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Effect of Phosphorus Placement Methods on the Yield & Quality of Tomatoes

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EFFECT OF PHOSPHORUS PLACEMENT
METHODS ON THE YIELD AND QUALITY
OF TOMATOES

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EFFECT OF PHOSPHORUS PLACEMENT

METHODS ON THE YIELD AND QUALITY

OF TOMATOES

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EFFECT OF PHOSPHORUS PLACEMENT
METHODS ON THE YIELD AND QUALITY
OF TOMATOES

Timothy Ross Hambrick May 1989 28 pages

Directed by: Ray E. Johnson, James P. Worthington, and Elmer Gray

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Research was undertaken in the summer and fall of 1988 to determine the effect of phosphorus placed below, below and to the side, banded and incorporated, and broadcast on the yield and quality of tomatoes.

The results of the field study were not statistically significant due to high levels of available soil phosphorus. However, there were trends toward higher total yields, higher yield of number one grade tomatoes, and higher tissue phosphorus levels when phosphorus was placed in a concentrated zone or band as contrasted with the more popular broadcast method.

The effect of phosphorus placement in the greenhouse was studied using two different soils, a high available phosphorus soil and a low available phosphorus soil. Again, phosphorus placed in a concentrated zone produced plants with higher tissue phosphorus levels, regardless of the soil the plants were grown on.

INTRODUCTION

Research was undertaken at the Western Kentucky University Farm to study the effect of phosphorus placement methods on the yield and quality of tomatoes. This research was done in order to determine some production methods that would help make the tomato an alternative crop to tobacco.

Two experiments were involved in this study. First, a field study was used to determine the effect of phosphorus placement on the quality and yield of tomatoes. Placement methods included a band directly under the plant, a band to the side and under the plant, broadcast incorporation and a band/broadcast combination.

The second experiment was conducted in the greenhouse in the fall following the field research. The purpose of this study was to determine the effects of phosphorus placement on early growth and phosphorus uptake by direct seeded tomatoes. Two different soils were used, one with a very low available phosphorus level and the other with a very high phosphorus content.

REVIEW OF LITERATURE

Phosphorus is an especially important nutrient for the production of vegetables. As in all plants, phosphorus is an important component of many organic compounds such as carbohydrates, nucleic acids, and phospholipids (14). Especially important from an economic standpoint is the hastening of maturity effect. Lorenz and Vittum (6) reported that adequate phosphorus fertilization may hasten the maturity of lettuce by as much as two weeks. As noted by Besford (2) in a study on tomatoes, vegetative growth is restricted and fruit yields are reduced when the levels of phosphorus are low in the soil. For the vegetable farmer, quality and timeliness of harvest are of utmost importance.

The addition of phosphorus is usually critical because the supply of phosphorus in many soils is low and/or is not in a form that is readily available for plant use. The total phosphorus in an average arable soil is approximately 0.1% by weight, of which only an infinitesimal part is available to the plant at any one time (4).

It has been shown that plants absorb phosphorus throughout their entire life cycle and that young plants absorb this element very rapidly. Plants often absorb 50% of the seasonal total demand by the time they accumulate just 25% of their total seasonal dry matter. Thus, the early season response to phosphorus fertilization commonly shown by crops is partially explained by this phosphorus absorption pattern (6).

It is generally an accepted premise that the efficiency of banded fertilizer applications is at least equal and often greater than that for broadcast applications. This potential economic advantage is often ignored by many growers because banding is an "at planting" operation. The usual preference in fertilizer placement is for broadcasting which is generally easier and quicker than banding. When comparing these methods, though, it should be remembered that the closer to time of plant utilization that the nutrient is applied, the greater will be the efficiency of uptake. Therefore, because of less phosphorus immobilization when applied in a band, utilization and plant efficiency of the phosphorus may be greater (6).

The effect of a phosphorus deficiency on vegetable crops is of particular importance because of its effect on market quality of the product. Phosphorus has a considerable effect on size and grade of fruit. Under phosphorus deficient conditions, the fruit size is often decreased and, therefore, will not meet acceptable size criteria (6). Results of several studies show that fruit and seed yields, as well as fruit quality, are affected not only by phosphorus but also by balanced amounts of other nutrients such as nitrogen and potassium (15).

