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FOLIAR APPLICATION OF PHOSPHORUS FOR COTTON

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Because of the emphasis on foliar application of nutrients to cotton, especially in the Mississippi Delta Area, many questions are being asked regarding the value of this practice in cotton production.

Foliar feeding of plants is not a new thing. That plants will absorb nutrients applied in solution to their leaves and use them effectively is well established. Whether or not foliar feeding is feasible depends on a number of factors, among them being the amount of nutrient required and the number of applications needed to correct a deficiency.

Because they are required in very small quantities, foliar feeding of "trace elements" or micronutrients, such as boron, is feasible and has become a standard practice in some areas. This practice is especially advantageous where availability of the nutrient cannot be maintained adequately by soil application. Foliar application often can be made conveniently and inexpensively with insecticides and fungicides. Application of boron to cotton with the insecticide during the fruiting period is a good example.

Because they are required in large amounts, foliar feeding of nitrogen, phosphorus, and potassium generally has not been found to be practical. This is because frequent application of small amounts is required to correct a substantial deficiency without injury to the leaves. Even so, there has been considerable emphasis as to the advantages of foliar feeding of cotton with NPK solutions during the fruiting period, particularly in the latter part as a heavy boll load is developed. Under these conditions, it is contended that uptake of phosphorus, for example, by cotton roots is inadequate to meet the demand and, as a result, foliar feeding is necessary to get maximum yields. Even if not necessary for maximum yields, foliar feeding of phosphorus might be practical if a much higher percentage of the phosphorus were utilized when applied to the leaves than when applied to the soil.

In previous experiments by the Mississippi Agricultural Experiment Station it was shown that foliar feeding of nitrogen to cotton during the fruiting period was not necessary for maximum yields, but yields were increased where there was insufficient nitrogen in the soils. Because of the lack of experimental information regarding foliar feeding of phosphorus to cotton, experiments were conducted in 1964 by the Mississippi Agricultural Experiment Station to: (1) determine the effect of foliar feeding of phosphorus on the yield and maturity of cotton at different levels of available soil phosphorus and at different rates of fertilizer phosphous applied before planting; and (2) measure the efficiency of foliar-applied phosphorus; and (3) determine the effect on yield of foliar application of phosphorus during the latter part of the fruiting period.

EXPERIMENTAL METHODS

Three field experiments and one simulated (cylinder) field experiment were conducted. The field experiments were located at the Black Belt Branch Station on Houston clay soil, very low in available phosphorus; at the Pontotoc Ridge-

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Flatwoods Branch Station on Atwood silty clay loam, low in available phosphorus; and at the Central Station on Kaufman fine sandy loam, high in available phosphorus.

At the Black Belt Branch Station the treatments consisted of rates of soil-applied phosphorus varying in 30-pound increments from zero to 120 pounds of P_2O_5 per acre both with and without foliar application of phosphorus. At the Pontotoc Ridge-Flatwoods Branch Station foliar feeding was compared with soil application of phosphorus. The rates of soil-applied phosphorus were 0, 30, and 60 pounds of P_2O_5 per acre. Two schedules of foliar application were employed, one beginning early and one later in the fruiting period.

Two sources of phosphorus, monoammonium phosphate and sodium polyphosphate, were compared for foliar application at the Pontotoc Ridge-Flatwoods and the Black Belt Branch Stations.

Two rates of phosphorus, 0 and 120 pounds of P_2O_5 per acre, were employed at the Central Station both with and without foliar application of phosphorus. There were two schedules of foliar feeding, one commencing early and one later in the fruiting period.

In each of the field experiments, ammonium nitrate and ordinary superphosphate were the sources of nitrogen and phosphorus, respectively. Muriate of potash was the source of potassium except at the Black Belt Branch Station where it was Sul Po Mag, a fertilizer containing both potassium and magnesium. Soils of the Blackland area, where the Black Belt Branch Station is located, are often deficient in magnesium for cotton. At each location the rate of potassium was 60 pounds of K_2O per acre; the rate of nitrogen was 80 pounds per acre except at the Black Belt Branch Station where 100 pounds per acre was applied. All fertilizers except those sprayed on the leaves were applied to the soil prior to planting the cotton.

