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Effect of phosphorus levels on nutrient availability, growth and yield of potato crop (*Solanum tuberosum* L.)

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ABSTRACT

The experiment was conducted on potato (cv. Kufri Khyati) at the main experiment station, Department of Vegetable Science, Acharya Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Ayodhya (U.P.) during the Rabi season of 2016-17. Seven treatments were arranged in randomized block design with four replications. The experimental findings showed that the use of RDF 100 kg P_2O_5 ha^{-1} was found better with respect to promotion of growth, yield and quality parameters of potato. The maximum value on growth characters were also recorded with RDF 100 kg P_2O_5 ha^{-1} in potato. It was found significantly superior over other treatments in almost all growth characters. The yield contributing characters such as the weight of A, B, C and D grade tubers per plot and the yield of tubers (q ha^{-1}) were influenced significantly by using different levels of phosphorus. The maximum yield (388.79 q ha^{-1}) was recorded with the application of RDF 100 kg P_2O_5 ha^{-1} in potato. It was found significantly superior over the rest of the treatments. An application of RDF 100 kg P_2O_5 ha^{-1} was found to be most effective for optimum growth: maximum tubers yield (388.79 q ha^{-1}) and maximum net return Rs. 139062 as benefit cost ratio 1.47 on this dose of Phosphorus in the year's investigation.

INTRODUCTION

Potato (*Solanum tuberosum L.*) is some whole food and belongs to the family Solanaceae. It has originated in South America and is now commercially grown all over the world. In India, it was introduced in the early 17th century by Portuguese traders and gradually became a commercial crop all over India. Potato is grown in almost all states of India. The leading states in terms of area, production and productivity are, Uttar Pradesh, West Bengal, Bihar and Gujarat. Potato is a relatively stable part of the diet of European and North American people. It is an important starchy food crop in both sub-tropical and temperate regions. Even in tropical regions, it is widely grown during the winter season. It occupies the largest area of any single vegetable crop in the world and it produces more food per unit amount of cereal. It provides significant quantities of protein, vitamin-c, carbohydrate, iron and, to a lesser extent, vitamin amounts of the B-complex and vitamin-A. Potato contains large amount of minerals like potassium, calcium, iron, Phosphorus and fair amounts of iron, magnesium and copper. Potato is the 4th major food crop after cereals in the world. It is a rich source of energy and utilized in the preparation of readymade products like fried items, i.e., chips, French fries dehydrated products like flakes, granules, starch, gray thicker, potato custard powder etc. The FAO had declared 2008 as the "International year of the potato" and has rightly identified as "food future". In India, per capita consumption is only about 18 kg whereas up to 175 kg per person per annum are consumed in Poland. Potato can be used for the production of high-quality starch, alcohol, glucose, pectin, sugar syrup and a by-product of high-quality protein and fodder. India contributes 10-11 per cent of world potato production and is the second largest producer of potato after China, which shares 22 per cent. The total area in the world under potato cultivation is 186.30 million ha and total production is 374.82 million tones with 18.7 tons ha^{-1} productivity (FAOSTAT, 2016).

As in India, the total area is 21.17 million ha. and production is 43.41 million tones with 23.07 tons ha^{-1} productivity. While in Uttar Pradesh, the potato occupies a 912.70 thousand hectares area with the production of 19571.60 million tones and 23.90 tonnes ha^{-1} productivity (NHB, 2015). Potato contains practically all essential dietary constituents like carbohydrates,