Notwithstanding the need for balanced fertilization, correct phosphorus use gives good results, especially early in the year. Phosphorus deficiencies have been shown to be more pronounced at low temperatures; therefore, some crops show a good response to starter phosphorus during cool spring weather. Without the use of starter phosphorus, there is danger of decreased translocation of phosphorus from the root into other plant parts, decreased phosphorus uptake in part because of less root growth, decreased mineralization of soil phosphorus, and slower reaction of fertilizer granules with corresponding decreased diffusion rate of phosphorus within the soil (6).

Phosphorus is relatively immobile in the soil; soluble phosphorus seldom moves more than two or three centimeters from a fertilizer granule before reacting with soil components, preventing further movement. The limited potential for phosphorus movement helps illustrate the importance of placement of phosphorus in order to receive maximum effectiveness. Iron and aluminum commonly react with phosphorus, especially in acid soils. Such reactions produce insoluble products which precipitate out of the soil solution and are then less utilized by plants (6).

Keeping the soil pH at a range of 6 to 6.5 maximizes phosphorus availability in two ways. First, at this pH range, several of the phosphorus minerals can exist in the primary orthophosphate form, the chemical form in which it is most available. Secondly, this pH range also serves to reduce the activities of iron and aluminum.

Plant species with high growth rate generally respond more favorably to fertilizer applications than those with low growth rates. Therefore, phosphorus fertilization must be adjusted considering the crop and its needs, the source of phosphorus fertilizer, and the type of placement methods that may be used (11).

Placement may be at least as important as the timing of application. Research by Sleight et al. (13) indicates that the amount of root-fertilizer contact is a major factor in phosphorus uptake. Their studies show that with more roots concentrated in soil adequately supplied with phosphorus, the greater the supply of phosphorus to the plant (13).

Band application of phosphorus often results in more efficient use than is obtained with broadcasting. It is believed that band application results in less phosphorus fixation than does broadcast application, resulting in more of the added phosphorus being available to the plant (13).

By concentrating the phosphorus to lessen the problem of fixation, the volume of root-fertilizer contact is also reduced. Therefore, placement of the band in relationship to distance from the plant becomes important.

The distance the band is placed from the plant affects phosphorus uptake in two ways. First, the distance affects the time at which root-phosphorus contact will occur. The farther the band is from the seed or transplant, the farther the roots must grow to reach the band. Second, the distance affects the likelihood that a root will come into contact with the phosphorus. As the band distance from the plant increases, fewer roots are present per given volume of soil so the chance that phosphorus will be intercepted also decreases (13). Sleight, et al. (13) stated that the higher predictability of roots intercepting banded fertilizer is of more importance than is the decreased distance of fertilizer contact. Therefore, in soils in which phosphorus is relatively immobile, the best use of phosphorus may be achieved by mixing the band and soil near the plant so that a higher proportion of roots will grow in areas of high phosphorus concentration even though this will result in more phosphorus fixation by the soil.

Research by Hipp (10) suggests that when the soil phosphorus level is low enough to obtain a response, the phosphorus should be placed in a band below the seed for high yields. This study was conducted in southern Texas and involved the direct seeding of tomatoes in January and February when soil temperatures were still low. Field evaluations were made to determine the effectiveness of broadcast versus band applications on three different soils. The phosphorus concentrations of plants grown on each of three soils were higher at 20 and 36 days after planting in the plants grown with the phosphorus placed in a band than in those grown where the phosphorus was broadcast. At 44 days after planting, the differences in phosphorus concentration were less evident.

Wilcox studied the effect of phosphorus rate and placement on tomato seedlings (16). He found that the rate was an important factor in determining depth of placement. According to Wilcox, phosphorus is the main limiting nutrient for seedling growth of tomatoes seeded directly into the field. He found that placement of 30 pounds of phosphorus per acre one and one half inches under the seed was superior to other placements for direct seeded tomatoes. Wilcox also found that when the band was placed one and one half inches to the side and two inches below the seed, seedling growth was only about ten percent of that of the plants that received the phosphorus banded directly under the seed. Wilcox further determined that at banded rates higher than 40 pounds per acre, it was more efficient to place the band two inches below the seed. At lower rates, the band closer to the seed was more beneficial.

