Proc. Indian natn. Sci. Acad. B47 No. 4 pp 560–566 (1981)

Fertilizer and Lime Effect of Different Combinations of Water-Soluble and Water-Insoluble P-Carriers on the Yield, Nutrients-Uptake and Chemical Composition of Maize (*Zea mays*) in an Alfisol

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(Received 16 October 1980)

Effect of various combinations of two Indian rock phosphates (100 mesh) and superphosphate, at a uniform rate of application of 53.45 ppm P_2O_5/pot, on dry matter yield and nutrients-uptake etc., by maize was tested in a pot culture experiment in an acid hill soil (*p*H 5.7). Almost all the rock phosphate-based treatments though proved inferior to superphosphate alone, yet that 50 to 60% of the water soluble phosphate requirement of the crop can be effectively substituted with rock phosphate. In this respect, Mussoorie RP was slightly better than Andhra RP. A significant increase in the uptake of N, P, K and Ca was evident from phosphorus application in general. This may be due to the liming action of phosphate rock on soil *p*H. The same effect, however, may have caused inhibition in Fe-uptake by maize tops. This antagonism increased with the increasing levels of either of the two sources of rock phosphate tried. On the other hand, phosphorus application did not affect the protein content of maize tops.

Key Words: **Rock Phosphate-superphosphate mixtures, Liming action, Maize yield, Nutrients uptake, Acid alfisol**

Introduction

Raw ground rock phosphate is an inexpensive concentrated material but a poor source of rapidly available phosphorus to the plants than most of the processed phosphatic fertilizers (Sahu et al. 1974, Hundal & Sekhon 1976, Hammond et al. 1976). The availability of rock phosphate phosphorus, however, is increased when applied in conjunction with small amounts of superphosphate (Fine et al. 1957, Anonymous 1974, Talashilkar & Patil 1979). The use of rock phosphate as a filler in fertilizers may also offer some advantage. It is a good conditioner and in addition to its phosphorus content it furnishes as much calcium as the best limestone or dolomitic filler (Murdock

& Seay 1955). This investigation aims at evaluating rock phosphate as a filler and especially attempts to find out as to what portion of the recommended dose of water soluble phosphate for maize could be substituted with rock phosphate.

Materials and Methods

A greenhouse experiment was conducted during 1978 on an acid hill soil tentatively classed as Alfisol at Palampur, situated at an average elevation of 1300 m. Bulk soil samples (0 to 15 cm) were collected, air dried and sieved through 4 mm sieve. Enamelled pots were filled with 8 kg of soil. A sample of the soil was tested by routine laboratory procedures. It was found to have a *p*H of 5.7, Olsen's P 11.0 ppm, available N 490.3 kg/ha, ammonium acetate extractable potassium 304.6 kg/ha, organic carbon 0.69%, exchange acidity 5.18 me/100g, base saturation 64.45% and C.E.C. 14.47 me/100g.

The experiment was conducted in a completely randomised design with 3 replications and 14 treatments as per following details:

Treatment Number	Treatment (ppm P_2O_5 per pot)*: Mussoorie Rock Phosphate		Andhra Pradesh Rock Phosphate		Superphosphate	Ratio of RP and SP (on P_2O_5 basis) in the phosphate mixture
T_1	0.00	+	0.00	+	0.00	—
T_2	0.00	+	0.00	+	53.45	0:10
T_3	26.75	+	0.00	+	26.75	1:1
T_4	32.07	+	0.00	+	21.38	3:2
T_5	40.09	+	0.00	+	13.36	3:1
T_6	44.54	+	0.00	+	8.91	5:1
T_7	48.11	+	0.00	+	5.34	9:1
T_8	53.45	+	0.00	+	0.00	10:1
T_9	0.00	+	26.75	+	26.75	1:1
T_{10}	0.00	+	32.07	+	21.38	3:2
T_{11}	0.00	+	40.09	+	13.36	3:1
T_{12}	0.00	+	44.54	+	8.91	5:1
T_{13}	0.00	+	48.11	+	5.34	9:1
T_{14}	0.00	+	53.45	+	0.00	10:1

