

Effect of Graded Saturation of Phosphorus Fixing Capacity of Soil on Yield and Yield Attributes of Maize (*Zea mays*)

Soumi Mukhopadhyay¹, Pabitra Kumar Biswas¹, Saptadeep Mondal² and Shreya Mondal¹

¹Dept. of Soil Science and Agricultural Chemistry, Palli Siksha Bhavana, Visva Bharati University, Sriniketan, West Bengal, India

²Dept. of Agronomy, Palli Siksha Bhavana, Visva Bharati University, Sriniketan, 731236, West Bengal, India

*Corresponding author: ppabitra07@rediffmail.com (ORCID ID: 0000-0002-7367-5960)

Paper No. 701

Received: 03-03-2018

Accepted: 23-05-2018

ABSTRACT

A pot experiment was conducted during the *summer* season, 2015 to study the effect of graded saturation of phosphorus fixing capacity of soil on yield of maize. Application of P equivalent to 100% P fixing capacity of the soil in addition to recommended dose of fertilizer (RDF) significantly increased the dry matter yield (48.33, 78.33, 65.00 g pot⁻¹) and yield attributes i.e. plant height (122.66, 131.44, 133.89 cm) and fresh yield (185.33, 319.67, 226.67 g pot⁻¹) of maize over the control in all the three different soils (loamy sand, clay loam and clayey). The significant highest nitrogen, phosphorus, potassium and sulphur content and uptake by plants were obtained through saturating the 100% phosphorus fixing capacity of the soil in addition to RDF in all the three different soils. Likewise, highest productivity of maize was obtained from clay loam textured soil.

Highlights

- ① Maize positively response to the higher saturation of phosphorus irrespective of soil types.
- ② Saturation of the 100 percent phosphorus fixing capacity of soils in addition to recommended dose of fertilizer promotes growth, productivity and nutrient uptake in maize.
- ③ Clay loam soil is superior in terms of productivity over the clayey and loamy sand soils of Gujarat.

Keywords: Fresh and dry matter yield, maize, nutrient content in plant, nutrient uptake by plant phosphorus fixing capacity of soil, plant heights

The phosphorus is an essential nutrient both as a part of several key plant structure compounds and as a catalyst in the conversion of numerous key biochemical reactions in plants. The origin of P deficiencies in these soils is threefold (Brady and Weil 1999). First, the total P level of the soils is low, ranging from 0.01 to 0.1% (Chen and Ma 2001). Second, the P compounds commonly found in these soils are highly insoluble. Third, when soluble sources of P, including those in fertilizers and manures, are added to soils they are sorbed to the soil, changed into unavailable forms and, over time, incorporated into highly insoluble compounds. The soil characteristics that influence P fixation include the amount and type of clay-fraction

minerals, soil pH, soil organic matter content, soil temperature, time of reaction, exchangeable Al³⁺, soil redox condition (Sanchez and Uehara 1980), and root exudates. These factors are interactive rather than additive, which makes it difficult to predict inorganic P fixation under a wide range of soil conditions. Therefore, this study was undertaken using maize as a test crop at pot experiment at Anand, Gujarat.

MATERIALS AND METHODS

A pot experiment was carried out at net house during the *summer* season. Before starting the experiment in pots, soils from three locations were analyzed to estimate the phosphorus fixing



capacity of the soils in laboratory condition as per the procedure outlined by Waugh and Fitts (1966).

The experiment was laid out in a completely randomized design with factorial concept, comprising fifteen treatment combinations of five levels of phosphorus (F_1 : only recommended dose of fertilizer (RDF) ($N:P_2O_5:K_2O = 120:60:00 \text{ kg ha}^{-1}$), F_2 : RDF + 50% saturation of P fixing capacity of soil, F_3 : RDF + 75% saturation of P fixing capacity of soil, F_4 : RDF + 100% saturation of P fixing capacity of soil and F_5 : RDF + 100% saturation of P fixing capacity of soil + 5 mg Zn kg^{-1} + 10 mg Fe kg^{-1}) and three types of soil (S_1 : loamy sand, S_2 : clay loam and S_3 : clayey soil) which were replicated three times. Ten kilograms of soil was taken in earthen pots and initially six healthy seeds of maize were sown into each pot at proper depth and finally three plants were maintained for 60 days. Pots were watered regularly and weed free condition was maintained till 60 days after sowing (DAS) required for tasseling stage of maize crop. Then treatment-wise calculated quantities of fertilizers were applied in solution form (N through urea, phosphorus through KH_2PO_4 , Zn through $ZnSO_4$ and Fe through $FeSO_4$) with irrigation water. Top dressing of 50% nitrogen through urea was done at 30 days after sowing (DAS).

