Effect of phosphorus level on nutrient availability and economics of potato crop (*Solanum tuberosum* L.)

Abstract

The experiment was conducted at Narendra Deva University of Agriculture and Technology's Main Experiment Station, Department of Vegetable Science, Narendra Nagar (Kumarganj), ayodhya (U.P.), during the Rabi season of 2016–17. The soil in the experimental field has a sandy loam texture. Four replications of a Randomized Block Study were applied to seven treatments. The experimental findings showed that the use of RDF 100 kg P_2O_5 per ha was found better with respect to promotion of growth, yield and quality parameters of potato. The maximum value on growth characters were also recorded T_7 -RDF kg P_2O_5 ha^{-1} ^{is} better as compare to (T_5-90 kg P_2O_5 ha^{-1} and T_6-120 kg P_2O_5 ha^{-1}) using in potato variety Kufri Khyati. It was found significantly superior over rest of all the treatments. An application of treatment T_7 -RDF 100 kg P_2O_5 ha^{-1} in was found to be most effective total phosphorus uptake by plant and tuber (24.31kg h^{-1}) and available phosphorus (13.50 kg h^{-1}). The tuber and plant content of phosphorus was found T_7 (.280 %) and (0.156%) and dry matter (18.10%) tuber and (10.86%) in plant for highest tubers yield (388.79 q per ha) and maximum net return Rs. 139062 as benefit cost ratio 1.47 on this dose of phosphorus in the years investigation.

Keywords: Economics, Nutrient, Phosphorus, Production, Productivity, Yield

Introduction

Potato (*Solanum tuberosum* L.) is whole some food and belongs to the family Solanaceae. It has originated in South America and now commercially grown in all over the world. In India, it has been introduced in early 17^{th} century by Portuguese traders and gradually become a commercial crop of all over states and India. It occupies the largest area under any single vegetable crop in the world and it produces more food per unit area than cereals and that too in a short time. Potato is the 4^{th} major food crop after cereal of the world. It is rich source of energy and utilized in preparation of readymade products like fried items. *i.e.* chips, French fries dehydrated products like flakes, granules, starch, gray thicker, potato custard powder and canned products. In recognition of virtues and importance of potato as a staple food, the FAO had declared 2008 as the "International year of the potato" and has rightly identified as "food future". Potato contains practically all essential dietary constituents like carbohydrates, essential nutrients, protein, vitamins, and minerals.

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 world under potato cultivation is 186.30 million ha and total production is 374.82 million tones with 18.7 tons per ha productivity (FAOSTAT,2017)

The leading states in terms of area, production and productivity are Gujarat, Uttar Pradesh, Bihar, West Bengal and Punjab. The other major potato growing states are Assam, M.P., Haryana, Meghalaya, Karnataka, Tamil Nadu, Himachal Pradesh, and Maharashtra. Potato is a relatively stable part of the diet of European and North American people. It provides significant quantities of protein, vitamin-c, carbohydrate, iron and to a lesser extent vitamins of the B-complex and vitamin-A. On a worldwide basis the potato crop produces more dry matter and protein per hectare then the major cereal crops. Potato contains large amount minerals like potassium, calcium, iron, phosphorus and fair amounts of iron, magnesium, and copper.

The phosphorus is the most important nutrient of potato growth and development for promotes rapid canopy, 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). Phosphorus need of crop 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. 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 (Hopkins *et al.*, 2008). P nutritional status affects the absorption of other nutrients and, consequently, influence crop nutrition and production.

The plant requirement of magnesium (Mg) can be related to the P levels in nutrient solution (Fernandes et al 2012. Phosphorus also interacts the application of high P levels increases the severity of zinc (Zn) deficiency in soils with low Zn levels (Fageria, 2001). A healthy crop of potato removes about 25-30 kg P_2O_5 ha^{-1} indicating that potato need for P is much higher than most of cereals.

