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THE INFLUENCE OF TIME AND METHOD OF APPLICATION OF SUPERPHOSPHATE ON THE AVAILABILITY OF P TO COTTON AND THE P CONTENT OF COTTON LEAVES

S. M. Shere, M. M. Iqbal, S. Ahmad and K. S. Memon

Atomic Energy Agricultural Research Centre, Tandojam, Sind

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Abstract. Fraction of P taken up by cotton (*Gossypium hirsutum* L.) from labelled superphosphate fertilizer varied from as little as 2% (30 days after sowing) to as high as 65% (60 days after sowing). The available P supplied by soil ('A' value) was highest at the initial stages of growth and decreased gradually with time. The maximum benefit of applied fertilizer was obtained when it was applied at least 30 days after sowing. No significant difference in the P content of cotton leaf was observed when superphosphate was applied by broadcast or by banding.

When a labelled phosphatic fertilizer is added to soil, P from the fertilizer will tend to exchange with P from almost any fraction of the soil-P until the whole system has attained the same specific activity in all its forms. The rate of exchange depends inversely upon the bond energies of the different soil-P fractions.[3]

A major portion of the labelled P is fixed or sorbed in an insoluble form shortly after addition to the soil, resulting in a low specific activity of labelled P in the soil solution. In this system, labelled P atoms from the fertilizer will exchange with P in the soil solution at a given rate, as will P between soil solution and different fractions of P on soil particles. These exchange reactions will determine the specific activity, at any moment, of the labelled P in the soil solution.[3] As the plants derive their nourishment from the soil solution, the specific activity of the plant material grown on this soil–fertilizer mixture will vary accordingly.

Wheat plants obtained the larger portion of their P from fertilizer in the early stages of growth, but after 4–6 weeks of growth by far the greater amount was obtained from the soil. The highest 'A' values (available soil P) were found at maturity.[6] When the tagged carrier was banded with the seed, the fertilizer P had considerable advantage over the soil P and the 'A' values were appreciably lower compared to the carrier when it was mixed throughout the soil.[6] Lee and Bromfield[4] noted that the position in which the superphosphate fertilizer was placed had no effect on the total amount of P taken up by cotton or on dry matter produced. However, when the added phosphorus was placed close to the seed a greater proportion of the total P uptake by the plant came from fertilizer and this P reached the plant sooner.

Specific activity of P^{32} in plants grown on soil fertilized with radioactive P may be influenced, among other things, by the time of application of the fertilizer. Method of application also needs further investigation. The present experiment was carried out to study the effect of two modes of superphosphate application at four different stages of growth on the availability of P to cotton and the P concentrations of cotton leaves at various times.

Materials and Methods

The experiment was carried out at an agricultural farm near Tandojam during 1970. Cotton variety M-100 was sown in plots of size 3 × 9 m on April 17. The following treatments were established for the experiment :

Times of application of fertilizer : (i) at sowing (T_1); (ii) at first irrigation 30 days after sowing (T_2); (iii) at second irrigation, 45 days after sowing (T_3); and (iv) at third irrigation, 60 days after sowing (T_4).

Methods of application of fertilizer : (i) broadcast (M_1); and (ii) depth placement in bands 7.5 cm deep and 22.5 cm on either side of the row (M_2).

Each plot consisted of 2 subplots.

(a) Radioactive (3 × 3 m): This was used for the determination of specific activity and total P content of cotton leaves. There were 4 rows of cotton in this subplot. Out of 4 rows, only the inner two were used for sampling and analysis. One plant on either side of the inner rows was left as guard plant. The analysis for specific activity and total P was made on the recently matured leaf (4th from top).

(b) Nonradioactive : (3 × 6 m): This was used for yield study only and harvested at the end of the experiment. The soil type for the experimental plots varied from loam to sandy loam.

Phosphorus was applied as single superphosphate (20% P_2O_5) at the rate of 56 kg P/ha. The superphosphate added to the portion of the plot designated as radioactive was labelled with P^{32}, the specific activity of which was 0.2 mc/g P_2O_5. All the treatments containing P received N at the rate of 84 kg N/ha as urea (one-third applied at sowing and the rest at third irrigation) to ensure that N was not a limiting factor from view point of yield.

