.5 inches and at a depth of one-eighth of an inch. Temperatures in the greenhouse were maintained at about 60°F during the nights and 70°F during the days. Two weeks after germination the plants had grown to a height of 1.25 inches. On May 2, the plants were transferred to a coldframe type of bed, as the day and night temperatures inside of the greenhouse were too high for the plants. On May 5, a solution of one teaspoon of ammonium sulfate per gallon of water was applied at a rate of one gallon per flat. The plants were transplanted to the field near Longmont on May 17 when they were six weeks and two days old. Those set out in Platteville on May 22, were seven weeks old, the delay between the two dates was caused by the inclement weather. The average height of the plants when set out was 6.6 inches, and the diameter of the stem at ground level was from one-fourth to five-sixteenths of an inch.

The Nevada plants were grown under field conditions in the State of Nevada for the Kuner Empson Company. The tomatoes were seeded on beds in double rows, eight inches apart with 20 inches between the double rows. This spacing allowed for 17 plants per square foot of space. The plants which were used by the Colorado growers were pulled so that they were available to them by May 15. The plants were graded, and sorted, and inspected by the Nevada State Inspectors before shipment. Lettuce crates which had been previously treated to remove Russet Mites, were used and the bottoms were packed with wet peat moss to keep the bare roots from drying out during shipment. These plants were shipped to the various tomato growing areas in Colorado by railway express and were in transit from three to five days. The Nevada plants averaged 12 inches in height, with an average stem diameter of five-sixteenths of an inch, and had a tendency to be woody.

The Kuner Empson plants were grown in flats, which were 12 inches wide, 30 inches long and four and one-half inches deep, under company supervision at Brighton, Colorado. Seeds were drilled in soil of sandy loam texture, allowing for 2.8 plants per square inch. The seeding was done from February 14 through April 11, to allow the growers a wide range of planting dates. Plants from the later seedings are usually used for resetting purposes in the fields where the first sets have failed to survive. The plants were started in the greenhouse and later removed to the coldframes. The greenhouse temperatures were maintained at 60°F during the nights and 70°F during the day. The average height of plants when set in the field was from eight to ten inches with an average stem diameter of three-sixteenths of an inch. The plants had a marked tendency to be succulent in growth.

Transplants were set out into the field, using a dibble to make the holes into which the plants were inserted by hand. They were spaced at 3.5 feet between rows and 3.5 feet between plants. Resetting was made where necessary in order to obtain as near a perfect stand as possible.

Field seeding

The preparation of the field for seeding was done by the cooperating growers. Four dates of seeding were made, as close to seven-day intervals as the weather would permit. The first seeding was made on April 23 at Platteville and on April 26 at Longmont. Eight, 12, 16, and 20 ounces of seed per acre were the four rates of seeding applied. The seeding was done with a "V" belt single row seeder.

The plants were thinned when they were six inches tall. Four stand counts were made during the growing season, the final count was made at the end of the picking season. The ripe fruit were picked at approximately weekly intervals, the weight in pounds was recorded at each picking.

Greenhouse tests

The greenhouse tests were conducted in a ground bench with an inside measurement of 51 inches in width by 36 feet in length, which contained ten inches of sandy loam soil. The bottom, which had a 22 degree slope to the center where a five-inch drain pipe was located, was filled with coarse gravel.

There were six treatments in this experiment, each randomized and replicated three times. The six treatments used were:

1. Thinned when plants were two inches high.

2. Thinned when plants were four inches high.

3. Thinned when plants were six inches high.

4. Blocked when plants were two inches tall and thinned when five inches high.

5. Kuner Empson method of growing transplants.

6. A & M method of growing transplants.

The transplants grown by the Kuner Empson method were drill seeded on November 13 into flats which allowed 2.8 plants per square inch. Transplants grown under A & M method were seeded on November 13, into flats at a rate of two seeds per 1.5 inch by 1.5 inch spacing. These were thinned to a single plant when the plants were an inch tall and were allowed to grow in the flats for six weeks. On December 24 the transplants were set in the benches.

Direct seeding into the benches was done on December 4, at a rate comparable to 12 ounces per acre. Treatment one was thinned on January 2, when the plants were two inches high; treatment four was blocked on the same day. Treatment three was thinned on January 14, when the plants were four inches high, and treatment four was thinned on January 19 when the plants were five inches high. Treatment three was thinned on January 24, when they had reached the height of six inches. When plants were all thinned, each plant had an area of 152.4 square inches.

Beginning January 14, the height and spread measurements of the plants were taken at seven-day intervals and recorded. Two plants which appeared to be typical or average of the center four plants in each treatment within a replication, was marked. The soil around the plants to be saved was well moistened before any digging was attempted. The first replication was dug on February 15. A square foot of soil around the plants to be saved was carefully washed away, using a garden hose with a moderate stream of water. These plants were then laid out between moistened newspaper and placed in cold storage. The second and third replications were dug on February 20. All plants which were saved and placed into cold storage were photographed for comparison of top and root development. A 5 x 7 Graphlex type of camera was used with the f stop at 3.2 and set on time at one second. Iso-pan and Super Pan Press films were used and the Iso-pan film proved to give the best results. The negatives were developed in a Dechtol solution and dried. Contact printing was done on F1, F2, F3, E1, and E2 contact paper, with the F3 paper giving the best results.