*A uniform level of 53.45ppm P_2O_5/pot was used in respect of phosphatic treatments

Two sources of Indian rock phosphates (RP) viz., Mussoorie RP (17.8% P_2O_5 and 39.2% CaO) and Andhra Pradesh RP (24.7% P_2O_5 and 36.4% CaO) and single superphosphate (SP) (having 15.8% P_2O_5) were used as P carriers @ 53.45 ppm P_2O_5 per pot. Basal dose of 110 ppm N and 44.5 ppm K was also applied to each pot at the time of sowing. Maize (var Vijay Composite) was used as the test crop.

Crop was harvested at tasseling stage and dry matter yield per pot was recorded. Agronomic effectiveness of various rock phosphate based treatments relative to superphosphate was then worked out. Chemical composition of maize tops was determined. Based on the content of N, P and K in the plant portions and the dry matter, total uptake of N, P and K was estimated to find out the possible effect of phosphate application on plant composition and nutrient uptake. Total uptake values of Ca and Fe in respect of various treatments were also computed. On the basis of nutrient uptake data, the availability coefficient ratios were worked out (Peaslee 1960).

Results and Discussion

Crop yield

Dry matter yield and agronomic effectiveness of various phosphate mixtures relative to an equal dose of superphosphate was compared (table 1). Effectiveness of superphosphate was significantly higher than all the other treatments except the rock phosphate-superphosphate mixtures in the ratio of 1:1, which proved as effective as superphosphate. In turn, Mussoorie RP based mixtures at 1:1 and 3:2 ratio were found to be at par. Both the phosphate rocks were equally effective and superior to the non phosphorus treatment.

As regards the performance of various rock phosphate-superphosphate mixtures, the yield generally increased as the proportion of water soluble P in various mixtures increased. A positive but non-significant correlation of yield with phosphorus applied either through Mussoorie RP (r =0.42) or Andhra Pradesh RP based treatments (r =0.31) further implies that though RP based treatments were effective in increasing the dry matter yield they probably could not supply available P to plants in adequate amounts. Similar observation is also borne out from the data on correlations between plant P-uptake and applied P, the corresponding r values for the two sets of RP based treatments being 0.38 and 0.30.

These observations show that plants do need certain amount of readily available P in early stages. But 50 to 60% of the optimum water soluble phosphate requirement of maize plants could be substituted by water insoluble phosphate. The advantage of using rock phosphate in conjunction with superphosphate even in small amounts lies firstly, in an assured supply of readily available P in the early stages which helps in the development of normal root system of plants and enables them to forage over constantly widening area and at increasing depths (Waggaman & Hoffman 1967). Secondly, rock phosphate being a water insoluble apatitic mineral phosphate solubilizes gradually with the passage of time (Mandal & Khan 1972, Singh & Datta 1976, Hundal et al. 1977). As a consequence, the plants were able to satisfy a part of their phosphate requirement in initial stages through the water soluble phosphate in such mixtures and in latter stages they were probably able to draw their phosphorus requirement at least in part from the solubilizing rock phosphate. The net result of these is better growth and yield with rock phosphate-superphosphate mixtures than with rock phosphate alone.