A study by Duncan and Ohlrogge involved determining the effect of phosphorus on the root growth of corn (5). In this study, whenever nitrogen and phosphorus were present together, a mass of fine, silky, roots developed. When phosphorus was the only nutrient present, the mass of roots was noticeable but much less developed than when nitrogen was also present. When nitrogen in various forms was the only nutrient present, there was little or no tendency for the aforementioned root development. Plants grown using treatments that produced the desired root mass, developed root systems that were finer, silkier, and more numerous allowing for a much greater ratio between roots and soil which is desirable.

Another major benefit of phosphorus is its effect on moisture use by plants. It has been found that plants with high levels of phosphorus are less susceptible to moisture stress than plants lower in tissue phosphorus levels. An 18 year midwest soybean experiment involving different nutrients and their effect on moisture use was conducted (6). This study showed that when moisture was low in the 12 weeks following planting, a greater percentage yield increase was received when soybeans received higher rather than lower phosphorus amounts.

In the tomato plant, phosphorus moves from older tissue into younger tissue if a deficiency develops. Much of the plant phosphorus is translocated from vegetative parts of the plant into the fruit and seeds. It has been shown that after 70 days, 90 percent of total nitrogen, phosphorus, and potassium uptake had been translocated into the fruit (9). Therefore, a phosphorus deficiency will show up in the older plant parts and will ultimately result in lower fruit numbers.

A study by Gibson, et al. (8) on tomato fresh fruit weight and shoot dry weight showed both were reduced, by 15 and 23 percent respectively, when phosphorus supply was reduced from 2.34 to .78 kg m^{-3} of phosphorus applied to tomatoes grown in a mixture of peat and grit.

Fontes and Wilcox (7) studied vigor of tomato plants grown in either high or low phosphorus concentrations. Four cultivars were grown in either 113 or 226 micromolar phosphorus solutions. The higher concentration resulted in 63 percent more dry weight than the lower concentration. This study also showed that the higher concentration of phosphorus increased the root surface area but decreased the root surface to shoot area ratio.

A study by Besford (1) measured the uptake and distribution of phosphorus of tomatoes grown in peat. The plants were originally started in peat containing an intermediate level of phosphorus and later transplanted to peat in which phosphorus had either been added or omitted.

The plants received liquid ammonium nitrate in high or low concentrations. He showed that adequate levels of phosphorus are important not only for early root growth but also for subsequent growth. Tomatoes transplanted to a phosphorus deficient medium showed a rapid export of phosphorus from older growth to new growth. This resulted in phosphorus deficiency symptoms before fruit on the first truss had ripened. The fruit was also shown to be the dominant sink when phosphorus was in short supply. For plants receiving the added phosphorus, most of the phosphorus taken up was located in the lower portions of the plant, such as the developing fruit, laminae of mature leaves, and the lower stem regions. Nitrogen was shown to have a significant effect on the distribution of phosphorus. Increasing the supply of nitrogen in the added phosphorus treatment facilitated the transport of phosphorus to the shoot and fruit trusses. More importantly, it significantly increased the total phosphorus uptake. The total phosphorus uptake in 11 week old tomato plants indicated that plants receiving high nitrogen and high phosphorus concentrations had a total phosphorus uptake of 279.2 mg of which 35 percent was located in the first two fruit trusses. By contrast, plants receiving high nitrogen and no phosphorus only absorbed 30.3 mg of phosphorus of which 58 percent was located in the first two fruit trusses. In all treatments, the probability of a phosphorus deficiency in plants grown on low phosphorus soils was greatly enhanced since one half of all available phosphorus was found in the first two fruit trusses.