After photographing, the stem diameter was measured at the soil line with a .001 inch calibrated caliper and recorded. The plants were then cut at the soil line, the tops and roots of which were placed into separate paper bags. These bags were placed into an automatic drying oven which was thermostatically controlled. Plants were dried at 65°C for a period of 24 hours. After drying, the tops and roots were crushed and weighed on a Torsion Balance scale and recorded.

<u>Statistical methods</u>

Yield records were obtained on 19 experimental treatments as follows:

1. Kuner Empson grown transplants.
2. Colorado A & M grown transplants.
3. Nevada grown transplants.

	Field seeding dates	Field seeding rates per acre
4.	April 21	8 ounces
5.	April 21	12 ounces
6.	April 21	16 ounces
7.	April 21	20 ounces
8.	April 28	8 ounces
9.	April 28	12 ounces
10.	April 28	16 ounces
11.	April 28	20 ounces
12.	May 5	8 ounces
13.	May 5	12 ounces
14.	May 5	16 ounces
15.	May 5	20 ounces
16.	May 12	8 ounces
17.	May 12	12 ounces
18.	May 12	16 ounces
19.	May 12	20 ounces

All treatments were replicated five times in a randomized complete block design using ten plants in each plot. The same design was used at both locations.

The analysis of variance was employed to determine the significant differences between treatments. In certain cases where differences between treatments were not significant when based on a generalized error the "t" test was used to make finer comparisons. Analysis of variance and covariance, and the "t" test as described by Snedecor (18) were used in this experiment.

Chapter IV

ANALYSIS OF DATA

Field results

The yield data for the three transplants and 16 direct seeded treatments tested at Longmont and Platteville are given in Table 1.

In the Longmont test, the Colorado A & M grown transplants yielded 119.3 pounds per plot, as compared to 87.2 pounds for the Kuner Empson grown and 99.0 pounds for the Nevada grown transplants. These differences in yield are not statistically significant.

In a comparable test at Platteville, the Nevada grown plants yielded 100.1 pounds, Kuner Empson plants yielded 66.3 pounds and A & M grown plants yielded 60.1 pounds. The differences were not statistically significant at the five per cent level.

In comparing field seeded treatments with transplants, the transplants in all cases yielded higher than the field seeded treatments. In the Longmont test the transplant treatments, significantly out-yielded the highest yielding field seeded treatment. The differences between the A & M and Nevada grown plants and the highest yielding field seeded treatment were 81.2 and 60.3 pounds

Table 1.--COMPARISON OF ADJUSTED MEAN YIELDS IN POUNDS PER PLOT OF DIRECT SEEDED AND TRANSPLANTED TOMATOES.

Treatments				Transplants vs. Field Seeding Platteville	Transplants vs. Field Seeding Longmont	Field Seeding Platteville	Field Seeding Longmont
K.E.	grown transplants			66.3	87.2		
A & M	grown transplants			60.1	119.3		
Nevada	grown transplants			100.1	99.0		
F.S.	4/23	8	oz.	29.4		29.4	
F.S.	4/26	8	oz.		38.1		38.1
F.S.	4/23	12	oz.	30.0		30.0	
F.S.	4/26	12	oz.		27.1		27.1
F.S.	4/23	16	oz.	35.5		34.6	
F.S.	4/26	16	oz.		26.8		26.5
F.S.	4/23	20	oz.	21.8		21.7	
F.S.	4/26	20	oz.		20.6		20.0
F.S.	4/28	8	oz.	30.3	33.1	30.3	33.1
F.S.	4/28	12	oz.	24.5	28.2	24.5	28.8
F.S.	4/28	16	oz.	21.3	23.9	21.3	23.9
F.S.	4/28	20	oz.	25.6	27.9	25.6	27.9
F.S.	5/4	8	oz.	25.4	27.9	25.5	27.9
F.S.	5/4	12	oz.	25.9	28.7	25.9	29.0
F.S.	5/4	16	oz.	20.3	25.8	20.3	26.1
F.S.	5/4	20	oz.	25.9	27.1	25.9	27.1
F.S.	5/12	8	oz.	18.8		18.8	
F.S.	5/20	8	oz.		4.5		4.2
F.S.	5/12	12	oz.	15.7		15.7	
F.S.	5/20	12	oz.		10.3		9.7
F.S.	5/12	16	oz.	13.2		13.2	
F.S.	5/20	16	oz.		6.1		6.1
F.S.	5/12	20	oz.	17.1		17.1	
F.S.	5/20	20	oz.		7.5		7.8
L.S.D. at 5% level				34.70	39.36	15.24	17.04
L.S.D. at 1% level				46.09	52.29	20.27	22.06

A & M - Colorado A & M College
F.S. - Field seeding
K.E. - Kuner Empson

per plot, respectively. These differences are significant at the one per cent level. At Platteville only the Nevada grown transplants yielded significantly more than the highest yielding field seeded treatment, the difference being significant at the five per cent level.

Within the field seeded treatments, treatment six (seeded April 23 at 16 ounces per acre) with a yield of 35.5 pounds was the highest yielding at Platteville, and treatment four (seeded April 26 at eight ounces per acre) with a yield of 38.1 pounds, was the highest yielding at Longmont.

