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SS Tembhurne
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

NM Konde
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

SD Jadhao
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Jaipal Yadav
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

VS Mapari
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Corresponding Author:
SS Tembhurne
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Soil fertility, nutrient uptake and yield of soybean as influenced by various levels of phosphorus in vertisols

SS Tembhurne, NM Konde, SD Jadhao, Jaipal Yadav and VS Mapari

Abstract
The present investigation entitled, "Soil fertility, nutrient uptake and yield of soybean as influenced by various levels of phosphorus in Vertisols" was undertaken during 2019-20 at Research Farm, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra. The experiment was laid out in Randomized Block Design with five treatments randomized in four replications. Among the various treatments, the significantly higher soybean yield was recorded with the application of 30:90:30 kg N, P_2O_5 & K_2O ha^{-1} (T_5) however, it was at par with 30:75:30 kg N, P_2O_5 & K_2O ha^{-1} (T_4) and 30:60:30 kg N, P_2O_5 & K_2O ha^{-1} (T_3). The total uptake of nutrients by soybean was significantly influenced by different phosphorus based treatments over control. However, uptake of nitrogen (136.67 kg ha^{-1}) phosphorus (20.33 kg ha^{-1}) and potassium (57.52 kg ha^{-1}) were significantly highest with the application of 30:90:30 kg N, P_2O_5 & K_2O ha^{-1} (T_5) over the remaining treatments. Hence, it is concluded that the increasing levels of phosphorus along with recommended dose of nitrogen and potassium resulted in increased nutrient uptake as well as yield of soybean grown in Vertisols.

Keywords: Soil fertility, yield, nutrient uptake, soybean and vertisols

Introduction
Soybean (*Glycine max* L. Merrill) is the world's most important seed legume, which contributes to 25% of the global edible oil. The cultivation and use of soybean could be traced back to the beginning of China's agricultural age. Chinese medical compilations, dating back 6,000 years, mention its utilization for human consumption. To the populace of China, Japan, Korea, Manchuria, Philippines and Indonesia, for centuries, soybean has meant to be meat, milk, cheese, bread, and oil. This could well be the reason, why in these countries, it has earned epithets like ''Cow of the field'' or ''Gold from soil''. Owing to its amino acids composition, the protein of soybean is called a complete protein. Its nutrition value in heart disease and diabetes is well known. Today, USA, Brazil and Argentina are the ''Big-3'' producers of soybean in the world. Versatility of soybean was recognized within the West Country recently. At present, India ranks fifth in the area and production in the world after USA, Brazil, Argentina and China (Source statista, 2018). The contribution of India within the world soybean area is 10%, but the contribution to total world soybean grain is merely 4 % indicating the poor levels of productivity in India (1.1 t/ha) as compared to other courtiers (world average 2.2 t/ha) (Agarwal *et al*. 2013) [2].
Soybean performs well under balanced nutritional conditions. The application of nitrogen, phosphorus and potassium has vital significance in enhancing yield and quality of soybean. Especially, phosphorus has very vibrant role in soybean.
Soils are known to vary widely in their capacity to supply phosphorus to plants. Only a small fraction of total P in soil is found in plant available form. Its bioavailability in the soil is governed by several factors like soil pH, texture, moisture, lime content, applied nutrients, etc. Besides these, the fact that the form in which phosphorus exists in the soil is also a factor which contributes the complication in the mode of its availability (Kothandaraman and Krishnamoorthy, 1979) [14]. The total P content in Indian soils ranges from 100-2000 mg kg^{-1}. Since the different forms of soil phosphorus have different solubility under different soils and environmental conditions; the availability in soil and the uptake of phosphorus by crops should largely depend upon the different factors prevailing in and through the soils. Thus, knowledge of the dynamics of P in soil is helpful in understanding the soil processes influencing the availability of P and its uptake by plant.
Considering the behaviour of phosphorus in black soils, the doses and its application need to be refined. The oilseeds are responding well to application of phosphorus, if the time and method of phosphorus application is proper.

Similarly, the transformation of phosphorus in black soils is also major concern. Keeping this in view, the present study was planned.

Materials and Methods

The field experiment was conducted during the kharif 2019-20 at Research Farm, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra. The soil of the experimental site was Vertisols which was moderately alkaline in reaction, low in available nitrogen, Low in available phosphorus and high in available potassium. The experiment was laid out in Randomized Block Design with five treatments randomized in four replications. The treatments comprised of various levels of phosphorus *viz*. 0, 45, 60, 75, and 90 kg ha^{-1} along with recommended dose of nitrogen and potassium @30 kg each excluding control treatment. The N, P and K were applied in the form of urea, single super phosphate and muriate of potash.

