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Optimization of Phosphorus requirement of potato (*Solanum tuberosum* L.) through organic and inorganic sources under current scenario of P use

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Abstract
A field experiment was conducted during 2015-16 at ICAR- CPRS, Gwalior M.P. during *Rabi* season, to determine the optimum phosphorus dose of potato (*Solanum tuberosum* L.) through organic and inorganic sources under current scenario of P use. The experiment consisted of 10 treatments with four replications. The results revealed that both farmers practice and application of 120 Kg P_2O_5/ha through fertilizer produced significantly higher fresh biomass (g/plant), fresh weight of tuber(g/plant), dry weight of tuber(g/plant), NPK content in soil (kg/ha), NPK % in both tuber and haulm, yield (tuber, haulm and biological) and both these treatments were statistically at par to each other. On the other hand 100 % P_2O_5 through FYM recorded significantly higher number of leaves/plant. From the quadratic equation line ($Y = 21.748 + 5.489 X – 0.587X^2$) for inorganic doses of P, 116.93 and 63.42 kg P_2O_5/ha were the optimum physical and economical levels, respectively for getting higher yield of tuber. Therefore, it is concluded that application of 120 and 60 Kg P_2O_5/ha through fertilizer was the best optimum dose of phosphorus for achieving higher optimum physical and economical productivity, respectively. Therefore, application of 60 Kg P_2O_5 through fertilizer is the optimum dose of phosphorus for central India.

Keywords: Farmyard manure, Optimization, Phosphorus, Potato, Vermicompost

Introduction

Potato (*Solanum tuberosum* L.) is an herbaceous annual that grow up to 100 cm and contributes substantially towards food and nutritional security in the world and ranked by FAO of United Nations as the world's 4th most important food crop after rice, wheat and maize.

India ranks 2nd in area and production of potato in the world after China which contribute 11 per cent of world potato production (Anonymous, 2014) [1]. In India, potato production is mainly confined to Uttar Pradesh, West Bengal, Bihar, Madhya Pradesh, Gujarat, Punjab, Assam and Haryana.

Phosphorus is the 2nd limiting nutrient after nitrogen. Final tuber yields is a function of tuber set, tuber growth rate and the duration of tuber growth. Phosphorus also influences potato growth and yield in several ways, including increasing growth rate of all plant parts for several weeks after emergence (Dyson and Watson, 1971) [4]. In India, it is grown on an area of 2 million hectares with the production of 44.3 million tonnes and the productivity of 21967 kg/ha (Anonymous, 2015) [2]. Productivity of Gujarat was (29750 kg/ha) highest in India among potato

Potato is highly responsive to soil-applied nutrients, especially to phosphorus (P), due to its short cycle and high yield potential. The efficiency of potato plant to adsorb soil P is considered low, 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 economical problems as well as a nutritional imbalance in potato plants (Hopkins *et al.*, 2008) [5].

In general, Indian farmers apply DAP in excess to fulfils 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.

In view of the above facts, the present investigation was conducted to optimize phosphorus requirement of potato through organic and inorganic sources under the current scenario of phosphorus use by farmers.

Materials and Methods

A field experiment was conducted during the *Rabi* season of 2015-16 at ICAR- Central Potato Research Station, Gwalior. Geographical conditions of experimental field, Gwalior was 26º13' N latitude, 78º14' East longitude and 206 m above mean sea level. The soil was silty-clay-loam with pH 7.4 and EC 0.23 dS/m, being low in organic carbon (0.37%) and available nitrogen (165.93 kg/ha), medium in available phosphorus (20.35 kg/ha) and high in available potassium (395.20 kg/ha). Bulk density, particle density and water holding capacity of experimental field were 1.28 g/m^3, 2.56 g/m^3 and 44.47 %, respectively. The experiment was laid out in randomized block design with 4 replications. There were 10 treatments, viz. T_1: farmers practice (180:120:60 kg N:P_2O_5:K_2O, respectively), T_2: Zero P_2O_5/ha (control), T_3: 30 kg P_2O_5/ha through fertilizer, T_4: 60 kg P_2O_5/ha through fertilizer, T_5: 90 kg P_2O_5/ha through fertilizer, T_6: 120 kg P_2O_5/ha through fertilizer, T_7: 50% P_2O_5 through FYM + 50 % P_2O_5 through fertilizer, T_8: 50% P_2O_5 through vermicompost + 50% P_2O_5 through fertilizer, T_9: 100% P_2O_5 through FYM and T_{10}: 100% P_2O_5 through vermicompost.