Potato being a shallow rooted crop and the fertilizer P use efficiency is 10-15 per cent. Therefore, there is need to optimize phosphorus requirement of potato through organic and inorganic sources. In general, Indian farmers apply DAP in excess to fulfill N need of potato crop which causes buildup of P in soil. Excess P disturbs the soil physical and chemical properties in different manner and result in, reduction in production and productivity of 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.)" The research farm is situated at about 45 km in south- east from Ayodhya on Raibareli road. An investigation on the topic "Effect of Phosphorus on nutrient availability and productivity of potato" (Solanum tuberosum L.)" was planned for executing the experiment. 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-RDFkg P_2O_5, (150:100:100 NPK) levels viz., allocated randomly. The different growth parameters studied were potatoes, like dry yield, was recording the fresh weight of plant, the separated plant material was kept in hot air oven at 60^{0C} for 24 hours for removal of moisture. After drying in Hot air oven, the material was weighed and the observation was recorded. The dry matter percentage of tuber were determined on the fresh weight basis. Five samples of 100g tuber from each treatment were taken, cut into small pieces and dried in oven 60 ± 2^0C for 8-10 hours per day till the complete drying to have constant weight. The content percentage of phosphorus was determined on dry weight basis at harvesting as per standard procedures given in phosphorus (Koeing and Johnson, 1942). Analytical method, Vanado molybdate yellow colour method and Nutrient uptake of haulm as well as tuber was calculated in $kgha^{-1}$ in relation to (dry matter production) yield ha^{-1} by using the following formula. Nutrient uptake (kg) = Nutrient content (%) X yield on dry weight basis (qha^{-1}). The phosphorus content of soil was estimated by extraction procedure as described by Olsen *et al.* (1954). Available soil phosphorus was extracted using 0.5 M NaHCO3 (pH 8.5) and determination was done by ascorbic acid method . The absorbance of blue colour was read after 10 minutes, on spectrophotometer at 660 nm wavelength. Economics like cost of cultivation, gross returns, net returns and B:C ratio were also calculated under different treatments during the course of experiment.

Result and Discussion

1.1: Effect of different level phosphorus on dry yield, dry matter, total yield of tubers and plant q ha^{-1}.

Data pertaining to effect of different levels on phosphorus dry yield of potato plant and tubers have been presented in table 1. The data on dry matter yield plant of tubers showed the significant difference during the years and dry matter yield tubers improved in comparison to control. The maximum dry matter yield plant and tuber 29.56 and 70.37 in T_7 (RDF 100 Kg P ha^{-1}) and the at par was T_6 during year of investigate. However, the minimum dry matter yield plant and tuber was recorded in T_2 (control) 18.03 and 42.93 during year of study. Among the different levels of phosphorus treatments, T_7 (RDF 100 kg P ha^{-1}), was found superior that become dry matter of (%) and plant dry matter (%) increased the yield of tuber. Similar trend was recorded with regards to dry matter tuber (%) and dry matter plant (%) during the years of experimentation.

An examination of data presented in significantly improved the total yield of tubers per hectare. Maximum total yield of tubers per hectare 388.97 q per ha were recorded in treatment T_7 (RDF 100 kg Pha^{-1}), which was significantly higher than T_1, T_2, T_3, T_4 it was at par with T_6 and T_5 while the treatment T_6 was found at par with T_1.

Table 1: Effect on dry yield, dry matter total yield of tubers and plant per hectare (q) as influenced by various phosphorus level in potato.

Treatments	Dry yield of plant (qha^{-1})	Dry yield of tuber (qha^{-1})	Dry matter tuber (%)	Dry matter plant (%)	Total yield of tubers per hectare (q)
T_1 Farmer's practices	23.08	54.96	17.85	10.71	307.97
T_2 0 kg P_2O_5 ha^{-1}	18.03	42.93	17.45	10.47	246.01
T_3 30 kg P_2O_5 ha^{-1}	21.97	52.30	17.68	10.61	295.91
T_4 60 kg P_2O_5 ha^{-1}	24.96	59.42	17.75	10.65	334.88
T_5 90 kg P_2O_5 ha^{-1}	27.30	65.00	17.80	10.68	364.97
T_6 120 kg P_2O_5 ha^{-1}	28.88	68.75	18.10	10.86	380.02
T_7 RDF kg P_2O_5 ha^{-1}	29.56	70.37	18.10	10.86	388.79
S.Em. ±	0.486	1.156	0.095	0.057	6.315
C.D. (p=0.05)	1.442	3.434	0.284	0.170	18.754

1.2: Effect on various chemical properties of soil influenced by different level Phosphorus in content and uptake of potato.