In a second study, Besford (2) measured the effect of phosphorus on flowering and fruiting of tomatoes. All plants initially received an adequate phosphorus supply and were then transplanted into one of four treatments: high nitrogen and high phosphorus, high nitrogen and low phosphorus, low nitrogen and high phosphorus, and low nitrogen and low phosphorus treatments. He found no significant effect of phosphorus nutrition on the number of flowers formed on the first two fruit trusses. In trusses three and four, however, differences become more evident. Reducing the phosphorus supply while using high nitrogen levels resulted in accelerated development of flowers on the third and fourth trusses. This was an undesirable outcome because subsequent fruit set and development were impaired to the extent that 11 week old plants had less than one sixth of the weight of developing fruit as compared to plants that received high levels of both nitrogen and phosphorus. Plants that received low levels of phosphorus showed severely reduced fruit set when measured as percent efficiency of number of fruit per truss greater than one centimeter in diameter. The high nitrogen, high phosphorus treatment had an efficiency rating of 82 percent; the low nitrogen, high phosphorus treatment had a rating of 80 percent efficiency; and the two treatments with low phosphorus had an average efficiency rating of 62 percent.

This study also provided information on how the different nutrient treatments affect fruit development on older plants. On 11 week old plants, the total fruit larger than one centimeter was weighed. Fruit weights on the high nitrogen and high phosphorus, low nitrogen and high phosphorus, and low phosphorus treatments were 1296, 881, and 219 grams, respectively.

MATERIALS AND METHODS

Field Research

Tomatoes, *Lycopersicon esculentum* var. 'Mountain Pride', were grown on the Western Kentucky University farm during the summer of 1988. The objective was to evaluate phosphorus placement methods on yield and quality. The soil type was a Pembroke silt loam, Mollic Paleudalf containing 190 kg ha^{-1} of available phosphorus. The experimental design was a randomized complete block with four replications.

The experiment consisted of five treatments. They were: (1) placement of 20 kg ha^{-1} of phosphorus banded 5 cm under the plant, (2) 20 kg ha^{-1} phosphorus placed 5 cm below and 5 cm to the side of the plant, (3) 20 kg ha^{-1} of phosphorus broadcast over the entire treatment area, (4) 20 kg ha^{-1} of phosphorus applied as a band and then rototilled, and (5) no phosphorus added. All plants received 68 kg ha^{-1} of potassium and 45 kg ha^{-1} of nitrogen broadcast and incorporated prior to transplanting. Fertilization rates were made according to University of Kentucky recommendations. All treatments received supplemental water via drip irrigation at a rate of approximately 23,000 l of water per application. This was enough water to wet the soil to a depth of approximately 0.5 m around each plant.

Each treatment consisted of two 6.1 m rows spaced 1.5 m apart with plants placed approximately 46 cm apart to give 12 plants per row. Each plot was bordered by one row of tomatoes which received no phosphorus application.

Weed control was achieved in two ways. Naprapomide [N_1N-diethyl-2-(1-naphthalenoxy)-propionamide] was preplant incorporated at a rate of 1.68 kg ha^{-1} and periodic hoeing followed as needed.

All plants were staked and tied as needed throughout the growing season. Nylon string was interwoven using the San Diego system of trellising (12).

Malathion 50 [0.0-dimethyl phosphorodithionate of diethyl mercapto succinate], at a rate of 9.45 g per liter was used for insect control as needed. Maneb [Manganese ethylenebisdithiocarbamate] at a rate of 4 kg ha^{-1} was used for control of fungal diseases. Fungal treatment began before there were visible symptoms and continued approximately every two weeks throughout the growing season.

All plants were suckered and pruned to three or four branches approximately two weeks after transplanting.

Tissue samples from 24 plants per treatment were taken on June 11 and again on July 23. The first sample was taken during flowering and early fruit set. The second sample was taken just as the first fruit began to ripen. Samples consisting of lower leaves and petioles were used to determine phosphorus content, using the method described by Cottenie (3).

Fruit was harvested at four to five day intervals in early stages of color change regardless of size or quality. Fruit was then graded into number one, two, or cull categories depending on color, size, quality and weight. Grades were determined by what local markets would allow, but number one grade generally consisted of tomatoes with no visible flaws and were at least 6.4 cm in diameter. Number two grade fruits were either smaller or had some visible flaw but were still of marketable quality. Cull tomatoes were those that were either too small or flawed to sell. Harvest began on July 15 and continued through August 22.

