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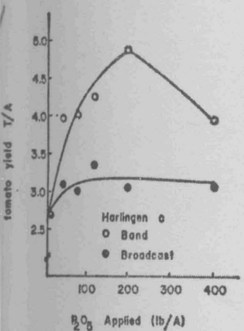
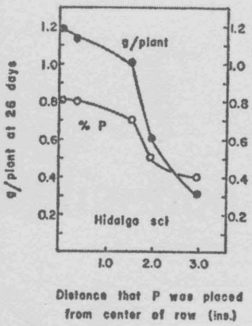
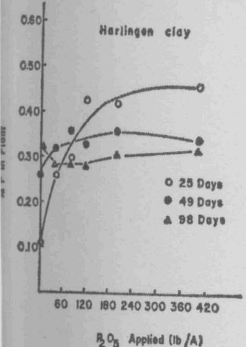
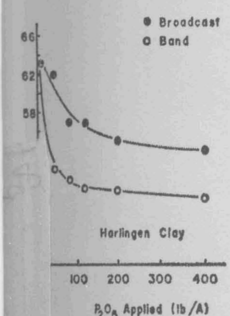
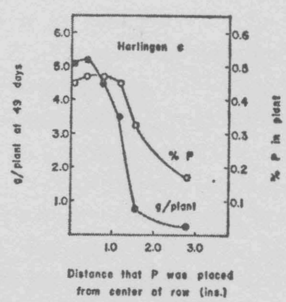


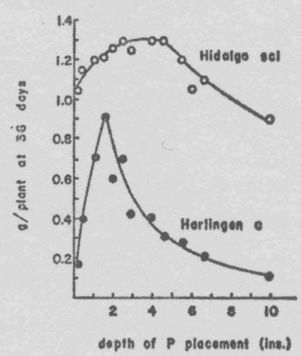






Phosphorus Fertilization of Direct Seeded Tomatoes





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Contents

Summary

Phosphorus fertilization of direct seeded tomato was studied in field, laboratory and greenhouse expe ments over a 3-year period in the Lower Rio Grand Valley of Texas. Results indicated that tomatoes a very sensitive to placement of phosphorus in that rap early growth and high yields were obtained with pho phorus banded below the seed, but little benefit w obtained from broadcast phosphorus. Phosphorus upta by young plants was higher from banded than fro broadcast phosphorus. Uptake of certain other nutrien was influenced by phosphorus rate and placement.

Phosphorus response was increased under cold co ditions of January and February, but phosphorus fe tilization of fall tomatoes also increased yields. Lit benefit was obtained from phosphorus applied th previous year. For maximum response to phospho by tomatoes, the phosphorus must be placed 2 to inches below the seed. Other fertilizers such as nitrog should not be placed with the phosphorus because decreased seed germination and damage to seedlin

Phosphorus Fertilization of Direct Seeded Tomatoes

y W. Hipp*

THE DIVERSITY OF FARMING PRACTICES in the Lower Rio Grande Valley of Texas results in one of the most complex agricultural areas found in the United States. About 40 different kinds of crops on almost as many soil types are grown in the area. The many soil types have a wide range of chemical and physical properties. This soil variation along with erratic rainfall patterns and intensive irrigation gives rise to a variety of plant and soil relationships that would be expected to influence the levels of soil nutrients required for adequate nutrient absorption by plants. The soils of the Rio Grande Valley are relatively young compared with soils of other areas that have been cropped for many years. Phosphorus (P) fertilizers have been applied to many soils of the valley, but information is lacking regarding how, when and how much should be applied.

Many of the vegetable crops grown in the area are winter crops. There is considerable evidence that temperature influences the uptake of P by plants (14). Mechanization has influenced the need for fertilization in that time and uniformity of rate of maturity are of utmost importance in crops adapted to maximum mechanization. The increasing need for further knowledge about methods of using P fertilizers and their requirements by crops is evidenced by the increase in sales of P fertilizer in Texas from 1959-1960 through 1967-1968 (5, 6). Decreased acreage and demands for increased output have created a need for precision in diagnosing fertility needs of crops to be grown on the limited acreage allocated to each crop.

In the Lower Rio Grande Valley of Texas, spring tomatoes are direct seeded during January and February when soil temperatures are still low. Phosphorus fertilization is a common practice, but little attention is directed to placement. Phosphorus deficient tomato plants are a common sight, even in fields having had applications of high rates of P. Phosphorus deficient tomato plants in the seedling stage can be recognized easily by their dwarfed growth and purple coloration. The underside of leaves becomes purple before the remainder of the plant, but in severe cases the entire plant, including the stem, will be purple. The leaves are generally small, and the plant does not appear to be growing. As a result of the slow growth, length of time to fruiting and maturity is increased, and yields are decreased. Direct seeded tomatoes for fall production are also susceptible to P deficiency, but the deficiency is not as common as in spring tomatoes because of higher temperatures at seeding.

Results from P experiments indicate that the same rate or method of placement is not equally effective

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for all crops and soil types. Numerous P placement and rate experiments have been conducted in greenhouse pots. However, P placement and rate data from greenhouses are necessarily limited to short-term early growth experiments. Because most of the P field experiments with tomatoes have been conducted with transplanted tomatoes, very little information is available regarding the P requirements of direct seeded tomatoes.

Although research from other areas contributes to the knowledge of P fertilization of tomatoes in the Lower Rio Grande Valley of Texas, complete guidelines cannot be established because of differences in soils and environmental factors.

Rooting habits and high P requirements of tomato seedlings are primary factors to consider in developing a P fertilizer program for tomatoes. Locascio and Warren (10) found that the growth of tomato plants was related to the time required for their roots to reach applied P and that the initial root growth was of the taproot type. These findings suggest that distance of lateral placement of P fertilizer would be of primary importance in obtaining early growth and yield of tomatoes. In other studies by Locascio, Warren and Wilcox (11), good yields were obtained from low rates of P applied as a seed treatment alone, but placement of P in a band 1 to 1.5 inches below the seed was the best method. For transplanted tomatoes, deep placement of P was found to be more efficient than shallow P placement (9).

In shallow rocky Florida soils, Orth (12) indicated that it is difficult to place P in uniform bands, but early P requirements of direct seeded tomatoes can be satisfied by placing P with the seed. Results of studies of the effect of soil temperature on P nutrition, reviewed by Sutton (14), suggest that in certain cases adverse effects of cold soils can be reduced by P fertilizers.