The soil pH showed that different phosphorus levels did not affect significant it was slight varied from 8.17 to 8.20 i.e. tends to slightly decrease in pH as compare to initial readings of soil pH which is due to acidic nature of fertilizer and manures which were used during experimentation.

The electrical conductivity of soil almost same, though the values recorded after statistical analysis varied from 0.24 to 0.25 dS/m in different levels of phosphorus which were statistically significant as camper to control ready of EC. The soil organic carbon increase in OC content due to application of phosphorus when compared with initial value. The data also revealed that organic carbon content differed significantly with different phosphorus levels through organic and inorganic sources and ranges from 0.36 to 0.34% and Control registered with lowest OC % compared to the other treatments. The total phosphorus content tubers as influenced by different levels of Phosphorus have been displayed in Table 2. Under different treatments, P content in tuber were observed in the range of 0.21 to 0.28 % and respectively. Amongst all treatments, minimum P (0.2%) content observed under control. The significantly higher P contents were noted with treatment T_7 ,and T_6 (RDF100 kg P_2O_5 ha^{-1}through fertilizer) showed higher P % as compare to other treatments. However, treatment, T_1, and T_5, T_3, and T_4 were at par to the T_6 in case of P content with 0.260.25,0.24,0.23,0.21, respectively.

The Phosphorus contents in haulm were observed in the range of 0.156 to 0.116 % respectively. Amongst all treatments, minimum P (0.116%) content were observed under control.

Significantly higher P content was noted with treatment T_7 (RDF 100 kg P_2O_5 ha^{-1} through fertilizer). However, treatment T_6, were at par to the T_7 in case of content with 0.28, P, respectively.

Table 2: Effect on different chemical properties of soil influenced by various level Phosphorus in content and uptake of potato.

Treatments	pH	O C (%)	EC (dSm^{-1})	P content in Plant (%)	P content in tuber (%)	P uptake plant ($kgha^{-1}$)	P uptake tuber (kg ha^{-1})	Total P uptake ($kgha^{-1}$)	Available Phosphorus ($kgha^{-1}$)
T_1 Farmer's practices	8.18	0.35	0.24	0.144	0.260	3.32	14.29	17.62	13.50
T_2 0 kg P_2O_5 $P_2O_5ha^{-1}$	8.2	0.34	0.25	0.116	0.210	2.09	9.01	11.11	13.00
T_3 30 kg P_2O_5 ha^{-1}	8.19	0.35	0.24	0.128	0.230	2.81	12.03	14.84	13.20
T_4 60 kg P_2O_5 ha^{-1}	8.19	0.35	0.24	0.133	0.240	3.32	14.26	17.58	13.35
T_5 90 kg P_2O_5 ha^{-1}	8.18	0.36	0.24	0.139	0.250	3.79	16.24	20.04	13.40
T_6 120 kg P_2O_5 ha^{-1}	8.17	0.36	0.24	0.155	0.280	4.47	19.24	23.72	13.45
T_7 RDF kg P_2O_5 ha^{-1}	8.17	0.36	0.24	0.156	0.280	4.61	19.70	24.31	13.50
S.Em. ±	0.077	0.003	0.002	0.001	0.002	0.07	0.29	0.36	0.125
C.D. (p=0.05)	NS	0.009	0.007	0.004	0.007	0.191	0.86	1.04	NS

