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EFFECT OF SOURCE AND LEVEL OF POTASH ON YIELD AND QUALITY OF POTATO TUBERS

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Abstract

Field experiments were conducted for two consecutive seasons at NARC potato research area Islamabad, Pakistan, to study comparative effect of source, levels and methods of K fertilization on yield and quality of potato produce. Nitrogen and phosphorus were applied at 250 and 125 kg ha $^{-1}$, respectively whereas three K_2O levels, 0, 150 and 225 kg ha^{-1} from two sources of potash (SOP and MOP) were tested. Potassium was also applied as foliar spray at 1% K_2O solution at 30, 45 and 60 days after germination (DAG) and soil was also amended by 150 kg K_2O ha^{-1}. A significant increase in tuber yield with K application at 150 kg ha^{-1} as K_2O from both the K sources over NP treatment was recorded. Increase in tuber yield with K_2O @ 225 kg ha^{-1} was statistically non-significant compared to 150 kg K_2O ha^{-1}. A positive interaction between soil applied P and K with N in plant system was observed. Potassium treatments not only increased K concentration but also affected N and P contents in potato tubers. The quality parameters like dry matter, specific gravity, starch contents, vitamin-C and ash contents were also affected with P and K fertilization.

Introduction

Potato is fourth most important crop of the world in terms of production and occupies 6th position in the world with the world average being 15.3 t ha^{-1}. It is the third highest yielding crop on the basis of fresh matter, after sugarcane and sugar beet. It is cheep source of energy due to its large content of carbohydrate and containing significant amount of vitamin B, C and mineral. Moreover it is used in many industries for starch and alcohol production (Abdel *et al*., 1977). The area under potato is 133.4 thousand hectares with production of 2581.6 thousand tones and the national yield is 18.10 t ha^{-1} (Anon., 2005) which is lower than that of our neighboring countries. Fertilizer use in Pakistan is about 169 kg ha^{-1} of N, P_2O_5 and K_2O which is highly imbalanced and skewed towards N being used as 130 kg N ha^{-1}, followed by 38 kg P_2O_5 and 1.2 kg K_2O ha^{-1} (Akhtar, 2005). Thus the use of K fertilizer is almost negligible in the country. This has resulted not only in stagnation of crop yield but also affected quality of the crop produce. Soil quality is being degraded because of continual removal of K along with other nutrients from soil by cropping.

Potato crop yield can be enhanced significantly with balanced fertilization. Potato plants require much more K than any other vegetable crop. It plays important role for maintaining the tone, vigor of the plants. This crop sometimes is regarded as an indicator crop for K^+ availability because of its high K^+ requirement. (Ulrich & Ohki, 1996). Potassium is essential for the synthesis of simple sugars and starch and in the translocation of carbohydrates (Smith & Smith, 1977). The quality of crop produce can also be improved to a great extent with K use. Imbalance fertilizers use has led to K mining from soils. Akhtar *et al*., (2002) reported that the skewed and excessive use of N and P fertilizer might aggravate the situation in different cropping system because of nominal K use in the country and continuous use of N and P would accelerate drainage of soil native K reserves. It will not only impoverish soil K but also adversely affect crop yields. Hence the study was carried out to investigate the effect of sources, levels and methods of K application on yield and quality of potato crop.

Materials and Methods

Field experiments were conducted during 2005 and 2006 in collaboration with National Potato Program at National Agricultural Research Centre (NARC) Islamabad (latitude 33^o 43′ N, longitude 73^o 5′ E) to study comparative effects of different sources, doses and methods of K fertilization on yield and quality of the produce of potato (Desiree variety). The soil was coarse loamy, mixed, hyperthermic Udic Ustocrept, deep, well drained, moderately calcareous developed on level to nearly level deposition of the flood plain. It lies under sub-humid to humid and medium to high rainfall zone with annual rainfall ranging from 517 to 1550 mm with a mean value of 1080 mm (Ali, 1967). The soil was low in organic matter, calcareous in nature, alkaline in reaction, deficient in N, P and K (Table 1). Potassium was applied @ 0, 150, 225 kg K_2O ha^{-1} from two sources; sulphate of potash, (SOP) and muriate of potash, (MOP). Nitrogen, 250 kg ha^{-1} as urea and phosphorus, 125 kg P_2O_5 ha $^{-1}$ as DAP were applied as basal dose. Potassium from both sources; SOP and MOP were applied as foliar spray @ 1% K_2O solution after 30, 45 and 60 days of germination. In this treatment potassium was also applied at 150 kg K_2O ha^{-1} as soil application. The experiment was laid out according to the randomized complete block design with three replications. The plot size was kept at 4 m x 3 m in each treatment. All the cultural practices were kept same for all treatments.