In order to limit the effect of environmental factors such as drought and low light intensity on yield, and to intensify the need of plants for phosphorus during the fruiting period by increasing the yield per plant, cotton was grown in widely spaced cylinders (rims) that could be irrigated as needed. The experimental site was on Shubuta fine sandy loam at the Central Station, State College, Mississippi.

The cylinders, or rims, were constructed of sheet aluminum and were two feet in diameter and one foot deep. Holes were dug into which the cylinders were nested. The cylinders were arranged in rows of ten and the distance, from center to center, between adjacent cylinders was 8 feet. Each cylinder was filled with Brooksville clay soil which was very low in available phosphorus. The soil was taken from the Black Belt Branch Station.

The treatments applied to the cylinders consisted of five rates of phosphorus both with and without foliar application, the rates being 0, 2.9, 5.8, 8.8, and 11.7 grams of P_2O_5 per cylinder. Ordinary superphosphate was the source of phosphorus for soil application. In addition to the phosphorus treatments, all cylinders received 50 pounds of nitrogen as ammonium nitrate and 100 pounds of K_2O as Sul Po Mag prior to planting. Each cylinder was top dressed with additional nitrogen as ammonium nitrate on June 26, July 23, and August 15, at rates of 5.5, 5.5, and 3.6 grams per cylinder, respectively.

A preliminary experiment was conducted to determine what sources of phosphorus and solution concentrations might be best for foliar application. From these results it was evident that very dilute solutions would have to be used to avoid injury to the leaves. Solutions of monoammonium phosphate and of sodium polyphosphate (mixture of orthophosphoric acid and sodium pyrophosphate) ranging in concentration up to one percent

Cotton growing in cylinders to intensify the need for phosphorus during the experiment.

P_2O_5 caused no noticeable injury. Stronger solutions injured the leaves, and the degree of injury increased with increasing concentration of P_2O_5. Solutions containing two percent P_2O_5 caused noticeable burning of the leaves. Solutions of orthophosphoric acid containing as little as 0.5 percent P_2O_5 burned the leaves. As a result of these experiments, monoammonium phosphate was selected as the source of phosphorus for foliar application, but sodium polyphosphate was included for comparison at the Black Belt and Pontotoc Ridge-Flatwoods Branch Stations.

Foliar application of phosphorus was begun on July 20, at the Black Belt Branch Station; on July 21, at the Pontotoc Ridge-Flatwoods Branch Station; on July 13, at the Central Station; and on July 14, in the cylinder experiment at the Central Station, State College, Mississippi. Late-season foliar feeding was begun on August 5, at the Central Station and on August 6, at the Pontotoc Ridge-Flatwoods Branch Station.

The rate of foliar-applied phosphorus varied with the stage of development of the plants. At the beginning of the spray program a solution containing 0.6 percent P_2O_5 was employed. Later it was increased to 0.7 percent and then to 0.8 percent of P_2O_5. Late in the season when the leaf area was at, or near maximum, the amount of P_2O_5 applied to the foliage was increased by increasing the volume of solution applied.

In the beginning two applications per week were intended. However, this schedule had to be abandoned because of weather conditions and the foliar applications were made approximately once per week. Of a total of some twelve foliar applications of phosphorus at least four were washed off by rain before 24 hours had elapsed. Such applications were disregarded in calculating the total amount of foliar-applied phosphorus because with some other plants it has been found that a 24 hour period was required for absorption of 50 percent of the phosphorus applied to the leaves. The schedule for foliar application of phosphorus for all the test locations is given in Table 1. The amount of phosphorus per application varied from 1.5 to 3.5 pounds of P_2O_5 per acre while the total applied varied from 14.4 to 21.7 pounds of P_2O_5 when application was begun early and from 7 to 13.4 pounds when begun late in the fruiting period.

In the field experiments the nutrient solution was sprayed on the cotton with a compressed air, garden-type sprayer and in the cylinder experiment with a hand-operated atomizer.

In order to obtain a measure of the effect of the various treatments on the earliness of cotton, two harvests were made in each of the field experiments and three in the cylinder experiment.