The recommended dose of N, P_2O_5 and K_2O were 180, 80 and 120 kg/ha, respectively for the crop. Nitrogen, phosphorus and potassium were applied in the form of urea, dia-ammonium phosphate (DAP) and muriate of potash (MOP), respectively. Half dose of nitrogen and full doses of phosphorus and potassium were applied through Urea, DAP and (MOP), respectively, as basal dose at the time of planting, whereas remaining nitrogen was applied at the time of earthing up through urea. FYM and vermicompost were applied according to the treatments to replace the recommended doses of phosphorus. Cultural practices were followed as per standard recommendation to potato. Variety 'Kufri Jyoti' was used for experimentation. Prior to planting, the field was prepared as per the standard procedure and planting was done on 19th October, 2015.

Chemical properties of soil viz., pH, EC, Organic carbon, NPK content (kg/ha) were determined before start of the experiment and after completion of trial under different treatments to monitor the changes in soil chemical properties as per the standard methods. NPK content (%) also determined in plant (haulm, tuber and total) as per the standard methods at harvesting. Five potato plants were randomly sampled from the inner rows of the each plot leaving the border rows. The sampled plants were carefully dunged up, the roots thoroughly washed under running water, put in labeled envelop bags and taken to the laboratory where the growth and yield parameters were recorded. The plant samples were partitioned into various plant fractions and after sun drying sample were subjected to oven-drying at 62°C until a constant weight was attained. Completely dried samples were weighed and the dry matter (DM) content of different plant parts was measured and expressed in g/plant. Growth parameter and yield attributes were recorded at 30, 60 DAP, maturity stage. Economics was worked out taking both variable and fixed costs into account. Data were analyzed as per standard procedure with 5% probability level.

Results and Discussion

Compound leaves/plant

P levels caused a marked variation in number of leaves/plant at all the crop growth stages. P doses significantly increased number of leaves/plant over control. The maximum value of this growth parameter was recorded with 100% P_2O_5 through FYM at all growth stages over control whose values were 32.26, 28.33, 21.94% higher compare to control at 30 DAP, 60 DAP and maturity, respectively. It may be owing to increased supply of nutrients in balanced proportion, positive impact of plant growth regulators and beneficial effect of microflora of FYM which is a rich source of nutrients, vitamins, enzymes, antibiotics, plant growth hormones and a number of beneficial microorganisms resulting in higher number of leaves/plant. The result is also in line with findings of Baishya *et al.* (2012) [3].

Stem/plant

It is obvious from the data given in Table no. 2 that the number of stem/plant gradually increased with the advancement in growth stages up to maturity. Rare increment in stem during the period between 60 DAP to maturity may be due to genetic nature of plant as stems are formed only on or before 60 DAP.

The different doses of P significantly affected the number of stem/plant over control at all the stages. Application of 120 kg P_2O_5/ha through fertilizer recorded the maximum stem/plant as compared to other treatments whereas control recorded the minimum stem/plant at all the stages. It might have been possible due to positive response of P on number of stem/plant (Kumar *et al.*, 2007) [7]. Similar results on the observations were reported by Baishya *et al.* (2012) [3] and Misgina (2016) [8].

Fresh biomass per plant

Application of different doses of P augmented fresh biomass/plant from 30 to 60 DAP and 60 DAP to maturity. Production rate of fresh biomass was higher at 30 to 60 DAP compared to60 DAP to maturity stage. Increase in biomass might be due to increased number of stem/plant and number of leaves/plant which were higher at 30 DAP to 60 DAP compare to 60 DAP to maturity. Although, fresh biomass/plant increased till maturity, therefore biomass was maximum at maturity.

The fresh biomass/plant was significantly higher in different phosphorus levels at all growth stages due to significant effect of P on plant height, leaves, stem/plant and per plant yield of tuber (Zelalem *et al.*, 2009) [14]. At all the stages, significantly higher fresh biomass was noted with 120 Kg P_2O_5/ha through fertilizer over control and at final stage it was at par with farmers practice and 90 Kg P_2O_5/ha through fertilizer. It might be due to adequate supply of nutrients including P at different stages (Ranganathan and Selvaseelan 1997) [9]. The results are in conformity with Yadav *et al.* (2014) [13] and Misgina (2016) [8].