A comparison of plant mortality under the different transplants is given in Table 2. The results indicate that transplants grown under Colorado A & M method were more able to withstand the shock of transplanting.

Table 2.--MORTALITY RATE OF TRANSPLANTS TWO WEEKS AFTER FIELD SETTING.

Source of trans-plants	Number of plants reset 50 plant - 100 % stand		Ave. No. of plants re-	Per cent mortality of each treatment
	Platteville	Longmont		
Kuner Empson	9	14	11.5	23
Nevada	4	15	9.5	19
Colorado A & M	1	-	.5	1

Greenhouse tests

To determine whether the date of thinning used in the field test during the summer of 1951 was the most desirable, a greenhouse test was conducted during the winter of 1951-1952, using four heights at which direct seeded plants were thinned. Growth comparisons were made between transplants and direct seeded plants. Records were taken on height, spread, stem diameter, dry weight of tops and dry weight of roots of plants thinned at different stages of growth. These data are presented in Table 3.

Height of plant.—Field seeded treatments, one (thinned at two inches) and four (blocked at two inches and thinned at five inches) were significantly taller than treatments three (thinned at six inches) and five (Kuner Empson method grown transplants) as shown in Column 1, Table 2. The differences were significant at the five per cent level. In comparing height of transplants, treatment six (Colorado A & M method grown transplants) was significantly taller than treatment five. In determining the levels of significance within field treatments, treatments one and two, thinned at two inches and blocked at two inches and thinned at five inches, respectively, were consistently taller than treatment three (thinned at six inches), but the differences were not significant. Colorado A & M grown transplants (treatment six) were

Table 3.--MEASURED DIFFERENCES BETWEEN THINNING FIELD SEEDED AND METHOD OF GROWING PLANTS FOR FIELD SETTING.

Treatments	Height of Plants Inches	Spread of Plants Inches	Dry Weight of Tops Grams	Dry Weight of Roots Grams	Diameter of Stem Inch
1	12.8	14.0	.860	6.383	.2532
2	12.3	14.0	.628	4.490	.2817
3	11.2	13.0	.408	3.483	.2028
4	13.0	14.0	.760	5.285	.2650
5	11.2	12.6	.753	5.013	.2548
6	18.0	19.8	.990	13.965	.3010
L.S.D. 5%	1.49	1.18	.244	2.509	.0684
L.S.D. 1%	2.12	1.68	.383	3.935	.0973

Treatment 1 - Thinned when plants were 2 inches high.
2 - Thinned when plants were 4 inches high.
3 - Thinned when plants were 6 inches high.
4 - Blocked when plants were 2 inches high and thinned when 5 inches.
5 - Kuner Empson method of growing transplants.
6 - A & M method of growing transplants.

taller than the plants in all other treatments and the difference was significant at the one per cent level.

Spread of plant.--In comparing spread measurements (Column 2, Table 3), treatments one, two, four, and six had a significantly wider spread than did treatment three, at the five per cent level. Within the field seeded treatments, the spread of plants in treatment four was significantly greater than the spread of plants in treatment three. The difference was highly significant. Treatments one and two were consistently greater in spread than treatment three, but the differences were not significant. Within transplants, treatment six was significant at the one per cent level over treatment five. Treatment six was also significant at the one per cent level over all other treatments in the test.

Dry weight of tops.--The data for dry weight of tops (Column 3, Table 3) indicate that treatments one, four, five and six were significantly heavier at the five per cent level when compared to treatment three. Within the field seeded tests, treatment one, with .860 gram, as compared to treatment three, with .408 gram, was significant at the one per cent level (.383 gram). Within transplants treatment six, with a weight of .990 gram, was greater than treatment five, with .753 gram, but the difference was not significant.

Dry weight of roots.--In the dry weight of roots (Column 4, Table 3) only treatments one and six with weights of 6.383 and 13.965 grams, respectively, were significantly heavier than treatment five with 3.483 grams. Within field seeded treatments only treatment one was significant at the five per cent level as compared to treatment three. When comparing transplants, treatment six was significantly heavier at the one per cent level than treatment five.

Stem diameter.--The stem diameter measurements, (Column 5, Table 3), indicated that treatments two and six with measurements of .2817 and .3010 inch respectively, were significantly larger than treatment three with .2028 inch stem diameter. Treatment six was the only treatment significant at the one per cent level as compared to treatment three. Within the transplanted treatments, treatment six had a consistently larger stem diameter than treatment five, but was not significantly larger.

Photographic comparisons.--Photographic comparisons of top growth and root developments can be made from the prints in Figs. 1, 2, 3, 4, 5, and 6. To compare growth developments of the direct seeded plants, thinned at various stages of development, Figs. 1, 2, 3, and 4 must be compared. The plant in Fig. 3 was thinned at six inches, the height at which the plants were thinned in the