Greenhouse Research

Mountain Pride tomatoes were directly seeded into 15.24 cm plastic pots containing 3.9 kg of soil per pot. Two different soils were used, the Pembroke silt loam high in phosphorus from the field research and a low phosphorus Nolin silt loam, (Dystric Fluvantic Eutrochrept), obtained from a farm in rural Warren County, Kentucky. Soil tests determined the Pembroke soil to have 190 kg ha^{-1} of available phosphorus and the Nolin soil to have 24 kg ha^{-1} of available phosphorus.

Each soil received four treatments: (1) a band placed 5 cm under the seed, (2) a band placed 5 cm under the seed and 5 cm to the side of the seed, (3) all the phosphorus broadcast throughout the pot, and (4) no phosphorus added. Due to the high amount of phosphorus that was added to the Nolin soil, each pot received the equivalent of 91 kg ha^{-1}, three fourths of the phosphorus was added as broadcast for each pot. The remaining one fourth was added as a band in those treatments that received band application.

All plants were thinned to one plant per pot. Forty six days after planting, whole plants were measured for height, harvested, oven dried, and weighed. Tissue samples were analyzed for phosphorus concentration using Cottenie's method (3).

RESULTS AND DISCUSSION

Field Research

Cumulative total weights of tomatoes at the indicated harvest dates are given in Table 1.

Table 1. Effect of phosphorus placement on tomato fruit weights (kg) at individual harvest dates.

Harvest date	Ck*	Br*	5u*	5s*	P_{bi}*
7/15	8	3	2	6	6
7/20	19	21	19	7	12
7/25	45	36	32	39	30
7/28	88	101	101	103	104
8/2	40	35	41	41	56
8/5	19	23	31	35	33
8/9	39	33	42	56	44
8/13	66	58	87	67	68
8/18	60	64	67	67	62
8/22	14	14	20	18	17
Season total	398	385	442	439	432

*Ck - no phosphorus added
*Br - phosphorus broadcast and incorporated
*5u - phosphorus banded 5 cm below the plant
*5s - phosphorus banded 5 cm below and 5 cm to the side of plant
*P_{bi} - phosphorus placed in a band on the soil surface and then rototilled into a concentrated zone

There were no significant differences between total weights of tomatoes (Appendix, Table 1). There was a trend toward higher total weights on treatments that received band applications of phosphorus (Figure 1).

There was a trend for the treatments involving a concentrated band of phosphorus to have higher total yields as compared to the broadcast treatment (Figure 1). In this study, the trend began manifesting itself in the period between the fourth and fifth harvests which was still early in the growing season. This effect could become much more important with lower soil phosphorus levels.

Table 2 shows the yield of number one grade tomatoes at each harvest date. There was no significant difference between treatments (Appendix, Table 2), but again there was a trend towards higher yields of number one tomatoes on the banded treatments. This is especially true for the plants grown with the band placed 5 cm under the plant at the middle and later harvest dates.

The percent of total production of tomatoes which graded number one was very similar among treatments. The range among the five treatments varied only between 43 percent and 47 percent of number one fruit. There was no significant difference between treatments (Appendix, Table 3), and even though there were indications of higher yields from banding, no such trend for percentage of number one fruit was evident.

Table 3 shows the percent phosphorus of the tissue samples collected on June 11 and on July 23. While there were no significant differences between treatments from the early sample (Appendix, Table 4) or the late sample (Appendix, Table 5), a trend was again evident. The banding methods resulted in higher concentrations of phosphorus in the leaf tissue at both sampling dates. It is important to note that for most

