THE EFFECTS OF HIGH ANALYSIS SOLUBLE FERTILIZERS AS INTERRELATED WITH ENVIRONMENTAL CONDITIONS AND CULTURAL PRACTICES ON THE GROWTH AND YIELD OF VEGETABLES WITH SPECIAL REFERENCE TO THE TOMATO

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By

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HERMAN TIESSEN ABSTRACT

Transplants of various vegetable crops were grown under various environmental conditions and treated with different analyses and concentrations of soluble fertilizer. Records were taken of plant composition, growth, and yield.

Greenhouse and laboratory studies indicated that nitrogen absorption by tomato plants was influenced more by nitrogen application in the fertilizer solution than by soil temperature (46 to 70° F). Phosphorus absorption by tomato plants apparently occurred at low temperatures (54 to 62° F) only at high concentration in readily available form. A high soluble phosphorus content in tomato plants from starter solutions shortly after field setting was correlated with subsequent growth and yield. The fertilizer solutions also tended to decrease flower abscission of tomato plants and increase the fruit set and early yield. Starter solutions had little or no effect on tomato plant growth at the lower soil temperatures (46 to 54° F).

The crops tend to vary in their response to the fertilizer solutions. Tomato root development was benefitted particularly from phosphorus and nitrogen, whereas potassium was as important as nitrogen and phosphorus for tobacco root development. Earlier maturing tomato varieties, such as Valiant responded more to fertilizer solutions than the later maturing varieties, such as John Baer. Stokesdale tomatoes produced higher yields when

nitrogen was low, whereas Longred required a high nitrogen as well as a high phosphorus. This is probably the result of prevailing soil types in regions where they were developed. The cole crops and celery respond to starter solutions containing a high nitrogen and phosphorus (23-52-0).

The most important factor in high analysis soluble fertilizer solutions is their ability to supply immediately available nutrients in close proximity to plant roots at the time of the plants most critical need, thereby increasing vegetable crop yields when applied to transplants on soils of medium to low fertility. Other uses are in fertilizing greenhouse crops with a reduction in the osmotic value of their soil solutions. Nutrient additions to seedling plants can be more easily manipulated by starter solutions than by dry fertilizers. The rate, analysis and time of application of the high analysis soluble fertilizer solutions vary with the crop, variety, plant maturity, soil type and fertility.

INTRODUCTION

Solutions of high analysis soluble fertilizer materials are known as "starter solutions".

Interest has been increasing in the use of these fertilizers with transplanted and greenhouse crops. Although "starter solutions" have been in use for over twenty years, they have been recognized by the fertilizer industry only recently. Improved technology has resulted in materials that permit the application of increased amounts of nitrogen, phosphorus and potassium without markedly increasing the danger of high salt concentrations. These soluble chemical mixtures are better adapted for machine application during transplanting or through irrigation water than regular fertilizers.

The application of concentrated fertilizers in solution to transplanted crops also supplies nutrients to the plants in more available form. Readily available nutrients help plants to overcome the shock of transplanting, and to become established more rapidly without injurious salt residues being left in the soil. This has often led to higher survival of transplants, earlier maturity, and frequently larger early and total yields.

There is considerable literature regarding the use of different fertilizer salts, concentrations, and analyses for many crops. However, there exists a need for more specific information on the concentrations and analyses to be used for individual crops. This study is an attempt to determine the salts, formulae, and concentrations of the salts in solution which are most favorable to the growth and production of transplanted vegetable crops.

REVIEW OF LITERATURE

"Starter Solution" Investigations

The use of fertilizers in solutions was employed in the field of hydroponics over seventy-five years ago by Sachs (36). Baker (3), one of the first workers to report the use of "starter solutions", added 4.6 pounds of mono-ammonium phosphate to 50 gallons of water and each tomato plant received one-half pint of this solution at transplanting time. The early yields were increased 80 per cent and the total yields were increased by 20 per cent. He concluded that the use of starter solutions with tomatoes promoted early recovery from the shock of transplanting, resulted in less replanting, earlier fruiting, and increased the total yield.

Sayre (37, 38, 39) working with tomatoes (variety Baerosa) found that a mixture of two parts of "Ammo Phos A" and one part of nitrate of potash at a concentration of 8 pounds per 50 gallons of water, and applied at the rate of one-quarter pint per plant, increased the early yield by 1.44 tons, and the total yield by 1.85 tons. In another experiment, using 50 per cent by weight of di-ammonium phosphate and 50 per cent of mono-potassium phosphate (10-52-17) at a concentration of 5 pounds per 50 gallons of water and one-half pint per plant, he obtained earlier yields of tomatoes. Dipping the roots of tomato plants in starter solutions gave no significant differences in yield. Sayre (38) did not observe any differences in yield by the addition of Vitamin B or hormones to the transplanting water. He concluded that starter solutions were effective in promoting early maturity even in dry weather, and felt that this may have been due to a high nutrient availability at the critical time.

Other workers (7, 33) using a 10-52-17 starter solution fertilizer on tomato plants, have obtained significant increases in both early and total yields. Odland (30) concluded that early tomatoes responded to N, P, and K in a starter solution, whereas summer tomatoes responded only to the phosphorus portion. Osborn (31) stated that the most important factor for a rapid recovery from transplanting in tomatoes was the immediate availability of plant nutrients. He concluded that a 1:2:1 ratio of N, P_2O_5, K_2O was desirable on average soils and that even higher proportions of phosphorus should be applied on soils low in this nutrient. Arnold (2) has shown that a 10-52-17 starter solution produced maximum response on a low phosphorus soil and that its effect was proportionately reduced on more fertile soil, and gave no response on a soil containing 300 pounds to the acre of available P_2O_5. Jones and Warren (20) working with radioactive phosphorus in a 6-57-17 starter solution concluded from their work that early phosphorus uptake was more important in affecting early yields of tomatoes than total phosphorus uptake. Rahn (32) using 10-52-17 on tomatoes (variety Rutgers) obtained results similar to those of Sayre. He believed that N and K are low in cold soils due to low microbial activity, however, that phosphorus was still the most limiting nutrient. Therefore, all three nutrients are necessary in fertilizer solutions to meet all soil and climatic conditions.

Stair and Hartman (41) found no appreciable difference in the use of starter solutions, even in soils testing low in available phosphorus. No benefit seemed to be derived from the phosphorus in the starter solution. This is contrary to Arnold's conclusion (2) that responses to starter solutions are experienced where soils are low in phosphorus. The starter solutions used by Stair and Hartman were (1) di-ammonium phosphate, and (2) a mixture of two parts treble superphosphate, one of calcium nitrate and one of potassium nitrate, at a concentration of 4 pounds per 50 gallons of water applied at the rate of 1 pint to a plant.

Starter solutions were found to be beneficial to crops other than tomatoes. Reath (33) in his work with two cabbage varieties, obtained increases in field of 5 tons per acre with Globe, and 3 tons per acre with Copenhagen Market variety, when he applied one-half pint of a solution containing 9 pounds of 10-52-17 in 50 gallons of water. In his strawberry work, by applying on each plant one-half pint of a solution containing 6 pounds 10-52-17 per 50 gallons of water, he increased the number of runner plants, which was significantly correlated with the yield the following season. Rahn (32), like Reath, experienced increases in yield from the use of 10-52-17 on Marion Market cabbage, and believed that nitrogen was the important nutrient for the crop.

Jacob and White-Stevens (19) obtained increase in neither head weight nor in early yield of cauliflower or broccoli from the use of starter solutions. They believed that this was probably due to the high fertility of soils on Long Island. This would bear out Arnold's findings with tomatoes that the response to starter solutions decreased as the soil fertility increased.

Other Crops

Carrier and Snyder (8) using a solution of two parts of monoammonium phosphate and one part of potassium nitrate at a concentration of 8 pounds per 50 gallons of water, and giving each plant 25 cc of this solution at the time of transplanting, and before transplanting, found that *Taxus cuspidata* showed a significant increase in survival and number of breaks, and a gain in height with starter applied before transplanting when compared with the control. They also observed a significant decrease in the number of days to bloom when snapdragon plants were treated 5 days or more before field planting and Delphinium plants were treated 8 days or more before field planting. Kamp and Bluhm (21) using 10-52-17 at the rate of 6 grams per liter of water, dipped the basal end of chrysanthemum cuttings in 1 inch of nutrient solution for one hour. They found that the improvement in growth of root cuttings from the use of nutrients was highly significant.

McManus (27) stated that potassium applied in a starter solution in soils low in potassium increased the growth of Montmorency cherry trees, averted potassium deficiency symptoms, and increased leaf potassium. Hewetson (15) noted that approximately one-quarter pound of 23-21-17 (Ra-Pid-Gro) in 2.5 gallons of water applied to Halehaven peaches when they were transplanted, produced outstanding shoot growth, increase in trunk diameter, better leaf color, and greater weight and size of the trees.

Seeley (40) recommended the use of starter solutions in the greenhouse to supply nutrients after the crop was established. In his work with flowers he found that soluble fertilizers could be applied with a spray tank through fertilizer or spray pipe lines, by means of a specially constructed movable tank and pump units, or through the watering system. Davis and Cook (11) have recommended applying fertilizers in the irrigation water. This is mainly for supplementary feeding or for adding minor elements.

Wittwer (52) in foliar feeding work with radioactive isotopes, concluded that although foliar feeding made more efficient use of the nutrients, its main use would be in supplementing the supply of plant nutrients ordinarily absorbed by the roots. It would not replace soil fertilization, but could probably be quite useful to some plants during critical periods of growth, or when root absorption was limited.

Salt Effects

Plants often have salt injury, due to high osmotic pressures exerted by low analysis dry fertilizers, since it is necessary to apply large volumes of fertilizers to supply adequate plant nutrients. High analysis soluble fertilizers are able to supply the required nutrients without increasing the osmotic pressure of the soil solution, and thereby lessen the hazzard of salt injury.

Ahi and Powers (1) in their work with salts and temperatures indicated that some plants are more resistant to salt injury at cool temperatures of 55° F than at warmer temperatures of 75° F.

Magisted (25) reported that the salt concentration was a greater factor in determining the amount of growth reduction than the effects caused by specific ions; although salts of both monovalent and divalent ions suppressed plant growth, monovalent ions were in some cases more toxic. Crops grown on soils high in salt were depressed more at high than at low temperatures.

Van Koot (46) found that the most favorable soil temperature for tomato growth was 59° F, and at a lower soil temperature insufficient phosphorus was absorbed by roots. With radioactive phosphorus and monoammonium phosphate the plants at 64.4° F had absorbed 80 per cent more phosphorus two weeks after potting than plants growing in soil at 61.7° F soil temperature.

Wall and Hartman (49) stated that salt toxicity to plants is apparently due to the high ionic concentration, the reduction in availability and absorption of other ions, and the effect of the change in pH.

Merkle and Dunkle (26) showed that a close relationship existed between the total and inorganic soluble matter and the electrical conductivity readings of aqueous soil extracts. They found that the conductivity readings from 1:2 soil water extracts of greenhouse soils were from 10 to 100 times greater than readings from field soils, and that the "ceiling value" for greenhouse tomatoes was from 140 to 265 x 10^{-5} mhos.

Effect of Soil Temperature on Plant Absorption and Growth

The absorption of soil nutrients by plant roots is markedly influenced by soil temperatures. In work with tomatoes Went (49, 50) concluded that under conditions of good aeration and abundant nutrient supply, shoot growth was not materially increased or decreased by root temperatures varying from 60° F to 90° F. He suggested that root temperatures would not affect shoot growth of tomatoes when nutrition and other conditions are very favorable, but that low root temperatures under less favorable conditions may depress top growth.

Hoagland (16, 18) stated that the shoot growth of the tomato was not materially affected when the plants were grown at root temperatures between 60° F and 90° F, but at soil temperatures outside this range growth was apparently appreciably reduced. He believed that absorption of solutes decreased with a decrease in temperature, but it was difficult to separate the effects of low temperature on the absorption process from the effects on translocation and utilization of nutrients within the plant. Riethmann (34) however, reported that in tomatoes the stem growth and the fruit set depended largely upon root temperature.

Nightingale (29) could detect no difference in the permeability of tomato roots to nitrate at 55°, 70° or 95° F. He stated that low temperatures did not appear to retard seriously the absorption of nitrogen, but they did affect the capacity of the roots to assimilate the absorbed nitrate. The NO_3 ion was slowly assimilated in tomatoes at 55° F.

Kramer (22) stated that the reasons for the reduced rate of water absorption at low temperatures is caused principally by the increased resistance to water movement across the living cells of roots. He attributed this increased resistance to the combined effects of both the higher viscosity and lower permeability of protoplasm and greater viscosity and reduced molecular activity of water. He also found that slow cooling permits protoplasmic adjustments that lessen the effects of low temperatures on the absorption of water.

In his work with grapefruit and lemon cuttings, Haas (13) found that transpiration of grapefruit cuttings ceased above 80.6° F and of lemons above temperatures of 87.8°F. He believed that the reduction in water uptake under high soil temperature conditions possibly resulted from a decrease in absorbing surface caused by injury to some fine roots and by rapid maturation of others.

In working with water cultures, Ellie and Swaney (12) found that the rate of water absorption may be so diminished at high root temperatures as to produce wilting and the eventual death of the plants. They believed that in this case the retarded water uptake may have been a consequence of an inadequate oxygen supply.

STATEMENT OF THE PROBLEM

The production of vegetable crops, such as cabbage, cauliflower, sprouting broccoli, celery, tomatoes and peppers, involves starting young seedlings in beds, flats, or pots, and then transplanting them to the field. When transplanting the seedlings to the field every effort should be made to minimize the hazards of transplanting, and to promote early resumption of growth for optimum production. Starter solutions are often used to aid in the early establishment of transplants.

This investigation attempts to evaluate the effect of starter solutions on the physiology, composition, growth and yield of plants under various environmental conditions.

PART I

GREENHOUSE AND LABORATORY STUDIES

Growth Response of Tomato Plants to Soluble Fertilizer Solutions on Three Different Soils

The response of tomato plants grown on three soils treated with different concentrations of starter solution and sucrose was studied. Sucrose was added to determine if it would alleviate injury induced by high salt combinations.

Methods and Materials:

Six weeks old Valiant tomato plants were set one to a can on April 25, 1952 in No. 10 tins containing sand, muck, or sandy loam soil. Four one-plant replicates were treated at the time of transplanting with one-half pint of one of the solutions indicated in Table I.

The plants were completely randomized on two benches in a greenhouse with a 66° F night temperature. Records were taken on June 4, 40 days after treatment, of the fresh weights, the heights and roots, and the number of flowers that had developed.

Results:

Table I indicates that there was a highly significant increase in the total weight of the plants receiving starter treatments, with or without

TABLE I

Influence of Soluble Fertilizer Formulations on the Growth and Flowering of Valiant Tomatoes.

Treatments*	Avg. fresh top wt. per plant (inches)	Avg. height per plant (inches)	Avg. root length per plant (inches)	Avg. no. flowers per plant
	Mean values for 12 plants			
Water	45.9	16.0	9.1	3.83
Water + sucrose	44.4	14.9	8.7	2.25
4 lb. 10-52-17[1/]	99.4	17.7	9.9	4.25
4 lb. 10-52-17 + sucrose	96.5	17.7	10.6	4.25
6 lb. 10-52-17	112.8	18.1	10.4	4.33
6 lb. 10-52-17 + sucrose	107.6	17.1	10.3	4.50
8 lb. 10-52-17	118.6	17.0	10.6	5.25
8 lb. 10-52-17 + sucrose	115.8	17.5	10.3	4.58
L.S.D. .05	8.36	1.56	1.05	.58
.01	11.10	2.07	1.39	.77

*Pounds of starter treatments per 50 gallons of water. When indicated sucrose was added at rate of 4 pounds per 50 gallons.

[1/] 10-52-17 (Takehold) supplied by the Victor Chemical Works, Chicago, Illinois, and composed of 50% $(NH_4)_2HPO_4$ and 50% KH_2PO_4.

sucrose, over those receiving only water or water and sucrose. There was also a significant increase in the total weight of the plants from the four-pound to the six-pound starter solution concentration, and a highly significant increase in weight in the eight-pound concentration over the four-pound treatment. In each case the plants receiving sucrose with the starter solution produced slightly less total weight than at the same concentration of starter solution without sucrose.

There was a slight but significant increase (Table I) in height and the length of the roots with the use of starter solution in the presence or absence of sucrose. Plants receiving only water had a significantly greater number of blossoms than those receiving the sucrose water treatment. The eight-pound concentration of starter solution without sucrose significantly increased flower number as compared to the other treatments. A possible explanation for plants having fewer flowers when sucrose was added could be that plant nutrients were utilized to a greater extent by soil organisms, growth of which was encouraged by the addition of sucrose.

Table II indicates the effect of the different soils on plant growth. The average weight of the plants grown in sand was significantly less than those grown on muck or loam soil, and in turn, plants grown on loam were better than those grown on muck. Plant heights were also significantly greater in muck and loam than in sand. On muck soil plants had significantly longer roots than those grown on sand or loam. This was probably

TABLE II

Interactive Effect of Soluble Fertilizer and Soil Type on Growth and Flowering of Tomatoes.

Treatment		Average fresh top weight per plant (grams)			Average height per plant (inches)			Average root length per plant (inches)			Average number flowers per plant		
		Sand	Muck	Loam	Sand	Muck	Loam	Sand	Muck	Loam	Sand	Muck	Loam
Water		*13.88	46.25	75.38	10.63	17.75	18.00	7.63	9.75	9.13	1.5	3.38	4.25
4 lb. 10-52-17		79.13	108.75	106.00	17.50	17.38	18.13	10.25	11.13	9.38	4.28	4.00	4.38
6 lb. 10-52-17		92.0	113.50	125.25	17.25	17.13	18.38	10.50	11.25	9.25	3.75	4.50	5.00
8 lb. 10-52-17		99.38	118.50	133.88	16.50	16.88	18.38	10.13	11.75	9.38	4.38	4.50	5.88
Mean		71.2	96.75	110.1	15.5	17.3	18.2	9.6	10.97	9.03	3.50	4.09	4.87
L.S.D.	.05		10.26			1.91			1.29			.712	
	.01		13.59			2.53			1.71			.943	
L.S.D. for mean values	.05		5.12			.96			.646			.356	
	.01		6.78			1.27			.856			.472	

*Average of 8 plants

a result of better aeration in the muck soil. Flower number was significantly greater on plants grown on muck soil.

Differences in the effect of starter solution treatments on these three soils on the total fresh weight, height, root length, and flowering are shown in Table II. The weight of tomato plants was increased significantly for all three soils with the addition of the first increment of fertilizer (four pounds) over plants receiving only water. The increases in plant weight from the starter treatment were 470, 135, and 40 percent in sand, muck, and loam. A comparison of the four with the eight-pound concentration indicated little or no increase in plant weight on muck soil. On the loam or sand soils, increases in plant weight were observed between the four- and the six-pound concentrations, but not between the six- and the eight-pound concentrations. The weight of plants receiving only water and grown in muck was three times and in loam five times greater than on sand, and in turn, plants grown on loam were almost twice the weight of plants on muck.

Height of plants grown on sand and receiving only water were significantly less than for those grown on sand and receiving starter treatments, or plants grown on muck and loam receiving either water or starter. Height data suggest that the increase in weight from starter treatment was from a stockier but not necessarily a taller plant. Root lengths on sandy soil were significantly less for plants receiving water than for those grown on sand with starter solution, or on either muck or loam soil. There was no difference in root length for the different fertilizer concentrations in the same soil, in fact root growth was about the same on the loam soil for either water or starter treatment. There was also no difference in root length for the different starter treatments between sand and muck soil, however, plants grown on muck with starter had a longer root system than those grown on loam.

The flower number (Table II) of plants grown on sand and receiving only water was significantly less than for any other treatment. Flower number in sand and muck grown plants reached its peak after the addition of the four-pound concentration of starter treatment. With plants grown on loam soil, on the other hand, flower number increased with each increase in concentration of starter. Soil type had a pronounced influence on flower production, which was partly modified by fertilizer treatments.

In general, starter solutions were more effective on soils of very low fertility (sand) in increasing the plant weight, top and root growth, and flower production. On soils of moderate fertility, there was an increase in plant weight (stockier plants) and blossom number (at higher concentrations) although root and top elongation were only slightly affected.

Influence of Soluble Fertilizers on Growth and Petiole Composition of Tomato Plants

a) Air Temperature Effects:

The composition of tomato plants at different air temperatures as influenced by starter solutions of varying analysis was investigated.

Methods and Materials:

Stokesdale tomato plants, seeded on February 1, 1954 were transplanted seven per 12-inch pots into soil composed of a mixture of 50 percent sandy loam and 50 percent sand, and were given 800 ml. of distilled water on March 23. Seven days pervious to planting, one-half pint of one of the six starter treatments indicated below was added to each of nine pots. The po s were then completely randomized within each of the three replications at night temperatures of 50, 60, or 70°F.

The treatments were as follows:

	Chemical Used
1. Control (water only)	
2. 10-52-17	50% *Di-ammonium phosphate 50% Mono-potassium phosphate
3. 10-26-17	50% Mono-potassium phosphate 31% Ammonium nitrate
4. 10-5-17	10% Di-ammonium phosphate 37% Potassium nitrate 10% Ammonium nitrate

	Chemicals Used*
5. 5-52-17	50% Mono-potassium phosphate 1.5% Ammonium nitrate Phosphoric acid (amount of acid added to make up the analyses)
6. 10-52-5	50% Di-ammonium phosphate 1.5% Mono-potassium phosphate Phosphoric acid (amount of acid added to make up the analyses)

At time of planting fresh leaf petioles were taken for chemical analysis for comparison with subsequent samples to show the early effect of the various treatments. At the final sampling, green fresh weights were recorded for each of three replicates. The fresh petioles were tested for soluble nitrogen and phosphorus, as outlened by Carolus (6). Potassium was determined with a Beckman model B flame Spectrophotometer, using a procedure similar to Brown et al. (4) with hydrogen used a fuel burned in the presence of oxygen.