The influence of P fertilizers on the uptake of other nutrients has been studied (1, 2). The primary effect seems to be a reduction in zinc and iron uptake with increasing amounts of P added. Recently, a magnesium-phosphorus interaction in tomatoes was reported (8). Occurrences of these interactions have been observed, but their significance has not been fully evaluated.

Preliminary experiments with P placement methods on Harlingen clay (c) soil (7) indicated that tomatoes grown under Lower Rio Grande Valley conditions were extremely sensitive to P rate and method of placement. This led to a more complete investigation in which field, greenhouse and laboratory experiments were conducted at the Texas A&M University Agricultural Research and Extension Center at Weslaco to gain additional information concerning the P requirements of direct seeded tomatoes.

MATERIALS AND METHODS

Soils used in the study were Harlingen clay, Willac fine sandy loam (fsl) and Hidalgo sandy clay loam (scl) all of which are common to the Rio Grande Valley area of South Texas and Northern Mexico. Harlingen c is uniform in texture to a depth of several feet, and due to its fine texture, water penetration is very slow. Willacy and Hidalgo soils are medium textured and allow rapid water penetration. Harlingen and Hidalgo soils are calcareous throughout the soil profile. Willacy soils are not calcareous in the surface but become calcareous below the topsoil. Soil test characteristics of the soils are shown in Table 1.

Field experiments were conducted on Harlingen c and Willacy fsl in spring 1967 to determine the influence of P rate and placement on tomato growth, nutrient uptake, maturity rate and yield. Phosphorus rates of 40, 80, 120 and 200 pounds of P_2O_5 per acre were applied by two methods (400 pounds of P_2O_5 per acre were also included on the Harlingen c). One method consisted of applying P as a band directly beneath the seed row (banded); the other method consisted of broadcasting the P over the entire plot area and then mixing it into the surface 3 inches with a rolling cultivator. A check without P was also included. The form of P used was 0-46-0. 'Chico' tomatoes were seeded in 76-inch rows and immediately watered to obtain a stand. Three replications were included in the field experiment. Plant samples from all treatments were taken periodically to gain information concerning nutrient uptake and growth rate. Normal cultural and irrigation practices for the area were followed throughout the growing season. Similar experiments were conducted on Hidalgo scl in 1969 except that the rates of P_2O_5 used were 50, 100, 150 and 200 pounds per acre; the row spacings were 38 inches; and the variety of tomato grown was 'Chico III'.

An experiment to evaluate the influence of P application on fall-grown Chico tomatoes was conducted on Harlingen c in 1967. The rates of P_2O_5 were 0 and 1[illegible] pounds per acre applied in a band below the seed.

Phosphorus treatments of 0, 400, 800 and 1,60[illegible] pounds of P_2O_5 per acre were broadcast on Harlingen

TABLE 1. CHARACTERISTICS OF THE SOILS USED IN THE STUD[illegible]

	pH	lb P_2O_5/acre[1] extracted with sodium bicarbonate at pH 8.5	lb P_2O_5/acre extracted with ammonium acetate at pH 4.2
Harlingen c	8.2	106	300
Willacy fsl	7.8	74	474
Hidalgo scl	8.2	28	28

[1]Based on 0 to 6-inch depth.

in 1968. Other treatments included placement of 14 and 36 pounds of P_2O_5 per acre in direct contact with the seed and 60 and 120 pounds of P_2O_5 per acre in a band 3 inches below the seed. Chico tomatoes were grown. Chico III tomatoes were grown on the broadcast plots in 1969 to determine the residual effect of P applied the previous year. Additional treatments were included to determine the yield level with 200 pounds of P_2O_5 per acre applied 3 inches below the seed and with the same rate placed 3 inches below and 4 inches to the side of the seed. Growth and P uptake were determined by plant sample analysis.

Field experiments were conducted in 1968 and 1969 on Harlingen c and Hidalgo scl to evaluate the influence of P placement on early growth of tomatoes. To evaluate depth of placement on growth, trenches were excavated in the center of the row and sloped from the surface at one end to a depth of 12 inches at the other end of a 25-foot row. Phosphorus at the rate of 120 pounds of P_2O_5 per acre was placed in the bottom of the trenches; then the trenches were covered and the tomatoes seeded directly over the trenches. To evaluate the influence of lateral placement of P, trenches were excavated at a constant depth (2.5 inches) but started in the center of the row at one end and gradually moved away from the row to a maximum distance of 8 inches at 25-foot row length. Phosphorus at the rate of 120 pounds of P_2O_5 per acre was placed in the bottom of the trenches, then covered, and the tomatoes were seeded directly in the center of the row. This resulted in variable lateral placement of P from 0 to 8 inches from the center line of the seed placement. The area was watered to ensure germination. Plant samples were taken for growth measurements and P analysis.

Greenhouse studies were conducted to determine the influence of soil temperature on tomato response to P. Soil temperatures were thermostatically controlled with a circulating water bath. Soil temperatures used for Harlingen c were 60 ± 4, 70 ± 3 and 82 ± 4° F. Temperatures for Hidalgo scl were 65 ± 3 and 84 ± 5° F. Air temperatures varied from about 74° F at night to 90° F during the day. Rates of P_2O_5 used were 0 and 120 pounds per acre. Placement was in a band 2.5 inches below the seed. Temperature treatments were initiated after germination. Plant data were taken to evaluate the influence of P on growth at each soil temperature.

Undisturbed cores (3 inches in diameter by 3 inches deep) were taken from Willacy fsl and Harlingen c and placed in a greenhouse. Tomatoes were seeded in the cores and allowed to grow for 30 days. At the end of the growth period, the plants were clipped at the soil surface, dried and weighed. The cores were then divided into the upper 1.5 inches and lower 1.5 inches. The roots were removed from each half of the cores and oven-dry root weights obtained.

Plant samples taken in these studies were dry ashed according to the methods of Chapman and Pratt (3). Phosphorus determinations were made by the molybdenum-blue method, and cation determinations were made with an atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

Influence of Phosphorus Rate and Placement on Early Growth of Tomatoes

Growth of tomato plants at any given stage is a function of several factors such as light, moisture, temperature, variety and nutrient availability. Phosphorus significantly influenced early growth of tomatoes on Hidalgo scl (Figure 1). The Hidalgo scl used was very low in P; consequently, there was a sharp increase in plant growth with 50 pounds per acre of P_2O_5 placed in a band below the seed. Increases in growth were not obtained with 50 pounds of P_2O_5 broadcast. Maximum early growth of tomatoes was obtained from a band application of 100 pounds of P_2O_5. Broadcast application of 200 pounds of P_2O_5 appeared to be equivalent to about 30 pounds banded.