Experimental data generated during the pot experiment were analyzed statistically for their test of significance as per Completely Randomized Design (factorial), at 5% level of significance Panse and Sukhatme (1978). After the analysis of most of the parameters, interaction effect of $S \times F$ was calculated. Then modified anova was prepared wherever applicable.

The initial physico-chemical properties of soils were as follows:

Sl. No.	Parameter	Values		
		S_1	S_2	S_3
A	Physical Property (Soil Separates, g 100^{-1} g)			
1	Coarse sand	0.10	1.30	0.00
	Fine sand	73.50	32.72	34.96
	Silt	15.60	32.14	23.11
	Clay	10.30	29.71	41.18
2	Texture Class	Loamy Sand	Clay loam	Clayey
3	Bulk density (mg m^{-3})	1.32	1.21	1.23

B		Chemical Properties		
1	pH (1:2.5)	7.95	6.30	7.80
2	EC (1:2.5) dSm^{-1}	0.28	0.20	0.24
3	CEC ($\text{Cmol(P}^+ \text{)} \text{kg}^{-1}$)	16.50	30.00	35.20
4	Organic Carbon (%)	0.35	0.70	0.43
5	Available N (kg ha^{-1})	141.12	203.84	188.16
6	Available P_2O_5 (kg ha^{-1})	17.02	28.39	22.69
7	Available K_2O (kg ha^{-1})	287.03	213.33	306.60
8	Available S (mg kg^{-1})	8.24	10.89	8.91
9	DTPA-Fe (mg kg^{-1})	4.59	18.11	8.27
10	DTPA-Zn (mg kg^{-1})	2.75	2.77	0.77
11	P-fixing capacity (mg kg^{-1})	7.00	10.50	13.50

RESULTS AND DISCUSSION

Plant height

The highest mean plant height (129.00, 138.67, 137.44 cm) was recorded in treatment RDF + 100% saturation of P fixing capacity of soil + 5 mg Zn kg^{-1} + 10 mg Fe kg^{-1} (F_5). The plant height was not significantly increased among the treatments as well as types of soil. Increase in plant height with the increase in phosphorus levels was recorded in all the three soil types but the difference in plant heights were statistically non significant (Table 1.). Plants grown in the clay loam textured soil gave significantly highest plant heights (128.76 cm).

Fresh yield

All the treatments differed from the only recommended dose of fertilizer (RDF) in respect of fresh yield of maize during the experimentation (Table 1). Saturation of phosphorus fixing capacity of soil increased the fresh yield of maize in all the soils. This increase was found statistically non significant in the loamy sand and clayey soil but under clay loam soil it gave significant difference (Table 1.). Significantly highest fresh yield was noted under the treatment RDF + 100% saturation of P fixing capacity of soil + 5 mg Zn kg^{-1} + 10 mg Fe kg^{-1} (F_5). Treatments RDF + 50% saturation of P

Table 1: Effect of graded saturation of phosphorus fixing capacity of soils on plant height, fresh and dry matter yield of maize

Treatments	Plant heights (cm) (Average of three replications)				Fresh yield (g pot ⁻¹) (Average of three replications)				Dry matter yield (g pot ⁻¹) (Average of three replications)		
	S ₁	S ₂	S ₃	Treatment Mean	S ₁	S ₂	S ₃	Treatment Mean	S ₁	S ₂	S ₃
F ₁	97.55	119.00	115.33	110.63	141.67	236.67	196.00	191.44	31.67	56.67	51.67
F ₂	107.00	126.67	124.44	119.37	175.67	281.67	207.00	221.44	41.67	63.33	58.33
F ₃	112.33	128.00	130.34	123.55	177.33	294.00	220.67	230.67	45.00	71.67	61.67
F ₄	122.66	131.44	133.89	129.33	185.33	319.67	226.67	243.89	48.33	78.33	65.00
F ₅	129.00	138.67	137.44	135.04	193.00	332.67	244.67	256.78	53.33	83.33	71.67
Soil Mean	113.71	128.76	128.29		174.60	292.93	219.00		44.00	70.67	61.67
Effect	S.E.m.±	C.D. (P=0.05)		C.V. (%)	S.E.m.±	C.D. (P=0.05)		C.V. (%)	S.E.m.±	C.D. (P=0.05)	
S	2.63	7.59			5.98	17.28			1.47	4.23	
F	3.39	9.66			7.72	22.01			1.89	5.39	
SXF	5.87	NS			13.38	NS			3.28	NS	
Treatment effects within the soil types				8.23	Treatment effects within the soil types			10.12	Treatment effects within the soil types		
F/S1						NS					
F/S2	5.87	NS			13.38	38.64			3.28	9.47	
F/S3						NS					