Results:

Green Weight at Final Sampling

The results indicate that 17 days after treatment, at the final harvest, temperature had a more pronounced effect than soluble fertilizer on plant growth with the average green weight varying from 13.2 grams at 50° F to 34.3 grams at 70° F. The fertilizer treatments increased growth more at the 70° than at the 50° F, and plants at 50° and 60° F grew to approximately the same size with water treatment.

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*Percentages equivalent to four pounds in 50 gallons of water.

Soluble Nitrogen Concentrations as Influenced by Treatments

Table III indicates that the concentration of nitrogen in leaf petioles was highest in the plants three days after treatment at the 50 and 60° F temperatures, and then decreased as the plants began to grow. But at 70° F nitrogen concentration in the petioles was still high seven days after treatment. At 50 and 60° F petioles of plants treated with the starter solution 10-5-17 (low in phosphorus) had a higher concentration of nitrogen seven days after treatment than was found with any other treatment. The concentration of soluble nitrogen present in petioles of plants seven days after treatment was in the following decreasing order: 10-5-17 (low phosphorus), 10-26-17 (medium phosphorus), 10-52-5 (low potassium), and 10-52-17. These differences were probably the result of nitrogen accumulation at the low temperature, however only a small amount of phosphorus was being absorbed, but at 70° F the plant was growing more rapidly, which resulted in a greater absorption of soluble phosphorus and nitrogen. There was an increase in nitrogen in leaf petioles of plants receiving only water with an increase in temperature. Two weeks after treatment there was no great variation in the nitrogen content of petioles, indicating that the plants were re-established.

When the soluble nitrogen contents of leaf petioles of the plant, a week after treatment, were plotted against the average weight of the

TABLE III

Influence of Temperature and Starter Treatment on Concentration of Soluble Nitrogen, Phosphorus, and Potassium in Tomato Plants, Three, Seven, and Seventeen Days after Treatment (Expressed on Fresh Weight Basis).

Treatment	Temperature (Degrees F)	Avg. Wt. of Plant	Soluble N			Soluble P			Soluble K_2O		
Initial Sample	March 23, 1954		920 ppm			292 ppm			3900 ppm		
			Mar. 26	Mar. 30	Apr. 9	Mar. 26	Mar. 30	Apr. 9	Mar. 26	Mar. 30	Apr. 9
Water	50***	11.7**	750*	537	688	131	25	10	2169	2410	2327
10-52-17		16.6	1050	725	683	131	190	115	2410	2412	2448
10-26-17		15.9	600	925	790	231	65	80	2412	2291	2408
10-5-17		13.3	1100	1050	563	157	50	45	2290	2410	2528
5-52-17		15.3	775	612	560	198	190	81	2772	2079	2608
10-52-5		16.1	725	823	735	198	206	90	2531	2169	2688
Water	60	11.2	850	625	573	112	30	100	2410	2410	2668
10-52-17		18.7	950	850	683	219	212	130	2290	2590	2608
10-26-17		19.4	1225	1050	830	198	125	75	2531	2651	2608
10-5-17		17.8	1225	1375	872	203	40	55	2651	2892	2400
5-52-17		20.7	1050	800	780	247	240	165	2892	2531	2738
10-52-5		22.7	850	950	832	209	181	85	2290	2290	2407
Water	70	27.8	1000	840	880	94	30	100	2169	2531	3020
10-52-17		41.3	990	825	782	197	180	160	2531	2772	3110
10-26-17		36.2	1050	1175	812	172	203	145	2531	2627	2900
10-5-17		29.3	1000	1175	780	153	100	115	2772	2892	2900
5-52-17		33.5	825	950	756	230	240	190	3013	2651	3711
10-52-5		38.0	950	1175	795	181	247	185	2531	2892	3310

*Average of two samples in parts per million in fresh plant material.

**Average weight of three fresh plants in grams (April 9).

***Minimum night temperature.

plant (Fig. 1) two weeks after treatment, the graph indicates that when no fertilizer was used there was no difference in growth with temperature increased from 50 to 60° F. However, with an increase from 50 to 60° F with starter treatments, both growth and nitrogen content values of the petioles were increased, and the slope of the lines indicate that nitrogen was accumulating more rapidly, particularly with 10-52-17 and 10-5-17 than plants were utilizing it in growth. A more pronounced influence on growth with little or no effect on nitrogen accumulation occurred when the temperature moved from 60 to 70° F, and with the 10-52-17 fertilizer, growth kept pace with nitrogen accumulation. With the 10-5-17 treatment, nitrogen accumulation was more pronounced than growth from 50 to 60° F, but did not increase with a temperature change from 60 to 70° F.

Soluble Phosphorus Concentrations as Influenced by Treatments

The influence of temperature and soluble fertilizer treatment on the soluble phosphorus accumulation of tomato leaf petioles at three stages of early growth are shown in Table III. A decrease in phosphorus from 292 ppm found in petioles at the time of setting to from 94 to 131 ppm with the water treatment found in petioles three days later suggests a dilution by rapid growth or a conversion of the phosphorus to some insoluble form. At the end of one week phosphorus declined to 30 ppm, but by the end of two weeks, under more favorable 60 to 70° F temperatures, an increase

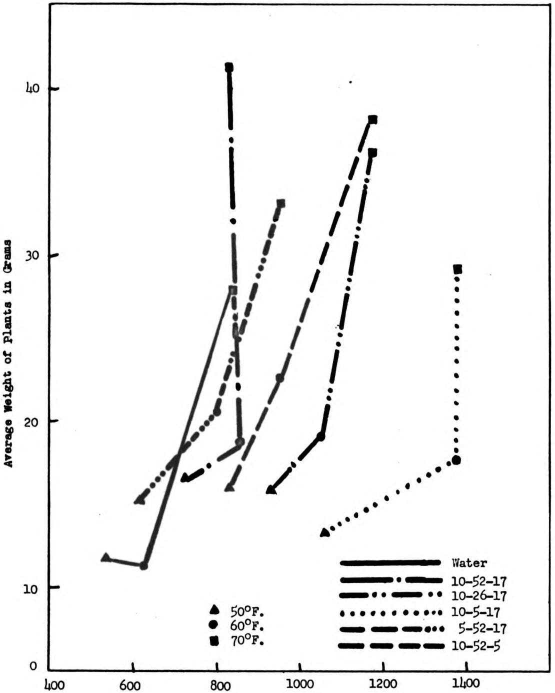

Figure 1

Influence of Treatment and Temperature on Growth and Soluble Nitrogen Content of Tomato Plants Fourteen Days After Treatment was found. At all temperatures after one week, the low phosphorus treatment resulted in the lowest phosphorus content in the petioles. It is interesting that at 70° F the phosphorus content was maintained at as high a level after two weeks growth as at 60° F in spite of the fact that fresh plant weight was 2. 5 times as great. This would indicate that the temperature conditions that favored growth favored the availability of the soil phosphorus and its absorption by the plant.

When the soluble phosphorus concentrations in leaf petioles a week after treatment were plotted against the average weight of the plant (Fig. 2), two weeks after treatment, it was found that phosphorus concentration in the petioles was definitely correlated with the quantity applied in the fertilizer. With the 10-5-17 and the 10-52-5 treatments, an increase in temperature from 50 to 60° F resulted in a growth rate that exceeded the rate of phosphorus accumulation. However, with the 10-26-17, 10-52-17, and 5-52-17 a change in temperature from 50 to 60° F resulted in both an increase in growth and phosphorus accumulation. An increase in temperature from 60 to 70° F resulted in no increase in phosphorus accumulation in the plant with either water, 5-52-17, or 10-52-17 which was probably due to the fact that at this temperature phosphorus accumulation was just keeping pace with growth. However, a temperature change from 60 to 70° F with the other treatments resulted in an increase in phosphorus accumulation that more than kept pace with the increased growth. Soluble phosphorus

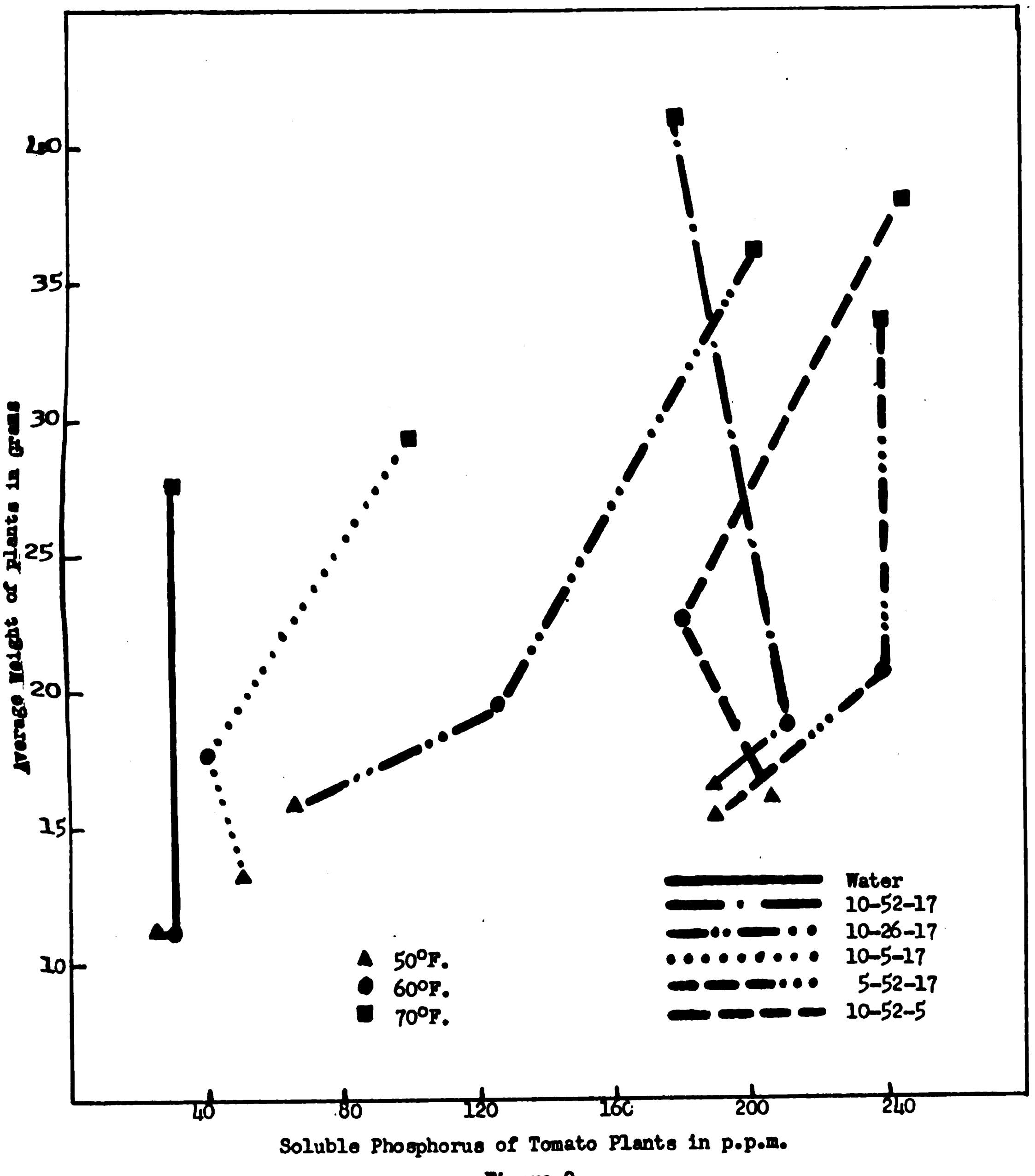

Figure 2

Influence of Treatment and Temperature on Growth and Soluble Phosphorus Content of Tomato Plants Fourteen Days After Treatment was maintained without much change in growth at the lower temperature, however at the higher temperature, plant growth increased rapidly and phosphorus utilization progressed at a higher rate than absorption, causing considerable growth, which resulted in a lower concentration of phosphorus. At the low temperatures (50 and 60° F), phosphorus was accumulated, but not utilized by plant growth.

Soluble Potassium Concentration as Influenced by Treatments

Table III shows that the potassium content of plant petioles was not appreciably influenced by the fertilizer treatments during the first 17 days of growth. At a later stage in growth, due to the potassium requirements of developing fruit, a different situation would likely occur. The values indicate that potassium absorption is influenced by temperature, as indicated by higher potassium values at the higher temperatures even with increased growth.

b) Soil Temperature Effects:

(1) Plant Growth

This study was undertaken to determine to what extent soil temperatures affect nutrient absorption of tomato plants. Various workers (16, 18, 50, 51) found that top growth of tomatoes was not materially affected by root temperatures between 60 and 70° F when nutrition and other growth conditions were favorable. Wanner (49) suggested that salt absorption from a higher external concentration varied more with root temperature than it did from concentration.

Methods and Materials:

Stokesdale tomatoes seeded September 14, 1954 were transplanted on November 15, three plants per culture, to two-and-a-half gallon glazed crocks containing a mixture of one-third peat and two-thirds loam soil that had been fertilized with a 3-12-12 mixture at the rate of 300 pounds per acre. The soil temperatures were regulated by placing the pots in tanks of water. The temperature in the four tanks, each containing 12 pots, was thermostatically controlled at either 46°, 54°, 62° or 70°F. The minimum night air temperature was 68°F. Each of the treatments listed below was applied at time of planting to three pots at the rate of one-half pint per pot.

Chemical Used

1. Water

	Chemical Used*
2. 10-52-17	50% *Di-ammonium phosphate 50% Mono-potassium phosphate
3. 10-52-0	50% by weight - Di-ammonium phosphate + phosphoric acid to make up analysis.
4. 10-52-0	Mono-ammonium phosphate 85% by weight.

Plant petiole samples were taken at planting time, November 15, and after planting, on November 17, 18, 19, 20, 22, and 24. One plant in each pot was allowed to grow to January 25, and then harvested, and pertinent data recorded.

The same experiment was repeated with similar soil, with plants transplanted to the pots on January 27. Fresh petioles of two plant samples were taken on January 27, 29, 30, 31, February 1, 3 and 4, 1955. The individual analyses from both experiments were combined with respect to time of sampling for chemical analysis.

Results:

Three days after transplanting all the plants in the 62° and 70° F temperature tanks were turgid and showed signs of root growth. The plants at the 54° F root temperature were slightly wilted and had made very little root growth, whereas the plants in the 46° F tank were quite wilted and displayed no visible signs of renewed root growth. Fifteen days after transplanting, all the leaves on the plants at the 46° F root temperature were

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*Percentages equivalent to one ounce per gallon of water.

chlorotic and the lower leaves were abscissing. Plants at the 54° F root temperature showed fair growth, and plants at the 62° and 70° F root temperature had good growth and color. Thirty days after treatment, plants at the 46° F root temperature were very chlorotic and stunted; however, plants at the 54°, 62° and 70° F root temperatures showed good growth and color.

Table IV shows that the average total weight per plant after 70 days growth increased very significantly with an increase in the root temperature. There were no differences in plant growth between the soluble fertilizers; however, they were all significantly greater than plants receiving only water. At 46° F plant growth was somewhat better with water than with any fertilizer treatment. At the higher temperatures, starter treatments were beneficial and significantly so at 62 and 70° F. At the 70° F soil temperature, treatments 10-52-0 (di-ammonium phosphate + phosphoric acid) and 10-52-0 (mono-ammonium phosphate) produced heavier plants than those receiving either water or 10-52-17. The increase in plant weight with an increase in root temperature may be related to accelerated water absorption at the higher soil temperature, as indicated by Kramer (22).

When the relative values for plant growth at different soil and air temperatures were compared from data in Figure3 it was evident that there was a 47 percent drop in plant weight when the air temperature was lowered from 70° to 60° F, and only a 16 percent drop in plant weight when the soil temperature was lowered from 70° to 62° F. Apparently, plant

TABLE IV

Average Fresh Weight of Tomato Plants Grown at Different Root Temperatures and with Various Starter Treatments.

Treatment	Degrees F 46	54	62	70	Avg. Fresh Weight of Plants
	(grams fresh weight per 3 plants)				
1. Water	10.67	70.66	107.30	113.0	75.41
2. 10-52-17	5.67	91.66	145.32	133.33	94.00
3. 10-52-0 $(NH_4)_2HPO_4$ + H_3PO_4	6 33	84.00	135 65	177.98	100.99
4. 10-52-0 $NH_4H_2PO_4$ 85% by weight	7.67	75.33	115.32	174.30	93.16
Temperature Avg. Fresh Weight of Plants	7.58	80.41	125.90	149.65	

		Treatment X Temperature	Treatment	Temperature
L.S.D.	.05	24.02	11.99	10.68
	.01	32.65	16.30	16.18

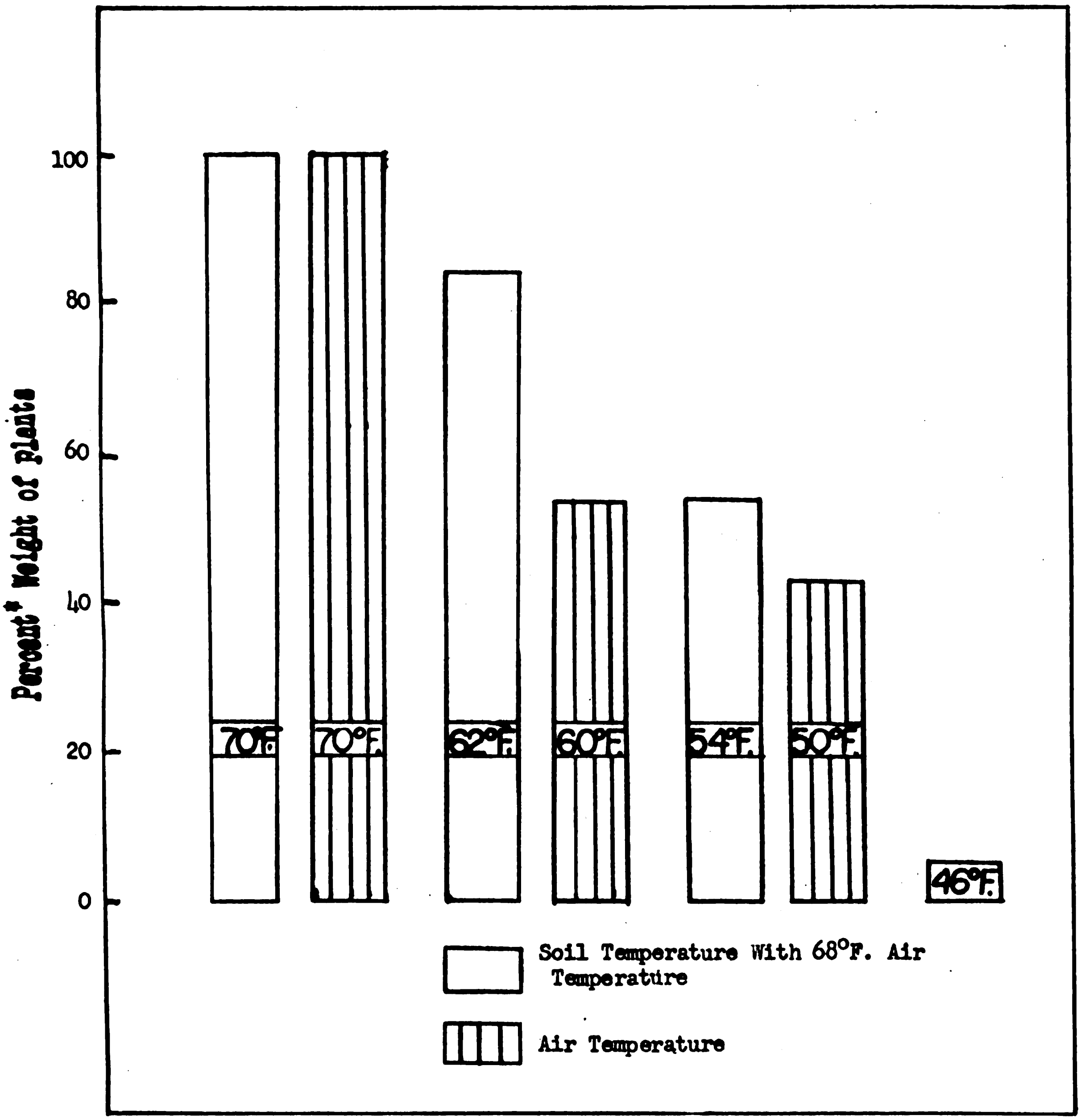

Figure 3

Comparative Effect of Root and Air Temperature on Growth of Tomato Plants

*Percent weight of plants with those grown at 70°F.

growth is not depressed to any extent at 62° F soil temperature, if the air temperature is 68° F. When the soil temperature was lowered from 62 to 54° F, there was a 30 percent decrease in plant weight, indicating that the critical soil temperature for tomato plant growth lies somewhere between 62 and 54° F. A lowering of air temperature of 10° F from 60 to 54° F reduced growth 10 percent. A further decrease of 48 percent in plant weight resulted when the soil temperature was lowered from 54 to 46° F.