While in case of P content all remaining treatments were at significant at different level of P. The maximum uptake of P by plant (4.61kg ha^{-1}) and tuber (19.70 kg ha^{-1}) were observed under T_7 (RDF100 Pkg ha^{-1}), followed by T_6 (120 kg P_2O_5 ha^{-1} through fertilizer) and both the treatments were statistically at par with each other. The lowest P uptake was recorded from control with (9.0 kg P ha^{-1}) tuber (2.09 kg P ha^{-1}) plant respectively, the total uptake of P 11.11 kg ha^{-1} in respect to tuber, and haulm. The Data show that available P content in soil increased with increasing dose of P fertilizer. Application of P (RDF100 kg P_2O_5 ha^{-1}) through fertilizer gave non significantly that available P content in soil (13.50 kg ha^{-1}) as compare to other treatments. The treatment T_6 (13.45 kg ha^{-1}) also recorded higher available P content in Soil, followed by T_5(13.40 kg ha^{-1}), T_4 (13.35kg ha^{-1}), T_3(13.20 kg ha^{-1}), T_2 (13.00 kgha-1) and these were at par with each other. However, minimum (13.00 kg ha^{-1}) available P content in Soil was registered under control.

1.3: Benefit cost ratio of potato crop:

The different levels of Phosphorus involved in potato production view to accept recommendation of results; it becomes essential to economics. Therefore, it was thought desirable to work out the cost of cultivation (Rs ha^{-1}), gross income (Rs ha^{-1}), net return (Rs ha^{-1}), and benefit cost ratio which have been presented in (Table.3) . An average rate of potato prevailing during crop season i.e. Rs. 600 per quintal. were used for calculating the economics.

It is obvious from data that the maximum cost of cultivation Rs. T_6 Rs. 95147 and net returns and 133007 and cost benefit ratio is 1.40 during respectively under treatments T_5 (RDF 100 kg P ha^{-1}). Other parameters of economics (gross income, net return and benefit: cost ratio). Were found to be maximum with the application of T_7 (RDF 100kgP ha^{-1}).

Table 3: Economics and net return per hectare as influenced by various Phosphorus level in potato.

Treatments	**Tuber Yield (q ha^{-1})**	**Cost of Cultivation (Rs ha^{-1})**	**Gross income (Rs ha^{-1})**	**Net return (Rs ha^{-1})**	**Benefit cost Ratio**
T_1 Farmer's practices	307.97	91899	184924	93025	1.01
T_2 0 kg P_2O_5 ha^{-1}	246.01	89603	147748	58145	0.65
T_3 30 kg P_2O_5 ha^{-1}	295.91	90991	177688	86697	0.95
T_4 60 kg P_2O_5 ha^{-1}	334.88	92368	201070	108702	1.18
T_5 90 kg P_2O_5 ha^{-1}	364.97	93746	219124	125378	1.34
T_6 120 kg P_2O_5 ha^{-1}	380.02	95147	228154	133007	1.40
T_7 RDF kg P_2O_5 ha^{-1}	388.79	94479	233416	138937	1.47
S.Em. ±	6.315	82	58	54	0.042
C.D. (p=0.05)	18.754	239	167	155	0.121

Discussion

The results have been discussed in the light of literature available for the different parameter under study. Generally, Indian farmers apply excess quantity of P in the potato. The Excess P disturbs the soil chemical and physical properties in different manner there by resulting reduction of production and productivity of crop. Since, applied P accumulates in the soil and study the effect of phosphorus on nutrient availability and productivity of potato.

2. Biometrical Attributes:

2.1. Dry matter yield Plant and tuber

Accumulation of Dry matter ha^{-1}. due to effect of different P doses linearly augmented with the advancement in the growth stages till the maturity. Rapid rate of increase was observed during the period between 30 to 75 DAP. The rate of increase in Dry matterha^{-1}. was very slow at early growth stage (30 DAP) in all the treatments. The rapid development of vegetative parts increased the rate of $DMha^{-1}$ which was continued up to 75 DAP. During 30 DAP to 75 DAP, plants attained their maximum height, number of stem/plant, tuber weight/plant and number of leaves/plant, therefore rate of dry matter production/ ha plant and tuber was maximum (29.56 and 70.37 q/h) under the treatment T_7 RDF 100 kg $P_2O_5ha^{-1}$ and minimum (18.03 and 42.93 qha^{-1}) under the control. Different P levels significantly varied in their Dry matter/plant and tuber at all growth stages till the maturity due to positive effect of P on dry weight of plant and tuber. These results are in close conformity with the findings of Eleiwa *et al.* (2012) Jenkins (1999), Fernandes (2012) and Zelalem *et al.* (2009).