Plant tissues were sampled at tuber initiation stage i.e., 50 days after germination from each treatment (Reuter *et al*., 1997), washed with distilled water, oven dried at 65^{o}C and prepared for N, P and K determination. Fresh tubers were dug out, cleaned and yield was recorded as total and marketable tuber yield. Nitrogen, P and K concentration in leaves and potato tubers were determined using standard methods described by Winkleman *et al*., (1990). Specific gravity of the potato tubers was determined using the method described by Dinesh *et al*., (2005):

$$\text{Specific gravity} = \frac{\text{Weight of tuber in air}}{\text{Weight of tuber in air - Weight of tuber under water -}}$$

Dry matter contents was determined by drying potato tuber at 105^{o}C till constant dry weight was obtained and starch content was determined by making dried tubers sugar free by repeatedly extracting with 80% iso-propanol. Tubers were then dried at 70^{o}C overnight in a hot air-flow oven. The dried pieces were ground to a fine powder and starch was hydrolyzed using 60% per-chloric acid (Haase, 2003). Vitamin C and sugar contents were determined by following the procedures given by Krik & Sawyer, (1991) and Starch by Anthrone Method (Clegg, 1956).

Statistical analysis: The collected data for various parameters were analyzed statistically by "analysis of variance" technique. Duncan's multiple range test (Steel *et al*., 1997) was applied to determine the least significance difference (LSD) at $p \leq 0.05$ unless otherwise mentioned, while for correlation analysis and plotting graphs Microsoft EXCEL package was used.

Table 1. Chemical characteristic of soil of the experimental site.

Soil depth (cm)	pH	EC_e dS m^{-1}	$CaCO_3$ (%)	Organic matter (%)	AB-DTPA extractable		
					NO_3-N	P	K
					---------(mg kg^{-1})-----------		
0-15	8.1	0.23	2.9	0.86	6.36	2.40	82
15-30	7.9	0.28	3.4	0.76	4.19	2.32	54
30-45	7.7	0.21	4.7	0.75	4.16	1.13	52

Results and Discussions

Effect of source, level of K on chemical composition of potato leaves and tubers: Nitrogen concentration in the potato leaves was lower than required limits of adequacy (Router, 1991). The results indicated an increased N concentration in leaves with P and K application. It increased from 3.55 g 100 g^{-1} in control treatment to 3.90 g 100 g^{-1} in P treatment. It was 4.30 and 4.20 g 100 g^{-1} in treatments where K was applied at 150 kg ha^{-1} from SOP and MOP respectively (Table 2). The differences in leaf N concentration between the applied K sources was non significant. A positive interaction between N and K in plant system was observed with K application. The N contents in tubers increased significantly with P application as it was 6% more in NP treatments as compared to alone N applied tubers and it decreased with K treatment. The P concentration was positively affected with K application and it remained unaffected in SOP treatment but in case of MOP, the P concentration positively affected with applied K at both rates. The K concentration increased with its application in leaves but in tubers it increased slightly. Zinc concentration decreased in potato leaves as well as in tubers with K treatment. At higher rate of applied K the Zn concentration was further suppressed in leaves with both the sources of K and same trend was observed in case of potato tubers. This indicates antagonistic effect of P and K on the Zn concentration in the plant system. There was no difference in the nutrient concentration in plants treated with K by different methods. Results of the study are pretty close to those reported by James *et al*., (1968).