Yield attributes

The factors which are directly responsible for tuber production *viz.*, number of tuber/plant, fresh and dry tuber weight/plant. These attributes were augmented significantly due to applied doses of phosphorus over control. The yield attributing characters increased significantly with increasing levels of phosphorus. These traits were significantly higher with application of 120 kg P_2O_5/ha through fertilizer and farmers practice and both treatments were significantly higher over rest of the treatments. Tuber fresh and dry weight/plant at all the stages were highest with farmers practice and 120 kg P_2O_5/ha through fertilizer which were significantly higher over other treatments except 90 kg P_2O_5/ha through fertilizer at 30 DAP and 50% P_2O_5 through vermicompost + 50% P_2O_5 through fertilizer at maturity. Application of 120 kg P_2O_5/ha through fertilizer recorded maximum no of tuber/plant at all the growth stages of crop. These results were in close agreement with the findings of Misgina N.A. (2016) [8] and Zelalem *et al.* (2009) [14].

Table I: Effect of different doses P on NPK content, pH, EC, OC, yield and HI

Treatment	NPK content						pH	EC	OC	NPK content in soil				Fresh yield t/ha		HI (%)
	N		P		K			dS/m	%	kg/ha						
	Haulm	Tuber	Haulm	Tuber	Haulm	Tuber				N	P	K	Haulm	Tuber	Biological	
T_1	2.65	1.70	0.48	0.51	1.68	1.71	6.78	0.25	0.45	187.65	46.02	427.60	20.19	35.07	55.26	73.61
T_2	2.08	1.26	0.36	0.30	1.42	1.40	6.93	0.23	0.40	170.80	19.54	275.71	13.51	20.98	34.50	66.13
T_3	2.30	1.39	0.43	0.32	1.50	1.42	6.83	0.23	0.44	176.79	25.24	295.83	14.87	29.32	44.20	69.99
T_4	2.47	1.51	0.45	0.40	1.62	1.53	6.98	0.23	0.45	178.66	32.40	346.08	17.49	30.66	48.15	71.34
T_5	2.59	1.60	0.47	0.49	1.64	1.60	6.88	0.21	0.46	185.03	36.20	394.13	19.48	33.25	52.74	73.12
T_6	2.67	1.72	0.48	0.50	1.79	1.74	7.03	0.23	0.42	184.28	46.84	415.64	21.11	35.05	56.17	73.21
T_7	2.53	1.50	0.45	0.37	1.59	1.59	6.93	0.25	0.48	177.16	34.64	350.07	18.70	31.69	50.40	69.77
T_8	2.45	1.50	0.42	0.52	1.44	1.55	6.80	0.23	0.49	177.16	34.46	348.84	19.40	26.76	46.16	64.14
T_9	2.54	1.61	0.47	0.34	1.65	1.63	6.88	0.22	0.50	173.79	34.38	390.37	18.57	30.56	49.14	67.16
T_{10}	2.60	1.63	0.47	0.50	1.57	1.57	6.78	0.23	0.52	182.41	34.01	357.80	18.70	27.70	46.40	66.53
S.E.(m)±	0.05	0.07	0.02	0.03	0.07	0.07	0.11	0.008	0.02	3.11	1.08	14.57	0.42	0.61	0.81	0.85
C.D. (at 5%)	0.16	0.21	0.05	0.08	0.19	0.21	NS	NS	0.06	9.01	3.13	42.28	1.22	1.77	2.35	2.46
							7.4	0.23	0.37							

Table II: Effect of different phosphorus doses on number of leaves, number of stem, fresh biomass and economics of potato