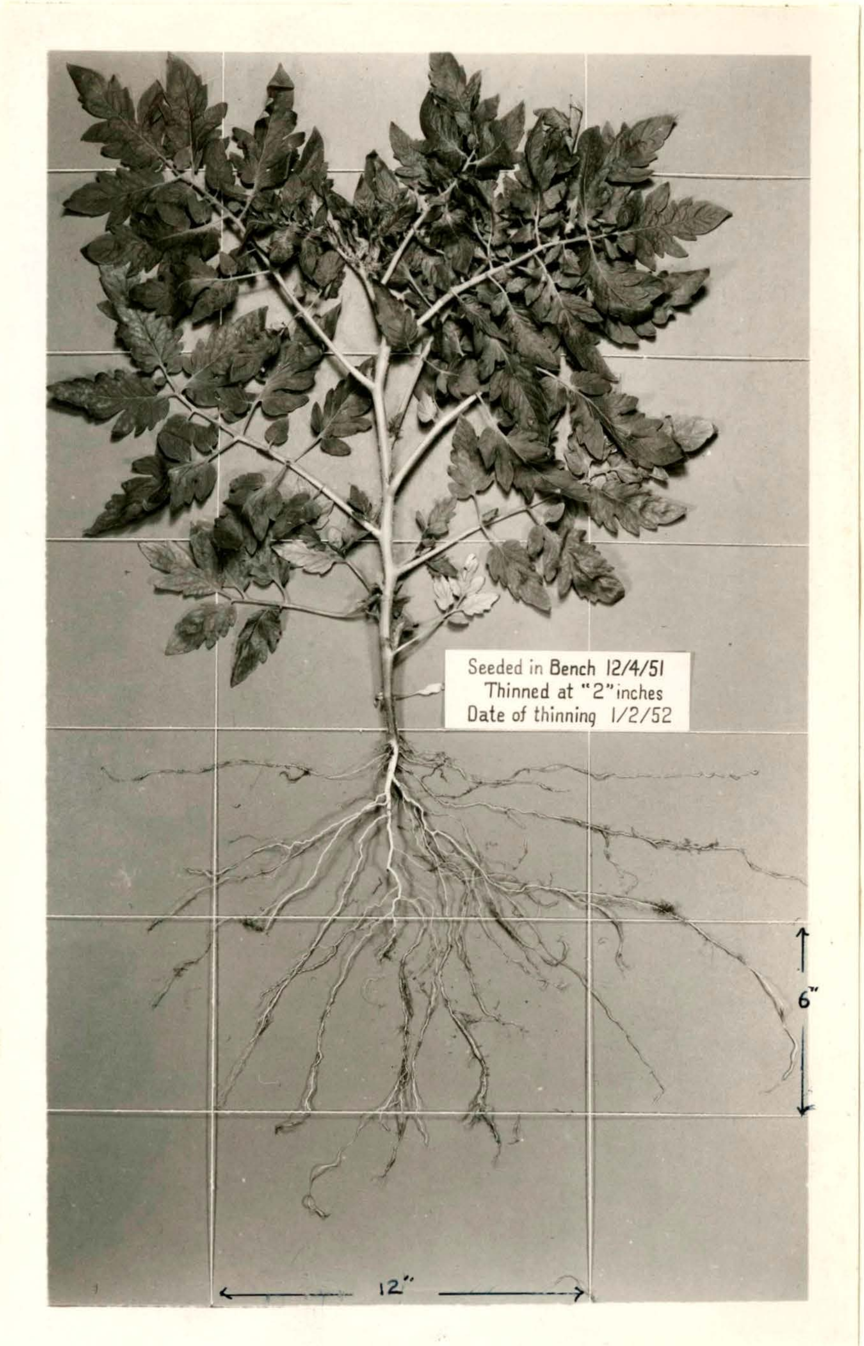

Fig. 1.--Treatment number one, root system and top growth of "K" Stone tomato 11 weeks after direct seeding into a ground bench.

Fig. 2.--Treatment number two, root system and top growth of "K" Stone tomato 11 weeks after direct seeding into a ground bench.