Leaf samples for radioactive P and total P analysis were obtained 30, 60, 90 and 120 days after sowing. Leaf samples for total P were dried at 80°C, ground and digested with perchloric acid–sulfuric acid mixture. Total P was determined on a spectrophotometer by the vanadomolybdophosphoric yellow color method at 400 μ.[2]

Samples for P^{32} determinations were digested as whole plants without grinding by the above method and the counting was done on a Panax counter.

The availability of P in the soil was estimated by two methods : (i) Percentage of Phosphorus Derived by Plant From the Fertilizer: It was calculated as follows :

Percentage of phosphorus in the plant derived from fertilizer.

$$= \frac{\text{Specific activity of plant}}{\text{Specific activity of fertilizer}} \times 100$$

The underlying assumption is that the amount of the nutrient derived by plant from the applied fertilizer is a function of the amount of the nutrient already present in the soil. It is obvious that there are two routes by which the percentage of P derived from the fertilizer can be measured—either by a labelled fertilizer or by a labelled soil. Both methods have practical as well as theoretical limitations.

(ii) 'A' Value: It reflects upon the capacity of the soil to supply P to plants from the residual phosphorus. The method is similar to the one described above but the mathematical treatment and the interpretation of results varies. The concept of 'A' value as proposed by Fried and Dean[1] is based on the assumption that a plant confronted with two sources of nutrient, the soil and the fertilizer, will absorb this nutrient in direct proportion to the amounts available from each source. The quantity of available nutrient in the soil can be determined in terms of a standard, provided the proportion of the nutrient in the plant derived from this standard is determined. The mathematical expression for this relationship is :

$$A = B\left(\frac{Sf}{Sc} - 1\right)$$

where A, amount of nutrient available in soil; B, amount of labelled nutrient or fertilizer added; Sf, specific activity of fertilizer; and Sc, specific activity of plant.
or simply

'A' value=Rete of fertilization × (C/D) (kg P/ha)

Where C, Plant-P derived from the soil; and D, Plant-P derived from the fertilizer.

The estimated 'A' value is in terms of kg P/ha of equal availability to that of fertilizer standard. For example, if single superphosphate was the fertilizer standard, the 'A' value would be in terms of kg P/ha of the added single superphosphate.

Results and Discussion

The influence of time and method of application of phosphate fertilizer on the availability of P to cotton at 4 sampling times are given in Table 1. It is seen that the percentage of P taken up by cotton from the fertilizer was fairly low at the initial stages of growth. The major portion was supplied by the soil-P (higher 'A' values). The percentage of phosphorus taken from the fertilizer increased subsequently. The highest percentage of P (65) was derived from the fertilizer at the sampling time of 60 days after sowing. This is the period when crop stand has established and the flowering and boll formation starts.

Fertilizer application time of 30 days after sowing (T_2) appeared to be about most optimum as it led to the maximum amounts of P derived from the fertilizer on 2 out of 3 sampling times (60 and 120 days after sowing), the sampling time of 60 days after sowing being comparatively more important from view point of plant nutrition. Application time of 45 days after sowing (T_3) led to maximum amounts only at one ocassion—90 days after sowing. Superphosphate fertilization at sowing (T_1) proved to be the least effective because, except for the last sampling time, the values of P derived from the fertilizer were the lowest. Both methods of application of fertilizer were similar so far as the percentage of P derived from the fertilizer was concerned.

As regard the 'A' values, they were the lowest when the percentages of P derived from the fertilizer were the highest. Times of sampling and fertilizer application considerably altered the 'A' values. The values decreased gradually from the first to the last sampling when superphosphate was applied at sowing. No regular pattern was observed for other times of fertilizer application.