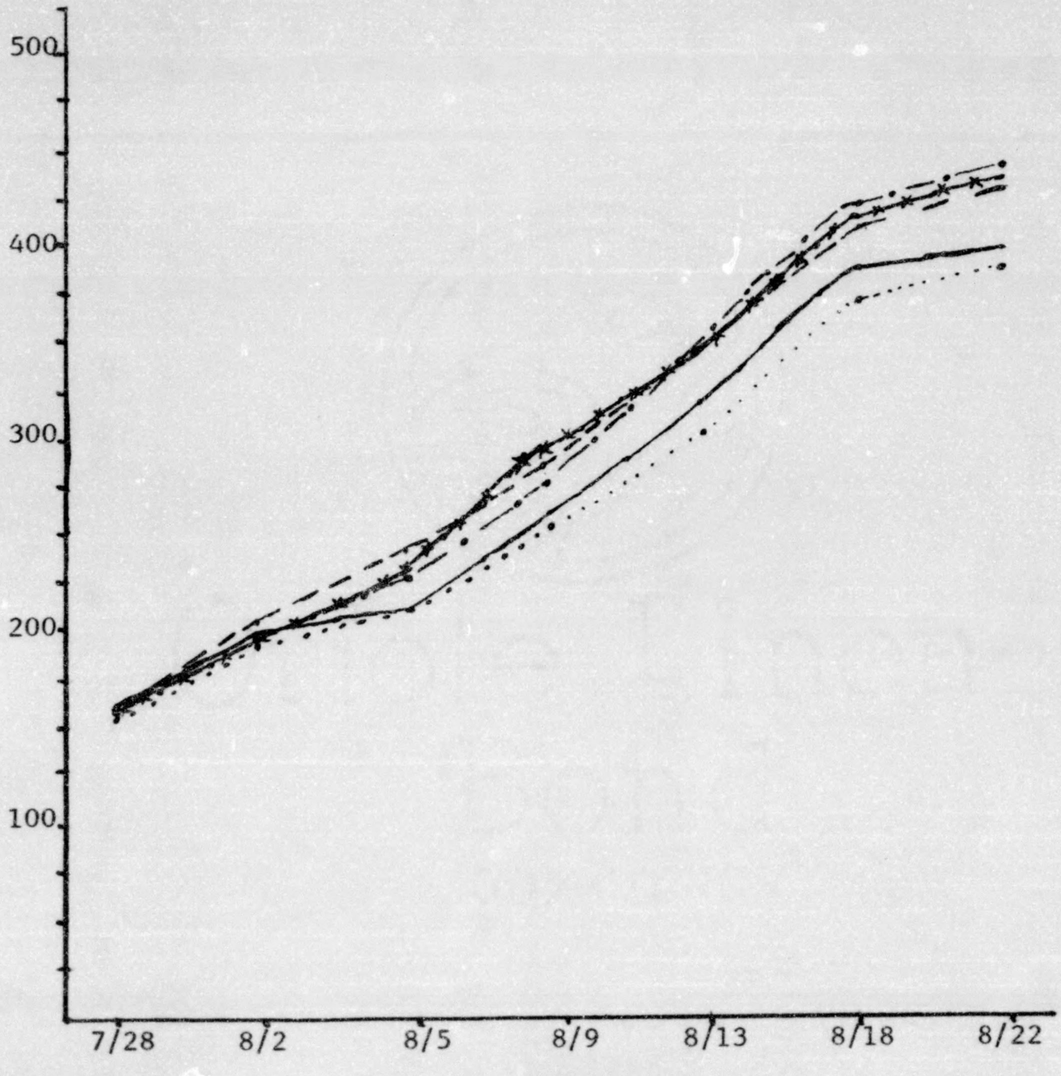

Figure 1. Effect of phosphorus placement on the cumulative total weights (kg) of harvested fruit (no P applied ———; P applied as broadcast .....; P applied 5 cm under plant -.-.-; P applied 5 cm under and 5 cm to side of plant -x-x-; P applied as band and rototilled in ----).

Table 2. Effect of phosphorus placement on yield (kg) of number one grade tomatoes.

Harvest date	Ck*	Br*	5u*	5s*	P_{bi}*
7/15	8	6	5	6	4
7/20	16	20	20	17	12
7/25	27	23	25	25	20
7/28	20	23	19	20	23
8/2	17	18	18	14	22
8/5	10	15	18	18	21
8/9	21	21	28	30	32
8/13	30	22	41	34	32
8/18	22	16	28	22	26
8/22	5	4	7	4	5
Season total	176	168	210	190	197

*Ck - no phosphorus added
*Br - phosphorus broadcast and incorporated
*5u - phosphorus banded 5 cm below the plant
*5s - phosphorus banded 5 cm below and to the side of plant
*P_{bi} - phosphorus banded and rototilled into a concentrated zone

Table 3. Effect of phosphorus placement on percent phosphorus in tomato leaf tissue at two sampling dates.