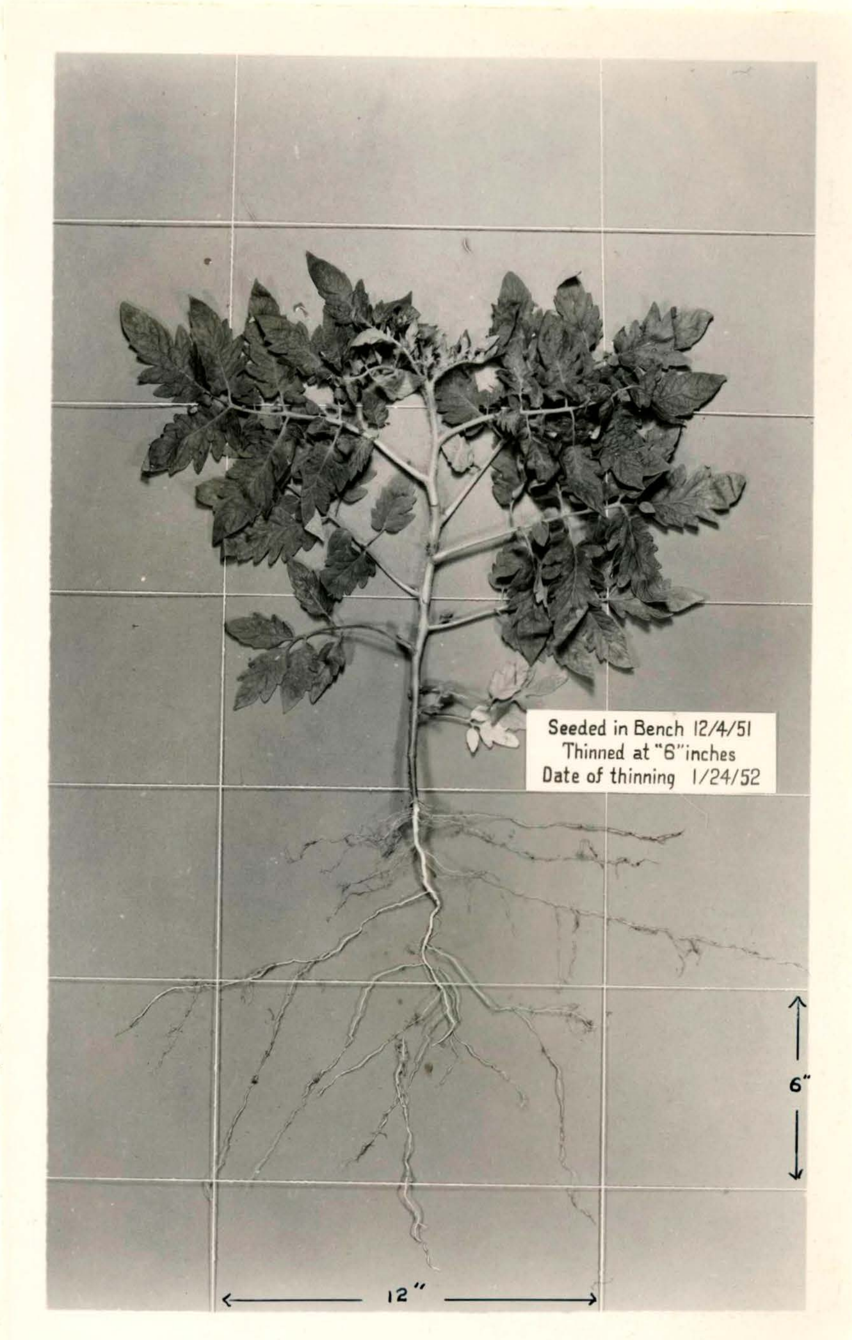

Fig. 3.--Treatment number three, root system and top growth of "K" Stone tomato 11 weeks after direct seeding into a ground bench.

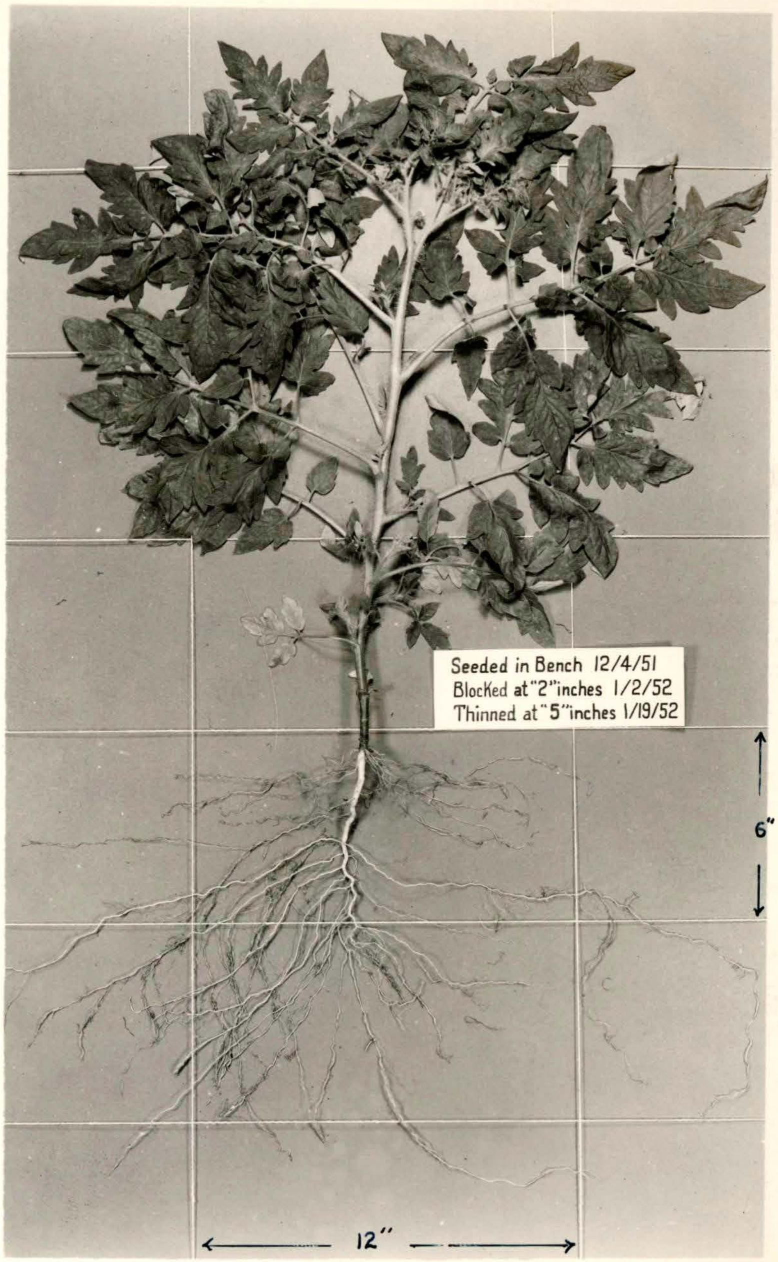

Fig. 4.--Treatment number four, root system and top growth of "K" Stone tomato 11 weeks after direct seeding into a ground bench.