Table V (a) indicates a significant increase in plant height when the root temperature was increased from 46 to 70° F. The height of the plant was also increased with an increase in temperature, especially between 46 and 54° F. The top weight at 70° F was almost twice that of plants grown at 54° F. The root weight of plants was also significantly increased with an increase in the soil temperature. Soil temperature influences top growth relatively more than root growth. The top weight increased about 17 times when the temperature was increased from 46 to 70° F, but the root growth increased only seven times for the same temperature change. It appears evident that soil temperature had a considerable influence on plant growth due to stimulating nutrient absorption and plant metabolism.

Tables V (b) and VI indicate that the starter treatments had no significant effect on the average root weight and height of tomato plants, and there was only a significant increase in the top weight (Table V-b) of plants

TABLE V

The Effect of Temperature and Soluble Fertilizer Treatment on Plant Development

(a) Root Temperature

Temperature (degrees F)	Avg. height (inches)	Avg. top weight	Avg. root weight	Avg. total weight of plants
46	7.27	5.54*	2.04	7.58
54	19.17	70.74	9.67	80.41
62	27.54	115.9	10.00	125.9
70	31.52	135.57	14.08	149.65
L.S.D. .05	1.83	7.62	1.90	10.68
.01	2.77	11.54	2.88	16.18

*Average of 12 plants in grams.

(b) Fertilizer Treatment

Treatments	Avg. top weight	Avg. root weight	Avg. total weight of plants
Water	66.83*	8.57	75.4
10-52-17	84.66	9.34	94.0
10-52-0 $(NH_4)_2HPO_4$ $+H_3PO_4$	92.00	9.00	101.00
10-52-0 $NH_4H_2PO_4$	84.33	8.84	93.17
L.S.D. .05	12.94	N.S.	11.99
.01	19.59		16.30

*Average weight in grams.

TABLE VI

The Average Height of Plants As Influenced by Temperature and Soluble Fertilizer.

Treatments	Temperature (degrees F)				Average height
	46	54	62	70	
Water	7.17*	18.0	28.5	27.16	20.3
10-52-17	6.92	19.8	29.6	31.3	21.8
10-52-0 $(NH_4)_2HPO_4+H_3PO_4$	7.50	18.3	27.7	35.0	22.1
10-52-0 $NH_4H_2PO_4$	7.50	19.0	25.7	32.6	21.2
L.S.D. for same treatment at different temperatures .05				3.63	N.S.
.01				5.20	

*Average height of three plants measured in inches.

receiving starter treatments when compared with those receiving only water.

Table VI shows a significant increase in height with an increase in temperature from 46 to 62°F for all the treatments, but no significant increase with water and 10-52-17 from the 62 to 70°F temperature. However, plants receiving either di-ammonium phosphate plus phosphoric acid or mono-ammonium phosphate were significantly taller than with water or 10-52-17 at 70°F. A possible reason for the lack of stem elongation for plants supplied with both water and 10-52-17 as compared to 10-52-0 (di-ammonium phosphate plus phosphoric acid) and 10-52-0 (mono-ammonium phosphate) with an increase in temperature from 62 to 70°F might be associated with earlier flowering on the shorter plants. Relative nitrogen accumulation was lower and potassium higher in the shorter plants than in plants receiving di-ammonium and mono-ammonium phosphate, resulting in a less vegetative condition of the plants. Other workers have found (23, 35) that when the soil nitrogen is increased it may encourage excessive vegetative growth, which in turn, delays maturity. Potassium in the soil tends to overcome the effects of high nitrogen (23) and if present in large amounts in the soil, will tend to be absorber and accumulated in excess of need.

Flowers

There was a significantly greater number of flowers and fruit 30 days after treatment on plants maintained at root temperatures of 70° F as compared with those grown at lower soil temperatures (Table VII). However, by the 50th day after treatment, flowering had increased at all temperatures except at 46° F. At 46° F flowering was less than that observed at any other temperature because the flowers had fallen off. Twenty-two days later there was still no increase in flower number at 46° F, but at each of the higher temperatures flower number showed progressive significant increases. Thus, from the table it is evident that the largest number of flowers or fruit 30, 50, and 72 days after treatment were at the 70° F soil temperatures.

Thirty days after planting there was no significant difference in the number of flowers produced among plants grown at the 46, 54 or 62° F soil temperatures. However, after 50 and 72 days the plants grown at 54 and 62° F had a significantly greater number of flowers than those grown at 46° F.

These results show that plants grown at a soil temperature of 70° F flowered earlier than those grown at a lower soil temperature and also retained a greater number of blossoms throughout the experiment. A possible explanation for this phenomenon could be that at the higher soil

TABLE VII

Effect of Soil Temperature on the Average Numbers of Flowers and Fruits per Plant.

Soil Temperature (degrees F)		Days After Treatment 30	50	72
46		0.167*	0.08	0.08
54		1.08	1.67	7.00
62		0.33	2.08	10.17
70		2.50	4.92	15.00
L.S.D.	.05	1.11	.715	2.32
	.01	1.68	1.08	3.52

TABLE VIII

Effect of Soluble Fertilizers on the Average Number of Flowers and Fruit per Plant.

Treatment		Days After Treatment 30	50	72	Avg. no. flowers that abscissed
Water		.50*	2.33	6.67	1.917
10-52-17		.42	2.58	9.00	1.417
10-52-0 $(NH_4)_2HPO_4$ $+H_3PO_4$		.83	2.08	9.08	1.167
10-52-0 $NH_4H_2PO_4$		.58	1.76	7.50	1.333
L.S.D.	.05	N.S.	N.S.	1.32	.511
	.01			1.80	N.S.

*Average number of flowers plus fruits per 12 plants.

temperature the plant grew more rapidly and reached flowering sooner, resulting in a greater number of blossoms; or, that the 70° F soil temperature was optimum for tomato plant growth and resulted in earlier maturity.

The data in Table VIII indicate that there was a significantly greater number of flowers and fruit on the plants receiving 0-52-17 or 10-52-0 (di-ammonium phosphate) as compared to those receiving only water 72 days after treatment. There was an increase in the number of flowers on the plants receiving di-ammonium phosphate plus phosphoric acid over those receiving mono-ammonium phosphate. Table VIII also indicates that plants receiving starter solutions had significantly fewer abscissed flowers than plants receiving only water.

Figure 4 shows the interactive effect of soil temperature and fertilizer solutions on flower production. At 62° F, plants receiving 10-52-17 produced more flowers after 72 days growth than plants of other treatments. At 70° F, however, plants receiving di-ammonium phosphate plus phosphoric acid or mono-ammonium phosphate produced more flowers than those treated with 10-52-17 or water.

(2) Plant Composition

Soluble Nitrogen: The low nitrogen content of the soil used in the experiment appeared to be the limiting factor for growth, as indicated by the low concentration of soluble nitrogen in tomato plant petioles four

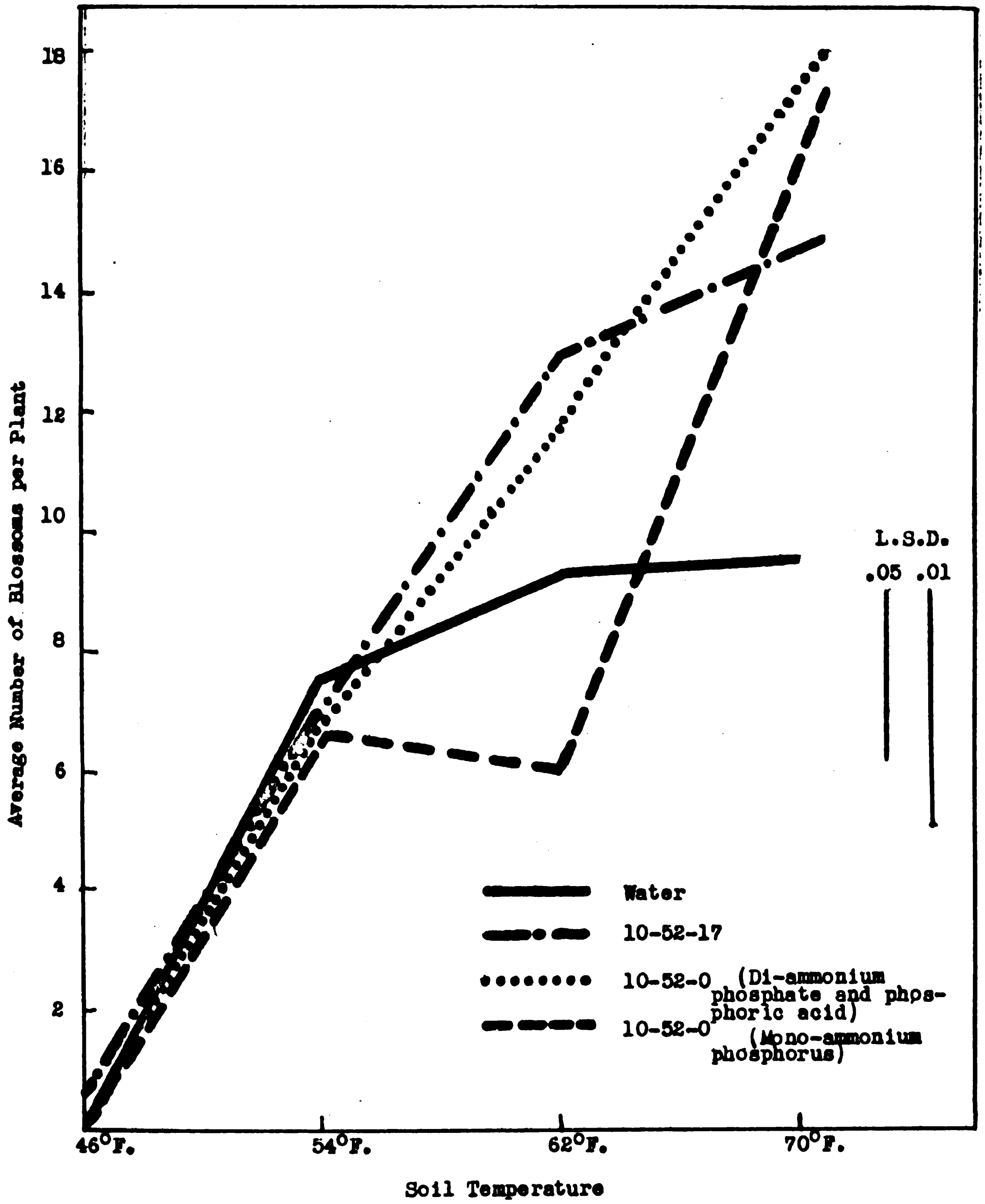

Figure 4

The Effect of Temperature and Fertilizer Treatment on Final Flower and Fruit Number per Plant days after treatment (Table IX). At the conclusion of the experiment 70 days after treatment, fertilized plant petioles grown at 46, 54 and 62° F (root temperature) contained from three to more than ten times as much soluble nitrogen as did those receiving only water. No differences occurred at the 70° F temperature.

Soluble Phosphorus: Two and a half days after treatment there was 50 percent more phosphorus in most of the petioles of the fertilized plants. Soil temperature apparently had little effect on accumulation. Four and a half days after treatment some new growth was visible. The effect of the starter solution became more pronounced and apparently plants accumulated phosphorus more rapidly as indicated by analysis of leaf petioles from mono-ammonium phosphate than from the complete starter or di-ammonium phosphate plus phosphoric acid. Seventy days after treatment the phosphorus content was still maintained at a high level while the nitrogen deficiency, particularly at higher temperatures, even on nitrogen treated plants partially masked any consistent difference caused by different sources of phosphorus.

When the soluble phosphorus concentrations of leaf petioles in plants treated with water, 10-52-17, or 10-52-0 (mono-ammonium phosphate) were plotted for the low (46° F) and the high (70° F) soil temperature at three different sampling dates (Figure 5a, b), it was found that at the

TABLE IX

Concentration of Soluble Nitrogen and Phosphorus in Tomato Leaf Petioles at Different Sampling Dates as Influenced by Soluble Fertilizer and Soil Temperature.

Treatment	Days After Treatment	46° F			54° F			62° F			70° F		
		Avg. wt.	Sol. N	Sol. P	Avg. wt.	Sol. N	Sol. P	Avg. wt.	Sol. N	Sol. P	Avg. wt.	Sol. N	Sol. P
	0		792*	359									
Water	2.5	10.67**	615	258	70.66	473	232	107.30	662	203	113.0	566	221
	4.5		464	188		351	212		529	231		488	170
	8.0		447	199		428	233		442	211		547	149
	70.0		170	47		87	566		69	320		52	563
10-52-17	2.5	5.67	436	325	91.66	372	385	145.32	557	316	133.33	398	368
	4.5		361	368		351	396		576	450		466	424
	8.0		487	583		570	479		592	364		536	454
	70.0		507	336		497	492		223	295		59	566
10-52-0 $(NH_4)_2HPO_4$ $+H_3PO_4$	2.5	6.33	489	418	84.00	360	287	135.67	629	275	177.98	288	331
	4.5		360	332		498	329		591	352		439	375
	8.0		526	574		585	361		729	309		822	280
	70.0		599	442		580	424		317	285		84	365
10-52-0 $NH_4H_2PO_4$	2.5	7.67	363	336	75.33	666	255	115.32	709	337	174.30	399	476
	4.5		478	424		543	534		600	610		562	500
	8.0		487	590		517	392		780	601		783	391
	70.0		569	534		488	353		783	189		34	522

	Treatment X Temperature	Treatment	Temperature
L. S. D. for plant weight .05	24.02	11.99	10.68
.01	32.65	16.30	16.18

*Average of 4 chemical analysis.

**Average weight of 3 plants 70 days after treatment and growth in the temperature tanks.

Figure 5

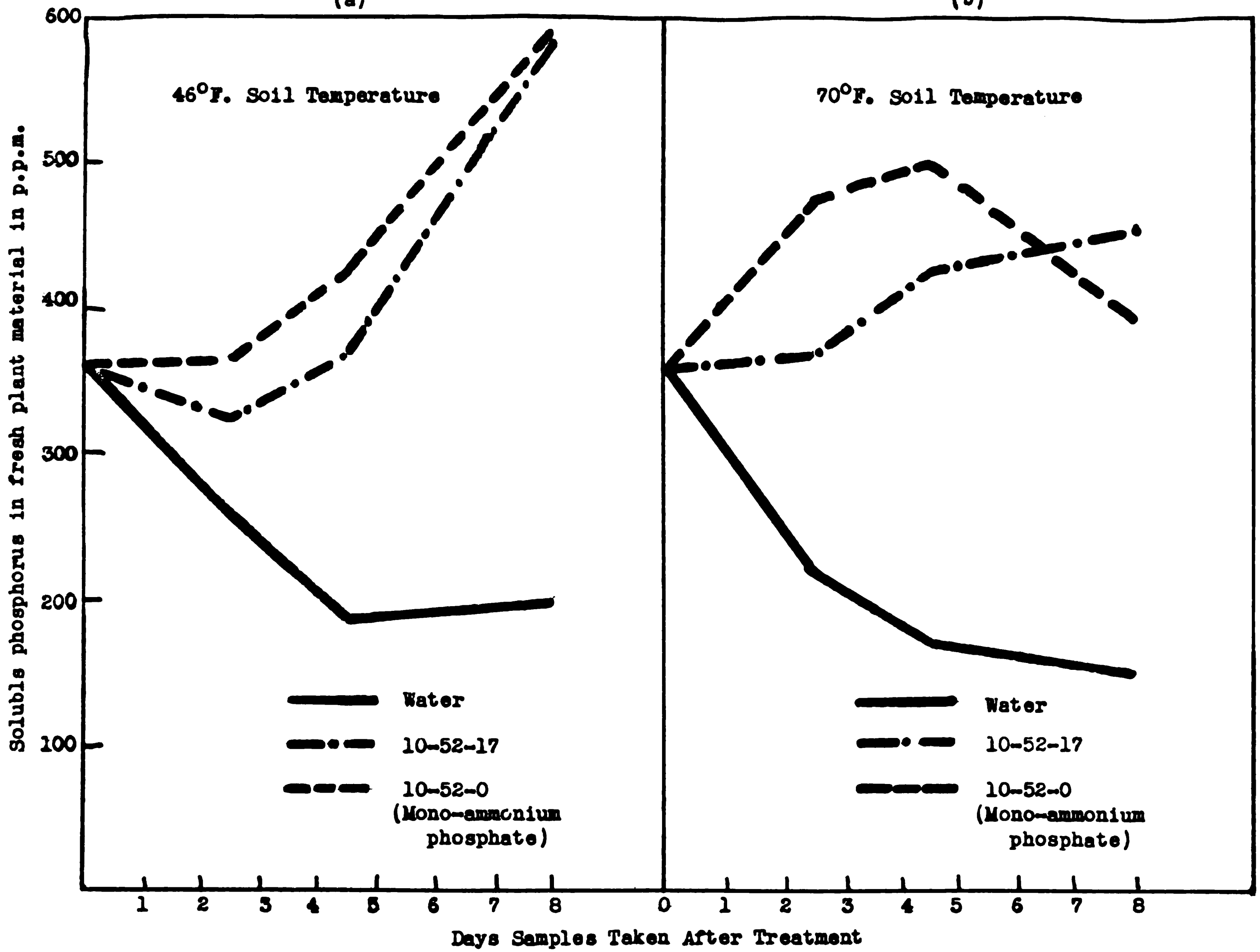

Figure 5 a, b,

Concentration of Soluble Phosphorus in Tomato Plants at Different Soil Temperatures as Effected by Various Starter Treatments high temperature the application of phosphorus as mono-ammonium phosphate resulted in a higher concentration 2.5 and 4.5 days after treatment than 10-52-17. Eight days after treatment, the phosphorus concentration of the leaf petioles was about the same for either fertilizer, but was low in non-fertilized plants.

Soluble Potassium: Soil temperature apparently had little influence on the concentration of soluble potassium found in the leaf petioles at any soil temperature or starter treatment, irrespective of date of sampling. The concentration found in plants averaged from 5,000 to 6,000 ppm.

Soluble Nutrient Levels in Tomato Leaf Petioles as Influenced by Different Soluble Fertilizer Solutions

A study was made of the rapidity of absorption of materials from starter solutions as reflected in their concentrations in tomato and pepper plants following treatment.

Methods and Materials:

Field planted tomatoes (variety Longred), and peppers (variety California Wonder) were treated with various fertilizer solutions, and samples were taken at three-day intervals for chemical analysis. The fresh leaf petioles were analyzed for soluble phosphorus, potassium and nitrate nitrogen (4, 6).

Tomatoes: Plants were set and treated in a replicated experiment in a fertile soil on July 18, 45 days after seeding. Leaf petioles from six plants were taken for analysis from each treatment on July 21, August 3 and 7, and compared with samples taken before treatment. The treatments follow:

	Chemicals Used*
1. Water	
2. 10-52-17	50% Di-ammonium phosphate 50% Mono-potassium phosphate
3. 10-26-17	50% Mono-potassium phosphate 31% Ammonium nitrate

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*Percentages equivalent to four pounds in 50 gallons of water. Each plant received one-half pint of the solution at transplanting time.

	Chemicals Used*
4. 10-0-17	37% Potassium 16% Ammonium nitrate
5. 21-52-0	100% Di-ammonium phosphate
6. 0-52-34	100% Mono-potassium phosphate

Peppers: Sixty day old California Wonder pepper plants were field planted, five plants to a plot, on June 12 in a replicated experiment and treated with three different starter solutions. They were sampled at three-day intervals on June 15, 18, 22, 25, 28 and July 3, 1953. The fresh leaf petioles were analyzed for soluble phosphorus, potassium and nitrate nitrogen (4, 6). Pepper plants received the following starter treatment:

	Chemicals Used*
1. Water	
2. 10-52-17	*50% Di-ammonium phosphate 50% Mono-potassium phosphate
3. 20-30-17	40% Potassium nitrate 40% Victamide 20% Urea

Results:

Tomatoes: Three days after planting (Table X and Figure 6), the concentration of soluble phosphorus in the leaf petioles of plants that had

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*Percentages equivalent to four pounds in 50 gallons of water. Each plant received one-half pint of the solution at transplanting time.

TABLE X

The Influence of Fertilizer Solutions on the Concentrations of Nutrients in Tomato Leaf Petioles at Different Stages of Development.

Date of Harvest	Nutrient	Water (ppm)	10-52-17 (ppm)	10-26-17 (ppm)	10-0-17 (ppm)	21-52-0 (ppm)	0-52-34 (ppm)
July 18 Prior to Planting	Nit. N	115					
	Sol. P	575					
	K_2O	7,600					
July 21	Nit. N	135*	585	815	800	365	185
	Sol. P	450	700	550	350	745	700
	K_2O	7,200	7,000	6,700	6,100	6,550	7,040
July 24	Nit. N	815	1,060	1,060	1,140	950	710
	Sol. P	290	500	450	230	700	560
	K_2O	4,700	5,390	6,520	---	4,450	5,800
July 27	Nit. N	925	1,005	960	970	850	800
	Sol. P	220	535	400	175	535	425
	K_2O	4,450	4,780	4,675	4,525	4,475	3,960
July 30	Nit. N	1,125	1,125	1,095	1,170	1,140	1,155
	Sol. P	255	450	325	200	375	320
	K_2O	6,190	5,280	5,080	4,800	4,760	5,240
August 3	Nit. N	1,205	1,075	1,060	1,125	1,295	1,280
	Sol. P	200	315	235	200	325	280
	K_2O	6,105	5,700	6,040	5,280	5,800	6,020
August 7	Nit. N	1,340	1,250	1,190	1,250	1,200	1,160
	Sol. P	190	275	220	180	335	250
	K_2O	6,580	6,440	6,560	6,420	6,520	6,980

*Averages from two three-plant petiole samples.