fixing capacity of soil (F₂), RDF + 75% saturation of P fixing capacity of soil (F₃), RDF + 100% saturation of P fixing capacity of soil (F₄) and RDF + 100% saturation of P fixing capacity of soil + 5 mg Zn kg⁻¹ + 10 mg Fe kg⁻¹ (F₅) produced 19.01%, 24.22%, 35.07% and 40.56% higher yield respectively over the RDF (191.44 g pot⁻¹). These result corroborated with the earlier findings of Hussein (2009) in corn and Dhar *et al.* (1977) in berseem. Among the different three soil types significantly highest fresh yield (292.93g pot⁻¹) of maize was obtained from the clay loam textured soil. The response of iron and zinc was not significant in all the three soils as the soils contain sufficient amount of iron (Fe) and zinc (Zn).

Increase in fresh yield of maize under different saturation treatments of phosphorus might be attributed to better availability of uptake of phosphorus and crop growth as against recommended dose of fertilizer (RDF)

Dry matter yield

Significantly highest dry matter yield was obtained under the treatment F₅ which was at par with RDF + 100% saturation of P fixing capacity of soil (48.33, 78.33 and 65.00 g pot⁻¹ in loam soil (S₁), clay loam

soil (S₂) and clayey soil (S₃) respectively) irrespective of three different soil types (Table 2). Dry matter yield in clay loam soil (S₂) was 14.59% higher over the clayey soil (S₃) and 60.61% higher over the loamy sand soil (S₁). The dry matter yield varied from 31.67 g pot⁻¹ (RDF (F₁)) to 53.33 g pot⁻¹ (RDF + 100% saturation of P fixing capacity of soil + 5 mg Zn kg⁻¹ + 10 mg Fe kg⁻¹ (F₅)) within the loamy sand soil (S₁) with the increase in levels of phosphorus. Yield increased by 68.39%, 52.61%, 42.09% and 31.57% with the treatments RDF + 100% saturation of P fixing capacity of soil + 5 mg Zn kg⁻¹ + 10 mg Fe kg⁻¹ (F₅), RDF + 100% saturation of P fixing capacity of soil (F₄), RDF + 75% saturation of P fixing capacity of soil (F₃) and RDF + 50% saturation of P fixing capacity of soil (F₂) respectively over the treatment RDF (F₁). Within the clay loam soil (S₂) treatments RDF + 50% saturation of P fixing capacity of soil (F₂), RDF + 75% saturation of P fixing capacity of soil (F₃), RDF + 100% saturation of P fixing capacity of soil (F₄) and RDF + 100% saturation of P fixing capacity of soil + 5 mg Zn kg⁻¹ + 10 mg Fe kg⁻¹ (F₅) produced 11.75%, 26.47%, 38.22% and 47.04% higher yield respectively over the RDF (F₁). Increment of dry matter yield in clayey soil over RDF (F₁) with treatments RDF + 50% saturation of P fixing capacity

Table 2: Effect of graded saturation of phosphorus fixing capacity of soil on N, P, K and S content in plants

Treatments	N content (%)				P content (%)				K content (%)				S content (%)					
	(Average of three replications)				(Average of three replications)				(Average of three replications)				(Average of three replications)					
	S ₁	S ₂	S ₃	Treatment Mean	S ₁	S ₂	S ₃	Treatment Mean	S ₁	S ₂	S ₃	Treatment Mean	S ₁	S ₂	S ₃	Treatment Mean		
F ₁	1.52	1.65	1.53	1.57	0.20	0.26	0.25	0.24	1.50	1.43	1.59	1.51	0.18	0.26	0.21	0.22		
F ₂	1.61	1.78	1.59	1.66	0.23	0.29	0.29	0.27	1.69	1.78	1.85	1.77	0.20	0.29	0.23	0.24		
F ₃	1.66	1.87	1.72	1.75	0.29	0.37	0.33	0.33	2.11	1.89	2.12	2.04	0.25	0.31	0.24	0.27		
F ₄	1.73	1.96	1.81	1.83	0.39	0.43	0.38	0.40	2.33	2.00	2.37	2.23	0.26	0.33	0.26	0.28		
F ₅	1.78	2.01	1.83	1.87	0.35	0.38	0.32	0.35	2.37	2.09	2.42	2.29	0.27	0.34	0.29	0.30		
Soil Mean	1.66	1.85	1.69		0.29	0.35	0.32		2.00	1.84	2.07		0.23	0.30	0.25			
Effect	S.E.m.±	C.D. (P=0.05)		C.V. (%)	S.E.m.±	C.D. (P=0.05)		C.V. (%)	S.E.m.±	C.D. (P=0.05)		C.V. (%)	S.E.m.±	C.D. (P=0.05)		C.V. (%)		
S	0.01	0.02			0.01	0.02			0.03	0.08			0.01	0.02				
F	0.01	0.03			0.01	0.03			0.04	0.10			0.01	0.02				
SXF	0.02	NS			0.02	NS			0.06	NS			0.01	NS				
Treatment effects within the soil types				1.85	Treatment effects within the soil types				8.41	Treatment effects within the soil types				5.57	Treatment effects within the soil types			
F/S1																		
F/S2	0.02	0.06			0.02	0.06			0.06	0.17			0.01	0.03				
F/S3																		