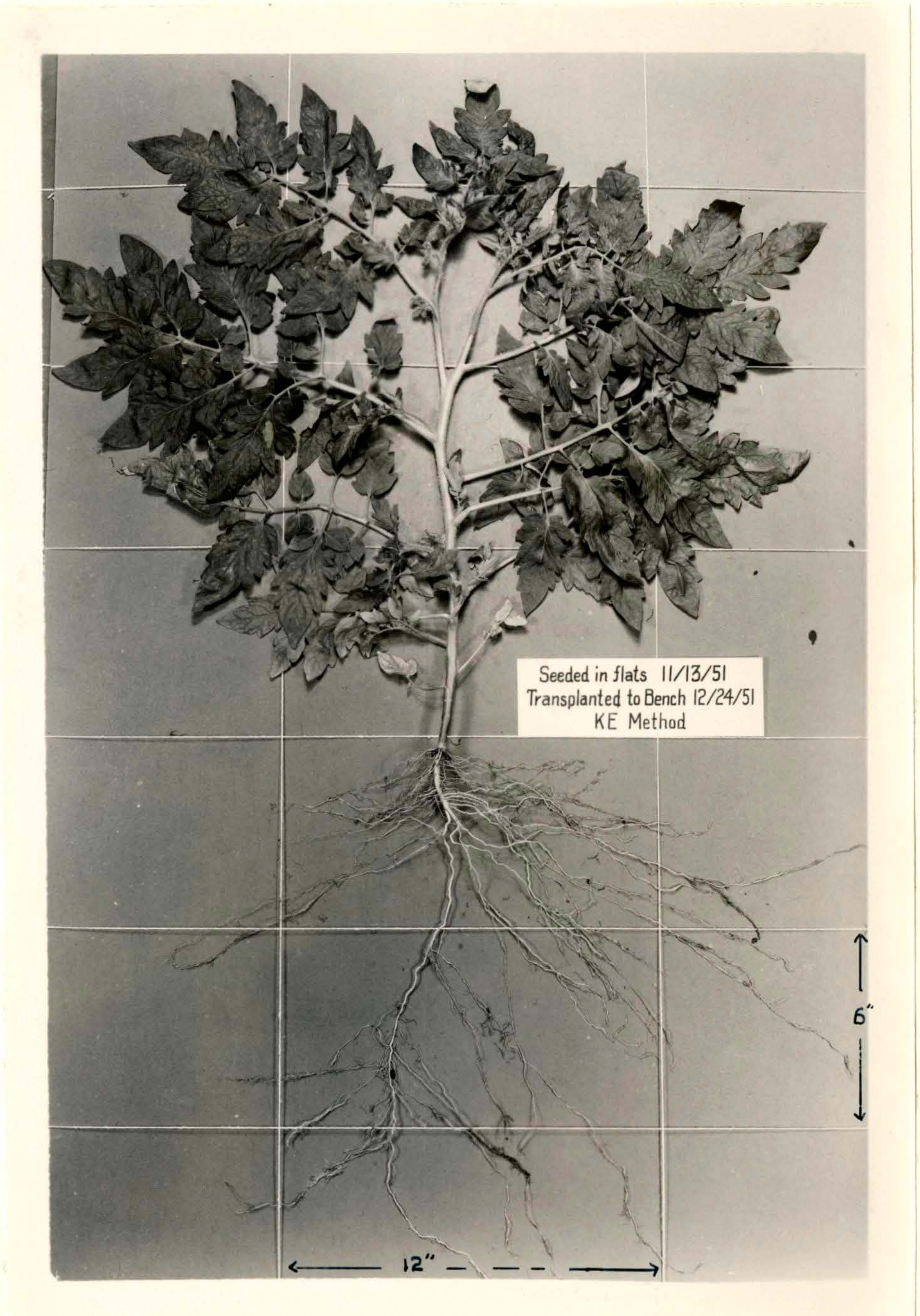

Fig. 5.--Treatment number five, root system and top growth of "K" Stone tomato 14 weeks after seeding in flats, and eight weeks after transplanting to ground bench.