Treatment	Compound leaves/plant			Stem number/plant			Fresh biomass/plant (g)			Total cost (`)	Income (`)		B:C ratio
	30 DAS	60 DAS	Maturity	30 DAS	60 DAS	Maturity	30 DAS	60 DAS	Maturity		Gross	Net	
T_1	49.70	50.65	62.05	4.05	4.48	4.83	178.43	408.00	760.00	81695	21043	128737	2.58
T_2	40.75	49.60	54.90	3.12	3.27	3.43	130.70	303.90	493.20	77434	125910	48476	1.63
T_3	44.75	49.70	57.40	3.14	3.32	3.59	141.35	365.80	674.17	78923	175974	97051	2.23
T_4	45.75	50.50	59.15	3.58	3.84	3.98	154.00	374.70	706.29	80413	183960	103547	2.29
T_5	45.90	57.65	58.80	3.90	3.95	4.58	171.45	393.20	748.90	81902	199536	117634	2.44
T_6	51.60	53.50	62.95	4.08	5.17	5.44	187.08	445.10	791.80	83391	210348	126957	2.52
T_7	46.90	56.00	63.10	3.91	4.27	4.39	142.30	378.20	653.00	95362	190152	94790	1.99
T_8	48.25	59.70	63.85	3.96	4.14	4.64	145.30	375.45	579.00	108478	160560	52082	1.48
T_9	55.23	63.65	66.95	3.80	3.93	4.00	162.10	329.70	623.60	11044	183414	72965	1.66
T_{10}	54.95	63.15	65.75	3.84	4.00	4.80	145.60	335.40	708.59	135800	166254	30454	1.22
S.E.(m)±	1.45	1.77	2.00	0.11	0.12	0.15	6.03	15.56	25.09				
C.D. (at 5%)	4.21	5.14	5.80	0.32	0.35	0.43	17.51	45.16	72.80				

The improvement in yield components might have resulted from favourable influence of P fertilizers on the growth attributes and, efficient and greater partitioning of metabolites as well as adequate translocation of photosynthates to the developing tubers.

Yield

Yield is considered to be the final expression of the physiological and metabolic activities of plants and is governed by various factors. Yield attributing factors which play an important role and have direct bearing on plant productivity.

Tuber and haulm yield (t/ha) were significantly affected due to different P treatments. Both 120 kg P_2O_5/ha through fertilizer and farmers practice recorded significantly higher tuber and haulm yield as compared to other treatments including control and it was 67.08 and 67.16% higher in case of tuber yield and 49.38 and 56.23% higher in case of haulm yield, respectively compared to control. It may be due to higher tuber wt/plant, higher no of stem/plant and supply of adequate amount of nutrients at different stages and increasing the P availability (Ranganathan and Selvaseelan 1997) [9]. This result is supported by Jatav *et al.* (2011) [6] and Kumar *et al.* (2007) [7].

Different phosphorus levels increased biological yield significantly over Control (Table no 1). Application of 120 kg P_2O_5/ha through fertilizer and farmers practice recorded significantly higher biological yield as compared to other treatments and it was 62.82 and 60.17%, respectively higher compared to control. It may be due to higher tuber and haulm yield. These results are in conformity with Zelalem *et al.* (2009) [14], Jatav *et al.* (2011) [6] and Kumar *et al.* (2007) [7].

Harvest index (HI) was highest under farmer's practice (73.61%). Further, HI were 73.21, 73.12 and 71.34% under 120 kg P_2O_5/ha through fertilizer, 90 kg P_2O_5/ha through fertilizer and 60 kg P_2O_5/ha through fertilizer, respectively. It may be owing to higher tuber yield as compared to haulm yield on dry weight basis.

NPK content in plant

Different doses of P gave remarkable variation in respect to NPK content in tuber and haulm. Application of 120 kg P_2O_5/ha through fertilizer and farmers practice recorded significantly higher content (%) of NPK by crop (haulm, tuber and total) as compare to other treatments. However, minimum contents of NPK were obtained under control treatment. It might be possible due to the fact that plant utilizes the nutrients proportionately from the soil available pool. This could be due to successive addition of fertilizer which resulted in higher availability in the soil. Hence, the lowest content of NPK coincided with control treatments. Similar finding have been reported by Sharma and Vikas (2007) [10].

Economics

In general, total cost of cultivation of a crop under particular treatment varies according to market value of the inputs and their rate of applications. For determining total cost of cultivation under a particular treatment, variable and invariable cost of inputs and operations were taken into consideration. The common inputs and operations for all treatments are invariable cost of cultivation, while cost of fertilizer, FYM and VC was the variable cost. To evaluate the total cost of cultivation, the cost involved for planting potato crop was taken into consideration in the present investigation. The common cost of cultivation for potato crop was `71,800/ha for all treatments. The total cost of cultivation for VC, FYM were high because of high rate of application (FYM and VC @ `1.2 and `8/kg, respectively).