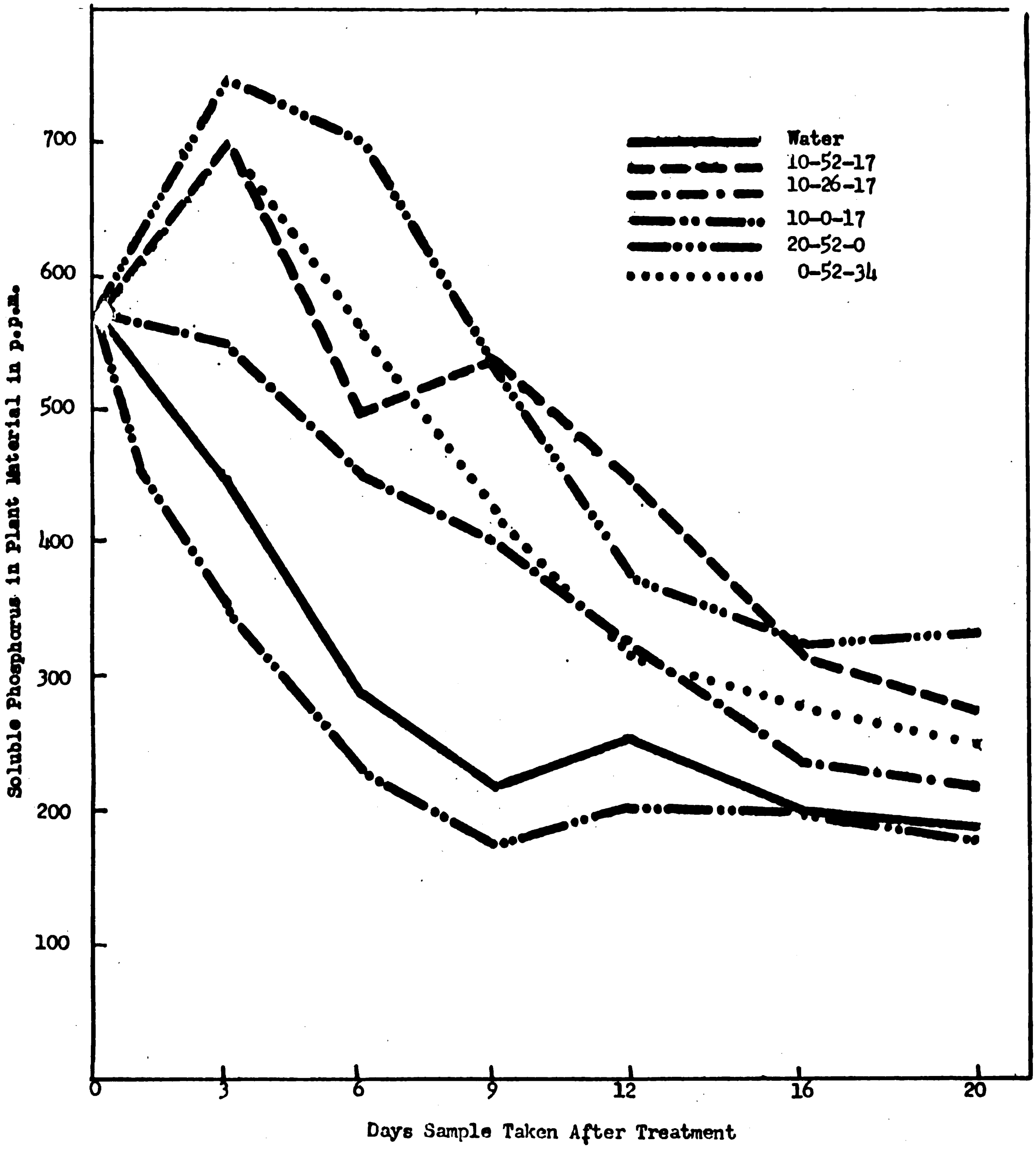

Figure 6

Concentration of Soluble Phosphorus in Tomato Plants at Different Sampling Dates received high phosphorus starter treatments had increased from 575 ppm to approximately 700 ppm. At later samplings, due to growth, phosphorus in petioles of plants with high P treatment declined, but was maintained at a higher level than in petioles of plants from the lower P treatments. Fifteen days after treatment, the phosphorus concentration in the leaf petioles was greatly reduced, probably due to phosphorus utilization in growth by the plant and fixation by the soil. Petioles of plants treated with phosphorus tended to have a higher phosphorus concentration for each sampling date up to fifteen days after treatment than plants receiving lower amounts of phosphorus, in fact, petioles of plants receiving starter treatments with only potassium and nitrogen had a lower phosphorus concentration than those receiving no fertilizer solution.

The nitrate nitrogen contents in leaf petioles of plants that had received water or 0-52-34 solution was much lower three and six days after transplanting than in plants that had received nitrogen in the fertilizer solution. However, after two weeks of growth in a fertile soil, there was little effect of the nitrogen fertilizer indicated in the nitrogen content of the petioles. All plant petioles contained relatively high nitrogen suggesting that the soil was adequately supplied with this nutrient.

The potassium content of the starter solution did not appreciably influence the potassium concentration in the tomato leaf petioles.

Peppers: The soluble phosphorus content of leaf petioles of pepper plants treated with 10-52-17 (Table XI and Figure 7), and sampled during early growth, was higher at all the sampling dates up to 21 days after transplanting than that of plants treated with 20-30-17 which, in turn, was higher than that of those which received only water. This indicates that starter solutions high in phosphorus tend to facilitate phosphorus accumulation in leaf petioles more readily than do those higher in nitrogen and lower in phosphorus.

The nitrate nitrogen content was higher (Table XI and Figure 8) in petioles of plants receiving the starter solution 20-30-17 than in those receiving 10-52-17 six days after treatment. Phosphorus concentrations remained higher 21 days after treatment in petioles of plants supplied with 10-52-17 fertilizer than in plants supplied with 20-30-17 or water, indicating a continued high accumulation of phosphorus as well as nitrogen.

TABLE XI

The Influence of Fertilizer Solutions on the Concentration of Nutrients in Leaf Petioles of Pepper Plants at Different Stages of Development.

Date Sample Taken	Nutrient	Water (ppm)	10-52-17 (ppm)	20-30-17 (ppm)
June 15	Nit. N	925*	840	1,290
	Sol. P	350	680	385
	K_2O	8,560	7,700	9,520
June 18	Nit. N	220	915	1,275
	Sol. P	435	660	450
	K_2O	7,320	8,990	8,620
June 22	Nit. N	530	1,300	1,410
	Sol. P	470	775	525
	K_2O	8,660	8,815	8,100
June 25	Nit. N	585	1,170	1,360
	Sol. P	350	680	445
	K_2O	7,600	8,670	8,330
June 28	Nit. N	425	1,385	1,425
	Sol. P	375	590	420
	K_2O	8,390	7,200	7,660
July 3	Nit. N	830	1,340	1,340
	Sol. P	320	600	460
	K_2O	8,130	7,625	7,390

*Average from two five plant samples.

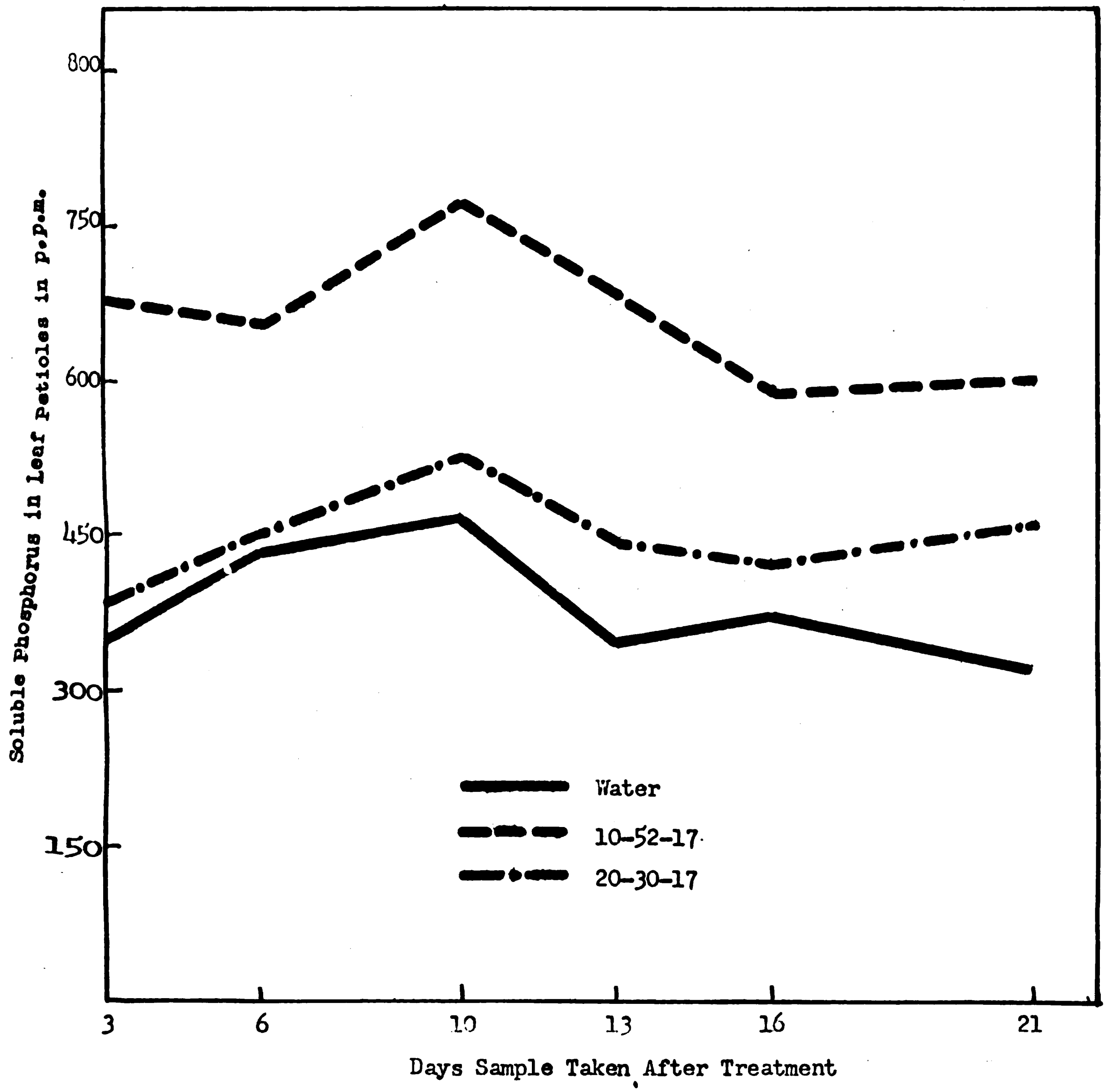

Figure 7

Concentration of Soluble Phosphorus in Pepper Plants at Different Sampling Dates

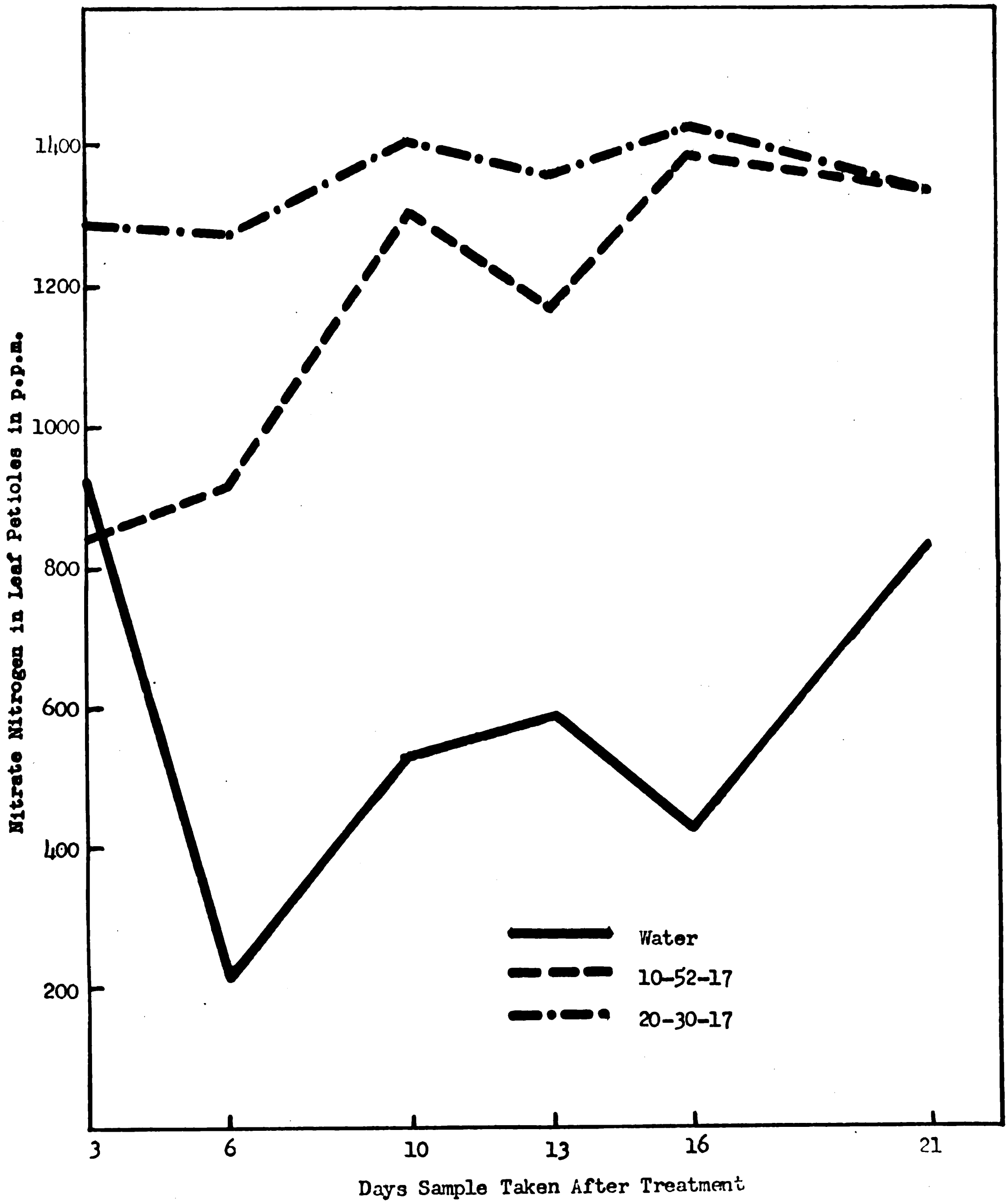

Figure 8

Concentration of Nitrate Nitrogen in Pepper Plants at [illegible]

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Tomato and Tobacco Root Growth as Affected by Different Analyses and Concentrations of Fertilizer Solutions

In transplanting a high survival is desirable. Sayre (37, 38, 39) in his work with tomatoes found that starter solutions resulted in high plant survival and early resumption of growth. The object of this study was to determine how tomato and tobacco root growth may be influenced by different fertilizer analyses and concentrations. Tobacco plants were used because favorable results have not always been obtained when this crop is transplanted together with a starter solution.

Methods and Materials:

On June 4, 1955 tomato (Stokesdale) and tobacco (flue cured type) seeds were sown in vermiculite. The tomatoes were transplanted on June 16, and the tobacco on July 7 to flats of sandy loam soil.

On July 12, 1955 when the tomato plants averaged 9 to 12 inches in height, they were removed from the flats and the roots were washed and trimmed to eight centimeters in length, and then transplanted to six-inch pots of sandy loam soil and grown in a coldframe at an average temperature of 87° F. Each pot containing one plant was then treated with 250 millimeters of starter solution. All pots were randomized and replicated three times for both treatments and harvest date. There were 13 treatments (as indicated below) and four replications. Root growth for the four replicates for each trea

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treatment was recorded two, four, and seven days after transplanting, necessitating the use of 156 observations. The treatments were as follows:

Treatment Number	Analysis	Concentration Ounces per Gallon	Chemicals Used
1.	Water (control)		
2.	10-52-17	1	50%* Di-ammonium phosphate 50% Mono-ammonium phosphate
3.	10-52-17	2	Same as Treatment 2.
4.	10-52-17	4	Same as Treatment 2.
5.	10-52-0	1	50% Di-Ammonium phosphate + phosphoric acid to make up analysis.
6.	10-52-0	2	Same as Treatment 5.
7.	10-52-0	4	Same as Treatment 5.
8.	0-52-17	1	50% Mono-ammonium phosphate + phosphoric acid to make up analysis.
9.	0-52-17	2	Same as Treatment 8.
10.	0-52-17	4	Same as Treatment 8.
11.	10-0-17	1	36% Potassium nitrate 15% Ammonium nitrate
12.	10-0-17	2	Same as Treatment 11.
13.	10-0-17	4	Same as Treatment 11.

Osmotic pressure was determined (43) by measuring the conductivity of a 2:1 diluted soil sample in a solubridge and using the formula:

*Percentage equivalent to one, two or four ounces per gallon of distilled water.

Osmotic pressure in atmospheres = Conductance in Mhos. X 10^{-5} X 360. The root length of tomatoes was obtained by measuring the average increase in length of four to six new roots on each plant.

The tobacco root study experiment was carried out in a similar manner with the exception that roots were trimmed back to four instead of eight centimeters prior to adding the shorter treatments.

Results:

Tomatoes: Table XII indicates that two days after treatment and at the low concentration the starter treatment without phosphorus significantly retarded the new root growth, and the starter solution without nitrogen gave no significant difference in root growth over plants receiving only water. When both nitrogen and phosphorus were included, there was a significant increase in root growth, and a further increase was observed with 10-52-17 at the one ounce per gallon concentration.

The plants receiving 10-52-17 at the one ounce concentration had four times as much root growth as 10-0-17, indicating that starter solutions should have a high phosphorus level. With applications at the low concentration, the treatments can be rated as follows with respect to increasing root growth: 10-0-17 Water 0-52-17 10-52-0 10-52-17. At the two-ounce per gallon concentration measured two days after application, the complete fertilizer gave a significant increase in root length over the other treatments, whereas the starter without nitrogen gave a

TABLE XII

Effect of Different Analyses and Concentrations of Fertilizer Salts on Root Growth of Tomato Plants.

Treatment	Rate	After 2 Days pH	After 2 Days Osmotic pressure	After 2 Days Avg. increase in root length (cm)	After 4 Days pH	After 4 Days Osmotic pressure	After 4 Days Avg. increase in root length (cm)	After 7 Days pH	After 7 Days Osmotic pressure	After 7 Days Avg. increase in root length (cm)
Water		6.58	.111**	.39*	6.94	.048	2.82	6.45	.042	11.80
10-52-17	1+	6.48	.167	.85	6.27	.126	4.60	6.27	.120	11.88
10-52-17	2	6.68	.175	.65	5.97	.193	2.53	6.27	.130	8.88
10-52-17	4	6.70	.246	.21	6.10	.252	.70	5.97	.240	1.93
10-52-0	1	6.42	.130	.58	5.59	.161	3.78	6.19	.102	11.33
10-52-0	2	6.49	.161	.33	5.68	.179	2.68	6.06	.150	8.38
10-52-0	4	6.52	.192	.10	5.80	.218	1.20	6.52	.135	5.50
0-52-17	1	6.48	.098	.41	6.03	.084	4.63	6.47	.049	12.18
0-52-17	2	6.23	.108	.07	5.99	.077	4.55	6.30	.063	10.43
0-52-17	4	6.10	.142	.02	5.91	.089	3.75	6.10	.069	5.38
10-0-17	1	6.96	.168	.20	6.78	.103	5.50	6.73	.058	11.30
10-0-17	2	6.54	.271	.18	6.74	.096	4.38	6.68	.049	7.93
10-0-17	4	6.65	.516	.14	6.97	.113	2.63	7.05	.082	9.58
L. S. D.	.05			.14			0.96			2.68
	.01			.11			1.29			3.59

*Average root length of four replicates.
**Osmotic pressure in atmospheres (average of three soil solution determinations).
+Rate - ounces of fertilizer salt per gallon of water.

highly significant decrease in root growth. This suggests that at a higher concentration an unbalanced fertilizer may have a more retarding influence on root growth than its osmotic concentration. This has been noted by Wallace (47) who believed that an excess of one element, phosphorus or potassium, could lead to the deficiency of N which could ultimately result in a deranged metabolism and injury. The roots of the plants which had received the low concentration starter solution lacking phosphorus were very poor two days after treatment, but in another two days had become significantly better than those which had received the other treatments. Seven days after treatment there was no difference in root growth between plants which had received water or any of the lower rate fertilizer applications. However, at high concentrations the complete fertilizer (10-52-17) was the most injurious resulting in one-quarter as much root growth as was found on plants treated with 10-0-17. The fertilizer without phosphorus did not result in better root growth than did water. The root injury from the complete fertilizer (10-52-17) at the four-ounce concentration may have been associated with the high osmotic pressure of the solution.

Tobacco: Two days after transplanting and treatment with the various salts the roots of tobacco plants which received the smaller fertilizer application without potassium were significantly poorer (Table XIII) than were those of plants from the other treatments, which in turn, were all significantly better than those which received only water. The plants

TABLE XIII

Effect of Different Analyses and Concentrations of Fertilizer Salts on Root Growth of Tobacco Plants.

