



Effect of Phosphorus Level on Nutrient Availability and Economics of Potato Crop (*Solanum tuberosum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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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 P₂O₅ 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 T₇ -RDF kg P₂O₅ ha⁻¹ is better as compare to (T₅-90 kg P₂O₅

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ha⁻¹ and T₆-120 kg P₂O₅ ha⁻¹) using in potato variety Kufri Khyati. It was found significantly superior over rest of all the treatments. An application of treatment T₇ -RDF 100 kg P₂O₅ 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 T₇ (.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.

1. 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 17th 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 4th 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 [1].

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 than 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 [2]. 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 [3], 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 [4]. 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. [5]. Phosphorus also interacts the application of high P levels increases the severity of zinc (Zn) deficiency in soils with low Zn levels [6]. A healthy crop of potato removes about 25-30 kg P₂O₅ 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.

2. MATERIAS AND METHODS

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, T₁- Farmer's practices, (200 kg DAP +150 kg Urea +100 kg Potash, ha⁻¹) (T₂- 0kg P₂O₅, T₃-30 kg P₂O₅, T₄-60 kg P₂O₅, T₅-90 kg P₂O₅, T₆-120 kg P₂O₅ ha⁻¹) T₇-RDFkg P₂O₅, (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^{OC} 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^{OC} 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 [7]. 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. [8]. 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.

3. RESULTS AND DISCUSSION

3.1 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 T₇ (RDF 100 Kg P ha⁻¹) and the at par was T₆ during year of investigate. However, the minimum dry matter yield plant and tuber was recorded in T₂ (control) 18.03 and 42.93 during year of study. Among the different levels of phosphorus treatments, T₇ (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 T₇ (RDF 100 kg Pha⁻¹), which was significantly higher than T₁, T₂, T₃, T₄ it was at par with T₆ and T₅ while the treatment T₆ was found at par with T₁.

3.2 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

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 ₂ O ₅ ha ⁻¹	18.03	42.93	17.45	10.47	246.01
T ₃ 30 kg P ₂ O ₅ ha ⁻¹	21.97	52.30	17.68	10.61	295.91
T ₄ 60 kg P ₂ O ₅ ha ⁻¹	24.96	59.42	17.75	10.65	334.88
T ₅ 90 kg P ₂ O ₅ ha ⁻¹	27.30	65.00	17.80	10.68	364.97
T ₆ 120 kg P ₂ O ₅ ha ⁻¹	28.88	68.75	18.10	10.86	380.02
T ₇ RDF kg P ₂ O 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

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 (kg ha ⁻¹)	P uptake tuber (kg ha ⁻¹)	Total P uptake (kg ha ⁻¹)	Available Phosphorus (kg ha ⁻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 ₂ O ₅ P ₂ O ₅ ha ⁻¹	8.2	0.34	0.25	0.116	0.210	2.09	9.01	11.11	13.00
T ₃ 30 kg P ₂ O 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 ₂ O 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 ₂ O 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 ₂ O 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 ₂ O 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

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 T₇, and T₆ (RDF100 kg P₂O₅ ha⁻¹ through fertilizer) showed higher P % as compare to other treatments. However, treatment, T₁, and T₅, T₃, and T₄ were at par to the T₆ in case of P content with 0.260,0.25,0.24,0.23,0.21, 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 T₇ (RDF 100 kg P₂O₅ ha⁻¹ through fertilizer). However, treatment T₆, were at par to the T₇ in case of content with 0.28, P, respectively.

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 T₇ (RDF100 Pkg ha⁻¹), followed by T₆ (120 kg P₂O₅ 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 P₂O₅ 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 T₆ (13.45 kg ha⁻¹) also recorded higher available P content in Soil, followed by T₅ (13.40 kg ha⁻¹), T₄ (13.35kg ha⁻¹), T₃ (13.20 kg ha⁻¹), T₂ (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.

3.3 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. T₆ Rs. 95147 and net returns and 133007 and cost benefit ratio is 1.40 during respectively under treatments T₅ (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 T₇ (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 ₂ O ₅ ha ⁻¹	246.01	89603	147748	58145	0.65
T ₃ 30 kg P ₂ O ₅ ha ⁻¹	295.91	90991	177688	86697	0.95
T ₄ 60 kg P ₂ O ₅ ha ⁻¹	334.88	92368	201070	108702	1.18
T ₅ 90 kg P ₂ O ₅ ha ⁻¹	364.97	93746	219124	125378	1.34
T ₆ 120 kg P ₂ O ₅ ha ⁻¹	380.02	95147	228154	133007	1.40
T ₇ RDF kg P ₂ O 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

3.2 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.

3.2.1 Biometrical attributes

3.2.1.1 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 matter ha^{-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 $\text{P}_2\text{O}_5\text{ha}^{-1}$ and minimum (18.03 and 42.93 q ha^{-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 [9], Fernandes [5] and Zelalem et al. [10].

3.2.1.2 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 $\text{P}_2\text{O}_5\text{ha}^{-1}$ and (RDF 100kg $\text{P}_2\text{O}_5\text{ha}^{-1}$) 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. [11], Yadav et al. [12], Yohana et al. [13], Sharma and Arora [14].