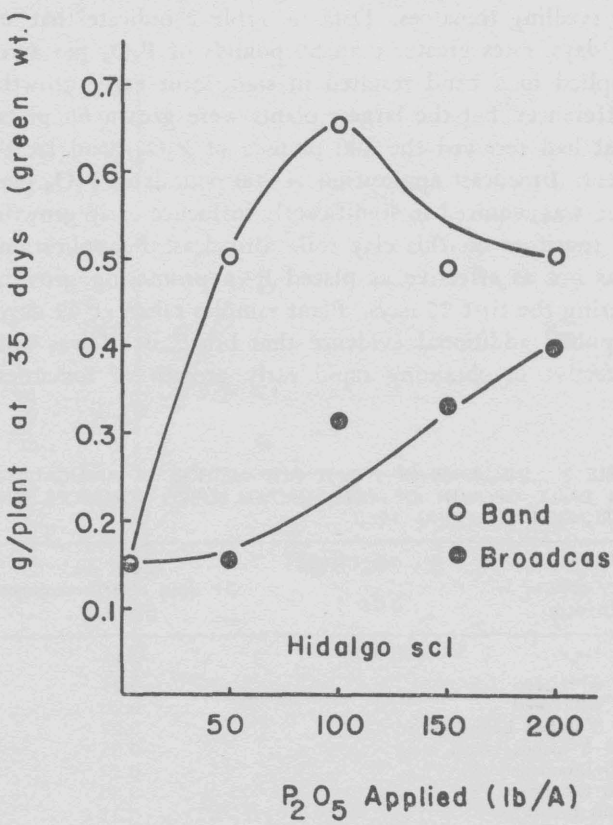

Figure 1. Influence of rate and placement of P on early growth of tomatoes on Hidalgo scl.

TABLE 2. INFLUENCE OF P RATE AND PLACEMENT ON EARLY GROWTH OF FIELD GROWN TOMATO PLANTS, SPRING 1967

P_2O_5 applied lb/acre	Harlingen c		Willacy fsl	
	25 days mgm/plant[1]	49 days g/plant	25 days mgm/plant	49 days g/plant
0	13.5[2]	0.42	29.0	1.24
40 band	16.5	1.94	35.6	1.25
80 band	21.8	2.42	38.6	1.33
120 band	24.1	2.85	36.1	1.25
200 band	23.9	2.90	31.6	1.06
400 band	26.0	2.47		
40 broadcast	14.0	0.69	32.7	1.28
80 broadcast	16.5	0.70	37.8	1.32
120 broadcast	17.1	0.63	33.3	1.01
200 broadcast	19.5	0.88	34.4	1.14
400 broadcast	20.0	1.03		
LSD (.05)	5.1	0.41	5.2	N.S.

[1] 1 gram (g) = 1,000 milligrams (mgm).
[2] Weights are on oven dry basis.

Early growth response on Willacy fsl was not as evident as on the Hidalgo scl (Table 2), but 25-day-old plants grown on plots receiving 40, 80 and 120 pounds banded and 80 and 200 pounds broadcast were significantly larger than the control. At 49 days there were no significant differences in size of plants due to rate or placement of P.

Results obtained on Harlingen c soil indicated an early growth response, but higher rates were required by seedling tomatoes. Data in Table 2 indicate that at 25 days, rates greater than 80 pounds of P_2O_5 per acre applied in a band resulted in significant early growth differences, but the largest plants were grown on plots that had received the 400 pounds of P_2O_5 band treatment. Broadcast application of 200 pounds of P_2O_5 per acre was required to significantly influence early growth of tomatoes on this clay soil. Broadcast P application was not as effective as placed P in promoting growth during the first 25 days. Plant samples taken at 49 days supplied additional evidence that broadcast P was not effective in obtaining rapid early growth of tomatoes

TABLE 3. INFLUENCE OF P RATE AND METHOD OF APPLICATION ON EARLY GROWTH OF FIELD GROWN CHICO TOMATOES ON HARLINGEN C, SPRING 1968

P_2O_5 applied lb/acre	Green wt 21 days after emergence g/plant[1]
0	0.15
14 with seed	0.21
36 with seed	0.20
60 3 inches below seed	0.28
120 3 inches below seed	0.35
400 broadcast	0.23
800 broadcast	0.30
1600 broadcast	0.35

[1] Based on 70°C drying weight.

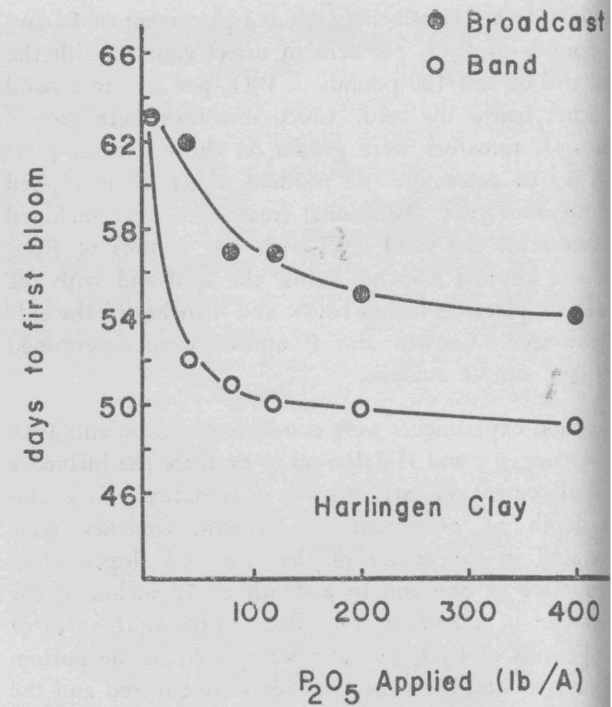

Figure 2. Influence of phosphorus rate and placement on time required by tomato plants to reach bloom stage.

on Harlingen c soil. Plants receiving 400 pounds of P_2O_5 per acre broadcast were much smaller than plants receiving 40 pounds placed in a band below the seed. Experiments in 1968 on Harlingen c indicated that a broadcast application of 1,600 pounds of P_2O_5 per acre was equivalent to a placed application of 120 pounds (Table 3). There was a slight increase in plant size with each additional 400-pound-per-acre increment of broadcast P_2O_5 up to 1,600 pounds per acre. The broadcast rate required for maximum early growth would not be economically feasible. Placement of low rates of P with the seed slightly increased early growth, but the rates used (14 and 36 pounds of P_2O_5 per acre) did not promote early growth as well as treatments banded below the seed.