	Ck*	Br*	5u*	5s*	P_{bi}*
June 11	.042	.043	.051	.041	.045
July 23	.037	.034	.045	.033	.045

*Ck - no phosphorus added
*Br - phosphorus applied as broadcast
*5u - phosphorus banded 5 cm below the plant
*5s - phosphorus banded 5 cm below and to the side of the plant
*P_{bi} - phosphorus banded and rototilled

treatments, the phosphorus levels dropped as the season progressed, but the banding was still preferable to broadcasting. The treatment with the band rototilled into the soil showed no drop in phosphorus levels and this was unexpected and difficult to explain. It is assumed that the concentrated zone of phosphorus provided more phosphorus rich soil per root area than did the other methods (12). From a research standpoint, this method of application appears to be promising. From the standpoint of the farmer, however, it may not be feasible due to the additional labor and time required.

Greenhouse Research

The greenhouse study was initiated September 30, 1988, by direct seeding into a high phosphorus content Pembroke soil and a low phosphorus Nolin soil. Plant heights were taken 46 days later and the entire above ground growth was harvested and analyzed for phosphorus. Table 4 shows the average height of the plants by treatment.

Table 4. Effect of phosphorus placement on plant heights (cm) of greenhouse grown tomato plants.

	Ck*	Br*	5u*	5s*
Nolin soil	5	12	10	11
Pembroke soil	10	12	13	12

*Ck - no phosphorus applied
*Br - phosphorus applied as broadcast
*5u - phosphorus applied 5 cm below the plant
*5s - phosphorus applied 5 cm below and to the side of the plant

Within the Pembroke soil, there was no significant difference among placement methods of phosphorus (Appendix, Table 4). The band placed five cm under the seed on this high phosphorus soil again showed results higher than the other placement methods. This trend was expected, however, and concurs with results from the field study of the same soil. The plants grown on the low phosphorus soil (Nolin) also showed no significant differences in plant height between placement methods. This is not completely surprising due to the large amounts of phosphorus that was added to this soil (equivalent of 91 kg ha^{-1}). This left little or no area in the pot that did not have a high supply of phosphorus. Therefore, placement method would be less likely to show positive results. This would not be expected in the field as a portion of the added phosphorus would fall in areas where it would not be highly utilized, such as row middles or between plants.

Table 5 shows the average percent of phosphorus found in the plants grown on the two soils.

Table 5. Effect of phosphorus placement on the percent phosphorus of plants grown on different soils.

	Ck*	Br*	5u*	5s*
Pembroke soil	.043	.046	.056	.053
Nolin soil	**	.074	.083	.083

*Ck - no phosphorus added
*Br - phosphorus added as broadcast
*5u - phosphorus added 5 cm below the plant
*5s - phosphorus added 5 cm below and to the side of the plant
** - insufficient sample weight for analysis

In agreement with the results from the field study, the plants grown on a band placed five centimeters under the seed show a trend towards higher seedling phosphorus levels, even though the difference was not significant (Appendix, Table 7). The same trend was evident on the low phosphorus soil. While there was no statistical significance (Appendix, Table 8), the trend towards higher concentrations on the banding applications was evident.

The effect of a phosphorus deficiency was clearly seen on the check plants grown in the Nolin soil. They were only one half the height of check plants grown in the Pembroke soil and had much less branching. As a result there was not enough plant tissue available to obtain an accurate analysis of phosphorus content.

Of further interest was the fact that the plants grown in the Nolin soil had higher phosphorus contents than plants grown in the Pembroke soil. Part of this is probably due to the much greater amount of phosphorus added to the Nolin soil (91 kg ha^{-1}) as compared to that added to the Pembroke soil (21 kg ha^{-1}). With the relatively short growth period involved, there was little time for phosphorus fixation by the Nolin soil; therefore, there was perhaps a higher level of water soluble plant available phosphorus in this soil.