Treatment	Rate	After 2 Days pH	After 2 Days Osmotic pressure	After 2 Days Avg. increase in root length (cm)	After 4 Days pH	After 4 Days Osmotic pressure	After 4 Days Avg. increase in root length (cm)	After 7 Days pH	After 7 Days Osmotic pressure	After 7 Days Avg. increase in root length (cm)
Water		6.35	.081**	.29*	6.23	.093	1.45	6.44	.060	8.88
10-52-17	1+	6.10	.186	.58	5.86	.164	2.13	5.93	.163	6.38
10-52-17	2	6.13	.209	.16	5.84	.234	0.80	5.47	.298	6.44
10-52-17	4	6.59	.280	.02	6.34	.264	0.13	5.80	.300	2.13
10-52-0	1	6.09	.132	.30	5.80	.156	1.88	5.93	.137	7.25
10-52-0	2	6.00	.161	.13	5.54	.213	0.85	5.45	.194	6.13
10-52-0	4	6.23	.197	.01	5.83	.204	0.08	5.69	.222	1.63
0-52-17	1	5.93	.088	.44	6.03	.083	2.73	6.27	.066	10.25
0-52-17	2	5.68	.126	.24	5.73	.081	1.50	6.17	.078	7.25
0-52-17	4	5.59	.141	.05	5.75	.116	0.05	5.69	.094	1.20
10-0-17	1	6.16	.166	.43	6.43	.119	1.80	6.53	.070	4.88
10-0-17	2	6.19	.276	.18	6.35	.185	0.98	6.73	.085	2.25
10-0-17	4	6.18	.414	.05	6.27	.358	0.08	6.32	.210	0.75
L.S.D.	.05			.10			.45			3.37
	.01			.12			.60			4.52

*Average root length of four replications.

**Osmotic pressure in atmospheres (average of three sample determinations).

+Rate - ounces of fertilizer salt per gallon of water.

which did not receive potassium also gave the poorest root growth at the higher concentrations. Seven days after treatment the best roots were found on plants which had received the one-ounce concentration of 0-52-17. These plants which had received the complete starter treatment (10-52-17) or the treatment 10-0-17 had produced significantly poorer roots than had those which received the fertilizer without nitrogen. The 10-0-17 treatment was somewhat toxic to root growth of the tobacco plants at all three concentrations.

Comparison of Fertilizer Effects on Root Growth of Tomato and Tobacco

Figure 9 and Tables XII and XIII indicate that, in general, the root growth of tomato was more rapid than that of tobacco; however, there were some variations in growth response due to treatment. Figure 9 (a) shows that after two days, and at the low concentration, the root growth was about the same for both tobacco and tomato for the 0-52-17 treatment. The 10-0-17 caused a sharp drop in the root growth of the tomato, but had little effect on the roots of tobacco, indicating the possibility that phosphorus was not as essential for root initiation in tobacco as in tomato. In tomato, phosphorus seemed to be the most important factor in root initiation, whereas, in tobacco, potassium appeared to be more necessary for this response, or else the nitrate nitrogen was more desirable to tobacco roots but more detrimental to tomato roots. The most new root growth of tomato and tobacco occurred with the complete "starter solution".

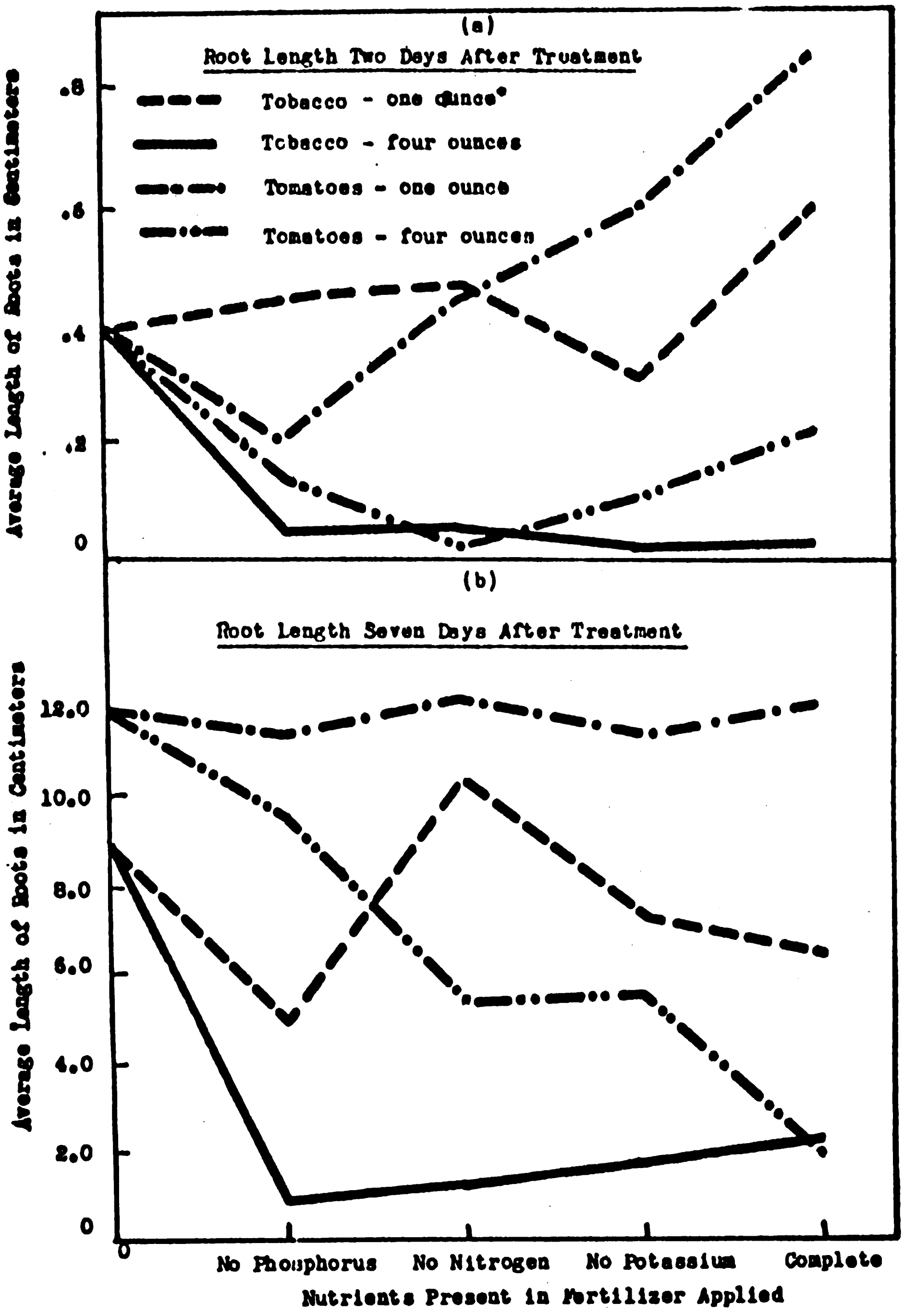

Figure 9 a, b.

Root Growth of Tobacco and Tomato Plants as Effected by Different Concentrations and Analyses of Fertilizer Salts Two and Seven Days After Treatment.

* concentration of fertilizer salt per gallon of water.

Two days after treatment root growth of both the tobacco and tomato was suppressed by the high concentration of the 0-52-17 treatment. The 10-0-17 treatment caused an increase in tomato but not in tobacco root growth. A possible explanation for this phenomena may be that tomato roots are more tolerant to the higher osmotic pressure of the solution than tobacco roots, or they are more tolerant to a lack of balance. With 10-52-0 there was a slight decrease in the root length for both the tomato and tobacco; however, tobacco root growth was still lower than that of tomato, yet the osmotic pressure of their soil solutions were the same, indicating either the possibility of a lower tolerance in tobacco to high osmotic pressures, or a higher potassium requirement.

Two days after treatment with 10-52-17 at the high concentration there was an increase in the root growth of tomato plants, whereas in tobacco root growth was depressed slightly more than for the other treatments. A possible explanation for differences in the response between the two crops could be that the complete fertilizer was better balanced to avoid toxicity for the tomato than for tobacco, and that with the better balance the high osmotic pressure of the solution was not as harmful.

The root growth of tomato plants (Figure 9 (b)) seven days after treatment at the one-ounce per gallon fertilizer concentrations showed only slight differences. A plausible explanation could be that the treatments that encouraged early root growth, favored top growth a little later.

Tobacco showed the most rapid seven-day root growth with the 0-52-17 treatment; however, when phosphorus was deficient, root growth was decreased considerably, but when phosphorus was added and potassium was absent from the treating solution, the root growth increased but not as much as when potassium and phosphorus were present together, in the absence of nitrogen. Also, root growth at the four-ounce concentration was greater for tomato than for tobacco plants with all treatments except the complete fertilizer. Both tomato and tobacco roots decreased considerably in length when nitrogen was absent from the starter treatment, indicating the need for nitrogen in root growth.

In tobacco the roots were three times as long with the complete fertilizer at the high concentration as with the starter solution lacking phosphorus, whereas tomato roots with the same concentration were three times as long with the 10-0-17 as with the complete fertilizer. Seven days after treatment and at the high concentration, tobacco roots were much smaller for all the fertilizer treatments than for those receiving only water, but in tomatoes only a slight reduction of root growth occurred with plants in the 10-0-17 treatment, but there was a marked reduction in root growth for the other treatments when compared with those receiving only water. There are various possible explanations for differences in root growth as the result of analyses and concentrations. The source of nitrogen in 10-0-17 is mainly nitrate, whereas analyses containing phosphorus contain an ammonium salt. Figure 9 (b) shows that seven days after treatment tomato plants treated with 10-0-17 had a good root growth perhaps due to the fact that nitrate nitrogen and potassium were absorbed together more readily, or tomato plants utilized some of the nitrogen and potassium in their growth, and so the osmotic pressure was reduced, whereas in tobacco root growth was stunted possibly because of little assimilation of nitrogen and potassium with a resultant higher osmotic pressure. Root growth was again decreased in the absence of potassium in the tomato plants, but increased in the tobacco plant. This injury could have been the result of the ammonium being absorbed quite readily and upsetting the metabolism in the plant roots (Hoagland 17).

The Solubility and pH of Different Chemicals Used in Starter Solutions

The solubility and pH of the different starter treatments in tap and distilled water were determined.

One pound of the starter treatment was dissolved in a gallon of high calcium tap and in distilled water, and the solution was checked for solubility after five minutes and 24 hours. Each solution was then diluted 1:16 in distilled or tap water.

The data (Table XIV) show that the following chemical mixtures: 23-27-11, 19-26-19, 12-61-0, 0-52-34, 14-0-46, and 16-63-0 were all highly soluble in both distilled and tap water within five minutes after they were added to the water. At the concentration of one pound per gallon, they did not precipitate out after 24 hours. The 10-52-17, 16-56-0 and 21-53-0 mixtures containing di-ammonium phosphate tended to form turbid solutions at the higher concentrations in distilled water, which cleared up when further diluted with distilled water. On the other hand, when these salts were dissolved in tap water at the high concentration, a precipitate occurred upon standing. The amount of precipitate depended on the concentration of di-ammonium phosphate used in the formula. However, when they were diluted in 1:16 distilled water, the precipitate usually disappeared, but if diluted in tap water, a slight turbidity persisted. The starter treatment Bonro 10-50-10 was less turbid when diluted either with distilled or tap water.

TABLE XIV

Solubility of Different Chemical Mixtures

Concentration - One Pound per Gallon of Water				Solubility				
				Salt dissolved in distilled water*		Salt dissolved in tap water**		
		pH at 23.5°C		Observed	Observed	Observed	Observed	Diluted
Analysis	Salts Used	Distilled water	Tap water	after five minutes	after 24 hours	after five minutes	after 24 hours	1:16 in tap water
23-27-11	25% Potassium nitrate 25% Urea 50% Di-ammonium phosphate	7.5	7.7	clear	clear	clear	clear	clear
10-52-17	50% Di-ammonium phosphate 50% Mono-potassium phosphate	6.8	6.6	slightly turbid	some precipitate	clear	moderately turbid	slightly turbid
19-26-19	25% Potassium nitrate 25% Urea 25% Mono-potassium phosphate	6.5	6.8	clear	clear	clear	clear	clear
16-56-0	50% Mono-ammonium phosphate 50% Di-ammonium phosphate	6.3	6.3	very slightly turbid	clear	very sl-ightly turbid	clear	clear
12-61-0	100% Mono-ammonium phosphate	4.1	4.2	clear in 1 minute	clear	clear in 1 minute	clear	clear
21-53-0	100% Di-ammonium phosphate	7.8	7.8	slightly turbid	some precipitate	very turbid	heavy pre-cipitate	medium turbid
0-52-34	100% Mono-potassium phosphate	4.4	5.5	clear	clear	clear	clear	clear
14-0-46	100% Potassium nitrate	6.2	6.2	clear in 2 minutes	clear	clear in 2 mins.	clear	clear
10-50-10	Bonro (commercial product)	4.3	4.4	slightly turbid	some precipitate	very turbid	some pre-cipitate	slightly turbid
16-63-0	100% Carbamide phosphate	1.4	1.5	clear in 1 minute	clear	clear in 1 minute	clear	clear

*All salts dissolved in distilled water were soluble when diluted 1:16 in both distilled and tap water except 10-52-17 which was slightly turbid in tap water.

**All salts dissolved in tap water were soluble when diluted 1:16 in distilled water except 21-53-0 which was slightly turbid.

PART II

FIELD EXPERIMENTS

Tomatoes

Starter Solutions and Irrigation Practices

This investigation was undertaken to study the effect of different starter solutions and irrigation practices on the yield of tomatoes. Flats of tomato plants received either starter treatment or water 10 days before field planting. At the time of field setting each plant, in addition, received one-half pint of one of the solutions listed below.

Methods and Materials:

Four tomato varieties, John Baer, Longred, Valiant and Wisconsin 55 were seeded on April 11, 1952 and transplanted to flats of sandy loam soil on May 3. On May 14, half the number of flats of each variety received two quarts of the startersolution 10-52-17 at a concentration of one ounce per gallon of water. The remainder of the flats received two quarts of water. On May 30, the plants were set in a field of snady loam soil which had received 700 pounds of 3-12-12 fertilizer per acre. The plot was divided with four blocks in each half. Each block received one of the irrigation treatments. The four varieties were randomized in each irrigation block with both the flat and non-flat treated plants receiving one of the three starter treatments at the time of field planting. Six plants spaced 3.5 feet by

5 feet were placed in each plot. Each treatment was replicated once. The starter treatments were as follows:

	Chemical Used*
1. Water	
2. 10-52-17	50% Di-ammonium phosphate 50% Mono-ammonium phosphate
3. 13-26-26	50% Di-ammonium phosphate 25% Potassium chloride 25% Potassium nitrate

Each plant received one-half pint of a solution of four pounds of chemical in 50 gallons of water.

The irrigation treatments were:

1. No irrigation.

2. Irrigated when calculated value indicated soil had fallen to 50% of field capacity.

3. Irrigated when soil had fallen to 50% of field capacity.

4. Irrigated when soil had fallen to 25% of field capacity.

Fresh petiole leaf samples, taken 19 and 24 days after treatment, were analyzed for soluble phosphorus, nitrogen, and potassium (4, 6).

Early and total numbers and weights of fruit were recorded. The early yield consisted of all tomatoes harvested up to September 1.

Results:

Adequate rainfall prevented a significant effect of irrigation on either the early or total yield of the tomatoes. The starter treatments increased

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*Precentage equivalent to four pounds in 50 gallons of water.

both the early and total number and weight (Table XV) of tomatoes. The two starter solutions (10-52-17 and 13-26-26, Table XV) did not affect weight or number of fruits. Likewise, no significant difference in early and total weight was evident as a result of variety difference where the two starter treatments were used.

Table XVI indicates that only the Valiant variety gave a significant increase of 1.8 tons per acre in early yield as the result of flat treatment. The increase amounted to 16 percent in weight, and 30 percent in number of fruits. This might be explained in that Valiant, an earlier maturing variety, was closer to the reproductive stage, and the addition of starter solution aided it in flower formation and fruit set. The plants treated also increased significantly the number of smaller sized early fruit in John Baer. No significant increases, however, were evident for either early or total number or weight in the case of Longred or Wisconsin 55, as the result of flat treatment. It is also of interest to note that all the flat-treated plants had a tendency to produce a greater number of smaller sized early fruits, which however, only resulted in an increase in early yield of 1.8 tons with Valiant. The flat treatment resulted in a decrease of 2.4 tons in total yield for the John Baer, but an increase of 2.1 tons per acre for Valiant.

A chemical analysis of leaf petioles (Table XVII) indicates that the non-flat treated plants of Longred, Valiant, and Wisconsin 55 contained more soluble phosphorus and less soluble nitrogen than did plants treated

TABLE XV

Effect of Soluble Fertilizer on the Yield of Tomatoes

Treatment	Variety	Early Yield Avg. Wt. tons/acre	Early Yield Avg. No.	Early Yield Avg. Fruit Wt.	Total Yield Avg. Wt. tons/acre	Total Yield Avg. No.	Total Yield Avg. Fruit Wt.
Water	John Baer	6.7*	92**	.351+	15.8	230	.332
	Longred	8.7	112	.376	17.7	218	.392
	Valiant	7.0	96	.349	14.8	237	.301
	Wisconsin 55	5.9	65	.438	17.2	227	.365
	Avg.	7.1	91	.375	16.4	228	.346
10-52-17	John Baer	11.6	153	.365	20.6	286	.348
	Longred	12.8	157	.393	20.9	264	.383
	Valiant	11.8	154	.370	20.7	304	.329
	Wisconsin 55	10.1	104	.468	22.2	277	.386
	Avg.	11.6	142	.393	21.1	282.8	.360
13-26-26	John Baer	11.4	150	.367	19.2	268	.345
	Longred	11.3	144	.378	18.0	234	.370
	Valiant	10.9	147	.367	18.9	288	.316
	Wisconsin 55	9.2	99	.449	19.5	249	.378
	Avg.	10.7	135	.383	18.9	260	.350
L. S. D. of Individual Varieties		N. S.	N. S.		N. S.	N. S.	
L. S. D. for Avg. of Varieties	.05	1.3	11.0	0.172	2.3	23.2	
	.01	2.0	16.0	0.234	3.3	33.7	

*Average weight of 16 six-plant plots in tons per acre.
**Average number of fruit per six plants.
+Average weight of fruit in pounds.

TABLE XVI

The Effect of Soluble Fertilizer Treatment in Flats on the Yield of Different Tomato Varieties.

Variety	Treatment	Early Yield of Tomatoes Avg. Wt. tons/acre	Early Yield of Tomatoes Avg. No.	Early Yield of Tomatoes Avg. Wt. of Fruit	Total Yield of Tomatoes Avg. Wt. tons/acre	Total Yield of Tomatoes Avg. No.	Total Yield of Tomatoes Avg. Wt. of Fruit
John Baer	No flat treatment	9.7*	122+	.382	19.8	270	.35
	Flat treatment	10.1**	142	.343	17.4	253	.33
Longred	No flat treatment	10.9	133	.396	19.4	242	.39
	Flat treatment	10.9	142	.370	17.8	236	.36
Valiant	No flat treatment	9.0	115	.377	17.2	254	.33
	Flat treatment	10.8	150	.347	19.3	299	.31
Wisconsin 55	No flat treatment	8.6	88	.469	19.9	249	.38
	Flat treatment	8.3	90	.443	19.6	254	.37
L. S. D.	.05	1.23	14.35	.017	1.96	26	.01
	.01	1.64	19.03	.023	2.61	34	.02

*Average of 24 six-plant plots receiving no flat treatment.

**Flat treatment plants were treated with starter solutions in flats 10 days before field planting.

+Average number of fruit per six plants.

TABLE XVII

Chemical Composition of Fresh Tomato Leaf Petioles Twenty-four Days after Treatment with Soluble Fertilizers (1952).

Variety	Treatment	Water				10-52-17				13-26-26			
		Early Wt.	Total Wt.	Sol. P ppm	Sol. N ppm	Early Wt.	Total Wt.	Sol. P ppm	Sol. N ppm	Early Wt.	Total Wt.	Sol. P ppm	Sol. N ppm
John Baer	No flat treatment	6.1**	17.4	98*	1350	11.5	22.0	174	1413	11.5	20.0	141	1500
	Flat treatment	7.3	14.6	73	1278	11.8	19.2	270	1050	11.3	18.4	128	1120
Longred	No flat treatment	8.2	18.3	112	1450	13.3	22.0	248	1508	11.3	17.8	106	935
	Flat treatment	9.1	15.2	100	1235	12.3	19.9	211	1563	11.3	18.1	145	1278
Valiant	No flat treatment	5.8	14.0	81	1503	10.7	19.8	364	1155	10.4	17.8	165	1350
	Flat treatment	8.1	16.6	131	1285	12.9	21.6	323	1425	11.4	19.9	188	1465
Wisconsin 55	No flat treatment	5.8	17.2	165	1238	10.7	22.7	442	890	9.3	19.7	201	1450
	Flat treatment	6.1	17.8	90	1108	9.5	21.8	271	1550	9.2	19.3	185	1123

*Average of two plant tissue samples taken four weeks after treatment.
**Average weight in tons per acre of eight, six-plant plots.

in the flats with the 10-52-17. The reverse was true for John Baer. With the treatment 13-26-26 leaf petioles of the non-flat treated plants of John Baer and Wisconsin 55 contained more soluble nitrogen and phosphorus than the flat treated plants, but the reverse was true for Longred and Valiant. This would suggest that the flat treated plants of John Baer and Wisconsin 55 were larger in size than the non-flat treated plants with a lower concentration of nutrients due to dilution. In Longred and Valiant, which are earlier maturing, leaf petioles of the flat treated plants contained more soluble phosphorus and nitrogen than the non-flat treated plants with the 13-26-26 treatment. There also appeared to be an increase in the total yield with an increase in the phosphorus concentration in the plants two weeks after field setting, regardless of the starter treatment. This can probably be associated with the availability of phosphorus to plants for rapid establishment and growth, which was reflected in the yield of the plants.