Treatments that resulted in rapid early growth of tomatoes on Harlingen c also caused plants to bloom earlier (Figure 2). Tomato plants grown without applied P bloomed in 63 days, whereas plants grown with 40 and 400 pounds of P_2O_5 applied in a band below the seed bloomed in 52 and 49 days, respectively. The broadcast P treatments were much less effective in promoting early bloom in that 400 pounds of P_2O_5 broadcast only reduced the days to bloom to 54.

Influence of Phosphorus Rate and Placement on Yield of Field Grown Tomatoes

Band application of P caused a large increase in yield at first harvest at all rates of P on Hidalgo scl

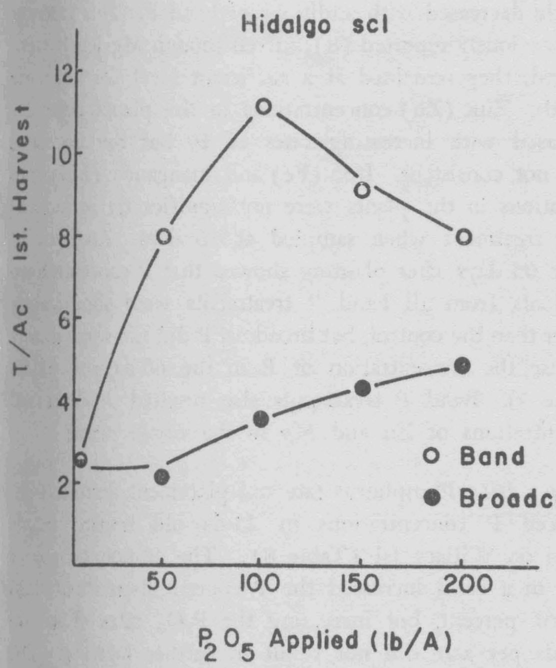

Figure 3. Influence of rate and placement of P on yield of tomatoes grown on Hidalgo scl.

(Figure 3). Highest yield was 11.5 tons (T) per acre with band applications of 100 pounds of P_2O_5 per acre. This was almost a fivefold increase over the plots that did not receive P. The greatest increase in yield occurred with the initial 50-pound increment applied in a band. Fifty pounds of P_2O_5 per acre did not increase yields when applied as a broadcast treatment, but increased rates above 50 pounds slightly increased yields with each additional increment. Highest yield from broadcast P application was only 4.5 T per acre and was obtained with the 200-pound-per-acre rate of P_2O_5.

Yield of tomatoes was not influenced by rate or placement of P on the Willacy fsl (Table 4). Data indicate that the concentration of available soil P in the Willacy soil was sufficient for the yields obtained.

Yield increases due to applied P on Harlingen c were very similar to those obtained on Hidalgo scl. Highest yields on the Harlingen c (Figure 4) were

TABLE 4. INFLUENCE OF RATE AND PLACEMENT OF PHOSPHORUS ON YIELD OF TOMATOES GROWN ON WILLACY FSL, SPRING 1967

P_2O_5 applied lb/acre	Tomato yield (T/acre)
0	7.8
40 band	7.4
80 band	7.9
120 band	6.9
200 band	7.0
40 broadcast	7.8
80 broadcast	7.8
120 broadcast	7.8
200 broadcast	6.4
	N.S.

obtained with the 200-pound rate of P_2O_5 placed in a band below the seed. Yields from the plots receiving 200 pounds of P_2O_5 placed were about two times greater than those without applied P. As on Hidalgo scl, the greatest yield increase was with the initial increment of P. These yield increases with low rates of band P indicate that correct placement of P is very important in final yield as well as in early growth response. Very little increase in yield of tomatoes was obtained with broadcast P at any of the rates used.

Yield data from the 1968 experiments involving extremely high rates of broadcast P on Harlingen c were unavailable because of prolonged rain at harvest time. Data from growth measurements in 1968 and yield data from broadcast rates up to 400 pounds of P_2O_5 per acre in 1967, however, indicate that broadcasting P for tomatoes is not a feasible practice.

Although most of the tomatoes are grown in the spring in the Lower Rio Grande Valley, considerable acreage is planted in the fall. Response to applied P would be expected to be less in the fall than in the spring because of higher temperatures when tomatoes are planted (July and August) for fall production. Results from application of P to fall-grown tomatoes (Table 5) indicate that a substantial yield increase can be expected. Yields were increased by about 50 percent as a result of band application of 115 pounds of P_2O_5 per acre.

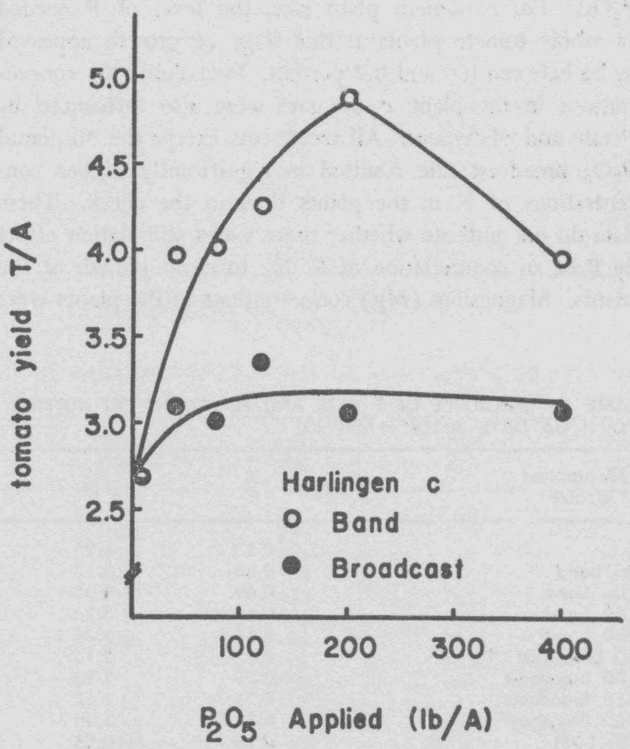

Figure 4. Influence of rate and placement of P on yield of tomatoes on Harlingen c.

TABLE 5. INFLUENCE OF APPLIED P ON YIELD OF FALL-GROWN TOMATOES ON HARLINGEN CLAY

P_2O_5 applied lb/acre	T/acre
0	6.1
115	9.3

These data indicate that large yield increases can be expected from the proper application of P fertilizer to tomatoes. To obtain maximum results from applied P, it must be placed in a band directly below the seed. Although response to applied P appears to be less in the fall, yield increases can be obtained from P applied to fall tomatoes.