Grain and straw yield of soybean were recorded. The treatment wise plant samples were collected by uprooting the entire plant carefully. The plant samples were first dried and then rinsed with distilled water. The samples were dried in shade and then oven dried at 65 ^{0}C. Then the plant samples were powdered with the help of grinder and stored in paper bags. Briefly, Nitrogen was determined from plant sample by Micro Kjeldahl's method using digestion mixture consisting of $CuSO_4$, K_2SO_4, Selenium powder and H_2SO_4. The plant samples (0.5 g) were digested in a micro processer block digestion unit. After complete digestion the samples were distilled using micro-processor based automatic distillation unit and the liberated ammonia is trapped in boric acid containing mixed indicator and liberated against 0.01 N H_2SO_4 (Piper, 1966) [20]. The phosphorus content in the plant sample was determined by Vanadomolybdate yellow colour method using diacid extract. Di-acid was prepared as per method outlined by (Jackson, 1973) [12]. It was carried out using 3:1 mixture of HNO_3:$HClO_4$. The intensity of colour was read at 420 nm wavelength using spectrophotometer (Jackson, 1973) [12]. Potassium content in the plant sample was estimated by atomizing the diluted plant extract in the flame photometer as described by (Piper, 1966) [20].

Results and Discussion

Grain and Straw yield of soybean

The data regarding grain and straw yield of soybean has been compiled and presented in Table 1. The data in respect of grain yield of soybean was significantly influenced by various levels of phosphorus treatments. The maximum grain yield (16.51 q ha^{-1}) was recorded with the application 30:90:30 kg N, P_2O_5 & K_2O ha^{-1}(T_5) which was significantly higher over lower levels of phosphorus application and at par with 60 and 75 kg P_2O_5 ha^{-1} along with recommended dose of N and K. The lowest grain yield (15.19 q ha^{-1}) was recorded in control treatment (T_1). The straw yield of soybean was significantly influenced by various levels of phosphorus. The yield of straw ranged between 20.58 to 26.96 q ha^{-1}. The maximum straw yield (26.96 q ha^{-1}) was recorded with the application 30:90:30 kg N, P_2O_5 & K_2O ha^{-1}(T_5). However, the application of 75 kg P_2O_5 ha^{-1} along with recommended dose of N and K was found at par with the application of 90 kg P_2O_5 ha^{-1}. Higher grain and straw yield at higher levels of phosphorus might be due to increased chlorophyll content and photosynthetic rate and stable acid phosphatase activity to accumulate more dry matter after anthesis. The results are in conformity with the findings of Narayana (2003) [18], Botha *et al.* (2003) [6], Dhage *et al.* (2014) [9], Bahadur *et al.* (2012) [3], Khaswa *et al*. (2014) [13] and Begum *et al.* (2015) [4].

Table 1: Effect of various levels of phosphorus on yield of soybean

Treatments	Yield (qha^{-1})	
	Grain	Straw
T_1 - Absolute Control	15.19	20.58
T_2 - 30:45:30 kg N, P_2O_5 & K_2O ha^{-1}	15.63	23.73
T_3 - 30:60:30 kg N, P_2O_5 & K_2O ha^{-1}	16.39	24.41
T_4 - 30:75:30 kg N, P_2O_5 & K_2O ha^{-1}	16.40	26.33
T_5 - 30:90:30 kg N, P_2O_5& K_2O ha^{-1}	16.51	26.96
SE (m) ±	0.214	0.529
CD at 5 %	0.666	1.648

Nitrogen content

The data regarding nitrogen content in grain and straw of soybean is placed in Table 2. The effect of various levels of phosphorus on nitrogen content in grain and straw was found to be non–significant. However, the highest nitrogen content in soybean grain (6.09%) and straw (1.34%) was recorded with the application of 90 kg P_2O_5 ha^{-1} (T_5) along with recommended dose N and K over remaining treatments.

Phosphorus content

The data presented in Table 2 indicate that the highest phosphorus content in soybean grain (0.66%) and straw (0.35%) was observed with the application of 90 kg P_2O_5 ha^{-1} (T_5) along with recommended dose of nitrogen and potassium. However it was at par with the application of 75 kg P_2O_5 ha^{-1} (T_4) along with recommended dose of N and K. The lowest uptake of phosphorus was recorded in control treatment. Phosphorus content in soybean grain and straw influenced significantly with the application of various levels of phosphorus. Phosphorus content was high in grain must be due to phosphorus taken up by the plant was utilized for grain formation. The results are in accordance with the findings of Patel and Chandravanshi (1996) [19], Bharambe and Tomar (2004) [5].

Potassium content

The data regarding potassium content in grain and straw of soybean is presented in Table 2. The potassium content in grain was ranged from 0.71 to 0.79 and in straw it was from 1.58 to 1.65 per cent. The highest potassium content in soybean grain (0.79%) and straw (1.65%) was recorded with the application of 30:90:30 kg N, P_2O_5 & K_2O ha^{-1}(T_5) over remaining treatments. While, the effect of various levels of phosphorus on potassium content in grain and straw was found non-significant.