Effect of source, level and method of K application on potato tuber yield: Potato tuber yield increased by P and K application over N (control) treatment. The highest average yield of 17.18 t ha^{-1} was produced in plots where 150 kg K_2O ha^{-1} was applied along with 1% K_2O foliar spray of SOP followed by 16.9 t ha^{-1} in case of 150 kg K_2O ha^{-1} + 1% K_2O foliar spray from MOP source. The lowest yield was obtained from plots where only N at 250 kg ha^{-1} was applied (Table 3). The tuber yield increased by 8.2% with NP treatment over that of N alone treatment. Potato tuber yield was 15.40 and 15.49 t ha^{-1} with K_2O application as SOP at 150 and 225 kg ha^{-1}, respectively while 15.49 and 15.80 t ha^{-1} with K_2O as MOP at 150 and 225 kg ha^{-1}, respectively. The difference between yields obtained from both the level of applied potassium was non-significant but the difference between K treatment and control was significant. Superimposing foliar spray of K_2O @ 1% solution increased potato tuber yield up to 11% over that of applied soil K at 150 kg ha^{-1} from both sources of K which indicated that K application in latter crop growth stage, potato can compensate in optimizing the yield (Table 3). Hence potato tuber yield increased with K application alone in soil as basal dose from both the sources (SOP and MOP) and further application as foliar spray contributed a lot in enhancing potato tuber yield.

Table 2. Effect of source, level and methods of K application on chemical composition of potato leaves and tubers.

Treatment	N	P	K	Zn*	N	P	K	Zn*
	($g\ 100\ g^{-1}$)							
	Diagnostic leaves				Potato tubers			
Control (N alone @ 250)	3.55	0.25	2.70	26.15	1.65	0.23	1.35	19.15
N and P @ 250 125 kg ha-1)	3.90	0.28	2.85	25.10	1.75	0.26	1.50	16.30
K_2O @ 150 kg ha^{-1} as SOP	4.30	0.31	3.30	23.05	1.50	0.26	1.50	15.65
K_2O @ 225 kg ha^{-1} as SOP	4.35	0.28	3.30	20.95	1.70	0.26	1.60	14.12
K_2O @ 150 kg ha^{-1} as MOP	4.20	0.31	3.65	24.40	1.65	0.27	1.55	14.95
K_2O @ 225 kg ha^{-1} as MOP	4.00	0.31	3.05	21.45	1.80	0.28	1.55	14.90
K_2O @ 150 kg ha^{-1} soil + 1% K_2O foliar SOP	4.30	0.29	3.10	21.15	1.45	0.25	1.55	16.95
K_2O @ 150 kg ha^{-1} soil + 1% K_2O foliar MOP	3.85	0.31	3.10	21.80	1.70	0.26	1.60	15.60
CV	14.7	15.6	9.56	13.43	10.7	5.6	11.56	11.43
LSD	0.09	0.05	0.072	1.34	ns	0.043	0.06	ns

*Unit is in mg kg^{-1} for Zn concentration

Table 3. Effect of source and level of K on yield of potato.

Treatment	Yield ($t\ ha^{-1}$)			Yield increase over N treatment
	2005	2006	Mean	
Control (N alone @ 250)	10.3	13.04	11.67	%
N and P @ 250 125 kg ha-1)	11.2	14.04	12.62	8.14
K_2O @ 150 kg ha^{-1} as SOP	14.4	16.54	15.47	22.60
K_2O @ 225 kg ha^{-1} as SOP	14.9	16.58	15.74	24.72
K_2O @ 150 kg ha^{-1} as MOP	14.7	16.29	15.49	22.74
K_2O @ 225 kg ha^{-1} as MOP	15.1	16.50	15.80	25.20
K_2O @ 150 kg ha^{-1} soil + 1% K_2O foliar SOP	15.6	18.75	17.18	36.13
K_2O @ 150 kg ha^{-1} soil + 1% K_2O foliar MOP	15.9	17.90	16.9	34.00
CV	23.5	19.5	21.5	-
LSD	2.09	1.43	1.76	-