Influence of Phosphorus Rate and Placement on Nutrient Uptake by Tomatoes

Hidalgo scl: Application of different P rates and placement had a marked influence on P uptake by tomatoes. Concentration of P in 36-day-old plants was significantly higher from band treatments than from broadcast treatments at all rates of P. Table 6 shows that P concentrations in the whole plant were increased from 0.13 percent without P applied to 0.58 percent with 50 pounds of P_2O_5 applied in a band below the seed. The P content of plants was increased to 0.69 percent with the 100-pound rate of P_2O_5. Broadcast P slightly increased P concentrations in the plants, but highest P concentration in the plants was only 0.35 percent with the 150 and 200-pound broadcast rates of P_2O_5. For maximum plant size, the level of P needed in whole tomato plants at this stage of growth appeared to be between 0.6 and 0.7 percent. Potassium (K) concentrations in the plant at 36 days were also influenced by P rate and placement. All treatments except the 50-pound P_2O_5 broadcast rate resulted in significantly higher concentrations of K in the plants than in the check. These data do not indicate whether there was a stimulation effect by P or an accumulation of K due to rapid growth of the plants. Magnesium (Mg) concentrations in the plants were slightly decreased with additions of band P. This reaction was previously reported (8). Even though Mg levels were reduced, they remained at a sufficient level for adequate growth. Zinc (Zn) concentrations in the plants generally decreased with increasing rates of P, but the decreases were not consistent. Iron (Fe) and manganese (Mn) concentrations in the plants were not significantly influenced by P treatment when sampled at 36 days. Analyses of plants 66 days after planting showed that P concentrations in plants from all band P treatments were significantly higher than the control, but broadcast P did not significantly increase the concentration of P in the 66-day-old plants (Table 7). Band P treatments also resulted in decreased concentrations of Zn and Mg in the whole plants.

Willacy fsl: Phosphorus rate and placement definitely influenced P concentrations in 25-day-old tomato plants grown on Willacy fsl (Table 8). The 40-pound rate of P_2O_5 in a band increased the P concentration from 0.28 to 0.61 percent, but increasing the P_2O_5 rates above 40 pounds per acre did not result in further increase. The 80, 120 and 200-pound-per-acre rates of broadcast P_2O_5 significantly increased P concentrations in the plants, but P concentrations in plants from band treatments were much higher than those from broadcast treatments. Manganese and Zn concentrations were not influenced by P treatments at the 25-day sampling. Magnesium and Fe concentrations in the plants were decreased with high rates of band P but were not influenced by broadcast P. Potassium concentrations in the plants were increased over the check by all rates of band P.

When sampled at 49 days, plants from all treatments with band P contained higher concentrations of P than the check (Table 9). Concentrations of P in plants from broadcast treatments were slightly higher but not significantly higher than the check. Concentrations of Mn, Mg, K, Ca and Fe in the plants were not significantly influenced by rate or placement of P. Zinc concentrations in the plants were reduced with high rates of P regardless of application method.

TABLE 6. INFLUENCE OF P RATE AND PLACEMENT ON NUTRIENT UPTAKE BY FIELD GROWN TOMATOES ON HIDALGO SCL SOIL (WHOLE PLANT 36 DAYS AFTER PLANTING)

P_2O_5 applied lb/acre	% P[1]	% K	% Ca	% Mg	PPM Fe	PPM Mn	PPM Zn
0	0.13	1.95	3.33	0.98	583	135	35
50 band	0.58	3.13	3.61	0.87	463	135	29
100 band	0.69	3.30	3.85	0.77	563	137	32
150 band	0.68	3.26	4.24	0.82	586	147	26
200 band	0.56	3.25	4.00	0.87	473	110	34
50 broadcast	0.22	2.15	3.11	0.90	440	126	26
100 broadcast	0.29	3.23	4.28	0.93	456	132	23
150 broadcast	0.35	2.68	3.95	0.94	656	134	27
200 broadcast	0.35	3.00	4.40	1.06	579	110	44
LSD (.05)	0.18	0.55	0.56	0.18	N.S.	N.S.	9

[1]*All values based on 70°C drying weight.*

TABLE 7. INFLUENCE OF P RATE AND PLACEMENT ON NUTRIENT UPTAKE BY FIELD GROWN TOMATOES ON HIDALGO SCL SOIL (WHOLE PLANT 66 DAYS AFTER PLANTING)

P_2O_5 applied lb/acre	% P[1]	% Mg	PPM Fe	PPM Mn	PPM Zn
0	0.24	0.96	482	98	52
50 band	0.33	0.72	426	75	33
100 band	0.44	0.76	426	98	28
150 band	0.41	0.83	416	108	29
200 band	0.37	0.77	440	95	36
50 broadcast	0.25	0.85	386	87	37
100 broadcast	0.24	0.97	463	120	44
150 broadcast	0.30	0.88	480	112	38
200 broadcast	0.30	0.89	393	86	48
LSD (.05)	0.07	0.12	N.S.	N.S.	15

[1]All values based on 70°C drying weight.

Harlingen c: Application of P in a band below the seed significantly increased the concentrations of P in the plant when sampled 25 days after planting (Table 10). Rates of 200 and 400 pounds of P_2O_5 were required, however, to significantly influence the concentration of P in the plants when applied as broadcast treatments. Concentrations of Mg, Mn, Ca and Fe in the plants were generally decreased with increasing rates of band applied P. Application of high rates of broadcast P resulted in reduced Mn and Fe concentrations in the whole plants.

Concentrations of nutrients in tomato plants grown on Harlingen c and sampled at 49 days are shown in

TABLE 8. INFLUENCE OF P RATE AND PLACEMENT ON NUTRIENT UPTAKE BY FIELD GROWN TOMATOES ON WILLACY FSL SOIL (WHOLE PLANT 25 DAYS AFTER PLANTING)

P_2O_5 applied lb/acre	% P[1]	% K	% Ca	% Mg	PPM Fe	PPM Mn	PPM Zn
0	0.28	3.64	3.75	1.00	318	138	26
40 band	0.61	4.29	3.50	0.91	297	96	25
80 band	0.56	4.05	3.49	0.89	310	122	21
120 band	0.60	4.28	3.34	0.87	258	114	24
200 band	0.64	4.09	3.43	0.95	235	115	23
40 broadcast	0.30	3.65	3.55	0.95	310	123	24
80 broadcast	0.36	4.08	3.63	0.97	282	143	23
120 broadcast	0.34	3.89	3.65	0.98	355	129	25
200 broadcast	0.35	4.06	3.50	0.94	312	126	22
LSD (.05)	0.06	0.32	0.25	0.11	61	N.S.	N.S.