Another evidence furnished by the data is that there is definite possibility of yield loss in using absolutely a water-insoluble phosphate, even in acid soils. This is because, the response of crops to phosphorus fertility usually is greater early in the season and decreases gradually as the maturity is approached. In this connection, it is worthwhile to mention the observation recorded by Black (1973) that by the time plants have accomplished 25% of the total of dry matter, they might have absorbed as much as 50% the total requirement of phosphorus. Accordingly, if soil phosphorus availability is low, as is the case with rock phosphate, young plants possibly absorb P less rapidly and the crop yield is likely to remain lower with rock

Table 1 *Dry matter yield and nutrients uptake by maize tops as affected by phosphate fertilization*

Treatment	Yield (g/pot)	Relative agronomic effectiveness (%)	Nutrients uptake (mg/pot)				
			P	N	K	Ca	Fe
T_1	17.63	—	17.42	10.29	27.31	35.96	29.73
T_2	60.96	100.00	58.95	63.37	106.64	82.63	33.42
T_3	54.89	85.99	44.73	53.78	90.03	63.11	21.94
T_4	52.21	79.81	39.84	51.73	69.19	59.99	15.67
T_5	42.56	57.54	28.48	46.15	67.21	63.01	17.40
T_6	38.74	48.72	30.91	35.58	56.73	50.54	13.48
T_7	41 08	54.12	33.03	35.40	59.73	51.23	18.12
T_8	27.21	22.11	21.48	28.81	41.39	44.97	13.61
T_9	55.20	86.71	40.45	52.23	82.48	63.71	16.56
T_{10}	41.30	54.63	29.92	43.23	65.16	66.07	26.83
T_{11}	35.90	42.16	29.96	37.48	55.63	43.08	23.35
T_{12}	37.43	45.70	27.13	35.24	58.13	56.01	18.72
T_{13}	28.40	24.86	21.86	30.39	43.23	48.23	17.04
T_{14}	23.00	12.39	17.71	23.80	33.81	39.16	11.50
S.Em(±)	2.02		2.33	12.40	7.92	7.09	2.83
C.D.5%	6 11		7.08	37.62	24.0	21.52	8.34

Table 2 *Chemical composition of maize tops as related to phosphate application*

Treatment	Average chemical composition						
	N (%)	P (%)	K (%)	Na (ppm)	Fe (%)	Ca (%)	Protein (%)
T_1	1.16	0.10	1.54	80	0.15	0.20	7.25
T_2	1.05	0.10	1.74	95	0.05	0.13	6.56
T_3	0.98	0.08	1.64	73	0.04	0.12	6.13
T_4	0.98	0.08	1.33	100	0.03	0.12	6.13
T_5	1.10	0.07	1.60	83	0.04	0.14	6.88
T_6	0.92	0 08	1.46	80	0.04	0.13	5.75
T_7	0.84	0.08	1.46	80	0.04	0.13	5.25
T_8	1.06	0.08	1.52	85	0.05	0.17	6.63
T_9	0.93	0.07	1.49	73	0.03	0.12	5.81
T_{10}	1.05	0.07	1.58	80	0.06	0.16	6.56
T_{11}	1.19	0.08	1.55	95	0.07	0.12	7.44
T_{12}	1.10	0.07	1.48	90	0.05	0.15	6.88
T_{13}	1.07	0.08	1.52	73	0.06	0.17	6.69
T_{14}	1.04	0.08	1.47	80	0.05	0.18	6.50

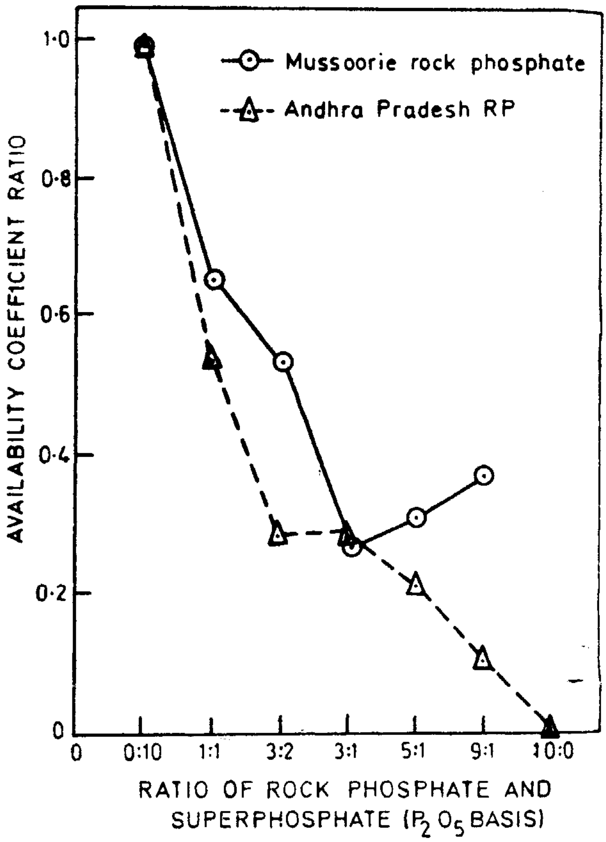
phosphate fertilization than with water-soluble phosphate.