Total P Content of Cotton Leaves

The total P content of cotton leaves (moles of P/1000 g of leaf wt) as influenced by 2 methods and 4 times of application of superphosphate at 4 sampling times is given in Table 2. Each figure is an average of 4 replications. The data were subjected to statistical analysis. Table 2 also reports the least significant difference (LSD) for mean P contents of methods and times of application and their interaction at 5% level of significance, obtained after performing the analysis of variance on the above data. The results are discussed as a function of each of the following factors :

Fertilizer Application Time. Time of application of fertilizer had a marked effect on the P concentration of cotton leaves at certain stages during the growth period. The statistical analysis (Table 2) showed that the effect of time of application on the P concentration of the leaves became apparent at two sampling times—60 and 90 days after sowing. At the sampling time of 60 days after sowing, significantly higher P concentrations were obtained when the fertilizer was applied 30 or 45 days after sowing (the concentrations from both application times being insignificant among themselves) whereas at the sampling time of 90 days after sowing, P application after 45 or 60 days of sowing (the concentrations from both being insignificant among themselves) gave significantly higher leaf P compared to other times of superphosphate application. The superphosphate application at sowing (T_1) did not prove better from the point of view of P in the leaf.

Method of Application of Fertilizer. No significant difference in P content of cotton leaves was found

TABLE 1. AVAILABILITY OF P TO COTTON AS AFFECTED BY TIME AND METHOD OF APPLICATION OF FERTILIZER.

Sampling time (days after sowing)	Criteria for P availability	Fertilizer application time: At sowing (T_1)		30 days after sowing (T_2)		45 days after sowing (T_3)		60 days after sowing (T_4)	
		M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
30	From fertilizer (%)	2·0	3·7						
	By 'A' value (kg/ha)	2744	1457						
60	From fertilizer (%)	20·6	24·8	60·3	64·9	42·2	41·9		
	By 'A' value (kg/ha)	216	170	37	30	77	77		
90	From fertilizer (%)	24·6	26·1	37·6	43·6	61·6	62·2	62·2	58·0
	By 'A' value (kg/ha)	172	159	93	73	35	34	34	40
120	From fertilizer (%)	41·5	44·8	56·2	56·2	38·6	38·9	37·3	32·3
	By 'A' value (kg/ha)	80	66	44	44	88	88	94	118

M_1, Broadcast; and M_2, depth placement in bands, 7·5 cm deep and 22·5 cm on either side of the row.

TABLE 2. TOTAL P CONTENT (mmole/1000 g) OF COTTON LEAVES AS AFFECTED BY TIME AND METHOD OF APPLICATION OF FERTILIZER (average of 4 replications).

Sampling time (days after sowing)	Fertilizer application time: At sowing (T_1)		30 days after sowing (T_2)		45 days after sowing (T_3)		60 days after sowing (T_4)	
	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
30	77·2	83·3	72·8	74·4	69·7	71·7	68·8	78·5
	LSD (0·05)	Methods N.S.		Timings N.S.				
60	65·6	74·7	80·8	86·6	85·6	82·6	52·4	63·2
	LSD (0·05)	Methods N.S.		Timings 12·9		M × T N.S.		
90	48·3	33·7	45·7	45·5	54·4	53·0	50·3	60·5
	LSD (0·05)	Methods N.S.		Timings 7·7		M × T 10·9		
120	47·1	42·2	52·8	54·5	51·0	52·2	55·7	54·1
	LSD (0·05)	Methods N.S.		Timings N.S.				

M_1, Broadcast; and M_2, depth placement in bands, 7·5 cm deep and 22·5 cm on either side of the row.

between the two methods of applying fertilizer (Table 2). This means that broadcast was as good as banding.

Interaction of Methods and Times of Application of Fertilizer. The effect of interaction of method of application of superphosphate with time of application was not apparent at all the sampling times. The interaction was significant only at one ocassion– 90 days after sowing. The extension of statistical analysis (details not shown) on the data for this sampling time to figure out the best combination of method of application with time of application showed that the application of superphosphate 60 days after sowing (T_4) by banding (M_2) gave significantly higher P concentration than the other possible combinations. But just one significant interaction and that at a relatively later stage during the growth period may not be enough to indicate the best combination of method and time of application.

Sampling Time. Phosphorus concentration of cotton leaf was generally the highest at first sampling and decreased gradually until the last sampling. Though the data on cotton yield is not available due to circumstances beyond the control of authors, it is expected that the reverse will be the case for P uptake by cotton. This is because the total uptake is estimated by multiplying the total yield (seed cotton plus dry matter) with the tissue P percentage. As the total yield tends to increase gradually until the last sampling and the magnitude of this increase is higher than that of the decrease in P concentration, the total uptake, theoretically, will also tend to increase with time.

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