[1]All values based on 70°C drying weight.

TABLE 9. INFLUENCE OF P RATE AND PLACEMENT ON NUTRIENT UPTAKE BY FIELD GROWN TOMATOES ON WILLACY FSL SOIL (WHOLE PLANT 49 DAYS AFTER PLANTING)

P_2O_5 applied lb/acre	% P[1]	% K	% Ca	% Mg	PPM Fe	PPM Mn	PPM Zn
0	0.26	3.18	4.2	0.96	270	198	28
40 band	0.32	3.16	4.3	0.93	310	185	24
80 band	0.36	2.98	4.4	0.99	283	164	24
120 band	0.36	2.96	4.5	0.97	273	164	20
200 band	0.34	3.06	4.5	1.03	305	210	23
40 broadcast	0.28	3.08	4.4	1.03	280	205	24
80 broadcast	0.29	3.10	4.2	0.95	263	172	23
120 broadcast	0.31	3.06	4.4	0.99	295	178	25
200 broadcast	0.29	3.35	4.5	0.99	288	172	21
LSD (.05)	0.06	N.S.	N.S.	N.S.	N.S.	N.S.	5

[1]All values based on 70°C drying weight.

TABLE 10. INFLUENCE OF P RATE AND PLACEMENT ON NUTRIENT UPTAKE BY FIELD GROWN TOMATOES ON HARLINGEN C SOIL (WHOLE PLANT 25 DAYS AFTER PLANTING)

P_2O_5 applied lb/acre	% P[1]	% K	% Ca	% Mg	PPM Fe	PPM Mn	PPM Zn
0	0.11	2.62	5.0	1.17	390	188	17
40 band	0.26	3.01	4.7	1.08	282	152	16
80 band	0.30	3.35	4.6	1.11	292	145	16
120 band	0.43	3.34	4.2	0.99	300	118	16
200 band	0.42	3.20	4.5	1.07	305	141	16
400 band	0.46	3.44	4.4	1.12	350	132	15
40 broadcast	0.14	3.09	5.1	1.20	430	175	17
80 broadcast	0.22	3.14	4.8	1.16	295	154	16
120 broadcast	0.19	3.20	5.0	1.21	328	162	13
200 broadcast	0.26	3.19	4.4	1.12	314	141	14
400 broadcast	0.28	3.20	4.8	1.13	288	138	13
LSD (.05)	0.12	0.23	0.4	0.07	80	36	N.S.

[1]All values based on 70°C drying weight.

TABLE 11. INFLUENCE OF P RATE AND PLACEMENT ON NUTRIENT UPTAKE BY FIELD GROWN TOMATOES ON HARLINGEN C SOIL (WHOLE PLANT 49 DAYS AFTER PLANTING)

P_2O_5 applied lb/acre	% P[1]	% K	% Ca	% Mg	PPM Fe	PPM Mn	PPM Zn
0	0.26	2.54	4.89	1.16	343	178	45
40 band	0.32	2.92	4.24	0.96	430	55	29
80 band	0.36	2.83	4.52	0.98	525	55	30
120 band	0.33	2.93	4.05	0.88	443	48	26
200 band	0.36	3.01	4.20	0.91	460	57	28
400 band	0.34	2.79	4.32	0.94	510	65	30
40 broadcast	0.28	2.27	4.57	1.02	536	163	39
80 broadcast	0.28	2.76	4.55	1.16	435	166	45
120 broadcast	0.28	2.39	4.76	1.12	465	165	50
200 broadcast	0.25	2.59	4.69	1.12	522	175	46
400 broadcast	0.28	2.64	5.02	1.17	565	168	42
LSD (.05)	0.03	N.S.	0.41	0.09	99	22	7

[1]All values based on 70°C drying weight.

Table 11. Band application of P resulted in higher concentrations of P in the plants; broadcast P did not significantly increase the P concentrations. Manganese, Zn, Mg and Ca concentrations were decreased in plants receiving band P, but concentrations of these elements were not affected by broadcast P. This would indicate either a dilution effect due to increased growth associated with high plant concentrations of P or an interaction between P and the uptake of these nutrients.

Plants were also sampled for leaf analysis at 98 days, but, of the elements determined, only P concentration was influenced by P rate or placement.

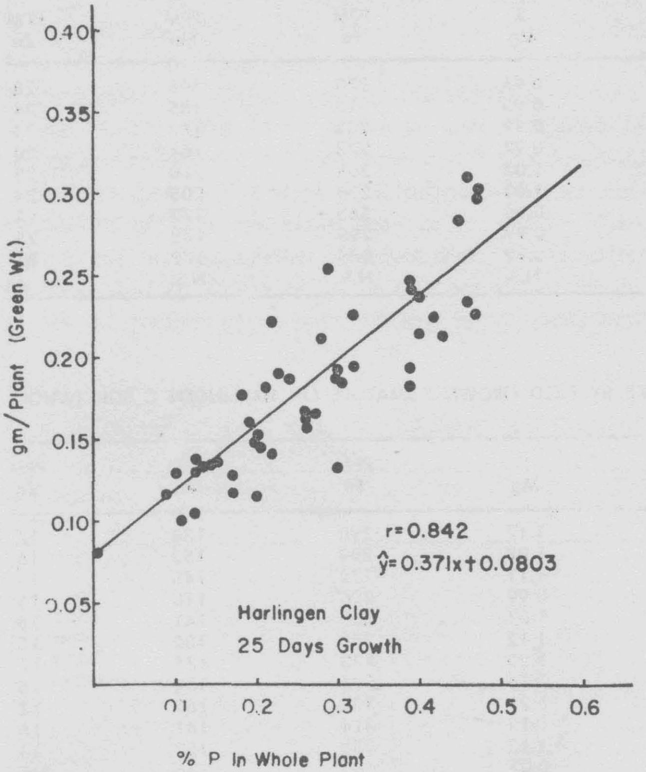

Figure 5. Relationship between P concentration in tomato plants and plant weight.

The importance of abundant P in the early growth stages of tomato plants grown on Harlingen c is shown in Figure 5. A linear relationship with an r value of 0.842 was obtained between percent P in the whole plant and green weight of 25-day-old plants. This indicates that high concentrations of plant P are required for rapid early growth. Figure 6 shows that P concentration in plants was a function of rate of P application and age of plant and that to obtain the levels of plant P needed for early growth, the P must be available at growth initiation. At 25 days there were increases in P concentration up to 120 pounds of P_2O_5, but by 49 days the influence of P application on P concentration was much less. By 98 days plants grown on the check plots contained a slightly higher concentration of P in the leaves than those with P applied. These data suggest that sidedress P would not be effective in stimulating rapid early growth.