RESULTS AND DISCUSSION

Yield results for the field experiments are given in Tables 2, 3, and 4 and for the cylinder experiment in Table 5. A response to soil application of phosphorus was obtained in all experiments

Table 1. Schedule for foliar application of phosphorus in field and cylinder experiments and rate per application.

Location of Experiment	July: Rate of P_2O_5/A per application and number made		August: Rate of P_2O_5/A per application and number made		September: Rate of P_2O_5/A per application and number made		Total P_2O_5 applied
	Rate	Number	Rate	Number	Rate	Number	
Black Belt							
Branch Station	1.50	3	2.66	5	-----	-	17.8
Pontotoc Branch Station							
Beginning Early	1.90	3	2.62	5	2.90	1	21.7
Beginning Late	-------	-	2.62	4	2.90	1	13.4
Central Station							
Beginning Early	2.46	3	3.50	2	-----	-	14.4
Beginning Late	-----	-	3.50	2	-----	-	7.0
Central Station							
In Cylinders[1]	0.16	4	0.24	3	0.24	1	1.6

[1]Rate is given as grams of P_2O_5 per cylinder.

Table 2. Effect of soil and foliar application of phosphorus on the yield and maturity of cotton on Houston clay at the Black Belt Branch Station.

Treatment pounds of P_2O_5: Soil	Foliar	Pounds of seed cotton[2]: Total	Increase for foliar feeding	Percent at first picking
0	0	2308 c	------	44
0	17.8	2436 bc	128	47
30	0	2372 c	------	51
30	17.8	2508 ab	136	48
30	17.8[1]	2544 ab	172	50
60	0	2528 ab	-----	51
6C	17.8	2576 a	48	49
90	0	2580 a	-----	49
120	0	2376 c	-----	47
120	17.8	2364 c	—12	52
		c.v.=11.9%		

[1]Applied as sodium polyphosphate.

[2]Any two values not followed by the same letter are significantly different from each other at odds of 19:1.

except the one at the Central Station on Kaufman fine sandy loam which was high in available phosphorus. The yield response of cotton to foliar application of phoshorus depended altogether upon the level of available phosphorus in the soil, whether present naturally or as a result of fertilization. Significant increases in yield from foliar application of phosphorus were obtained at the Pontotoc Ridge-Flatwoods Branch Station and in the cylinder experiment at the Central Station. Increases in yield for foliar application were obtained at the Black Belt Branch Station, but they were not statistically significant at odds of 19:1.

From the results at the Black Belt Branch Station and in the cylinder experiment, it is evident that the response of cotton to foliar application of phosphorus decreased with increasing rates of phosphorus applied to the soil until finally there was no increase at all for foliar application. The rate of soil-applied phosphorus at which foliar application no longer increased the yield coincided with the rate needed for maxmum yield.

Where there was no increase in yield from a soil application of phosphorus, as in the field experiment at the Central Station, then, there too was no increase for foliar application of phosphorus. For example, in the field experiment at the Black Belt Branch Station foliar application of phosphorus increased the yield of seed cotton 128 pounds per acre where phosphorus was not applied to the soil; but when 60 pounds of P_2O_5 was applied, there was essentially no increase for foliar application.

These results clearly indicate that foliar feeding of phosphorus during periods of high nutrient needs, as may be engendered by development of a heavy boll

Table 3. Effect of soil and foliar application of phosphorus on the yield and maturity of cotton on Atwood silty clay loam at the Pontotoc Ridge-Flatwoods Branch Station.

Treatments, pounds of P_2O_5/A		Pounds of seed cotton per acre[1]	Percent harvested at first picking
Soil	Foliar		
0	0	2164 c	46
30	0	2404 a	48
60	0	2425 a	55
0	21.7	2407 a	48
0	21.7[2]	2289 b	47
0	13.4[3]	2354 ab	47
	c.v.=9.4%		

[1]Any two values not followed by the same letter are significantly different from each at odds of 19:1.

[2]Phosphorus was applied as sodium polyphosphate.

[3]Foliar feeding was begun late in the fruiting period.

Table 4. Effect of soil and foliar application of phosphorus on the yield and maturity of cotton at the Central Station on Kaufman Fine Sandy Loam.