Table 2: Effect of various levels of phosphorus on nutrient content of soybean

Treatments	Nutrient content (%)					
	Nitrogen		Phosphorus		Potassium	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1 - Absolute Control	5.96	1.27	0.52	0.24	0.71	1.58
T_2 - 30:45:30 kg N, P_2O_5 & K_2O ha^{-1}	6.07	1.29	0.57	0.25	0.74	1.60
T_3 - 30:60:30 kg N, P_2O_5 & K_2O ha^{-1}	6.06	1.30	0.61	0.29	0.76	1.62
T_4 - 30:75:30 kg N, P_2O_5 & K_2O ha^{-1}	6.07	1.33	0.64	0.30	0.78	1.63
T_5 - 30:90:30 kg N, P_2O_5& K_2O ha^{-1}	6.09	1.34	0.66	0.35	0.79	1.65
SE (m) ±	0.076	0.056	0.012	0.020	0.256	0.303
CD at 5 %	NS	NS	0.04	0.06	NS	NS

Total uptake of nitrogen

The application of various levels phosphorus significantly influenced the uptake of nitrogen by soybean. The data in respect of nitrogen uptake by grain and straw of soybean as influenced by various levels of phosphorus is given in Table 3.

The highest total nitrogen uptake (136.67 kg ha^{-1}) was recorded with application of 90 kg P_2O_5 ha^{-1} (T_5) and was statistically at par (134.56 kg ha^{-1}) with the application of 75 kg P_2O_5 ha^{-1} (T_4) along with recommended dose of N and K. The lowest total uptake of nitrogen (116.67 kg ha^{-1}) was noted by control treatment (T_1). The N uptake was increased with the increased phosphorus levels. The results are in agreement with the findings of Nale (1996) [17] and Chafle *et al.* (1999) [7].

Table 3: Effect of various levels of phosphorus on uptake of nitrogen by soybean

Treatments	Uptake of nitrogen (kg ha^{-1})		
	Grain	Straw	Total
T_1 - Absolute Control	90.53	26.14	116.67
T_2 - 30:45:30 kg N, P_2O_5 & K_2O ha^{-1}	94.87	30.61	125.48
T_3 - 30:60:30 kg N, P_2O_5 & K_2O ha^{-1}	99.32	31.73	131.05
T_4 - 30:75:30 kg N, P_2O_5 & K_2O ha^{-1}	99.55	35.01	134.56
T_5 - 30:90:30 kg N, P_2O_5& K_2O ha^{-1}	100.54	36.13	136.67
SE (m) ±	0.344	1.182	1.054
CD at 5 %	1.06	3.64	3.25

Total uptake of phosphorus

The data regarding uptake of phosphorus by grain and straw of soybean as influenced by various levels of phosphorus is placed in Table 4. It shows the application of various levels of phosphorus significantly increased the uptake of phosphorus by soybean.

The highest phosphorus uptake (20.33 kg ha^{-1}) was recorded with application of 90 kg P_2O_5 ha^{-1}(T_5) which was at par with the application of 75 kg P_2O_5 ha^{-1}(T_4) along with recommended dose N and K. The lowest total uptake of P was recorded in control treatment (T_1). In general, the uptake of nutrient with the application of various levels of phosphorus along with recommended dose N and K was in the order of 90 kg P_2O_5 > 75 kg P_2O_5 > 60 kg P_2O_5 > 45 kg > 0 kg P_2O_5. The increasing level of phosphorus application has significant influence on the uptake of phosphorus. The similar results were noted by Bharambe and Tomar (2004) [5], Sharma *et al.* (2011) [21].

Table 4: Effect of various levels of phosphorus on uptake of phosphorus by soybean

Treatments	Uptake of Phosphorus (kg ha^{-1})		
	Grain	Straw	Total
T_1 - Absolute Control	7.90	4.94	12.84
T_2 - 30:45:30 kg N, P_2O_5 & K_2O ha^{-1}	8.90	5.93	14.83
T_3 - 30:60:30 kg N, P_2O_5 & K_2O ha^{-1}	10.00	7.07	17.07
T_4 - 30:75:30 kg N, P_2O_5 & K_2O ha^{-1}	10.50	7.89	18.39
T_5 - 30:90:30 kg N, P_2O_5& K_2O Pa^{-1}	10.89	9.44	20.33
SE (m) ±	0.227	0.505	0.634
CD at 5 %	0.70	1.56	1.96

Total uptake of potassium

The application of various levels of phosphorus significantly influenced the potassium uptake by soybean. The data in respect of uptake of phosphorus by grain and straw of soybean as influenced by various levels of phosphorus is placed in Table 5. The highest potassium uptake (57.52 kg ha^{-1}) was recorded with the application of 90 kg P_2O_5 ha^{-1} (T_5) and was at par with the 75 kg P_2O_5 ha^{-1}(T_4) level. The lowest uptake of potassium (43.29 kg ha^{-1}) was recorded in control treatment (T_1). The increasing levels of phosphorus also increase the concentration and uptake of K by grains and straw of soybean. This might be due to response of crops to incremental levels of nutrients. The results are in agreement with the findings of Dubey (1997) [10], Chaturvedi and Chandel (2005) [8].