Influence of Temperature on Growth and Phosphorus Response by Tomatoes

Results of experiments with controlled soil temperatures indicated that plant growth was a function of soil temperature and P application (Table 12). A definite P-temperature interaction was evident on Harlingen c and Hidalgo scl. Plant growth increased with increasing temperature from 60 to 82° F when no P was applied on

TABLE 12. INFLUENCE OF SOIL TEMPERATURE AND P APPLICATION ON EARLY GROWTH OF TOMATOES

Soil temperature °F	Green wt g/plant with 120 lb P_2O_5/acre	Green wt g/plant with O P
Harlingen clay soil		
82 ± 4	1.95	0.51
70 ± 3	2.40	0.20
60 ± 4	0.62	0.10
Hidalgo sandy clay loam		
84 ± 5	2.21	0.64
65 ± 3	2.32	0.32

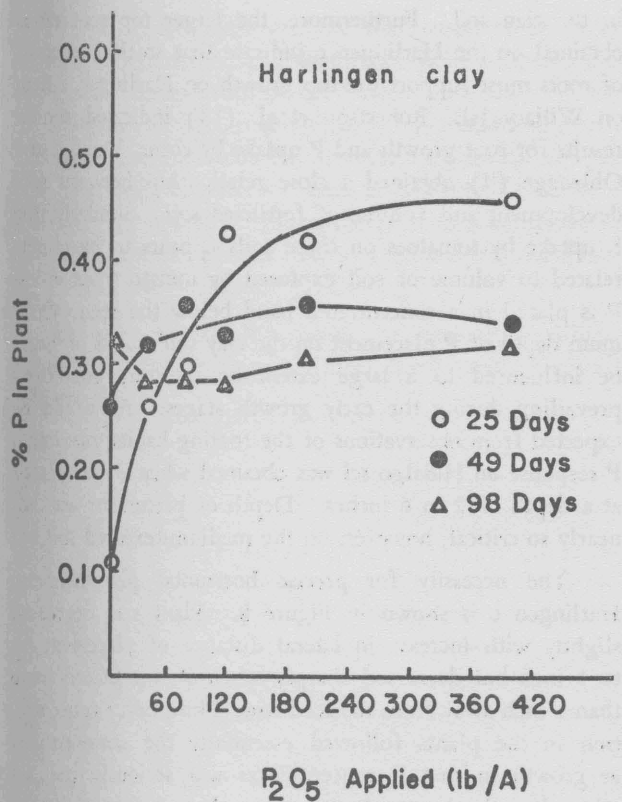

Figure 6. Relationship between rate of P_2O_5 applied in a band and percent P in plants grown on Harlingen c.

Harlingen c soil. However, when 120 pounds of P_2O_5 per acre were applied, plants grown at 70° were about four times larger than those grown at 60°. Similarly, growth was slightly increased on Hidalgo scl by increasing soil temperatures from 65 to 84° F without applied P. However, maximum growth response with P applied occurred at the 65° F temperature.

Influence of Residual Phosphorus on Growth and Yield of Tomatoes

Results indicate that tomatoes benefit very little from P applied to Harlingen c the previous year (Table 13). Percent P in 33-day-old plants was not influenced by P treatments of 1,600 pounds P_2O_5 per acre the previous year. Plant size 60 days after emergence was slightly increased by the residual effect of the previously applied treatments. However, the residual effect from 1,600 pounds of P_2O_5 was not enough to stimulate maximum early growth (Table 13). Plants grown in plots receiving 200 pounds of P_2O_5 3 inches directly below the seed in 1969 were two times larger than those from the residual 1,600-pound treatment and over three times larger than those from check plots. Placement of 200 pounds of P_2O_5 in a band 3 inches below and 4 inches to the side of the seed in 1969 resulted in much smaller plants at 60 days than the same rate placed directly below the seed. Phosphorus concentration in 33-day-old plants was much higher from

TABLE 13. INFLUENCE OF RESIDUAL SOIL P ON GROWTH AND YIELD OF TOMATOES ON HARLINGEN C SOIL

P_2O_5 applied lb/acre	% P in whole plant 33 days after emergence	g/plant oven dry wt 60 days after emergence	Yield of fruit, T/acre, 1969
0	0.15	0.27	3.9
400 broadcast, 1968	0.15	0.38	3.8
800 broadcast, 1968	0.15	0.33	4.5
1,600 broadcast, 1968	0.16	0.42	5.3
200 3 inches below seed, 1969	0.55	0.86	8.2
200 3 inches below seed and 4 inches to side, 1969	0.22	0.50	5.9

P placed directly below the seed in 1969 than from the residual P treatments and the 1969 treatment placed 3 inches below and 4 inches to the side of the seed.

Yield response in 1969 was very similar in pattern to early growth characteristics and P uptake by the plants. Yields were increased only from 3.9 to 5.3 tons per acre with the highest residual treatment, but the 200-pound P_2O_5 rate placed below the seed in 1969 increased yields to 8.2 tons per acre. Yields from the plots receiving P 3 inches below and 4 inches to the side of the seed were considerably lower than from the same rate placed directly below the seed. These data indicate further evidence of the critical placement requirements of P for maximum yields of tomatoes.

Phosphorus Placement Requirements for Tomatoes

Results of experiments with variable depth trenches indicate depth-of-placement requirements on medium and fine-textured soils (Figure 7). Depth of P placement is extremely critical on the fine-textured soil but less so on the medium-textured soil. Maximum early growth of tomatoes on the fine-textured soil was obtained when P was placed at a depth of 2 inches. When placed closer to the surface than 2 inches, drying and cracking of the clay soil left the P in a dry zone near the surface. Because root growth was below the dry zone containing the P, little response to P was obtained. When P was placed below a depth of 2 inches, there was less early growth of the tomatoes possibly because of slow root growth in the clay soil.