Treatment, pounds of P_2O_5/A		Pounds of seed cotton per acre[1]	Percent harvested at first picking
Soil	Foliar		
0	0	2260 a	74
0	14.4	2291 a	78
0	7.0[2]	2174 a	76
120	0	2246 a	75
120	14.4	2275 a	77
120	7.0[2]	2242 a	76
	c.v.=9.4%		

[1]Any two values not followed by the same letter are significantly different from each other at odds of 19:1.

[2]Foliar feeding was begun late in the fruiting period.

Table 5. Effect of soil and foliar application on the yield and maturity of cotton in the cylinder experiment at the Central Station.

Treatment, grams of P_2O_5/cylinder		Grams of seed cotton per cylinder		Percent harvested	
Soil	Foliar	Total[1]	Increase for foliar feeding	First picking	1st and 2nd picking
0	0	339 f	....	13	63
0	1.6	429 e	90	21	68
2.9	0	579 d	....	49	81
2.9	1.6	648 c	69	49	85
5.8	0	754 a		55	88
5.8	1.6	727 ab	—27	61	91
8.8	0	687 bc	....	66	91
8.8	1.6	682 bc	—5	58	89
11.7	0	652 c	....	52	86
11.7	1.6	653 c	1	62	90
		c.v.=21.7%			

[1]Any two values not followed by the same letter are significantly different from each other at odds of 19:1.

load, is not necessary to obtain maximum yield.

Accordingly, it may logically be concluded that the roots of the cotton plant have the capacity to absorb all the phosphorus needed by the above-ground portion of the plant during stress periods and that levels of soil phosphorus adequate to supply these needs may occur naturally or as a result of proper fertilization practices. Translocation of phosphorus previously accumulated in other plant parts to the developing bolls may reduce the need for absorption of phorphorus by the roots during stress periods to some extent. But, depending on the yield, 50 percent or more of the phosphorus used by cotton is taken up between the time of early boll formation and maturity.

As employed in these experiments, foliar feeding alone did not correct phosphorus deficiency at the Black Belt Branch Station and in the cylinder experiment at the Central Station even though 8 to 10 applications were made. Soil application or a combination of soil and foliar application of phosphorus was required to correct it. Yield increases for foliar application of phosphorus beginning early in the fruiting period at the Pontotoc Ridge-Flatwoods Branch Station were the same as for soil application of phosphorus, but only 30 pounds of P_2O_5 an acre as a soil application was needed to correct phosphorus deficiency at this location.

Although an increase in the yield of cotton was obtained under conditions of phosphorus deficiency, it is apparent from the results just presented that only a slight to moderate deficiency of phosphorus may be corrected by foliar feeding even with repeated application during the fruiting period.

If the phosphorus applied to the leaves had been utilized more efficiently, fewer applications would have been required. For example, in a field where 1000 pounds of seed cotton is produced without phosphorus the above-ground portion of the crop, including the seed cotton, is estimated to contain 14 pounds of P_2O_5 if phosphorus is added to correct the deficiency and the field then produces 2000 pounds of seed cotton per acre the phosphorus in the above-ground portion of the crop would be increased to about 30 pounds of P_2O_5 per acre, or an increase of 16 pounds of P_2O_5 per acre for 1000 pounds of seed cotton. This would give a 63-pound increase in the yield of seed cotton for each pound of P_2O_5 in the above-ground portion of the crop.

If 75 percent of the phosphorus applied

as a foliar spray to cotton were absorbed by the leaves and utilized, then one pound of foliar-applied phosphorus could increase the yield as much as 45 pounds of seed cotton per acre. But efficiency of this magnitude was not obtained in the field experiments.

At the Black Belt Branch Station, the increase for foliar-applied phosphorus was only a little more than 7 pounds of seed cotton per pound of P_2O_5 where no phosphorus was applied to the soil. At the Pontotoc Branch Station the increase for foliar-applied phosphorus was 11 pounds of seed cotton per pound of P_2O_5. In each of these field experiments foliar-applied phosphorus was slightly more efficient than soil-applied phosphorus.