Table 3: Effect of graded saturation of phosphorus fixing capacity of soil on N, P, K and S uptake by plants

Treatments	N uptake (mg pot ⁻¹) (Average of three replications)				P uptake (mg pot ⁻¹) (Average of three replications)				K uptake (mg pot ⁻¹) (Average of three replications)				S uptake (mg pot ⁻¹) (Average of three replications)			
	S ₁	S ₂	S ₃	Treatment Mean	S ₁	S ₂	S ₃	Treatment Mean	S ₁	S ₂	S ₃	Treatment Mean	S ₁	S ₂	S ₃	Treatment Mean
F ₁	484	934	789	736	64.03	149.12	131.20	114.78	476	814	821	704	57.33	148.83	109.00	105.06
F ₂	673	1126	928	909	94.28	184.47	169.27	149.34	704	1128	1078	970	84.67	182.00	136.33	134.33
F ₃	748	1340	1059	1049	132.05	261.48	204.63	199.39	951	1351	1305	1202	111.50	219.50	150.33	160.44
F ₄	836	1537	1175	1183	187.45	337.87	245.58	256.97	1129	1563	1537	1410	126.00	255.67	171.67	184.44
F ₅	949	1675	1312	1312	186.07	317.52	231.67	245.08	1262	1739	1730	1577	147.17	283.33	210.67	213.72
Soil Mean	738	1323	1053		132.78	250.09	196.47		905	1319	1294		105.33	217.87	155.60	
Effect	S.Em.±	C.D. (P=0.05)	C.V. (%)	S.Em.±	C.D. (P=0.05)	C.V. (%)	S.Em.±	C.D. (P=0.05)	C.V. (%)	S.Em.±	C.D. (P=0.05)	C.V. (%)	S.Em.±	C.D. (P=0.05)	C.V. (%)	C.V. (%)
S	28.66	82.78		6.55	18.91		30.58	88.32		5.94	17.16					
F	37.00	105.45		8.45	24.09		39.48	112.52		7.67	21.86					
SXF	64.08	NS		14.64	NS		68.38	NS		13.29	NS					
Treatment effects within the soil types				10.70	Treatment effects within the soil types				13.13	Treatment effects within the soil types				Treatment effects within the soil types		
F/S1																14.42
F/S2	64.08	185.05		14.64	42.28		68.38	197.47					13.29		38.38	
F/S3																



of soil (F_2), RDF + 75% saturation of P fixing capacity of soil (F_3), RDF + 100% saturation of P fixing capacity of soil (F_4) and RDF + 100% saturation of P fixing capacity of soil + 5 mg Zn kg^{-1} + 10 mg Fe kg^{-1} (F_5) were recorded by 12.89%, 19.35%, 25.80% and 38.71% respectively.

Similar result was revealed by earlier workers Ahmad *et al.* (2013) in wheat, Gichangi (2007) in maize and Majumdar *et al.* (2001) in soybean.

The response of iron and zinc was not significant in all the three soils as the soils contained sufficient amount of iron (Fe) and zinc (Zn). The application of phosphorus equivalent to 100 per cent phosphorus fixing capacity of a soil in addition to RDF is the best treatment in S_2 (clay loam) and S_3 (clayey) while 75% saturation was sufficient to increase the yield significantly in S_1 (loamy sand). Significantly highest dry matter yield of maize was recorded from the plants grown in the clay loam textured soil (70.67 g pot^{-1}) as compared to the rest two soils.