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essential nutrients, protein, vitamins and minerals. To maximize yields, P is a key nutrient that should therefore be available in adequate quantities from the early growth stages. The efficiency of potato plants to adsorb soil P is considered low (Dechassa*et al.*, 2003), which has led to the application of high soluble phosphate amounts to the crop, to ensure soil P availability. However, the application of high P doses causes environmental and economic problems as well as a nutritional imbalance in potato plants. P influences status and affects the absorption of other nutrient sand, consequently, influences crop nutrition and production. Normally, some potato tubers of Indian cultivars contain less than 20 mg glycol alkaloids per 100 g fresh weight and cause no harmful effects. The phosphorus for crops varies with the agro-climatic region, variety, crop sequence and soil type. (Management of fertilizer Phosphorus (P) is a critical component of potato production systems as potato has a relatively high P requirement and inefficiently uses soil P. Phosphorus promotes rapid canopy development, root cell division, tuber set, and starch synthesis. Adequate P is essential for optimizing tuber yield, solids content, nutritional quality and resistance to some diseases (Rosen *et al.*, 2008). Potato is a shallow rooted crop and the fertilizer P use efficiency is 10-15 per cent. Therefore, there is a need to optimize the phosphorus requirement of potato through organic and inorganic sources. In general, Indian farmers apply DAP in excess to fulfill the N need of the potato crop which causes buildup of P in the soil. Excess P disturbs the soil physical and chemical properties in deferent's manner and results in a reduction in production and productivity of the potato crop in India with advancement of time.

MATERIAL AND METHOD

The experiment was carried out during the rabi season 2016-17 at the vegetable research farm of the Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.). An investigation with the effect of phosphorus on nutrient availability and productivity of potato (*Solanum tuberosum* L.) was cuonducted for executing the experiment. Geographically, the experimental site falls under the sub-tropical zone and is located at 26.470N latitude, 82.120E longitude and altitude of 113 meters above mean sea level and is subjected to extremes of weather conditions. The experiment was conducted with a randomized block design and replicated four times. The treatment combinations consisted of four phosphorus doses, T_1- Farmer's practices, (200 kg DAP +150 kg Urea +100 kg Potash, ha^{-1}) T_2 (0kg P_2O_5), T_3 (30 kg P_2O_5), T_4 (60 kg P_2O_5), T_5 (90 kg P_2O_5), T_6 (120 kg P_2O_5 ha^{-1}) T_7 (RDF kg P_2O_5, (150:100:100 NPK) levels *viz.,* allocated randomly. The different growth parameters of potato were studied.

RESULT AND DISCUSSION

Number of haulms per hill and plant height

Data recorded for the number of haulms per hill as affected by different levels of phosphorus at 45 and 75 DAP have been presented in Table 1. An examination of data presented in the table showed that treatment RDP (100 kg P ha^{-1}) produced significantly higher number of haulms per hill 8.20 and 8.80 at 45 & 75 DAP during 2016-17 respectively which were statistically at par with T6, T_1 and T_5 at 45 and 75 DAP. Plant height (cm) as affected by different levels of phosphorus at 30, 45, and 75 DAP have been presented in Table 1. The plant height was recorded significantly higher under RDF (150:100:100 NPK kg ha^{-1}) as compared to150 N+100 K_2O+0 P_2O_5 kg ha^{-1} treatment. Whereas treatments 150 N+100 K_2O+120 P_2O_5 kg ha^{-1} and RDF (150:100:100 NPK kg ha^{-1}) were statistically similar to each other in respect of plant height. This might be due to an increased availability of nutrients to the plants. The dose of (RDF 100 kg P_2O_5 ha^{-1} produced a greater number of haulms per hill than control plots. Though the number of haulms per hill depends on the number of buds present on seed tubers, their survival with plant growth will depend on the nutrition available in the soil. Availability of phosphorus at increasing rates therefore seems the main cause of the increased number of haulms per hill. A positive significant effect of increased phosphorus doses on the number of haulms per hill was also reported by Zelalem *et al.*, (2009) and Adalton *et al.*, (2014).