Nutrient-uptake

An increase in the proportion of water soluble phosphate in the phosphate mixtures brought about a proportionate increase in phosphorus uptake (table 1). Nevertheless, the magnitude of increase at the comparable levels was generally higher with Mussoorie RP based treatments than those involving Andhra RP. Mixing of Mussoorie RP and superphosphate in the ratios of 1:1 and 3:2 (on phosphate basis) proved significantly better than all the remaining Mussoorie RP based treatments, while with Andhra Pradesh RP, corresponding effect remained limited to the 1:1 mixing level, thereby indicating the superiority of Mussoorie RP over Andhra RP when used either alone or in combination with superphosphate. The availability coefficient ratios also reflected similar trend and superiority of Mussoorie RP over Andhra Pradesh rock phosphate (figure 1).

It is quite apparent from the ACR values that the effectiveness of various RP-SP mixtures depended upon the degree of water soluble phosphate fraction in a particular mixture. While the differences were usually more prominent in case of fertilizer mixtures having higher proportion of SP, there were relatively narrow differences in the effectiveness of mixtures having lower proportion of water-soluble phosphate viz., 3:1, 5:1 and 9:1 RP-SP mixtures. The mixture comprising rock phosphate and superphosphate in the ratio of 1:1 was 66% as effective as superphosphate alone. The corresponding figures for 3:2, 3:1, 5:1 and 9:1 mixtures were 54, 27, 32 and 38, respectively. Similar beneficial effect of phosphorus application on phosphorus uptake and the ACR values has also been reported by Hundal and Sekhon (1976) and Hundal et al. (1979).

Similar to phosphorus, N, K and Ca uptake also exhibited marked and significant



improvement due to phosphate application, thereby suggesting the synergistic effect of P on the availability of N, K and Ca by maize plants.

Further perusal of the data given in tables 1 and 2 regarding Fe and phosphate relationship brings forth a strikingly distinct behaviour of two sources namely superphosphate and rock phosphate. While superphosphate revealed a synergetic effect on Fe uptake causing an increase of 12.5%, rock phosphate treatments exhibited a conspicuous antagonistic effect on the availability of Fe to plants. This antagonism became more acute at higher levels of rock phosphate. As regards the synergistic effect of P on Fe uptake several reports are available (Datta Biswas 1964, Baser & Ram Deo 1967). The observed antagonism seems to be due to a high calcium content of rock phosphate. A possible lime induced inhibition in Fe uptake due to rock phosphate fertilization similar to other liming materials, as has been postulated by Wallace et al. (1976a) and Patel and Wallace (1976) in soybean and Fe-inefficient corn inbreds.

This hypothesis of lime action of rock phosphate also lends support to the increased P and K uptake by maize plants from RP based treatments, in conformity with the observations of Thomas and Hipp (1968) regarding K uptake and of Ryan and Smillie (1975) pertaining to increased plant P-uptake due to liming.

Acknowledgement

My thanks are due to the Head, Department of Soil Science and Water Management, Himachal Pradesh Agricultural University, Palampur, for providing necessary facilities for this investigation.

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