Table 5: Effect of various levels of phosphorus on uptake of potassium by soybean

Treatments	Uptake of potassium (kg ha^{-1})		
	Grain	Straw	Total
T_1 - Absolute Control	10.78	32.51	43.29
T_2 - 30:45:30 kg N, P_2O_5 & K_2O ha^{-1}	11.56	37.96	49.52
T_3 - 30:60:30 kg N, P_2O_5 & K_2O ha^{-1}	12.45	39.54	51.99
T_4 - 30:75:30 kg N, P_2O_5 & K_2O ha^{-1}	12.79	42.92	55.71
T_5 - 30:90:30 kg N, P_2O_5& K_2O ha^{-1}	13.04	44.48	57.52
SE (m) ±	0.176	0.545	0.643
CD at 5 %	0.54	1.68	1.98

Soil fertility

The data in respect of organic carbon and available nutrients in soil as influenced by various phosphorus levels are presented in Table 6.

Organic carbon

Soil organic carbon is important as it determines agro-ecosystem functions, influencing soil fertility, water holding capacity and other soil parameters which ultimately stimulate crop productivity. The results showed that the organic carbon was non-significant and it ranged from 5.93 to 6.10 g kg^{-1}. The higher organic carbon (6.10 g kg^{-1}) was recorded with the application 90 kg P_2O_5 ha^{-1} (T_5).

Available nitrogen

The data pertaining to available nitrogen status of soil was non-significantly influenced by various levels of phosphorus treatments. The results showed that the soil available nitrogen ranged from 149 to 154 kg ha^{-1}. The available nitrogen was numerically increased with the application of 90 kg P_2O_5 ha^{-1} followed by 75, 60, 45 kg P_2O_5 ha^{-1} along with recommended dose of nitrogen and potassium. The results are in agreement with the findings of Yadav (1998) [23] and Mathew *et al.* (2018) [15].

Available phosphorus

The results indicated that there was significant effect of various levels of phosphorus treatments. The available phosphorous content of soil ranged from 10.92 to 17.62 kg ha^{-1}.

Significantly the highest available phosphorus (17.62 kg ha^{-1}) was recorded with the treatment where 90 kg P_2O_5 ha^{-1} was applied and at par with application of 75 kg P_2O_5 ha^{-1} (15.73 kg ha^{-1}) and 60 kg (13.81 kg ha^{-1}) along with recommended dose of N and K. The increment in available phosphorus might be due to additional supply of phosphorus with increasing levels. Dwivedi *et al.* (1989) [11] also observed the gradual increase in phosphorous availability with increasing level of phosphorus. Similar results were also reported by Yadav *et al.* (2010) [22] and Amba *et al.* (2011) [1].

Available potassium

The application of various levels of phosphorus has non-significant effect on available K. The available potassium content in soil was ranged from 384 to 391 kg ha^{-1} as influenced by various levels of phosphorus application. Progressive increase in the available potassium was noticed with each level of phosphorus, but the numerical increment was noticed. The similar findings were also quoted by Meena *et al.* (2017) [16].

Table 6: Effect of various levels of phosphorus on soil fertility

Treatments	Organic carbon (g kg^{-1})	Available nutrient (kg ha^{-1})		
		N	P	K
T_1 - Absolute Control	5.93	149	10.92	384
T_2 - 30:45:30 kg N, P_2O_5 & K_2O ha^{-1}	5.98	152	12.34	387
T_3 - 30:60:30 kg N, P_2O_5 & K_2O ha^{-1}	6.02	152	13.81	389
T_4 - 30:75:30 kg N, P_2O_5 & K_2O ha^{-1}	6.06	153	15.73	389
T_5 - 30:90:30 kg N, P_2O_5& K_2O ha^{-1}	6.10	154	17.62	391
SE (m) ±	0.038	4.23	1.28	15.22
CD at 5 %	NS	NS	4.017	NS

Conclusion

It is concluded that the higher doses of phosphorus enhanced the uptake of nitrogen, phosphorus and potassium as well as increases grain and straw yield of soybean grown in vertisols but the soil fertility is not affected by the incremental phosphorus doses.

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