CONCLUSION

All the information clearly shows that phosphorus in adequate amounts is needed for optimum growth and fruit production of tomatoes. What the results of this research fail to show clearly is whether fertilizer application method has any significant effect on plant growth, fruit yield, or quality. On a soil with high residual level of phosphorus, there are several noticeable trends that seem to show a need for more studies of this kind.

Future work might first be restricted to greenhouse studies. Due to greater accessibility, lack of labor needed, and time frame in which experiments can be conducted, this type of research could provide preliminary results before planning field trials.

It was expected that the soil on the Western Kentucky University Farm would not lend itself ideally to this type of experiment because of the high level of fertilization the farm has received in recent years. One would expect greater plant response on soils low in phosphorus.

The results gathered from the greenhouse study of the low phosphorus soil were not entirely as expected, due in part to the handling of the experiment itself. Three fourths of the added phosphorus was added as broadcast incorporated with the remaining one fourth added as a band in those treatments that received a band application. This was done to avoid any osmotic effects near the seed. In retrospect, it is believed that further studies need to be undertaken with varied percentages added as broadcast and banded. In so doing, the researcher could find several treatments to be examined. These results could then be used in designing field studies to determine their effect on yield and quality of the tomato fruit.

APPENDIX

Table 1. Analysis of variance for total weight of tomatoes produced.

Source	D.F.	S.S.	M.S.	F
Total	49	14464.41		
Treatment	4	1209.46	302.73	2.36^{ns}
Date	9	8645.88	9606.1	
Error	36	4609.07	128.03	

Table 2. Analysis of variance for total weights of number one tomatoes produced.

Source	D.F.	S.S.	M.S.	F
Total	49	17998.40		
Treatment	4	527.95	131.99	2.18^{ns}
Date	9	15290.40	1698.93	
Error	36	2180.05	60.56	

Table 3. Analysis of variance for percent of total fruit production as number one grade tomatoes.

Source	D.F.	S.S.	M.S.	F
Total	19	.06340		
Treatment	4	.00375	9.375×10^{-4}	.294^{ns}
Replication	3	.02140	7.133×10^{-3}	
Error	12	.03830	3.191×10^{-3}	

Table 4. Analysis of variance for tissue phosphorus levels of field grown tomatoes (Harvest 1).

Source	D.F.	S.S.	M.S.	F
Total	19	.148		
Replication	3	.029	.0097	
Treatment	4	.023	.0056	0.7^{ns}
Error	12	.096	.008	

Table 5. Analysis of variance for tissue phosphorus levels of field grown tomatoes (Harvest 2).

Source	D.F.	S.S.	M.S.	F
Total	19	.151		
Replication	3	.0142	.0047	
Treatment	4	.0558	.0140	2.06^{ns}
Error	12	.081	.0068	

Table 6. Analysis of variance of height of tomato plants grown in two soils.

Source	D.F.	S.S.	M.S.	F
Total	31	64.26		
Between soils	1	7.84	7.84	5.19*
Within soils	30	56.42	1.88	1.25^{ns}
Among treatment within soils	6	20.19	3.37	2.23^{ns}
Among treatment within Pembroke	3	2.27	.76	$.50^{ns}$
Ck vs. Others	1	6.72	6.72	4.45
Br vs. Bands	1	.012	.012	$.0079^{ns}$
2u vs. 2s	1	.018	.018	$.012^{ns}$
Among treatment within Nolin	3	17.92	5.97	3.95*
Ck vs. Others	1	49.74	49.74	32.94*
Br vs. Bands	1	1.36	1.36	$.90^{ns}$
2u vs. 2s	1	.66	.66	$.44^{ns}$
Within treatment within soils	24	36.23	1.51	

*Significant at the .05 level

Table 7. Analysis of variance on whole plant phosphorus levels of plants grown on a high phosphorus soil.

Source	D.F.	S.S.	M.S.	F
Total	13	.003938		
Treatment	3	.000348	.000116	$.323^{ns}$
Error	10	.003590	.000359	

Table 8. Analysis of variance on whole plant phosphorus levels of plants grown on a low phosphorus soil (check treatment not included).

Source	D.F.	S.S.	M.S.	F
Total	10	.01581		
Treatment	2	.00023	.000115	$.059^{ns}$
Error	8	.01558	.00194	

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