Soluble Fertilizer Solutions and Fertilizer Practices

This investigation was undertaken to see what effect different starter treatments had on the early and total yield of tomatoes with two levels of field fertilization. Two tomato varieties were treated in the flats at different dates with starter solutions and with different analyses of starter treatments when field planted to soils of differing fertility levels.

Methods and Materials:

Longred and Stokesdale tomato seeds were sown in vermiculite on March 27, 1953 and five plants per treatment were field set 3.5 feet apart in rows five feet apart on a low lying field of Hillsdale sandy loam soil on May 30. Moisture supply was supplemented with irrigation to overcome a dry period during July and August. Clover, plowed under the previous fall, had probably influenced the nitrogen content of the soil.

The field was divided into four strips, two of which were fertilized with 3-12-12 fertilizer at the rate of 800 to 900 pounds per acre, and the other two strips were not fertilized. The two varieties were planted on fertilized and non-fertilized plots after having been previously treated as follows:

1. No flat treatment (only two quarts of water).
2. One-half ounce 10-52-17 in two quarts of water per flat applied a day before field planting.
3. One-half ounce 10-52-17 in two quarts of water per flat applied 10 days before field planting.

In the field each plant received one-half pint of one of the following solutions at planting time:

	Chemical Used
1. Water	
2. 10-52-17	50% Di-ammonium phosphate 50% Mono-potassium phosphate
3. 18-76-0	Organic compound

4. 10-26-17*	50% Mono-potassium phosphate* 31% Ammonium nitrate
5. 0-52-34	Mono-potassium phosphate
6. 20-53-0	Di-ammonium phosphate
7. 10-0-17*	37% Potassium nitrate 16% Ammonium nitrate
8. 4-16-4*	Applied on June 18 at the rate of 500 pounds per acre - dry application.

The rate of the above materials were 4 pounds of the fertilizer mixture per 50 gallons of water.

The design of the plot was a split for fertilizer, variety, flat treatment and field starter treatment, giving two fertilizers x two varieties x three flat treatments x eight starter treatments x two replications, or 192 five-plant plots.

Plant petiole samples were taken 16 days after field planting of both varieties from the non-flat treated plants on fertilized and non-fertilized plots. The chemical analysis was carried out as recommended by Carolus (6).

The early yield consisted of tomatoes harvested up to and including September 1. The total yield consisted of tomatoes picked over the entire season.

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*Percentages equivalent to four pounds in 50 gallons of water.

Results:

There was a significant early yield increase (Table XVIII) (number and weight) of 2.1 tons per acre for plants that were flat treated 10 days before field planting, as compared with the plants flat treated the day before field planting, which in turn, yielded an increase of 1.4 tons per acre more than did the non-flat treated plants.

There was a pronounced varietal difference in response due to flat treatment. The flat treatments caused Longred to yield 3.5 and 5.5 tons per acre respectively more than did the non-flat treated plants, whereas in the Stokesdale a non-significant increase in early yield occurred only when plants were flat treated 10 days before field planting. The variety differences in early yield can be associated with increases in fruit numbers due to flat treatments.

Table XIX indicates that the starter treatment 10-26-17 resulted in a greater number of early fruits and an increase in early yield of 1.5 to 2.9 tons per acre more than was obtained for the other starter solutions or from water alone. Starter solutions had no significant effect on the total yield. This was probably the result of a high fertility level in the soil. There were no significant differences in the early yields or in the number of fruits between the two varieties or the two soil fertilizer treatments in the field.

The chemical analysis of fresh leaf petioles (Table XX) taken 19

TABLE XVIII

Effect of Soluble Fertilizer Treatment in the Flat on Number and Yield in Tons per Acre of Tomato Varieties.

Flat Treatment	Yield per Acre						Number					
	Early			Total			Early			Total		
	Longred	Stokesdale	Avg. 2 Var.	Longred	Stokesdale	Avg. 2 Var.	Longred	Stokesdale	Avg. 2 Var.	Longred	Stokesdale	Avg. 2 Var.
	(Average of 32 five-plant plots)						(Average per five-plant plot)					
Water	16.5	18.0	17.3	38.9	40.3	39.6	177	193	184	463	516	489
10-52-17 day before field planting	20.0	17.5	18.7	44.4	37.9	41.1	209	194	201	515	504	510
10-52-17 10 days before field planting	22.0	19.6	20.8	45.8	38.5	42.1	233	223	228	535	512	523
L. S. D. . 05	2.08	2.1	1.54	N. S.	N. S.	N. S.	N. S.	N. S.	21.2	N. S.	N. S.	N. S.
.01	3.02	3.0	2.1						30.8			

TABLE XIX

Effect of Soluble Fertilizer Treatments on Fruit Number and Yield in Tons per Acre of Longred and Stokesdale Tomatoes.

Treatment	Yield per Acre						Number					
	Early			Total			Early			Total		
	Long-red	Stokes-dale	Avg. 2 Var.	Long-red	Stokes-dale	Avg. 2 Var.	Long-red	Stokes-dale	Avg. 2 Var.	Long-red	Stokes-dale	Avg. 2 Var.
	(Average of 12 five-plant plots)						(Average per five plant plots)					
Water	18.7	18.2	18.4	42.0	37.8	39.9	197.2	199.2	198.2	494.4	505.0	499.7
10-52-17	19.2	16.7	17.9	42.1	37.3	39.7	199.2	181.8	190.5	480.4	482.4	481.4
10-76-0	19.1	18.2	18.6	42.7	37.9	40.3	193.2	197.6	195.4	482.5	483.1	482.8
10-26-17	21.3	20.4	20.8	45.6	39.4	42.5	226.1	224.1	225.2	532.0	519.2	525.6
0-52-34	19.6	20.0	19.3	42.7	39.8	41.2	210.2	210.4	210.3	509.2	530.4	519.8
25-53-0	19.0	18.8	18.9	41.3	39.2	41.5	203.2	208.0	205.6	482.2	510.4	496.3
10-0-17	19.6	17.6	18.6	42.9	37.9	40.4	214.0	203.2	208.6	520.0	525.0	522.7
4-16-4 Dry	19.4	18.3	18.8	44.8	40.0	42.4	207.5	200.1	203.8	537.0	533.2	535.1
L.S.D. .05	N.S.	N.S.	1.3	N.S.	N.S.	N.S.	N.S.	N.S.	15.23	N.S.	N.S.	33.16
.01			1.8						20.23			44.05

TAFEL XX

TABLE XX

Chemical Analysis of Fresh Tomato Leaf Petioles Sampled 19 and 24 Days After Field Planting (1953).

Treatment	Nitrate Nitrogen		Soluble Phosphorus		Soluble Potassium		Yield of Plants			
	*ppm	ppm	ppm	ppm	ppm	ppm	Early		Total	
							NF	F	NF	F
	NF	F	NF	F	NF	F	Tons per Acre			
				LONGRED						
Water	**1140	905	195	170	4885	4500	15.2	16.1	28.8	41.9
10-52-17	1105	945	300	225	4180	4115	15.7	17.5	33.3	45.6
0-52-34	1120	855	250	225	3600	4160	16.0	16.7	38.7	34.2
25-53-0	1340	730	315	250	4515	3435	15.0	14.0	38.1	33.6
10-0-17	1150	780	140	195	4970	4160	16.6	12.2	44.2	34.5
				STOKESDALE						
Water	1170	820	140	300	4420	5010	15.2	17.6	35.6	44.1
10-52-17	1260	860	235	310	4850	4915	16.0	18.3	36.1	41.6
0-52-34	1310	760	235	320	4540	5950	18.8	21.2	38.6	47.9
25-53-0	1270	760	230	360	4180	4360	18.2	16.8	36.1	41.1
10-0-17	1220	915	200	300	4765	4900	17.0	17.5	40.0	42.9

*Parts per million of concentration of element present in leaf petiole.

**Average of two chemical determinations made from samples taken 19 and 24 days after starter treatment and field planting. The samples were taken from plants from non-flat treated plants.

F - Plants grown on a fertilized plot.

NF - Plants grown on a non-fertilized plot.

and 24 days after field planting indicated that the fertilizer increased the soluble phosphorus and potassium content of the Stokesdale, but not the Longred plants. It was further noted that the nitrate nitrogen content of petioles in the non-fertilized plants was higher than that of fertilized plants. This may have been the result of smaller sized plants containing a higher concentration of nutrients. The starter solutions had no consistent effect on plant composition with respect to nitrate nitrogen, phosphorus, and potassium on the well fertilized soil. However, on non-fertilized areas the soluble phosphorus content of the plants was increased by application of starter solution.

When the total yields as affected by the flat treatments were compared with those affected by the starter treatments (Figures 10 and 11 from data in Tables B and C in appendix) on the fertilized and non-fertilized plots, the yield responses to the starter treatments varied. In the fertilized plots the complete starter treatments resulted in a higher yield of tomatoes for the non-flat treated plants than the plants flat treated the day before field planting. The plants flat treated 10 days before field planting gave the largest yield for the 0-52-34 treatment, indicating a need for potassium and phosphorus, when sufficient nitrogen was present. The plants flat treated 10 days before setting on the non-fertilized soil likewise indicated a need for phosphorus in the starter solution. However, non-flatted plants responded best to the dry 4-16-4 side dressing. The data suggest that the non-fertilized

Figure 10

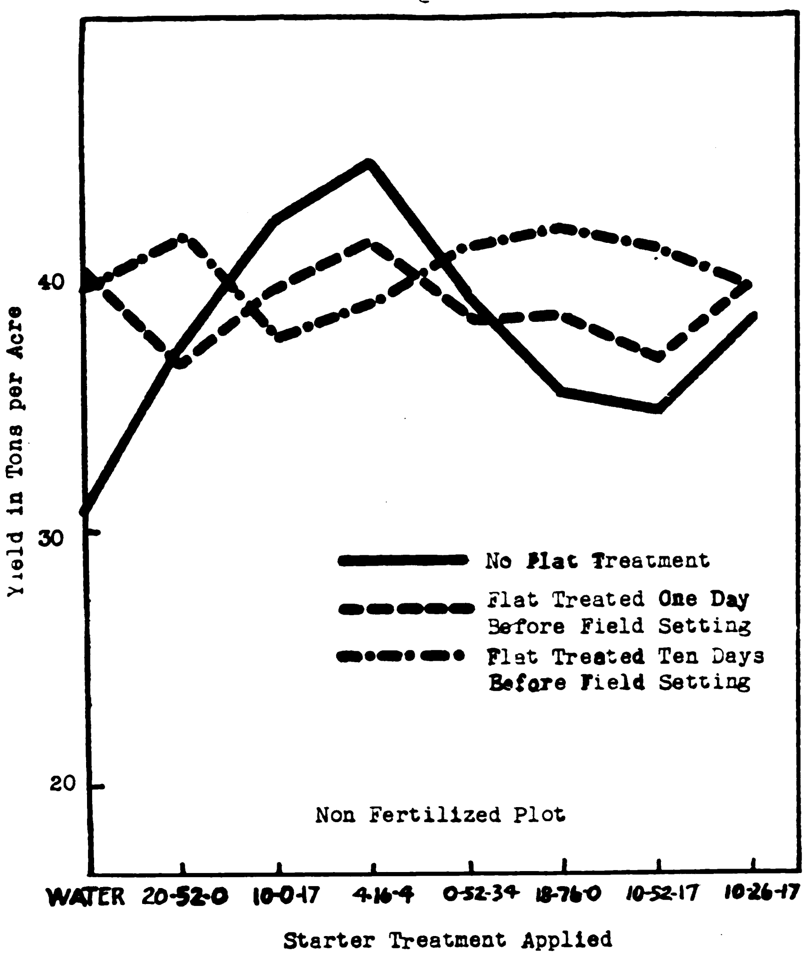

Figure 11

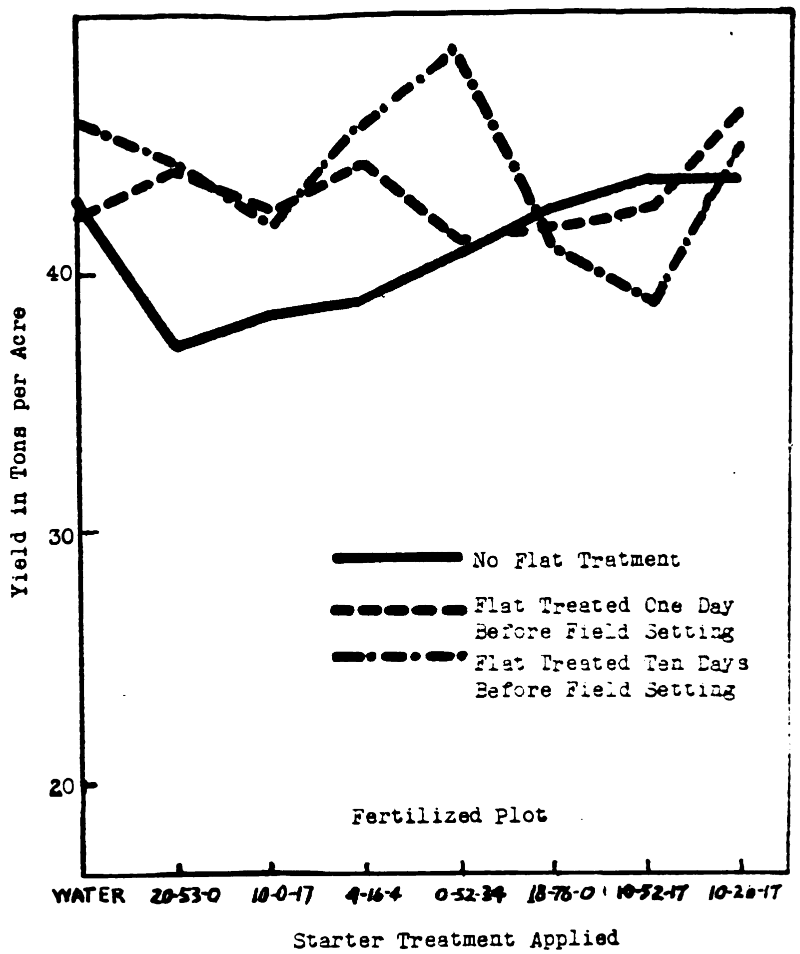

Figure 10, 11. Yield of Tomatoes as Effected by Flat and Field Starter Treatment in Non-Fertilized and Fertilized Plots.

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plants, flat treated 10 days before field planting, were in a more advanced stage of maturity and required more phosphorus at the time the plants were field set. Plants not receiving a flat treatment, or those receiving a flat treatment the day before field setting, would not require as high an amount of phosphorus in the starter solution at that time as those flat-treated 10 days before setting, and so would not be benefitted as much by its use as by the dry, more slowly available fertilizer application.

Effect of Soluble Fertilizer Solutions on Plants of Different Ages

In this investigation an attempt was made to determine if any differences occurred in early and total yield of tomatoes as the result of starter application to plants of different ages.

Methods and Materials:

Longred and Stokesdale tomatoes were seeded on April 24, 1954 and field planted on May 28 and June 7, on a Hillsdale sandy loam soil which had received 400 pounds per acre of 5-20-20. The plants received the following treatments:

	Chemicals Used
1. Water	
2. 10-52-17	*50% Di-ammonium phosphate 50% Mono-potassium phosphate
3. 10-26-17	50% Mono-potassium phosphate 31% Ammonium nitrate
4. 18-76-0	Victamide**

*Percentages equivalent to four pounds in 50 gallons of water.
**Victamide supplied by Victor Chemical Company.

5. 0-52-34 Mono-potassium phosphate

6. 20-53-0 Di-ammonium phosphate

The rate of the above materials was four pounds per 50 gallons of water and one-half pint of one of these solutions was applied to the soil at the plant root area at transplanting time.

Five plants per treatment, with each treatment replicated twice were placed 3.5 feet apart in rows 5 feet apart. The planting dates, starter treatments and varieties were randomized within each replication. Both the early and total number of fruits and yields were recorded. The early yield consisted of fruit harvested up to and including September 1, the total yield was the total harvest up to September 30.

Results:

Table XXI indicates that Stokesdale gave a significant increase in early yield and number over Longred. However, the reverse was true for the total yield. Both varieties produced a significantly greater early and total number and weight of tomatoes for the early field planting (May 28) over the late field planting (June 5). This was probably due to an earlier establishment and longer growing and bearing season for the earlier field set plants.

The best results (early yields) were obtained when a starter treatment containing nitrogen and potassium together with a high phosphorus starter was used (10-52-17) (Table XXII). The increase in fruit number was

TABLE XXI

Effect of Different Planting Dates on the Yield and Number of Fruit for Stokesdale and Longred Tomatoes.

Variety	EARLY YIELD*				TOTAL YIELD**			
	Weight		Number		Weight		Number	
	PLANTING		PLANTING		PLANTING		PLANTING	
	Early	Late	Early	Late	Early	Late	Early	Late
Stokesdale	12.6	4.6	175	63	37.7	33.1	508	415
Longred	11.0	3.5	140	51	42.1	37.6	543	451
L. S. D. for transplanting dates	.05	0.23	12.54		.71		36.36	
	.01	0.30	16.70		.94		48.42	

*Average of 18 five-plant samples harvested up to and including September 1 Tons per acre.

**Total yield of crop harvested during the season.

TABLE XXII

Effect of Soluble Fertilizer Treatment on the Yield and Number of Tomato Fruit at Different Field Planting Dates.

Treatment	EARLY YIELD* (Tons per acre of six five-plant plots)						TOTAL YIELD					
	Avg. Wt.			Avg. No.			Avg. Wt.			Avg. No.		
	May 28	June 7	Avg.	May 28	June 7	Avg.	May 28	June 7	Avg.	May 28	June 7	Avg.
Water	8.5	3.7	6.1	119	49	84	26.3	34.4	35.3	450	420	435
10-52-17	13.5	5.1	9.2	190	68	129	38.2	35.5	36.8	546	462	504
18-76-0	12.3	4.5	8.4	161	59	110	39.9	35.0	37.5	503	428	466
0-52-34	12.7	3.7	8.2	157	54	105	41.4	37.7	39.5	548	460	504
21-53-0	10.5	3.8	7.1	135	55	95	41.2	34.6	37.9	519	426	473
	13.6	4.2	8.9	184	56	120	42.8	35.2	39.0	587	404	495
Avg. Wt.	11.9	4.1	8.0	158	57	107	39.9	35.4	37.7	526	433	480
L.S.D. .05	N.S.	N.S.	2.0				N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

*Early yield - fruit harvested up to and including September 1.

mainly responsible for the increase in early yield. The starter solution also had no apparent effect on the total yield when compared with the control at either of the two planting dates. These results are similar to those obtained in previous investigations in that soils high in fertility tended to overcome the effect of starter solutions in the total yield. If the soils had not been fertile, the total yields would probably have been increased as the result of the starter treatment.

Soluble Fertilizer Solutions and Polyethylene Soil Covers

In this investigation a sheet of transparent polyethylene (18 inches by 18 inches) was placed at the base of tomato plants, half of the plants had been treated with starter solution at transplanting, and the remainder received only water. The polyethylene was used to determine whether the increase in the soil temperature facilitated better absorption of nutrients by the plant roots which, in turn, might result in an increase in yield.

Methods and Materials:

Stokesdale tomatoes were transplanted May 18, 1953 on Hillsdale sandy loam soil. Three plants per plot were spaced 3.5 by 5 feet, with treatments replicated three times. The treatments were as follows:

1. Water
2. Water + polyethylene
3. 10-52-17
4. 10-52-17 + polyethylene

The rate of application of 10-52-17 was four pounds per 50 gallons of water, each plant receiving one-half pint at transplanting.

The early yield consisted of tomatoes harvested up to August 27, and the total yield of fruit harvested up to September 16.

Results:

The study indicated (Table XXIII) that there was a significant increase in early yield of 5.9 tons per acre due to the use of starter solution in combination with polyethylene, but when polyethylene or the starter solution was used separately, no significant early increases were obtained over plants receiving only water. This increase was probably the result of either a higher moisture content or the polyethylene at the base of the plants warming the soil so that the added starter solution would be utilized more readily by the plants as the result of a higher soil temperature. The soil temperatures 1.5 inches deep were from 1 to 3 degrees higher (Table XXIV) under the polyethylene sheet than in soils not covered by the polyethylene. The increase in soil temperature was probably responsible for the increase in earlier fruit set and yield. Neither polyethylene nor starter solution produced an increase in total yield, but again when used together there was an increase of 6.0 tons per acre over plants receiving only water.

On May 18, 1955 the experiment was repeated and again increases of 2.8 tons per acre for early yield, and 3.5 tons per acre for total yield were obtained due to combination of starter solution and polyethylene when compared with plants receiving only water. These differences, however, were not significant, due to the variability between the replications.

TABLE XXIII

Effect of Polyethylene Covers and Starter Solutions on Yields of Stokesdale Tomatoes.

Treatment		YIELDS (Tons per Acre)			
		1953		1955	
		Early Yield	Total Yield	Early Yield	Total Yield
Water		9.0*	24.4	14.5**	25.5
Water + Poly-etylene		9.1	23.3	14.7	23.7
10-52-17		11.5	22.7	15.4	25.7
10-52-17 + Poly-ethylene		14.6	30.4	16.5	28.4
L.S.D.	.05	4.3	6.4	N.S.	N.S.
	.01	6.2	9.2		

*Average of four three-plant plots in tons per acre.
**Average of three five-plant plots in tons per acre.