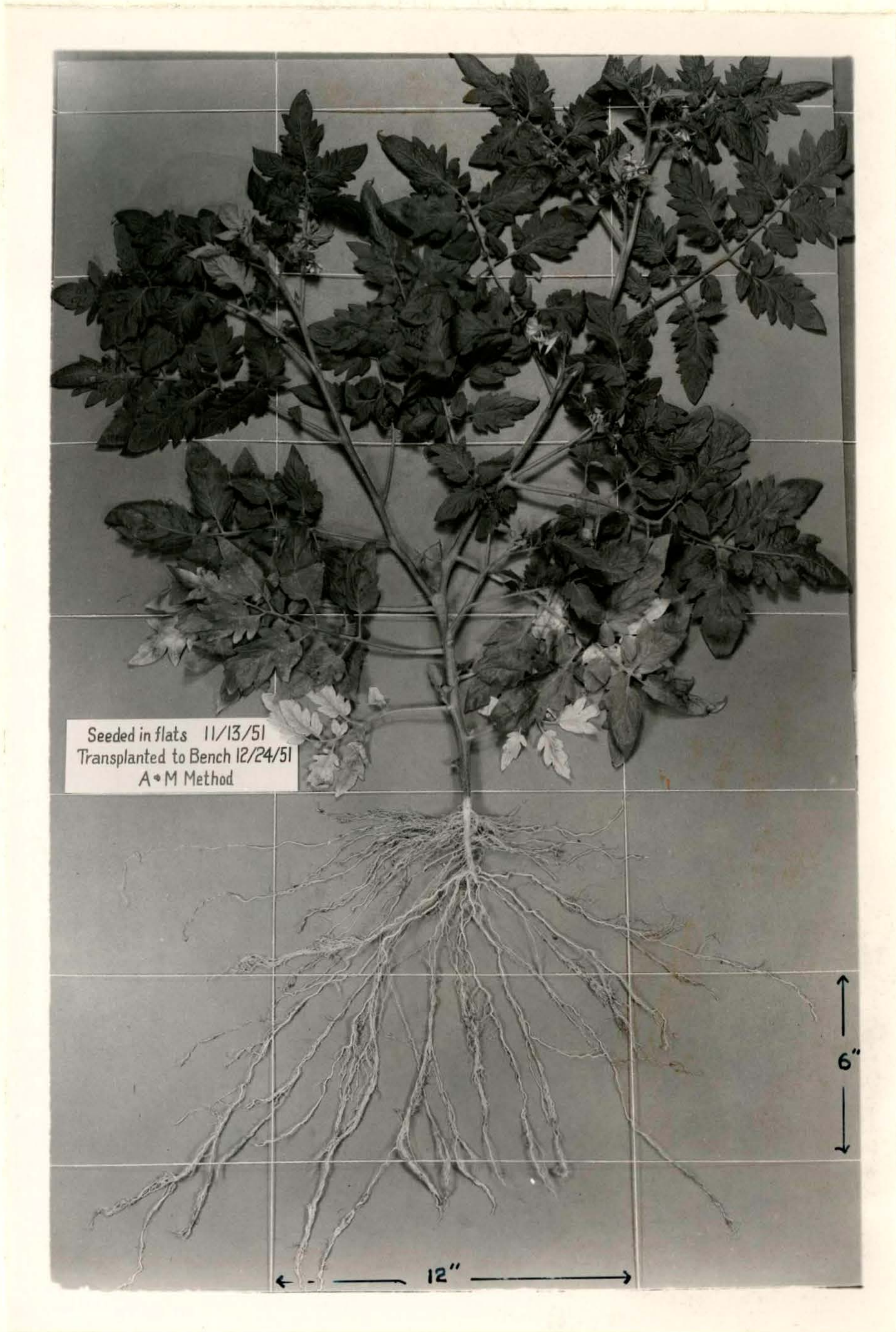

Fig. 6.--Treatment number six, root system and top growth of "K" Stone tomato 14 weeks after seeding in flats, and eight weeks after transplanting to ground bench.

field test. Fig. 6 shows a print of a Colorado A & M grown transplant which can be compared to Fig. 5, a Kuner Empson method grown transplant. The photographs were taken eight weeks after the plants had been transplanted. The plant measurement data were not only significant in favor of the Colorado A & M grown transplants, but the plant in Fig. 6 had seven clusters of blossoms as compared to three clusters of blossoms for the plant in Fig. 5. Plants in Figs. 1 through 4, had an average of a single cluster of blossoms.

Chapter V

DISCUSSION

In the field experiments, there are many factors which might account for the difference in the data obtained at the two different locations. Some of the factors which might have resulted in the yield differences at the two locations, are: (1) soil type, (2) soil moisture, (3) previous cropping history, (4) method of seed bed preparation, and (5) climatic effects (temperature and rainfall). Therefore, a one-year field test is not sufficient to obtain a sample of the variations which might exist in comparing direct field seeding with transplants.

In Platteville the tomato field selected for 1951, followed a barley crop seeded with clover for green manure in 1950. This was turned under just ten days prior to the first field seeding date. The Longmont plot was fall plowed, also plowing under clover. Of the two locations, the seed bed in Longmont was in much better condition. A factor which might be significant in this type of test is the method in which the seed bed is prepared for direct seeding. It appeared that the fall plowed land in Longmont was much easier to direct seed than the spring plowed land in Platteville. This would particularly be true in cases where the soil tended to be of the heavy loam type.

The direct seeding dates planned were: April 21 for the first seeding; April 28, second seeding; May 5, third seeding; and May 12, fourth and final seeding. This was altered some during the planting season due to rain and snow. The first seeding in Platteville was delayed until April 23 and to April 26 at Longmont. The second and third seeding was seeded on the dates previously planned. The second seeding in Platteville was done in very dry soil, but in Longmont the soil was in excellent condition. The third seeding in Platteville was done two days after some rain and the soil was in good condition. Longmont was somewhat dry but otherwise in good condition. The fourth seeding in Platteville was done on May 12 as previously planned. It was noted at the last seeding that the west strip of three rows in the Platteville experiment was very hard. At this time it was found that this strip had been used as a road in 1950. All plots located in this strip were consistently lower yielding when compared to plots in other positions. This was probably an important factor in the variability of the transplant yields, since three of the five Colorado A & M plots as compared to one each for the Nevada and Kuner Empson plots, were located in this area. On account of the many early spring showers in Longmont, the fourth seeding was delayed until May 20. This is probably one factor which contributed to the very low yields obtained from treatments 16, 17, 18, and 19, as shown in Table 1.