2.2. Effect of different P levels on yield

Each plant passes through the vegetative as well as reproductive phases of growth to complete its life cycle. Yield is the final expression of the physiological and metabolic activities of plants and is governed by various factors. Yield attributing factors play an important role and have direct bearing on plant productivity. The tuber and haulm yield/plot as well as tans ha^{-1} were significantly affected due to different P treatments. Both 120 kg $P_2O_5ha^{-1}$ and (RDF 100kg $P_2O_5ha^{-1}$) recorded significantly higher tuber and haulm yield as compared to other treatments including control and it was 37.55 and 39.99(%) higher in case of tuber yield 37.56 and 39.00(%) higher in case of haulm yield, respectively as compared to control. This result is supported by Jatav *et al.* (2011), Kumar *et al.* (2007), Yadav *et al.* (2014), Yohana *et al.* (2011), Sharma and Arora (1987).

2.3. Effect of different levels of phosphorus on physio-chemical properties of soil

The Chemical properties of soil viz., pH, EC, Organic carbon, Phosphorus content ($kgha^{-1}$) were determined after completion of trial under different treatments and presented in Table 2. Data indicated a slight improvement, but no remarkable change in chemical properties under different treatments except OC%, Phosphorus content where significant changes were observed. In case of pH and available Phosphorus both were non-significant but slightly decrease and increase, respectively as compare to initial value. It may be due to acid nature of used fertilizers. However, it was non significance decline and decrease in pH and increase Phosphorus, respectively due to different levels of phosphorus and it could have owed to buffering nature of soil. Application of 120 kg $P_2O_5ha^{-1}$ through fertilizer and RDF 100kg ha^{-1} recorded significantly higher Phosphorus content ($kgha^{-1}$) as compared to other treatments. Lowest Phosphorus was recorded with control.

The Phosphorus also play an important role in increasing availability of N and K, therefore higher application of P stimulates higher concentration of NK in soil solution. Similar finding has been reported by Bharadwaj *et al.* (1984) cand Sharma and Vikas (2007). The organic carbon % slight increase due to manure application, dried plant parts incorporation into the soil and decomposition of crop roots during crop duration. Similar findings were also reported by Swarup and who 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 Maier *et al* (1995) and Verma *et al.* (2005).

2.4. Effect of different phosphorus levels on Phosphorus content and their uptake

Different doses of P gave remarkable variation in respect to content and uptake of P in tuber and haulm. Application of 120 kg $P_2O_5ha^{-1}$ through fertilizer and RDF 100kg P_2O_5 ha^{-1} recorded significantly higher value of content (%) as well as uptake of P by crop (haulm, tuber and total) as compared to other treatments. However, minimum contents and uptakes of P in haulm, tuber and total were obtained under control treatment. It may be possible due to fact that plant utilizes the nutrients proportionately as the soil available pool concentrated with successive higher fertilizer or manure additions. The phosphorus also play an important role in uptake of N and K, therefore higher application rate of P stimulates higher concentration of N, K both in haulm as well as tuber. Similar finding has been reported by Bharadwaj *et al.* (1984) and Sharma *et al*. (1987)).

3. Benefit cost ratio of potato crop:

The benefit cost ratio is maximum cost of cultivation Rs 95147 and 228154 during the years (2016-17) respectively in treatment T_6(120 kg P_2O_5 ha^{-1}). Whereas maximum net return 133007 and B:C ratio 1.47 during 2016-2017 respectively from T_7 (RDF100 kg P_2O_5 ha^{-1} Melkamu, *et al.* (2018)

Conclusion

It can be concluded that application of (RDF 150,100,100 kg N_2, P_2O_5, K_2O ha^{-1} are the maximum tuber fresh as well as dry weight/plant, biological yield, slightly increase in OC%, the contents uptakes, and available P best optimum dose of phosphorus for getting higher productivity, ultimately leading to maximum net income and benefit: cost ratio in the potato crop. Therefore, application of T_7 (RDF100kg P_2O_5 ha^{-1}) gave best result in all aspects.

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