3.2.1.3 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 $\text{P}_2\text{O}_5\text{ha}^{-1}$ 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. [15] and Sharma and Vikas [16]. 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 [17] and Verma et al. [18].

3.2.1.4 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 $\text{P}_2\text{O}_5\text{ha}^{-1}$ through fertilizer and RDF 100kg $\text{P}_2\text{O}_5\text{ha}^{-1}$ 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. [15] and Sharma et al. [14].

3.2.2 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 T₆(120 kg P₂O₅ ha⁻¹). Whereas maximum net return 133007 and B:C ratio 1.47 during 2016-2017 respectively from T₇ (RDF100 kg P₂O₅ ha⁻¹ Melkamu, et al. [19], [20].

4. CONCLUSION

It can be concluded that application of (RDF 150,100,100 kg N₂, P₂O₅, K₂O 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 T₇ (RDF100kg P₂O₅ ha⁻¹) gave best result in all aspects.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO. FAOSTAT. Food and Agriculture Organization of the United Nations, Rome, Italy, (2017). National Horticulture Board. Ministry of Agriculture Government of India, Gurgaon. 2017;2(2):83-88.
2. Rosen CJ, Bierman PM. Potato yield and tuber set as affected by phosphorus fertilization. American J. Potato Res. 2008;85(2):110–120.
3. Dechassa N, Schenk M, Claassen N, Steingrobe B. Phosphorus Efficiency of Cabbage (*Brassica oleraceae* L. var. capitata), Carrot (*Daucus carota* L.), and Potato (*Solanum tuberosum* L.). Plant & Soil. 2003;250(2):215-224.
4. Hopkins BG, Rosen CJ, Shiffler AK, Taysom TW. Enhanced efficiency fertilizers for improved nutrient management: potato (*Solanum tuberosum*). Crop Management. 2008;7(1): 1-16.
5. Fernandes AM, Soratto RP. Nutrition, dry matter accumulation and partitioning and phosphorus use efficiency of potato grown at different phosphorus levels in nutrition solution. R. Bras. Ci. Solo. 2012;36: 1528-1537.
6. Fageria VD. Nutrient interactions in crop plants. Journal of plant nutrition. 2001; 24(8):1269-1290.
7. Koeing RA, Johnson CR. Industrial and engineering chemistry. Analytical Chemistry. 1942;14:155-164.
8. Olsen SR. Estimation of available phosphorus in soils by extraction with sodium bicarbonate (No. 939). US Department of Agriculture; 1954.
9. Jenkins PD, Ali H. Growth of potato cultivars in response to application of phosphate fertilizer. Annals of Applied Biology. 1999;135:431-438.
10. Zelalem A, Tekalign T, Nigussie D. Response of potato (*Solanum tuberosum* L.) to different rates of nitrogen and phosphorus fertilization on vertisols at Debre Berhan, in the central highlands of Ethiopia. African Journal of Plant Science. 2009;3(2):16-24.
11. Kumar P, Pandey SK, Singh BP, Singh SV, Kumar D. Optimizing phosphorus requirement of chipsona varieties for west-central plains of India. Potato J. 2007;34(3-4):199-202.
12. Yadav SK, Srivastava AK, Bag TK. Effect of integrated nutrient management on production of seed tubers from true potato (*Solanum tuberosum*) seed. Indian J. Agron. 2014;59 (4):646-650.
13. Yohana Carolina, Roza M, Carlos Eduardo. Núñez L. Effects of phosphorus and potassium levels on the yield of the tuber variety Criolla Colombia in the department of Cundinamarca Agronomía Colombiana. 2011;29(2):205-212.
14. Sharma VC, Arora BR. Effects of nitrogen, phosphorus, and potassium application on the yield of potato (*Solanum tuberosum* L.) tubers. Journal of Agricultural Sciences. 1987;108:321-329.

15. Bharadwaj VPK, Omanwar RA, Singh VN. Effect of intensive and continuous cropping and fertilization on the Potato yields and nutrients uptake (Abstract). Proc. Seminar on soil P resources and productivity management held at IARI, New Delhi from 7-10 December during 49th Annual convention of Indian Society of Soil Science; 1984.
16. Sharma AK. Bio-fertilizers for sustainable agriculture'. Agrobios Indian Publications. 2007;48(2):1-5.
17. Maier NA, Dahlenburg AP, Williams CMJ. Effects of nitrogen, phosphorus, and potassium on yield, specific gravity, crisp colour, and tuber chemical composition of potato (*Solanum tuberosum* L.) cv. Kennebec [1994]. Agris. 1995;34(6):813-824.
18. Verma A, Nepalia V, Kanthaliya PC. Effect of continuous cropping and fertilization on crop yields and nutrient status of a Typic Haplustept. J. Indian Soc. Soil. Sci. 2005;53(3):365-368.
19. Melkamu Alemayehu, Minwyelet Jemberie. Optimum rates of NPS fertilizer application for economically profitable production of potato varieties at Koga Irrigation Scheme, Northwestern Ethiopia Alemayehu & Jemberie, Cogent Food & Agriculture. 2018;4:1439663.
20. Jatav MK, Sud KC, Trehan SP. Effect of organic and Inorganic sources of phosphorus and potassium on their different fractions under Potato-Radish cropping sequence in a brown hill soil. Journal of the Indian Society of Soil Science. 2010;58(4):388-393.

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