Table 1: Plant height and number of haulms per hill as influenced by various phosphorus levels at 30, 45 and 75 days after planting (DAP) in potato

Treatments	Number of haulms per hill		Plant height (cm)		
	4 5 DAP	75 DAP	30 DAP	45 DAP	75DAP
T_1: Farmer'spractices, (200 kg DAP +150 kg Urea +100 kg K_2O, ha^{-1})	7.70	8.20	32.30	46.20	53.15
T_2: 150 N+100 K_2O+0 P_2O_5 kg ha^{-1}	6.80	7.30	28.85	41.20	47.35
T3:150N+100K_2O+30kg P_2O_5, ha^{-1}	7.20	7.70	30.40	43.40	49.80
T_4 :150N+100K_2O+60 kgP_2O_5 ha^{-1}	7.40	7.90	31.30	44.70	51.40
T_5 : 150N+100K_2O+90 kg P_2O_5 ha^{-1}	7.60	8.10	31.70	45.30	52.10
T_6 :150N+100K_2O+120 kg P_2O_5 ha^{-1}	8.10	8.70	33.90	48.50	55.75
T_7: RDF (150:100:100 NPK kg ha^{-1})	8.20	8.80	34.30	49.00	56.10
S.Em. ±	0.250	0.268	1.051	1.420	1.655
C.D. (p=0.05)	0.742	0.796	3.121	4.216	4.915

Fresh weight of plant and dry weight of plant

Observations recorded on account of the fresh weight of plant 60 and 75 DAP as influenced by different levels of Phosphorus have been illustrated in Table 2. Response to various levels of phosphorus was found significant at all the intervals. The maximum fresh weight of 187.00 (g) was recorded at 60 DAP under treatment T_7(RDF 100 kg P ha^{-1}). Which was significantly better than treatments T_1,T_2,T_3, T_4 and T_5, but at par with T_6 during the year of investigation. While the minimum fresh weight of plant was noticed in T_7. At 75 DAP, the significant highest fresh weight is 206.20 (g) recorded in T_7 (RDP 100 kg P ha^{-1}) and at par with T_6, which was significantly superior over the T_1, T_2, T_3, T_4 and T_5 during the year of investigation. Response to different levels of phosphorus was found significant at all the intervals. The maximum dry weight, i.e., 21.70 during the year of investigation was recorded at 60 DAP with the treatment T_7 (RDF 100 kg P ha^{-1}). It was at par with treatment T_6 and T_1, which was significantly better than treatment T_2, T_3, T_4, and T_5. While the minimum dry weight of plant was noticed in T_7. A similar trend was also observed at 75 DAP during the years of experimentation. The data pertaining to the number of tubers per plot (grade wise) as affected by different levels of phosphorus is presented in Table 3. It is because of the maximum plant height, number of stem/plant and number of leaf $plants^{-1}$ were from 30 DAP to 75 DAP as compared to 75 DAP at maturity. Although fresh weight $plant^{-1}$ increased till maturity, therefore the maximum biomass was at maturity Grewal, *et al.* (1993). Other hand, this might be due to supply of adequate amounts of nutrients at different stages and increasing the P availability (Ranganathan and Selvaseelan 1997). The results are in conformity with Yadav *et al.* (2014) and Misgina (2016).

Table 2: Fresh weight and dry weight of plant (g) as influenced by various Phosphorus levels at 60 and 75 Days after planting (DAP) in potato

Treatments	Fresh weight of plant (g)		Dry weight of plant (g)	
	60 DAP	75 DAP	60 DAP	75 DAP
T_1: Farmer'spractices, (200 kg DAP +150 kg Urea +100 kg K_2O, ha^{-1})	170.50	187.80	19.80	21.75
T_2: 150 N+100 K_2O+0 P_2O_5 kg ha^{-1}	148.50	163.50	16.35	18.00
T3:150N+100K_2O+30kg P_2O_5, ha^{-1}	154.00	170.00	17.35	19.15
T_4 :150N+100K_2O+60 kgP_2O_5 ha^{-1}	159.50	177.00	18.15	20.10
T_5 : 150N+100K_2O+90 kg P_2O_5 ha^{-1}	164.45	182.00	18.90	20.90
T_6 :150N+100K_2O+120 kg P_2O_5 ha^{-1}	185.35	204.50	21.50	23.70
T_7: RDF (150:100:100 NPK kg ha^{-1})	187.00	206.20	21.70	23.90
S.Em. ±	5.203	5.810	0.63	0.71
C.D. (p=0.05)	15.45	17.25	1.89	2.10