As an average, approximately 1.2 pounds of phosphorus was required to give the same increase when applied to the soil as one pound applied to the leaves during the fruiting period. Both soil-applied and foliar-applied phosphorus apparently was utilized more efficiently in the cylinder experiment than in the field experiments, but here phosphorus applied to the soil was slightly more efficient that that applied to the leaves.

Foliar application of phosphorus during the latter part of the fruiting period at the Central Station did not increase the yield of cotton. However, at the Pontotoc Ridge-Flatwoods Branch Station there was an increase in yield, but the increase was not as large as when application of phosphorus was begun early in the fruiting period.

These results show that phosphorus deficiency of appreciable magnitude is likely to exist throughout the fruiting period, not just late in the season, and that foliar feeding of phosphorus must be started early in the fruiting period and continued thereafter to correct such a deficiency. Phosphorus deficiency which does not develop until late in the fruiting period would be expected to reduce the final yield only slightly but could be corrected by foliar feeding.

Earliness of cotton was affected only slightly by foliar application of phosphorus even under conditions of severe phosphorus deficiency and not at all where application of phosphorus failed to increase the yield of cotton. On the other hand, the effect of soil-applied phosphorus was outstanding, especially in the cylinder experiment. As was the case with foliar-applied phosphorus, soil application did not increase earliness of cotton except where it increased the yield also. If the increase in yield for phosphorus were small, then earliness of the cotton was increased only slightly. If the increase were large, there was a marked increase in earliness.

In the cylinder experiment without phosphorus only 13 percent of the total yield was harvested at the first picking, but with an application of enough phosphorus to the soil for optimum yield 55 percent was harvested. Foliar application alone increased the percentage of the yield harvested at the first picking only 8 percent. That foliar feeding of phosphorus during the fruiting period should have affected the earliness of cotton only slightly seems logical because the factors which affect early boll-set and maturity must exert their influence early in the development of the plant.

Two sources of phosphorus, monoammonium phosphate and sodium polyphosphate were compared for foliar feeding at the Black Belt and Pontotoc Ridge-Flatwoods Branch Stations. At the Black Belt Station the two sources were equally effective, but at the Pontotoc Ridge-Flatwoods Branch Station monoammonium phosphate appeared to be more effective. More work is needed before a definite conclusion can be reached as to which, if either, is better. These sources were chosen because they represent the kinds of phosphate salts generally available for the formulation of liquid fertilizers containing phosphorus.

CONCLUSIONS

Foliar application of phosphorus to cotton frequently during the fruiting period increased the yield where a phosphorus deficiency existed but not beyond what could be obtained with soil application alone. Therefore, foliar feeding in addition to soil application is not required for top yields. Where only slight to moderate phosphorus deficiency existed foliar feeding was effective in correcting it but not if there was a severe to moderately severe deficiency. In such situations soil, or soil plus foliar feeding, was necessary.

Earliness of cotton was markedly increased by soil application of phosphorus where a large increase in yield occurred, but it was not affected where there was no yield increase for phosphorus. Phosphate fertilizers seldom increase the yield of cotton in the Delta Area. Foliar application of phosphorus increased the earliness of cotton only slightly even under conditions of severe phosphorus deficiency and not at all where there was not a yield increased for the application of phosphorus.

Late-season foliar feeding may be employed to correct a slight phosphorus deficiency, but application beginning early in the fruiting periods is necessary to correct even a moderate deficiency.

In the field experiments a pound of phosphorus applied to the leaves gave a slightly higher increase in yield than when applied to the soil, but the reverse was true in the cylinder experiment. A marked increase in the efficiency of phosphorus by foliar application would have provided additional justification for consideration of the practice.

Application of dilute solutions of phosphorus are necessary to avoid injury to the leaves. Solutions containing as little as 1.5% P_2O_5 caused some leaf injury. More concentrated solutions caused even more burning.

In view of these results and those obtained before with nitrogen, foliar of application of the primary (nitrogen, phosphorus, and potassium) and secondary (calcium, sulfur, and magnesium) nutrients to cotton does not appear to be a practical alternative to soil application. Foliar feeding of the micronutrients may be a satisfactory alternative but is not necessary in addition to soil applicaton for top yields.

Additional research may reveal some advantages for foliar feeding not now recognized, but the prospects are not too encouraging.