TABLE XXIV

Effect of Polyethylene Covers on Soil Temperature (Degrees Fahrenheit)

Date Temperature Recorded	Time of Day Temperature Recorded								
	8 A.M.			12 M			5 P.M.		
	No cover	Cover	Air Temp.	No cover	Cover	Air Temp.	No cover	Cover	Air Temp.
June 1, 1955	56.0*	57.0	61.0	67.9	71.1	73.0	74.9	78.9	74.0
June 2, 1955	62.3	64.5	72.0	71.8	74.6	80.0	76.3	80.3	78.0
June 6, 1955	67.9	67.9		74.4	77.6		65.3	66.7	
Avg. of 3 dates	62.0	63.0		71.4	74.3		72.1	75.3	

*Average of three different thermometer readings.
The thermometers were placed 1.5 inches in the soil.

Summary of Field Tomato Studies

The tomato field data indicated that starter solutions of medium nitrogen and potassium contents and high in phosphorus (10-52-17) generally increased the early and total number and weight of tomatoes. Flat treatment up to 10 days before field planting also increased early yield in most of the varieties. Varieties responded differently to the flat treatment. For example, a one- or ten-day treatment of the flats before field planting with Longred increased the early yield, whereas in Stokesdale the early yield was increased only when treated ten days before field setting. The increase in yield for both flat and field treatment was generally the result of an increased number of smaller sized fruit. Increases in yield, as a result of field applied starters, may not be realized in soils of high fertility as indicated by the 1953 results. The data also indicated the tendency for increases in total yield when the phosphorus content was high in plants two weeks after field setting. When tomatoes from the same seeding were field set at two consecutive dates, those set on the first date gave increases in early yield over plants set a week later, regardless of the treatment applied. This emphasizes the importance of a week's difference in plant growth on early production of fruit. Increases in early tomato yield were also obtained when starter solutions were used in combination with a polyethylene mulch. The polyethylene caused an increase in soil temperature of two to three degrees F, which probably permitted more rapid absorption of nutrients by the plants. Thus, the mulch increased the value of the starter fertilizer.

Peppers

Effect of Soluble Fertilizer Treatments on Yield of Peppers

In this investigation California Wonder pepper plants were given different starter solutions at field transplanting to determine the effect on early and total yield.

Methods and Materials:

The 1953 crop was seeded March 27, and field planted June 6, on soil that had received a 3-12-12 fertilizer at the rate of 400 pounds per acre. The 1954 crop was seeded April 8, and field planted June 4, on soil that had received a 5-20-20 fertilizer at the rate of 300 pounds per acre.

Both seasons the plants were placed two feet apart in rows three feet apart. There were ten plants per treatment, and each treatment was replicated three times. Natural precipitation was supplemented with irrigation.

The starter treatments were as follows:

	Chemicals Used
1. Water	
2. 10-52-17*	50%** Di-ammonium phosphate 50% Mono-potassium phosphate
3. 18-76-0	Victamide
4. 10-26-17	50% Mono-potassium phosphate 50% Ammonium nitrate
5. 0-52-34	Mono-potassium phosphate
6. 20-53-0	Di-ammonium phosphate
7. 10-0-17	37% Potassium nitrate 10% Ammonium nitrate

Chemicals Used

8. 19-28-14 Instant Vigoro

9. 16-63-0* Carbamide phosphate

10. 1953. 4-16-4 Dry application rate 500 pounds per acre two weeks after transplanting.
1954. 3-12-12 Dry application rate 500 pounds per acre.

Results:

The 1953 peppers showed (Table XXV) no significant differences in either early or total yields as the result of starter solutions.

Table XXV indicates that in 1954 treatments 0-52-34, 3-12-12 dry application and water produced the lowest early number of fruit and yield. The data also indicate that in 1954 the treatments 10-52-17, 20-53-0, 16-63-0, and 18-76-0 caused a significant increase from 43 to 65 percent in early yield and from 45 to 63 percent increase in early fruit numbers, as compared with yields and number of fruits where water, 0-52-34 or 3-12-12 were applied, thus indicating a need for a high phosphorus with a medium or high nitrogen for an early pepper yield. Potassium in the starter solution was of little or no benefit. The increase in early yield of peppers from starter solutions high in phosphorus was probably due to the phosphorus inducing an earlier maturation in plants, which resulted in a greater number of flowers and fruit. Nitrogen was necessary for plant growth. Peppers receiving the treatments 19-28-14, 10-52-17, 20-53-0, and 18-76-0 produced significant

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*Supplied by Victor Chemical Company

**In treatments 2 and 9, percentages equivalent to four pounds in 50 gallons of water were used.

TABLE XXV

Effect of Soluble Fertilizer Treatments on Early and Total Yield and Number of Peppers.

Treatment	1953 Harvest				1954 Harvest			
	EARLY YIELD*		TOTAL YIELD		EARLY YIELD		TOTAL YIELD	
	Avg. Wt.	Avg. No.	Avg. Wt.	Avg. No.	Avg. Wt.	Avg. No.	Avg. Wt.	Avg. No.
Water	6. 0**	19.0	24.3	119.5	10.3	29.0	34.3	109.0
10-26-17	7.4	25.0	21.6	104.6	12.3	35.3	39.6	120.3
19-28-14	10.4	37.0	26.1	121.0	12.5	37.0	40.9	117.3
10-0-17	5.3	18.3	18.6	94.2	12.7	36.0	39.3	122.0
10-52-17	7.9	27.3	18.8	86.6	14.8	42.0	41.9	122.7
20-53-0	8.4	28.6	22.8	104.9	14.9	43.0	44.6	136.0
16-63-0	8.1	29.0	22.1	108.6	15.2	44.6	39.3	120.7
18-76-0	8.8	32.3	21.9	103.2	17.0	47.0	42.4	123.7
0-52-34	7.0**	23.6	24.2	118.5	7.7	22.6	34.6	109.7
4-16-4 (1953) 3-12-12(1954) Dry application	6.7	23.6	18.8	92.2	8.8	25.0	34.6	104.7
L.S.D. .05	N.S.	N.S.	N.S.	N.S.	3.11	8.4	5.96	17.22
.01					4.27	11.5	8.17	24.30

*Early yield consisted of peppers picked up to August 20, and the total yield consisted of peppers picked during the whole season.

**Average weight in pounds of three 10-plant values.

increases in the total yield over those receiving treatments 0-52-34, 3-12-12, and water. This again indicates the need for nitrogen and high phosphorus in the starter solution. The increase in yield was associated with an increase in both size and number of fruit.

Differences in the response of peppers to starter solutions in 1954 and not in 1953 could be, in part, due to environment. In 1953 during the flowering and fruit set period, the weather was quite warm and continued to be so for the remainder of the growing season. On the other hand, for the 1954 crop, the weather was warm up to blossom and fruit setting time, and then turned cool. This latter environment seemed to be closer to the optimum and so expression of growth and yield, due to the starter solution, was more pronounced.

Celery

Concentrations of Soluble Fertilizer Solutions on the Yield of Several Varieties of Celery

In 1952 a study was made of the effect of different concentrations of 10-52-17 starter fertilizer on the yield of three celery varieties.

Methods and Materials:

Three varieties of celery, Cornell 19, Top Ten, and Ten Grand, were "hardened off" in a coldframe for eight days before field planting at the Michigan State University experimental muck farm, on a plot which had received 2,000 pounds per acre of 0-10-30, and 500 pounds of sodium chloride. Normal rainfall was supplemented by irrigation. The plants were spaced six inches apart in rows 32 inches apart. There were 20 plants per treatment and each treatment was replicated once. The starter treatments were:

1. Water
2. 10-52-17, 4 pounds per 50 gallons of water.
3. 10-52-17, 6 pounds per 50 gallons of water.
4. 10-52-17, 8 pounds per 50 gallons of water.

Each plant received one-half pint of solution at transplanting time. The crop was harvested August 5.

Results:

The starter solutions were an important factor in permitting the green varieties to reach full development (Table XXVI). They were significantly increased by the starter solution, but Cornell 19 was not.

It was also further evident that the six and eight pound concentrations of starter solutions produced a greater yield than plants receiving only water, however, no significant differences occurred between the different starter solution concentrations.

Different Soluble Fertilizers on the Yield of Four Celery Varieties

In 1953 the study in the use of fertilizers of different analyses in starter solutions on celery varieties was carried out on the Michigan State University muck farm. This experiment differed from the one in 1952 in that different fertilizer analyses were applied instead of the same analyses at different concentrations. The volume of solution was also decreased from one-half pint to one-quarter pint per plant.

Methods and Materials:

The plants were field planted May 25, 1953, 16 plants per treatment, six inches apart in rows 32 inches apart. Each treatment was replicated once. The soil received a 5-10-20 fertilizer at the rate of 1,000 pounds

TABLE XXVI

Effect of Different Concentrations of a Soluble Fertilizer on Celery Yield.

Treatment	Average Weight of Varieties			Average Weight All Varieties
	Cornell 19	Utah Ten Grand	Utah Top Ten	
Water	38.9*	44.1	48.6	43.9
10-52-17 (4 lb/50gal. water)	41.7	53.8	63.0	52.8
10-52-17 (6 lb/50gal. water)	47.0	57.9	68.0	57.6
10-52-17 (8 lb/50gal. water)	45.9	57.2	65.4	56.2
Effect of Soluble Fertilizer Treatment on Average Weight of All Varieties				
L.S.D. .05				12.3
.01				17.4

*Average weight of two 20-plant plots in pounds.

per acre. The varieties were Utah Ten B, Utah Top Ten, Utah Ten Grand, and Cornell 19.

The starter treatments were:

	Chemicals Used
1. Water	
2. 10-52-17 (6 pounds per 50 gallon water)	one-quarter pint per plant.
3. 10-52-17 (12 pounds per 50 gallons)	one-eighth pint per plant.
4. 18-76-0	Victamide
5. 0-52-34	Mono-potassium phosphate
6. 21-53-0	Di-ammonium phosphate
7. 16-38-23	50% Victamide 50% Potassium nitrate
8. 23-0-23	50% Ammonium nitrate 50% Potassium nitrate
9. 32-0-0	Ammonium nitrate
10. 32-0-0	Ammonium nitrate dry (applied at rate of 200 pounds per acre two weeks after field planting).

The above salts for treatments four to nine were applied at rates equivalent to six pounds per 50 gallons of water, each plant receiving one-quarter of a pint.

Results:

On the basis of the four varieties studied there was no significant influence of the starter solutions on plant weight (Table XXVII); but the green varieties produced increases in yield of up to 30 percent for the 21-53-0 treatment. The dry application of a high nitrogen fertilizer did not influence the yield. Eight of the nine treatments increased the yield of Utah Top Ten and Ten Grand, however all treatments except 21-53-0 reduced the yield of Cornell 19.

The investigation also indicated that 12 pounds per 50 gallons of 10-52-17 did not increase the yield over that obtained from the six-pound rate.

The Influence of Soluble Fertilizer Solutions on the Yield of Celery at Two Harvest Dates

This experiment was undertaken to determine if starter solutions influenced celery maturity. The celery was harvested at two dates so that the influence of soluble fertilizers on the rate of maturity could be studied.

Methods and Materials:

In this experiment on the Michigan State University muck farm two varieties, Utah Top Ten and Cornell 19, were given six different starter treatments and harvested at two different dates. The plants were transplanted on March 25, and field planted May 19. Each treatment which contained 16 plants was replicated once for each harvest date and variety. The plants were placed

TABLE XXVII

Effect of Different Soluble Fertilizer Treatments on Celery Yields.

Treatment	Average Weight of Varieties				Average Weight of All Varieties
	Utah 10 B	Utah Top Ten	Utah Ten Grand	Cornell 19	
	(Average weight of 16 plants in pounds)				
Water	52.7	45.3	46.3	45.8	47.5
10-52-17 (6 lb/50 gal. water)	54.6	54.1	50.1	40.6	49.9
10-52-17 (12 lb/50 gal. water)	52.8	51.4	49.9	42.1	49.1
18-76-0	41.7	46.4	48.8	39.4	44.1
0-52-34	53.7	54.4	51.3	41.6	50.3
21-53-0	58.1	57.9	51.3	47.5	53.7
18-38-23	50.3	49.8	49.9	41.7	47.9
23-0-23	48.7	44.9	46.6	42.4	45.7
32-0-0	48.8	48.1	51.0	41.9	47.5
32-0-0 (dry application)	51.2	47.4	43.6	40.3	45.6
Average Yield of Variety	51.3	50.0	48.9	42.3	
Effect of Starter Treatment on Average Weight of all Varieties					
L. S. D. .05					12.3
.01					17.4

There was no significant difference in the Variety X Treatment.

six inches apart in rows 32 inches apart. The two harvesting dates were July 27 and August 11. The soil on which the crop was grown had received a broadcast application of 5-10-20 at the rate of 1,000 pounds per acre. Each plant received one-quarter pint of solution during transplanting.

Treatments:

Treatment	Chemical Used
1. Water	
2. 10-52-17	50%* Di-ammonium phosphate 50% Mono-potassium phosphate
3. 10-52-17	(12 pounds per 50 gallons water) (one-eighth pint per plant)
4. 0-52-34	Mono-potassium phosphate
5. 21-53-0	Di-ammonium phosphate
6. 10-26-17	50% Mono-potassium phosphate 31% Ammonium nitrate

Results:

The results of this investigation (Table XXVIII) indicate that when celery was harvested on August 11 instead of July 27 a significant increase in yield of 36.8 percent for Cornell 19 and 39.3 percent for Top Ten was obtained. Yields of Top Ten were 30 and 32.4 percent above those of Cornell 19 for the early and late harvests respectively.

In observing the effect of the starter treatments on the different varieties (Table XXVIII), it is evident that at the time of early harvest no significant

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*Percent equivalent to six pounds in 50 gallons of water unless otherwise indicated.

TABLE XXVIII

Effect of Different Soluble Fertilizer Treatments and Harvesting Dates On Celery Yields.

Treatments	Average Weight of Varieties of Two Harvesting Dates				Average Weight of Two Harvesting Dates		Average Weight of Two Varieties and Harvesting Dates
	Early Harvest		Late Harvest				
	Cornell 19	Top Ten	Cornell 19	Top Ten	Cornell 19	Top Ten	
Water	27.7**	36.5	37.7	56.1	32.7	46.3	39.5
10-52-17 (6 lbs.)	28.1	37.4	39.4	49.4	33.7	43.3	38.7
10-52-17 (12 lbs.)	29.5	36.0	38.7	52.7	34.1	44.4	39.3
0-52-34 (6 lbs.)	26.9	38.5	41.3	55.8	34.1	47.2	40.7
21-53-0 (6 lbs.)	28.0	37.6	35.5	51.2	31.8	44.4	38.1
10-26-17 (6 lbs.)	27.8	32.0	37.2	38.9	32.5	35.5	34.1
Average Weight	28.0	36.4	38.3	50.7	33.2	43.6	

L. S. D. in average weight of varieties at different harvest dates	.05	3.60
	.01	8.02
L. S. D. in average weight of the two varieties at the same harvest dates	.05	2.63
	.01	6.06
L. S. D. in average weight between the two varieties at the same treatment	.05	3.63
	.01	5.38
L. S. D. in average weight for the same variety at different treatments	.05	3.64
	.01	4.94
L. S. D. in average weight due to starter treatments	.05	2.57
	.01	3.50

*Average weight in pounds from twelve 16-plant values.
** Average weight in pounds from two 16-plant values.

differences occurred between the starter treatments for Cornell 19, however, the early yield of Top Ten was somewhat less for the 10-26-17 treatment. This was again noticeable in the later harvest. This may indicate that the Top Ten variety responded more to the high phosphorus in the starter solution than did Cornell 19.

Summary of Celery Investigation

The larger more vigorous green celery varieties, probably because of their larger nutrient requirement, respond more to starter fertilizer treatment than the smaller Cornell 19 variety. In the 1953 investigation all the nine treatments slightly reduced Cornell 19 yields, while increasing the yield of Utah Top Ten with eight of the nine treatments. The starter treatment to which the celery responded most was 21-53-0, indicating a need for high nitrogen and phosphorus. The results indicate that on soils adequately supplied with nitrogen from a broadcast pre-planting application starter solutions are of little value to the celery crop.

Cole Crops

Effect of Soluble Fertilizer Solutions on Maturity and Yield of Fall Grown Cauliflower

The effects of different starter solutions on the yield of cauliflower were investigated in 1952. A problem in cauliflower production is the poor head development that results (buttoning) from any check in growth.

Methods and Materials:

Cauliflower plants (variety Snowball X) were transplanted 16 inches apart in rows 36 inches apart on Hillsdale sandy loam soil which had received an application of 3-12-12 at the rate of 800 pounds per acre. The 20 plants per treatment were replicated three times. The crop was transplanted July 8, treated July 9, and harvested October 7 to 21. Each plant was treated with one-quarter pint of one of the solutions listed below at planting time.

	Chemicals Used
1. Water	
2. 10-52-17 (2 lb. per 50 gallons)	50% Di-ammonium phosphate 50% Mono-potassium phosphate
3. 10-52-17 (4 lb. per 50 gallons)	50% Di-ammonium phosphate 50% Mono-potassium phosphate
4. 10-52-17 (6 lb. per 50 gallons)	50% Di-ammonium phosphate 50% Mono-potassium phosphate
5. 17-26-17*	50% Ammonium nitrate 50% Mono-potassium phosphate

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*Equivalent to four pounds in 50 gallons of water.

6. 25-0-23*	50% Ammonium nitrate 50% Potassium nitrate
7. 17-0-31*	50% Ammonium nitrate 50% Potassium chloride
8. 20-53-0	Di-ammonium phosphate
9. 0-52-34	Mono-potassium phosphate

Results

Table XXIX indicates that the starter treatment 20-53-0 resulted in a 149 percent weight increase and a 113 percent increase in number of heads cut for the first harvest date over plants receiving only water. The total yield (three cuttings) was also greater (53 percent) for the 20-53-0 treatment than for plants receiving only water. The increase in yield was the result of an increase in the percentage of heads cut, as well as an increase in the average weight of the heads from plants receiving the starter solution. The increase in the early and total yield for plants receiving the 20-53-0 could have been the result of the high nitrogen together with the high phosphorus, which tended to produce a more vegetative plant, as indicated by other workers (5). No other treatments were significantly better than water.

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*Equivalent to four pounds in 50 gallons of water.

TABLE XXIX

Response of Cauliflower to Different Soluble Fertilizer Solutions.

Treatment	Yield up to October 7 1st Cutting				Yield up to October 14 2 Cuttings				Total Yield up to October 21 3 Cuttings			
	Avg. No.	Per-cent Cut	Avg. Wt. (lbs) per Rep.	Avg. Wt. (lbs) per Head	Avg. No.	Per-cent Cut	Avg. Wt. (lbs) per Rep.	Avg. Wt. (lbs) per Head	Avg. No.	Per-cent Cut	Avg. Wt. (lbs) per Rep.	Avg. Wt. (lbs) per Head
Water	5.3*	26.5	16.3**	3.08	11.8	59.0	30.0	2.54	16.5	82.5	33.9	2.06
10-52-17 (2 lb/50 gal. water)	7.0	35.0	26.0	3.71	13.8	69.0	38.9	2.82	20.0	100.0	41.5	2.08
10-52-17 (4 lb/50 gal. water)	4.5	22.5	14.8	3.29	9.5	47.5	24.4	2.57	16.5	82.5	27.9	1.69
10-52-17 (6 lb/50 gal. water)	6.8	34.0	26.2	3.90	12.5	62.5	38.0	3.04	17.8	89.0	40.1	2.25
17-26-17	7.3	36.5	24.3	3.33	13.8	69.0	36.8	2.67	19.8	99.0	38.8	1.96
25-0-23	5.3	26.5	18.8	3.55	9.5	47.5	27.3	2.87	18.5	92.5	32.4	1.75
17-0-31	5.5	27.5	19.3	3.51	13.0	65.0	35.1	2.70	19.8	99.0	37.0	1.87
20-53-0	11.3	56.5	40.6	3.59	15.8	79.0	49.6	3.13	20.0	100.0	52.2	2.61
0-52-34	7.0	35.0	23.6	3.37	13.3	66.5	35.1	2.64	18.5	92.5	35.1	1.90
L.S.D. .05	3.1		13.0		3.3		11.8		2.1		12.5	
.01	4.3		17.7		4.5		16.0		2.8		17.0	

*Average number of heads cut from four 20-plant replications.

**Average weight in pounds from four 20-plant replicates.

Effect of Soluble Fertilizers on Maturity and Yield of Fall Grown Cabbage, Broccoli, and Cauliflower

Methods and Materials:

Both the 1953 and 1954 cabbage, broccoli and cauliflower were given the same starter treatments, as well as being transplanted on the same type of soil. Golden Acre cabbage, Midway broccoli and Snowball X cauliflower were used.

The crops were field seeded on Hillsdale sandy loam soil. The 1953 crop was "set" on soil in which a growth of clover had been ploughed under the previous fall, which resulted in a rather high nitrogen content. The 1954 crop was planted on the same soil type that had been in a row crop in 1953. The 1953 crop received a 5-20-20 fertilizer at the rate of 900 pounds per acre, the 1954 crop was fertilized at the rate of 200 pounds per acre.

Ten plant plots were replicated three times, 18 inches apart in rows three feet apart. The following treatments were applied:

	Chemicals Used
1. Water	
2. 10-52-17	50%* Di-ammonium phosphate + 50% Mono-potassium phosphate
3. 17-26-17	50% Ammonium nitrate + 50% Mono-potassium phosphate
4. 20-31-10	60% 10-52-17 + Ammonium nitrate
5. 20-53-0	Di-ammonium phosphate

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*Equivalent to four pounds in 50 gallons of water.