A comparison of mortality rates of plants (Table 2) after transplanting indicates that the Colorado A & M plant growing methods are superior to other methods tested. The high death losses in the Kuner Empson transplants were attributed to the soft, succulent condition, since the dead plants showed no indication of disease. The Nevada plants, although large and apparently vigorous, had suffered from the time lapse between pulling and field setting. Also the Nevada plants appeared to have been topped or pruned. Top pruning, according to Loomis (13), is a very poor practice for it reduces the area of food production for the plant, thereby reducing its ability to recover.

All three sources of transplants had an average of three to five flower clusters before the first cluster appeared on the direct seeded treatments. There was a considerable difference in the number of days between the first picking of transplants and the first picking of the field seeded treatments as indicated in Table 4.

Table 4.--DATE OF FIRST PICKING FOR TRANSPLANTS AND FIELD SEEDED PLANTS.

Location	Treatments Transplants	Field seeded	Difference in number of days
Platteville	August 10	August 21	11
Longmont	August 11	September 1	20

It was observed that the size of fruit did not vary too much between the transplants and the direct seeded plants. The Colorado A & M grown transplants seemed to have the better quality fruit as compared to the Nevada and the Kuner Empson grown transplants. Watts (20) found that woody or very succulent type of transplants caused deformed fruit on the early set. Records taken in 1951 verified Watt's statement, as both Nevada and Kuner Empson grown transplants produced fruit which was rather rough.

As shown by the data in Table 1, there was no significant difference in yield between the four rates of seeding at any of the four dates. This would indicate that the eight-ounce or lowest rate of seeding was sufficient to establish a good stand. Although there were no statistically significant yield differences between the April 23 and the May 4 seedings, it should be noted that the highest yields were obtained from the first seeding at both locations. At Platteville the yield of treatment six (April 23 seeding at 16 ounces) was significantly greater than all seedings after May 4. Treatment four (April 26 seeding at eight ounces) at Longmont was significantly higher yielding than all seedings after May 4. This is in agreement with the work of both Bushnell (7) and Haber (11) who found that the later seeding dates produced the lower yields.

One of the most serious problems that the tomato industry in Colorado faces is the killing of plants by late spring frosts. The grower must, therefore, choose between the risk of frost damage to early seeded tomatoes and the lower yields of a later seeded crop.

Outstanding growth differences noted in the field, two weeks after the field seeded treatments had been thinned, was the luxuriant growth of the transplants as compared to the poor foliage development and growth of the field seeded plants. The field seeded treatments were thinned when the plants attained a height of six inches. Thinning at six inches was recommended by Fraser (1), Haber (11), and Huelsen (12). It has been noted by some growers in the Brighton and Fort Lupton areas, who practice direct field seeding because of labor shortage, that better plants and higher yields were obtained when thinning was done before the plants reached a height of six inches. One particular grower in Brighton who for the past five years had field seeded, reported that blocking the plants when they were two inches tall and thinning to a single plant when they were five inches tall, gave very good results. A review of the literature on field seeding indicated a six-inch height was most satisfactory for thinning and blocking, so this practice was followed in the experiments.

Since the thinning at six inches did not appear too satisfactory in the field test, a greenhouse test was conducted to determine the most desirable height at which plants should be thinned.

The data from the greenhouse test, (Table 3) indicated that direct seeded plants when thinned at six inches were shorter, had a smaller spread and stem diameter and a smaller dry weight of root and top. In light of these results it is probable that the direct seeded plans in the field experiment were retarded by delayed thinning. This may account for the considerably lower yields obtained by direct seeding as compared to transplanting.

Chapter VI

SUMMARY

These tests were conducted for the year 1951 and 1952, using accepted methods of experimental design with five replications. It was recognized that more work must be conducted before any significant conclusions can be made under the variable conditions which exist in this type of an experiment.

1. It was found that there was no statistical significant differences in yield between the 8, 12, 16, and 20 ounce rates of seeding per acre in direct field seeding tests.

2. There was no statistical significant difference in the mortality rates and total yield on the four different dates of field seeding, under the conditions of this test.

3. Tomatoes grown from transplants produced ripe fruit 11 to 20 days before plants grown from the direct field seeded method.

4. The effect of different plant sources and methods of handling plants, previous to transplanting, had some affect on the yield but was not consistently significant between the two locations.

5. The yields of all transplant treatments were significantly higher than the highest yield obtained by field seeded methods at Longmont. At Platteville, only the Nevada grown plants were significantly higher yielding than the best performing field seeded treatments. The differences were significant at odds of at least 19:1.

6. Delayed blocking and thinning of plants in the greenhouse tests, indicated that there was a significant reduction in growth, root development and stem diameter of plants when they were thinned at a height of six inches.

7. The Colorado A & M method of growing transplants, which provides more space per plant, produced statistically significant increases in top growth and root development over the Kuner Empson method, in the greenhouse tests.

APPENDIX

B I B L I O G R A P H Y

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