Number of A, B, C and D grade tubers per plot and total yield

A critical examination of data indicated that all the treatments produced significantly higher numbers of A, B, C and D grade tubers per plot in comparison to control. The maximum number of A, B, C and D grade tubers is 20.30 kg and 18.21 kg respectively, but control was C grade recorded in treatments T_7 (RDF 100 kgPha^{-1}), which was significantly higher than other treatments during the year. Among the different levels of phosphorus treatments, T_7 (RDP100 kg P ha^{-1}) is at par with T_6, in respect of number of A, B, C and D grade tubers per plot. It is evident from table-3 that the minimum number of A, B, C and D grade tubers per plot were noticed in control plots. Total yield of tubers per plot (q ha^{-1}) Data for the total yield of tubers per plot and per hectare as influenced by different levels of phosphorus have been displayed in Table 3. The extent of increase in mean weight per tuber might be due to the impact of phosphorus yielding their different grades and their size further increased significantly due to Phosphorus application. These findings are supported by Fernandes *et al.* (2015). The higher yield attributes over control may be due to increased growth and physiological parameters as well as biomass plant^{-1} resulting in increased supply of all the essential plant nutrients with improved physico-chemical and biological properties of the soil. All these favorable conditions might have resulted in greater accumulation of carbohydrates, proteins and their translocation from source to the sink (reproductive organs) which, in turn, increased the yield attributing parameters Meena *et al.* (2012).

An examination of data presented in the table showed that different levels of phosphorus significantly improved the total yield of tubers per hectare. The maximum total yield of tubers per hectare is 388.97 qha^{-1} were recorded in treatment T_7 (RDF 100 kg Pha^{-1}), during the investigation period, which was significantly higher than T_1, T_2, T_3 and T_4 treatments, it was at par with T_6 and T_5, while the treatment T_6 was found at par with T_1. Among the different levels of phosphorus treatments, T_7 (RDF 100 kg P ha^{-1}), was found to have a superior total yield of tuber. Application of RDP 100 kg P_2O_5 ha^{-1} through fertilizer recorded the maximum number of tuberplant^{-1} at all the growth stages of tuber plants. These results were in close agreement with the findings of Misgina N.A. (2016), Zelalem *et al.* (2009) and Maier *et al.* (1995).

Table 3: Weight of A, B, C and D grade tubers per plot (kg) and total yield as influenced by the various levels of phosphorus levels in potato

Treatments	Weight of A,B,C and D grade of tubers plot^{-1} (kg)				Total yield of tubers per hectare (q)
	A	B	C	D	
T_1: Farmer'spractices, (200 kg DAP +150 kg Urea +100 kg K_2O, ha^{-1})	13.43	13.96	10.36	2.73	307.97
T_2: 150 N+100 K_2O+0 P_2O_5 kg ha^{-1}	10.14	10.80	8.21	2.16	246.01
T3:150N+100K_2O+30kg P_2O_5, ha^{-1}	12.59	11.80	10.36	3.60	295.91
T_4 :150N+100K_2O+60 kgP_2O_5 ha^{-1}	12.90	13.65	12.96	3.89	334.88
T_5 : 150N+100K_2O+90 kg P_2O_5 ha^{-1}	13.18	14.40	16.41	3.31	364.97
T_6 :150N+100K_2O+120 kg P_2O_5 ha^{-1}	19.73	17.43	8.79	3.31	380.02
T_7: RDF (150:100:100 NPK kg ha^{-1})	20.30	18.21	8.64	3.24	388.79
S.Em. ±	0.44	0.46	0.34	0.09	6.315
C.D. (p=0.05)	1.31	1.36	1.90	0.27	18.754