6. 0-52-34	Mono-potassium phosphate
7. 23-0-23	50% Ammonium nitrate + 50% Potassium nitrate
8. 17-76-0	Victamide
9. 30-0-0	Ammonium nitrate

The above concentrations were four pounds per 50 gallons of water and each plant received one-quarter pint at transplanting time of one of these solutions.

Cabbage

The 1953 cabbage crop was harvested on September 2, and the 1954 cabbage crop on September 23.

Table XXX indicates that there was no significant increase in the yield of cabbage in either season as the result of starter solution treatment. This was probably due in 1953 to the high residual nitrogen content of the field as a result of the clover crop. The 1954 crop showed a decrease where starter solutions low in either nitrogen and phosphorus were used. When 17-76-0 was used a decrease in yield was obtained, which was probably the result of injury from the use of the starter solution.

Broccoli

In the 1953 and 1954 broccoli (Midway) experiments, the early yield consisted of that cut to September 1, and the total yield that was cut for the entire season.

TABLE XXX

Effect of Different Soluble Fertilizer Treatments on Yield of Cabbage, Cauliflower and Broccoli.

Treatment	CABBAGE 1953	CABBAGE 1954	BROCCOLI 1953 Early Yield Sept. 1	BROCCOLI 1953 Total Yield Sept. 22	BROCCOLI 1954 Early Yield Sept. 1	BROCCOLI 1954 Total Yield Sept. 22	CAULIFLOWER 1953 Yield up to Sept.24		CAULIFLOWER 1953 Yield up to Oct. 5		CAULIFLOWER 1953 Total Yield		CAULIFLOWER 1954 Yield up to Sept.24		CAULIFLOWER 1954 Yield up to Oct. 5		CAULIFLOWER 1954 Total Yield	
	Avg. Wt.	Avg. Wt.	Avg. wt.	Avg. wt.	Avg. wt.	Avg. wt.	Avg. No.	Avg. Wt.	Avg. No.	Avg. Wt.	Avg. No.	Avg. Wt.	Avg. No.	Avg. Wt.	Avg. No.	Avg. Wt.	Avg. No.	Avg. Wt.
Water	45.3*	23.2	8.2	12.0			3.7	10.3	6.7	17.5	9.3	21.5	5.7	14.3	9.0	24.2	9.0	24.2
10-52-17	43.7	21.9	8.6	11.3	2.2	4.3	2.3	14.4	6.3	21.1	7.3	22.8	4.0	14.4	7.7	22.8	7.7	22.8
17-26-17	42.0	26.3	8.1	10.4	2.7	5.5	4.0	21.6	6.7	24.6	7.0	25.2	3.3	11.5	9.7	26.3	9.7	26.3
20-31-10	40.3	27.4	7.1	10.0	2.1	5.0	4.3	17.6	8.0	27.4	8.7	27.8	5.0	13.3	9.7	26.4	9.7	26.4
20-53-0	43.4	24.7	9.2	12.0	0.8	3.4	4.7	15.3	7.0	19.2	9.0	24.9	6.3	17.0	9.0	24.1	9.0	24.1
0-52-34	46.9	18.7	7.5	10.2	2.7	4.4	3.3	8.8	7.0	19.3	8.7	25.0	6.3	22.1	9.3	30.9	9.3	30.9
23-0-23	40.6	19.5	7.7	10.6	1.3	4.3	4.0	18.5	7.7	25.6	8.0	26.8	2.7	8.1	7.7	21.3	7.7	21.3
17-76-0	37.6	22.0	6.8	9.0	2.2	4.6	3.3	11.3	6.3	12.2	7.3	20.6	5.3	19.8	9.3	31.4	9.3	31.4
30-0-0	43.0	20.1	8.4	10.2	1.5	4.1	3.0	14.5	6.7	24.0	7.7	27.1	5.0	15.7	7.7	22.7	7.7	22.7
L. S. D. .05	7.5	8.9	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.
.01	N. S.	N. S.																

*Average weight in pounds from three 10-plant plots.

The absence of significant differences (Table XXX) in yield due to starter treatment in the 1953 yield for broccoli was probably the result of the naturally high fert ility of the soil.

In 1954, the broccoli crop failed due to premature heading, which resulted from an extremely hot and dry summer.

Cauliflower

Although no significant differences occur between the starter treatments for either the yield or number of heads cut (Table XXX) early yield was influenced as in 1952 by starter solutions high in nitrogen and phosphorus. The reasons for lack of significant responses to the starter treatment were probably due to the high fertility of the soil as well as the use of optimum sized plants that continued uninterrupted growth when transplanted.

Yield of Spring Cabbage as Affected by Soluble Fertilizer Solutions and Different Aged Cabbage Plants

In early spring when cabbage is transplanted to the field, soil temperatures are usually quite cool, which limits the availability of soil nutrients because of low microbial activity. Perhaps starter solutions might be especially beneficial to cabbage plants on cold soils.

Methods and Materials:

On April 24, 1953 ten Golden Acre cabbage plants were field planted for each starter treatment. Each treatment was repeated with plants of different ages. The plants were placed 18 inches apart in rows three feet apart on Hillsdale sandy loam. Chlordane solution was added to the starter for the prevention of maggot injury.

The treatments were:

	Chemicals Used
1. Water	
2. 10-52-17	50% Di-ammonium phosphate + 50% Mono-potassium phosphate
3. 0-52-34	Mono-potassium phosphate
4. 20-53-0	Di-ammonium phosphate
5. 18-0-35	75% Potassium nitrate + 25% Ammonium nitrate

Rate of the above material was one ounce per gallon. Each plant received one-half pint per plant at transplanting time of one of the above solutions.

Results:

Table XXXI indicates that on the average of plants from all age groups, treatments 20-53-0 and 18-0-35 produced a significantly greater yield than plants receiving only water. Starter treatments high in nitrogen were more beneficial to the spring cabbage crop than those low in nitrogen. Rahn (32) in his work also found that nitrogen in the starter solution was important in producing higher yields in cole crops.

Summary of Results with Cole Crops:

In the 1952 cauliflower investigation the starter solution 20-53-0 increased considerably the early number and weight of heads cut as compared to plants receiving only water. In 1953 and 1954 early yields were again increased by the use of starter solutions high in nitrogen and phosphorus, although no significant differences were evident, probably due to the high fertility of the soil.

The effects of starter solutions on the broccoli yield showed no significant differences in 1953 because of the high soil fertility and in 1954 because of the hot weather, which produced premature seedstalks.

The fall cabbage of 1953 and 1954 gave no significant increases in yield for the starter, probably due to the high soil fertility level, however the cabbage quality seemed to benefit from starter solutions high in nitrogen and phosphorus (20-53-0). This same starter solution increased the yield significantly with the 1953 spring crop.

TABLE XXXI

Influence of Starter Treatment on Yield of Cabbage Plants.

Treatment		Average Weight
Water		17.6*
10-52-17		20.6
0-52-34		17.3
20-53-0		23.0
18-0-35		23.5
L. S. D.	.05	5.1
	.01	7.4

* Average weight in pounds from three plots.

DISCUSSION

The application of solutions containing high analysis soluble fertilizers to vegetable plants at time of field setting has been shown to be beneficial under conditions where soil fertility is moderately low or the treatment promotes rapid recovery. These solutions are especially useful in transplanting crops that have a high top root ratio or have lost a large proportion of their roots during the process, resulting in transpiration losses that are in excess of the root system's capacity to absorb water. The introduction of available nutrients in the rooting zone of the transplants rapidly promote new root development which helps to overcome the shock of transplanting. This is of utmost importance, since any delay in growth of annuals may have pronounced effects on subsequent maturity, yield, and quality. When maturity is delayed, a poorer market often results, as in the case of early tomatoes, or in a shortened harvest with canning tomatoes. In cauliflower a delay in growth usually causes premature maturing or bottoning of the heads.

Starter solutions also tend to bring plants out of a hardened condition more rapidly, especially if applied two to seven days before field setting. The readily available nutrients in properly balanced starter solutions promote the regeneration of new roots which rapidly decrease the high top root ratio existing at transplanting and allow nutrient and moisture absorption to keep pace with plant metabolism and transpiration. Low analysis dry fertilizers applied to the soil in bands do not have an effect comparable to starter solutions because the dry salts must first be dissolved before the nutrients become available, and during this transition may cause some salt injury to the treated plant.

Fundamental Studies

In greenhouse and laboratory experiments the concentration of soluble nitrogen and phosphorus accumulated in tomato plants as a result of treatment was influenced by both air and soil temperatures. When tomato plants were grown at air temperatures of 50° F and 60° F, plant utilization and growth did not keep pace with nitrogen absorption. Other investigations indicated that nitrogen absorption occurs at lower temperatures than growth (29). Nitrogen absorption apparently is only slightly influenced by temperature, however its utilization is dependent on a fairly high temperature. It was found in this investigation that optimum growth of tomatoes occurred at an air temperature of 70° F in the presence of a readily available source of nitrogen and phosphorus.

When phosphorus is applied in the starter solution it must be readily available in large amounts, for absorption and accumulation to occur in tomato plants at lower temperatures. When plants were not treated with phosphorus solutions, lack of growth resulted in little change in their phosphorus concentrations. When soluble phosphorus was high in tomato plants two weeks after treatment, an increase in plant growth and yield occurred. This phenomena can probably be related to the phosphorus requirement during early stages of plant growth which have a pronounced effect on subsequent growth and yield. Other investigators have observed that phosphorus is necessary for tomato fruit setting and development (24). This study indicated that even with the application of nutrients to tomato plants grown at low soil temperatures (46° F) soluble nitrogen accumulated in the tissue, but the plants failed to grow and the foliage became chlorotic. This nitrogen accumulation is an indication of low metabolic activity or the unavailability of phosphorus to build up the metabolic compounds. Thus, there exists a continued belief, supported by some experimental evidence, that foliar applications of nutrients could have a marked effect on plant growth during the cold temperatures of early spring. Some experimental evidence presented indicates that starter solutions high in phosphorus tend to decrease flower abscission and increase early flowering and fruit setting in tomatoes. Thus, the reason for earlier yields of tomatoes when starter solutions are used, could be due, in part, to their ability to supply needed plant nutrients which permit the earlier development of a greater number of fruits.

Unbalanced plant nutrients are often responsible for root injury. Tomato roots withstood solutions of nutrient mixtures of higher salt concentrations when all three of the major elements were present, than when any one was absent. This investigation indicates that there is considerable crop variability with respect to the elements most important for root development.

All roots require nitrogen and phosphorus for their differentiation and development (14), thus tomato plants developed root systems most rapidly when these nutrients were present in high concentrations, but for rapid tobacco root development, potassium was equally as important as nitrogen and phosphorus.

The early rapid absorption of both phosphorus and nitrogen in tomatoes is of utmost importance, since a high level of nitrogen is required for plant growth and metabolism, and a high level of phosphorus is necessary for flower initiation and fruit set, as well as for many metabolic processes. These nutrients are often limited to the plants early in the spring, as nitrogen in the soil organic matter is not released by the soil organisms at the low soil temperatures and the phosphorus is often tied up in the soil colloid as calcium phosphate or in soluble precipitates of iron, aluminum or manganese. Thus, plants are benefitted by a concentrated available supply of these nutrients ealy in their growth. This can be provided in various ways, in most soils the nutrients are added as dry fertilizer salts, and are satisfactory for established or seeded crops, however there is generally a need for the more soluble fertilizer solutions to help transplants become established. This investigation indicated that phosphorus is more rapidly absorbed from mono-ammonium phosphate solutions than from other sources, which may be due to some unfavorable ionic or pH relationship in them. Perhaps the nitrogen in the mono-ammonium phosphate facilitated a better nutrient balance which permitted a greater absorption of phosphorus.

In further investigations with starter solutions, consideration should be given to the use of the various fertilizer salts in combination with minor elements in foliar sprays. Urea is commonly used in foliar sprays, but the incorporation of phosphorus and potassium still require considerable investigation before materials and their concentrations can be recommended for horticultural crops. The compatability of phosphorus and potassium materials with spray chemicals would also require a considerable study. It is likely that greater volumes of nutrients could be applied without danger of injury to the foliage by using chelates containing these nutrients. Further studies are necessary on nutrient absorption of these high analysis soluble salts at different soil and air temperatures, as well as different levels of soil moisture. Considerations should also be given to continued work on root injury of various plant species by different analyses and concentrations of salts, as well as time of application.

Application of Starter Solution Materials

The application of starter solutions to transplants supplies readily available nutrients near the damaged roots, insures their rapid regeneration, and enables them to utilize the regular fertilizer application sooner. In tomato investigations, starter solutions applied several days before field setting greatly increased the number, but slightly reduced the size of fruits. This increase in early yield was probably related to high phosphorus in the fertilizer solution, which accelerated plant maturity and induced earlier flowering and fruit set. An increase in fruit size might have been obtained from a heavier fertilizer application.

Starter solutions applied at transplanting have been found to increase the early and total yield of tomatoes (2, 3, 7, 32, 33, 37). This increase in yield was usually associated with increase in fruit number without affecting fruit size, indicating the ability of soluble plant starters to facilitate an increase in flower production and fruit set, or else the application of nutrients resulted in a decrease of flower abscission, as was observed in the present investigation. This investigation indicated that early planting had a greater effect on early tomato yield to a given date than starter solution applications. It appears that a longer bearing season, under favorable conditions is just as advantageous as startersolutions. However, under unfavorable growing conditions, early in the season, it might be more advantageous to put plants in later and use starter solutions.

Polyethylene mulches used on tomato plants in combination with starter solutions produced larger increases in early yield than when either was used separately. This indicates that with an increase of 2 to 3°F in the soil temperature under the polyethylene mulch, and with the addition of the readily available nutrients in the starter solution, the increase in nutrient absorption and metabolic activity tended to follow the Q_{10} phenomena for plant growth and metabolism.

Previous work has indicated that nitrogen was the most important element in starter solutions for early celery production (9). The results of this experiment indicated that phosphorus was the most important element because these tests were carried out in organic soil where nitrogen is seldom a limiting factor. With cole crops the results of this study agree with the work of Rahn (32) who found that nitrogen was the important nutrient. In addition, phosphorus was found to be of importance in the current investigation, but on soils of high fertility the effect of starter solutions were not evident at harvest. However, fall cabbabe appears to be able to grow well with a lower percentage of nitrogen in the starter solution than the spring crop. This is probably due to differences in nitrogen content, as influenced by differences in soil temperatures at which the two crops were grown.

Value of Starter Solutions

Starter solutions are effective in various ways. The most important single factor in their effectiveness lies in their ability to supply immediately available nutrients in proper balance in close proximity to plant roots at the time of a critical need by the plant. This lessens the shock of transplanting leading to an earlier establishment of the plants, and a higher percentage of survival. The use of starter solutions at the time of field planting increased both early and total yields of cauliflower, peppers, tomatoes, and celery. On the basis of their application, starter solutions supply a high nutrient concentration in the immediate area of the plant. For example, when one-half pint of a solution of a high analysis soluble fertilizer at a rate of four pounds per 50 gallons of water is applied to an area of about one square foot near the tomatc plant roots it is comparable to an application of 218 pounds per acre in terms of the treated area.

Also, the high concentration of nutrients per unit of material will help prevent injury in soils of high salt content, such as those on which greenhouse crops are grown, because they will not as markedly affect the osmotic value of the soil solution as those supplying an equal quantity of nutrients from a lower analysis. The ease of application of starter solutions by means of irrigation equipment can be very effectively used in overcoming developing plant deficiency symptoms in the field. Nutrient additions to seedling plants can be more easily manipulated and controlled by the use of starter solutions than by dry fertilizers. For example, tomato plants treated with starter solutions ten days before field planting will probably produce an increased early yield, due to the timely applicat ion of phosphorus which induces earlier flowering and fruit maturation (24). Although flat treated tomatoes tend to produce a larger number of earlier fruits, it may result in a decrease in total yield, due to forced flowering on smaller plants.

The use of starter solutions are especially effective on soils of low fertility, since the small addition of nutrients in solution have a profound effect on the yield because the crops are at the lower poverty section of the Mitscherlich's equation (28). With each additional increment of fertilizer the response in yield decreases until the maximum yield for the plant is attained and further fertilizer applications would be valueless and could prove harmful. And so it is evident why a little fertilizer in solution often induces increased yields, especially in low fertility soils, but is not noticeably beneficial in soils of high fertility.

Variation in Crops

Crops tend to vary in their response to both formulation and analysis of starter solutions. Tomatoes and peppers require starter solutions of medium nitrogen and high phosphorus (10-52-17), whereas, cole crops and celery appear to benefit more from a high nitrogen and a medium to high phosphorus (20-53-0). The Snowball X cauliflower variety receiving starter solutions high in nitrogen and phosphorus (20-52-0) produced more uniform earlier heads than plants receiving only water.

Variations exist not only among crops, but within crops between varieties. Early maturing tomato varieties, such as Valiant, produced greater increases in early yield when starter solutions were used than some of the later maturing varieties, such as Wisconsin 55. In celery the green Utah types responded to fertilizer solutions, whereas the yellow Cornell 19 variety gave little or no indication of a yield increase for the same treatments. When the root growth of tomatoes and tobacco were investigated, tomato roots showed a greater tolerance to higher concentrations of fertilizer salts than tobacco roots and also developed a better root system when salts containing phosphorus and nitrogen were used, whereas potassium was equally as important as phosphorus and nitrogen for tobacco root development.

SUMMARY

Starter solutions are effective in increasing vegetable crop yields when applied to transplants on soils of medium to low fertility. They promote rapid recovery and thereby increase plant stand, and in tomatoes, tend to reduce flower abscission.

When nitrogen and phosphorus are added to tomato plants grown at different temperatures, soluble nitrogen and phosphorus accumulated at low temperatures (46 to 54° F), but utilization in plant growth occurs only at higher temperatures. Phosphorus concentration in tomato plants two days after treatment with starter solutions is associated with an increase in yield in early maturing tomato varieties, such as Valiant. Phosphorus is absorbed more readily at 70° F temperatures than at lower temperatures; however, two weeks after treatment the difference in soluble phosphorus concentration is not readily apparent, due to plant growth. Starter solutions have little or no effect on plant growth at the lower soil temperatures (46 to 54° F).

Tomato roots appear to benefit more from phosphorus and nitrogen in the starter solution than from potassium, but potassium seems to be as important as nitrogen and phosphorus for tobacco root growth. Tomato roots are also more tolerant of unbalanced nutrient solutions or solutions of high osmotic pressure than tobacco roots. However, early root growth in both tomatoes and tobacco is considerably less when nitrogen is absent

from the starter treatment.

Increases in early tomato yields from starter solutions are usually associated with an increase in a larger number of smaller fruit. When the plants are treated two to ten days before field setting, the early yield is usually increased and total yield reduced.

Cole crops and celery respond to starter solutions containing a high nitrogen and phosphorus (23-53-0), whereas peppers and tomatoes respond more to solutions containing a medium nitrogen and high phosphorus (10-52-17).

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APPENDIX

Tables A, B, and C

TABLE A

Comparative Effect of Root and Air Temperature on Growth of Tomato Plants

Root Temperature* (Degrees F)	Average Weight of Plant*** (Grams)	Percent of Weight**	Air Temperature (Degrees F)	Average Weight of Plant (Grams)	Percent of Weight
46	7.58	5.07			
54	80.41	53.73	50	14.8****	43.09
62	125.90	84.13	60	18.4	53.57
70	149.65	100.00	70	34.35	100.00

*Air temperature was 68°F.

**Percent of weight when compared with plants grown at 70°F.

***Average fresh weight of 12 plants.

****Average fresh weight of 18 plants.

TABLE B

Effect of Soluble Fertilizer Treatment, Flat Treatment, and Field Fertilization on Total Yield of Tomatoes Produced (1953)

	Total Weight					
	Field Fertilized			Non-Field Fertilized		
Treatments	No Flat Treat-ment	Flat Treatment Day Before Field Planting	Flat Treatment 10 Days Before Field Planting	No Flat Treat-ment	Flat Treatment Day Before Field Planting	Flat Treatment 10 Days Before Field Planting
1. Water	43.0*	42.8	45.6	32.2	40.2	39.8
2. 10-52-17	43.9	42.9	39.0	34.7	36.8	41.2
3. 18-76-0	42.8	42.1	41.6	35.2	38.7	41.9
4. 10-26-17	43.7	46.4	45.25	38.8	39.8	39.8
5. 0-52-34	41.0	41.3	47.4	38.7	38.5	41.1
6. 25-53-0	37.3	44.3	44.5	37.1	36.9	41.3
7. 10-0-17	38.7	42.7	42.1	42.1	39.6	37.7
8. 4-16-4 Dry Application	39.0	44.8	46.2	44.5	41.4	39.0
Average Weight of Treatment	41.2	43.4	43.6	37.9	39.0	40.2

*Average of 4 five-plant values in tons per acre.

TABLE C

Effect of Soluble Fertilizer Treatment, Flat Treatment, and Field Fertilization on Total Number of Tomatoes (1953)

Treatment	Field Fertilized			Non-Field Fertilized		
	No Flat Treatment	Flat Treatment Day Before Transplanting	Flat Treatment 10 Days Before Transplanting	No Flat Treatment	Flat Treatment Day Before Transplanting	Flat Treatment 10 Days Before Transplanting
1. Water	536*	529	603	390	472	470
2. 10-52-17	570	532	466	392	427	489
3. 18-76-0	529	532	492	420	447	477
4. 10-26-17	551	627	607	419	467	482
5. 0-52-34	512	541	651	479	443	494
6. 25-53-0	525	536	567	435	443	473
7. 10-0-17	530	603	540	516	462	481
8. 4-16-4 Dry Application	500	607	609	532	485	478
Average Number of Treatment	532	563	567	448	456	481

*Average of 4 five-plant values.