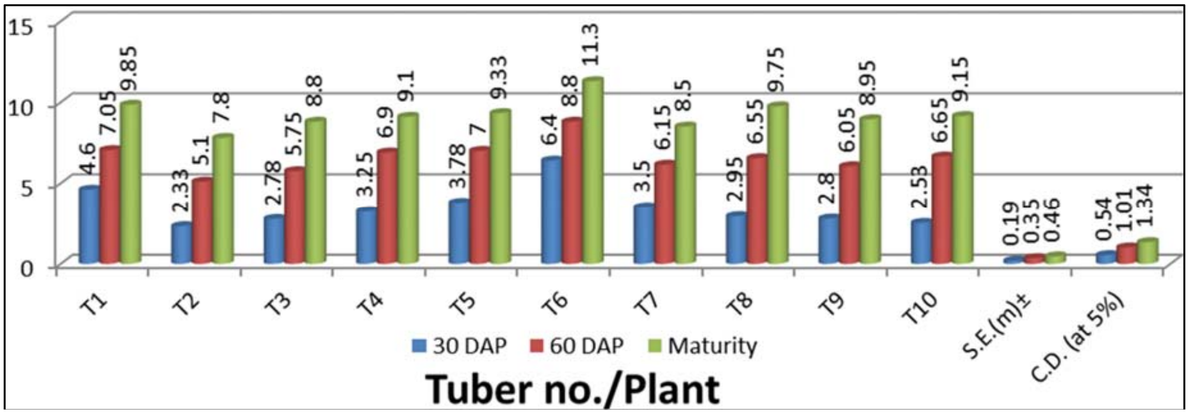

Fig 1: Effect of different doses of phosphorus on number of tuber

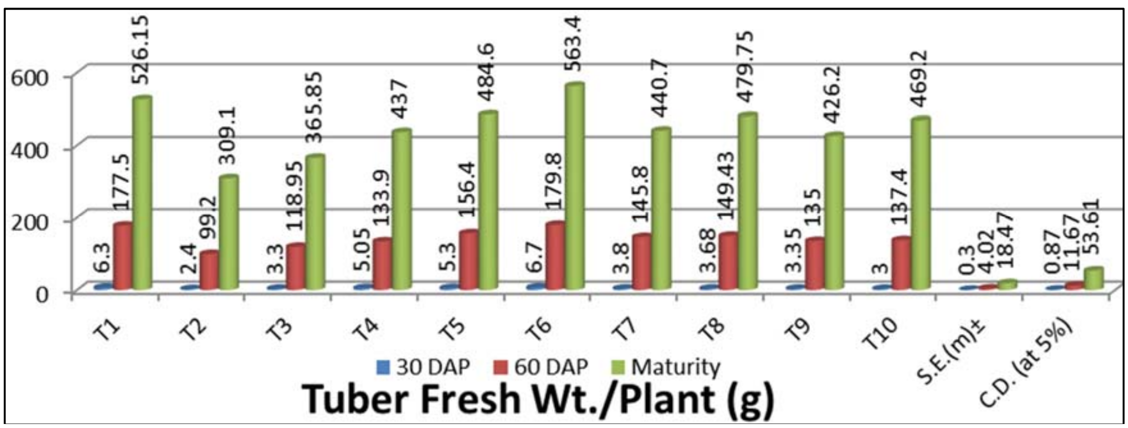

Fig 2: Effect of different doses of phosphorus on tuber fresh weight/plant

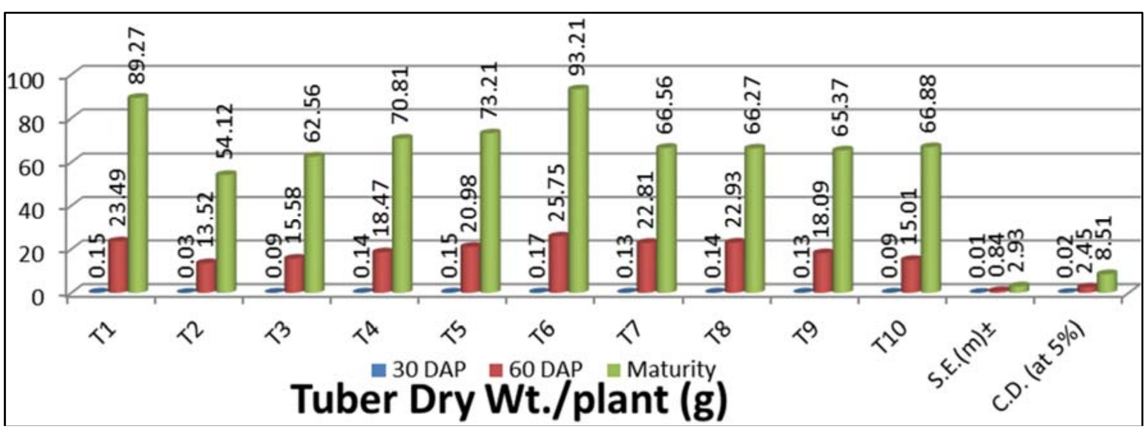

Fig 3: Effect of different doses of phosphorus on tuber dry weight/plant

The gross income of different treatments varied remarkably. The gross income is the value of tuber yields from different treatments. Thus, it is directly related to the tuber yield and sale rate of tubers. The gross income `2, 10,432/ha was maximum with farmers practice which was closely followed by 120 kg $P_2O_5$/ha through fertilizer (`2, 10,348/ha). Lowest gross income recorded with control (`1, 25,910/ha) having less tuber yields. Gross income of rest of the treatments was in intermediate range from `1, 60,560 to `199536/ha.

The net income is the actual monetary profit of a particular treatment, because it is determined by subtracting the total cost of cultivation of a treatment from the gross income of the same treatment. The net income of different treatments varied remarkably. The net income of different treatments followed the different trend due to diverse total cost of cultivation. Farmers practice fetched maximum net income (`128737/ha) closely followed by 120 Kg $P_2O_5$/ha through fertilizer (`126957/ha). Application of 100% P_2O_5 through vermicompost fetched the minimum net income among all the treatments. Rest of the treatments were in intermediate position for net income ranging from `52082 to `117634/ha.

B: C ratio is actual monetary profitability (gain) over each rupee of investment under a particular treatment. The B: C ratio was maximum (2.58) with farmers practice closely followed by 120 kg P_2O_5/ha through fertilizer (2.52). It was minimum under 100% P_2O_5 through vermicompost (1.22). Rest of the treatments were in intermediate position for B: C ratio ranging from 2.44 to 1.48. It gave an indication that both VC and FYM in general, were not remunerative compared to chemical fertilizer whether they were applied solely or in combination with inorganic fertilizers.

Chemical Property of soil