A comparative study of root growth demonstrates the slow root growth of tomatoes on Harlingen c soil (Table 14). In undisturbed cores from greenhouse studies, 88

TABLE 14. DISTRIBUTION OF TOMATO ROOTS IN UNDISTURBED CORES OF WILLACY FSL AND HARLINGEN C SOIL

Soil	% of roots in top 1.5 inches	Top/root ratio
Harlingen c	88	6.5
Willacy fsl	56	2.2

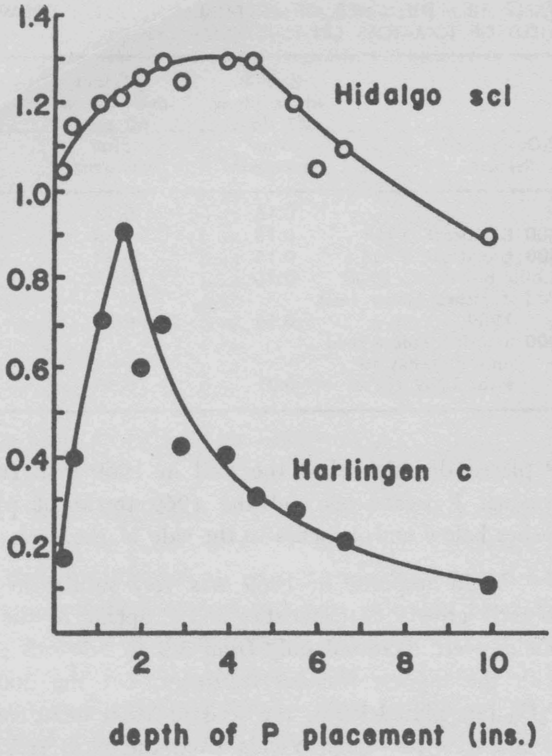

Figure 7. Influence of depth of phosphorus placement on early growth of tomatoes.

and 56 percent of the tomato roots were contained in the surface 1.5 inches when grown on Harlingen c and Willacy fsl, respectively. These data indicate that roots grow downward at a more rapid rate in the sandy loam soil than in the clay soil. Furthermore, the larger top/root ratios obtained on the Harlingen c indicate that smaller amounts of roots must support the top growth on Harlingen c than on Willacy fsl. Robertson et al. (13) indicated similar results for root growth and P uptake by corn. Duncan and Ohlrogge (4) obtained a close relationship between root development and volume of fertilized soil. Similarly, the P uptake by tomatoes on these soils appears to be closely related to volume of soil explored by tomato roots unless P is placed in a concentrated band below the seed. Optimum depth of P placement on the clay soil would probably be influenced to a large extent by moisture conditions prevailing during the early growth stages. As would be expected from observations of the rooting habits, maximum P response on Hidalgo scl was obtained when P was placed at a depth of 2 to 6 inches. Depth of placement was not nearly so critical, however, on the medium-textured soil.

The necessity for precise horizontal placement on Harlingen c is shown in Figure 8. Plant size decreased slightly with increase in lateral distance of placement up to 1 inch but decreased sharply when P was placed more than 1 inch away from the seed row. Phosphorus concentration in the plants followed essentially the same pattern as growth in that P concentration was seriously reduced when lateral placement was more than 1 inch. Lateral placement on the Hidalgo soil was also critical in obtaining maximum early growth (Figure 9). The plant reaction to P placement on Hidalgo scl was similar to that on Harlingen c except that the critical lateral distance of placement was 1.5 inches.

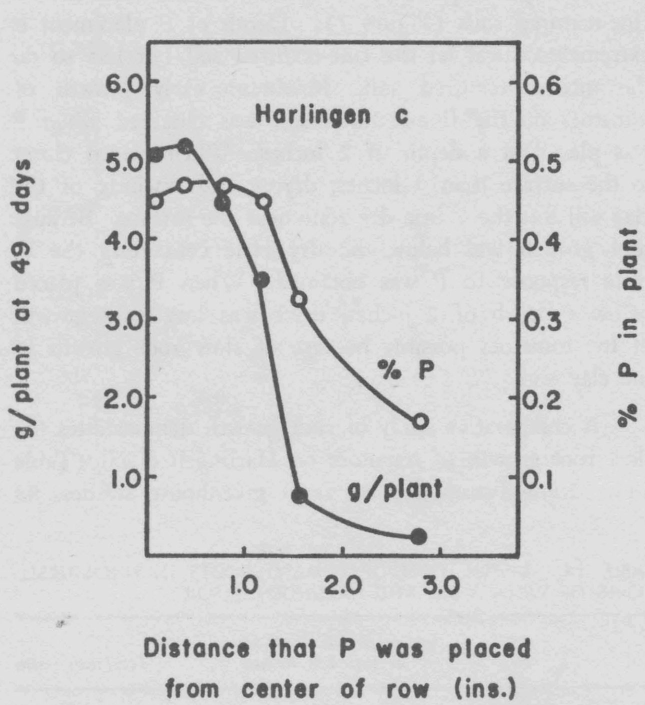

Figure 8. Influence of lateral distance of placement on early growth and P uptake by tomatoes grown on Harlingen c soil.

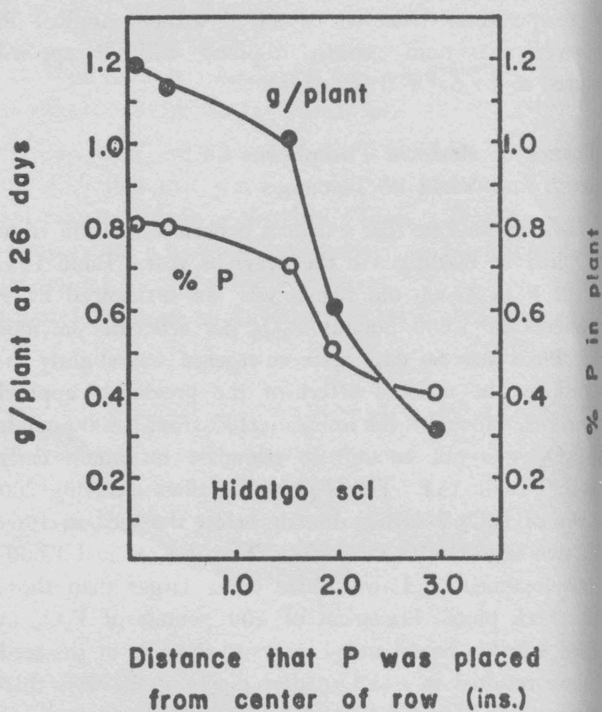

Figure 9. Influence of lateral distance of placement on early growth and P uptake by tomatoes grown on Hidalgo scl soil.

The foregoing data indicate that tomatoes are very sensitive to P nutrition and that large yield increases can be expected on most soils of the Lower Rio Grande Valley providing the intricate requirements of placement are met. To meet these requirements, P must be banded *directly below* the seed at planting time at a depth of 2 to 3 inches. This can best be accomplished with a combination fertilizer distributor-planter that will band the P and plant the seeds in one operation.

To prevent possible damage to seed or seedlings, nitrogen or other types of fertilizer should not be placed with the P.

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