Physio-chemical properties of soil

Data pertaining soil pH (Table 4) showed that different phosphorus levels did not affect the soil pH though there was a slight difference from 8.17 to 8.20 i.e., tends to slightly decrease in pH as compared to initial readings of soil pH and the acidic nature of fertilizer and it which were used during experimentation. The electrical conductivity of soil at different levels of phosphorus (Table 4.) remained almost the same, though the values recorded after statistical analysis varied from 0.24 to 0.25dSm^{-1} under different levels of phosphorus which were similar to each other. Soil organic carbon under different phosphorus

levels (Table 4) showed an increase in OC content. The data also revealed that the organic carbon content differed significantly with different phosphorus levels and between them ranged from 0.34 to 0.36%. Although a slight increase in OC% in soil was observed as compared to the initial value of OC present in soil. Control registered with the lowest OC % compared to the other treatments. The data shows that the available P content in soil increased with an increasing dose of P fertilizer. Application of P (RDP 100 kg P_2O_5 ha^{-1}) through fertilizer gave no significant comparison to the available P content in soil (13.50 kg ha^{-1}) as compared to other treatments. It was at par with T_1 treatment. Further, treatment T_6 (13.45 $kgha^{-1}$) also recorded higher available P content in Soil, followed by T_5 (13.40 $kgha^{-1}$), T_4 (13.35$kgha^{-1}$), T_3 (13.20 $kgha^{-1}$), T_2 (13.00 $kgha^{-1}$) and these were at par with each other. However, the minimum (13.00 $kgha^{-1}$) available P content in Soil was registered under control. Phosphorus also plays an important role in increasing the availability of N and K. Therefore, higher application of P stimulates higher concentration of N and K in soil solution. Similar findings have been reported by Bharadwaj *et al.* (1984) and Sharma and Vikas (2007). The other hand, organic carbon % recorded a slight increase as compared to initial value and showed significant variation because of applied P doses. It could be due to manure application, dried plant parts incorporation into the soil and decomposition of crop roots during crop duration. The observed increasing levels of fertilizer application increased the OC content of soil due to root decomposition. Stubble and crop residue could also be expected to follow the same trend. Similar findings have been reported by Verma *et al.* (2005).

Table 4: Effect on different phsico-chemical properties of soil influenced by various Phosphorus level in potato

Treatments	pH	OC (%)	EC(dSm^{-1})	Available P ($kgha^{-1}$)
T_1: Farmer'spractices, (200 kg DAP +150 kg Urea +100 kg K_2O, ha^{-1})	8.18	0.35	0.24	13.5
T_2: 150 N+100 K_2O+0 P_2O_5 kg ha^{-1}	8.2	0.34	0.25	13.00
T3:150N+100K_2O+30kg P_2O_5, ha^{-1}	8.19	0.35	0.24	13.20
T_4 :150N+100K_2O+60 kgP_2O_5 ha^{-1}	8.19	0.35	0.24	13.35
T_5 : 150N+100K_2O+90 kg P_2O_5 ha^{-1}	8.18	0.36	0.24	13.40
T_6 :150N+100K_2O+120 kg P_2O_5 ha^{-1}	8.17	0.36	0.24	13.45
T_7: RDF (150:100:100 NPK kg ha^{-1})	8.17	0.36	0.24	13.50
S.Em. ±	0.077	0.003	0.002	0.125
C.D. (p=0.05)	NS	0.009	0.007	NS

It can be concluded that the application of (RDF 150,100,100 kg N, P_2O_5 and K_2Oha^{-1}) is the best optimum dose of phosphorus for getting the highest plant height, the number of haulms $plants^{-1}$, Tuber fresh as well as dry weight $plant^{-1}$, significantly increased due to all treatments and superior over control plot. Therefore, application of RDP (100kg P_2O_5 ha^{-1}) gave the best result in all aspects.

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