From the table no. 1, in case of pH and EC both were non-significant but slight decrease and increase, respectively as compare to initial value. It may be due to acidic nature of applied fertilizers. However, there was non-significant decline and increase in pH and EC, respectively due to different levels of phosphorus. It may be owing to buffering nature of soil.

On the other hand, organic carbon % recorded slight increase as compared to initial value and also showed significant variation because of applied P doses. Treatments T_7, T_8, T_9, T_{10} and T_6 gave higher OC (%) as compared to other treatments. It could be 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 Yaduvanshi (2000) [11] who observed increasing levels of fertilizer application increased the OC content of soil due to decomposition of root, stubble and crop residue. Similar findings have been reported by Verma *et al.* (2005) [12].

Application of 120 kg P_2O_5/ha through fertilizer and farmer practice recorded significantly higher NPK content (kg/ha) as compare to other treatments. Lowest NPK was recorded with control. It might be due to addition of fertilizer which caused buildup in the soil. Hence, the lowest content of NPK coincided with control treatment. Phosphorus also play an important role in increasing availability of N and K, therefore higher application of P stimulate higher concentration of NK in soil solution. Similar finding have been reported by Sharma and Vikas (2007) [s].

Conclusion

It is concluded that based on findings of this experiment, application of 120 kg P_2O_5/ha was the best optimum dose of phosphorus for getting higher productivity, ultimately leading to maximum net income and benefit: cost ratio in potato crop. Therefore, application of 120 Kg P_2O_5 through fertilizer gave best result in all the aspects.

From the quadratic equation line ($Y = 21.748 + 5.489 X - 0.587X^2$) for inorganic doses of P, 116.93 and 63.42 kg P_2O_5/ha were the optimum physical and economical levels, respectively for getting higher yield of tuber. Therefore, it is concluded that application of 120 and 60 Kg P_2O_5 through fertilizer was the best optimum dose of phosphorus for achieving higher optimum physical and economical productivity, respectively. Therefore, application of 60 Kg P_2O_5 through fertilizer is the optimum dose of phosphorus for central India.

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