N, P, K and S content and uptake

Nitrogen, phosphorus, potassium and sulphur contents in plants and uptake by plants were significantly increased with the increase in phosphorus levels. Significantly higher nutrient contents (Table 2.) and uptake (Table 3.) were recorded under the treatment F_4 where 100 per cent phosphorus fixing capacity of soil was saturated with the additional dose of phosphorus in addition to RDF. Addition of Fe and Zn failed to give significant effect in nutrient contents and uptakes over the RDF + 100% saturation of P fixing capacity of soil (F_4). The results corroborate with the findings of Malik *et al.* (2014), Ijgude and Kadam (2008), Nagar and Meena (2004) and Teotia *et al.* (2000). As compared to RDF, each level of saturation of phosphorus fixing capacity of soil was found superior. Nutrients content and uptake were found highest in the clay loam textured soil.

Interaction effects of $S \times F$

Interaction effects of $S \times F$ remained statistically non significant for all the above parameters.

CONCLUSION

The results indicated that maize could positively respond to the higher saturation of phosphorus

irrespective of soil types. Higher plant heights, fresh and dry matter yield, nutrient content in plants and nutrients uptakes in plants were achieved through saturating the 100 percent phosphorus fixing capacity of soils in addition to recommended dose of fertilizers (RDF) irrespective of soil types. Clay loam soil was found superior in terms of productivity over the clayey and loamy sand soils.

REFERENCES

- Ahmad, M., Khan, M.J., Dost Muhammad and Amanullah Jr. 2013. Response of wheat (*Triticum aestivum* L.) to phosphorus application in different soils series having diverse lime content. *Intl. J. Agron. Plant. Prod.*, **4**(5): 915-927.
- Brady, N.C. and R.R. Weil. 1999. The nature and properties of soils, 12th ed. Prentice Hall, Upper Saddle River, NJ.
- Chen, M. and Ma, L.Q. 2001. Taxonomic and geographic distribution of total phosphorus in Florida surface soils. *Soil Sci. Soc. Am. J.*, **65**: 1539-1547.
- Dhar, S.N., Modgal, S.C., Pal, R.N. and Negi, S.S. 1977. Effect of different levels of phosphorus fertilization on yield, composition and in vivo nylon bag digestibility of berseem cultivated in Kangra Valley. *Herb. Abstr.*, **48** (4): Ab.1115, 1978.
- Gichangi, E.M. 2007. Enhancing phosphorus availability in some phosphate fixing soils of the Transkei region, South Africa using Goat manure. Ph.D Thesis. Department of Agronomy, University of Fort Hare, South Africa.
- Hussein, A.H.A. 2009. Phosphorus use efficiency by two varieties of corn at different phosphorus fertilizer application rates. *Res. J. Applied Sci.*, **4**(2): 85-93.
- Ijgude, M.B. and Kadam, J.R. 2008. Effect of sulphur and phosphorus on yield and quality of soybean [*Glycine max* (L.) Merrill]. *An Asian J. Soil Sci.*, **3**(1): 194-196.
- Majumdar, B., Venkatesh, M.S., Lal, B. and Kumar, K. 2001. Response of soybean (*Glycine max*) to phosphorus and sulphur in acid Alfisol of Meghalaya. *Indian J. Agron.*, **46**(3): 500-505.
- Malik, M.A., Wani, M.A. and Wani, J.A. 2014. Effect of P, FYM and PSB on macronutrient concentration and uptake by sunflower. *J. Indian Soc. Soil Sci.*, **62**(3): 269-273.
- Naagar, K.C. and Meena, N.L. 2004. Effect of phosphorus, sulphur and phosphate solubilizing bacteria on yield components, yield and quality of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]. *Legume Res.*, **27**(1): 27-31.
- Pansee, V.G. and Sukhatme, P.V. 1967. Statistical methods for Agricultural workers, ICAR New Delhi.
- Sanchez, P.A., and Uehara, G. 1980. Management considerations for acid soils with high phosphorus



- fixation capacity. p. 471–514. In F.E. Khasawneh *et al.* (ed.)
The role of phosphorus in agriculture. ASA, Madison, WI.
- Teotia, U.S., Mehta, V.S., Ghosh, D. and Srivastava, P.C. 2000.
Phosphorus and sulphur interaction in mungbean (*Vigna
radiata*) yield N, K, and Ca and Mg contents. *Legume Res.*,
24 (2): 272-274.
- Waugh, D.L. and Fitts, J.W. 1966. Soil test interpretation
studies: Laboratory and potted plant. *Tech. Bull. N. Carol.
Ste agric. Exp. Stn* (ISTP Series) No. 3.