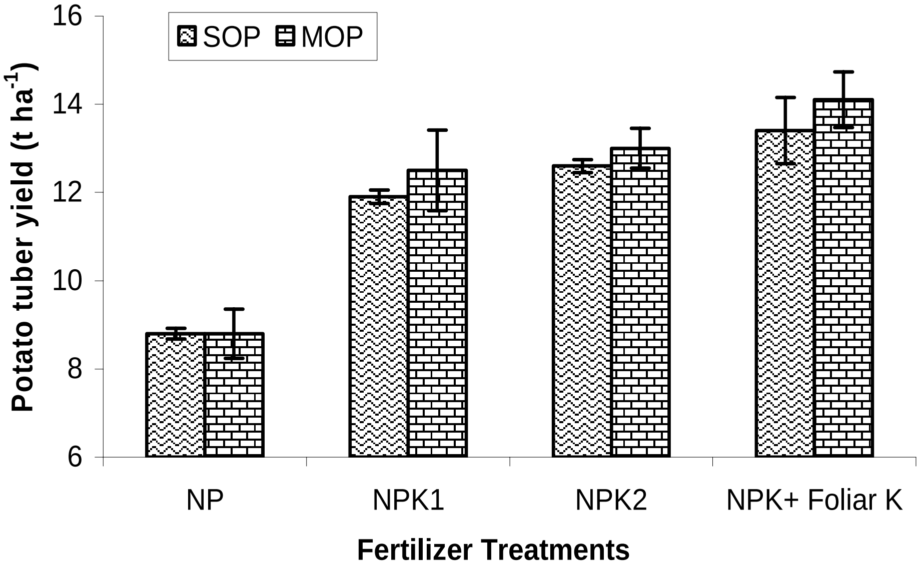

Fig. 1. Effect of K application on marketable potato tuber yield.

Marketable potato yield was significantly affected by K application (Fig. 1) as more marketable potatoes were produced form K treated plots as compared to NP and N alone treatments. Application of K_2O at 150 kg ha^{-1} enhanced the marketable potato tuber yield significantly; the increase in yield was more with MOP as compared to SOP. The difference between marketable potato yields at different K levels was non-significant; yield increase was only 6% from applied at 225 kg K_2O ha^{-1} over that of 150 kg K_2O ha^{-1} treatment for SOP, while it was only 4% for MOP source. This gave clue about the economics of the K fertilizer use in terms of return in yield (kg) per unit use of K fertilizer. Superimposed foliar application of K increased tuber yield significantly (12.7%) over that of soil applied K at 150 kg K_2O ha^{-1}. However, it is necessary to apply K through foliar spray in the concentration of salt to be kept as low as on safer side to cause phyto-toxicity. In the present study, salt concentration was 1 % only, so it was on safer side to cause the phyto-toxicity and it improved the plant vigor instead of harming plants. Langhlin (1962) used successfully K_2SO_4 spray at up to 10%, while KCl solution above 4% caused leaf damage.

Effect of source and method of K application on quality of potato tubers: Vitamin C content in potato tubers was affected by fertilizer application. The NP alone treatment increased vitamin C content in tubers to 3.5% over N application alone and K_2O application as SOP and MOP at 150 kg K_2O ha^{-1} increased it by 10.8% and 14.7%, respectively. The difference in vitamin C content regarding sources of K was significant, while for the levels and methods of K application were non significant. It means that MOP could be more favorable for enhancing vitamin C content than that of SOP (Table 4). The favorable effect of P on vitamin C content had been reported by Ciecko (1974 b) and Tashkodzaev (1975). Higher rate of applied K suppressed vitamin C contents in potato tuber with both the K sources used. The result of the study indicated that 150 kg K_2O ha^{-1} would be favorable for improving vitamin C content and higher doses of K (>150 kg ha^{-1}) would tend to decrease it in potato tuber. Smith (1977) in his experiments over three years in Poland reported that applying 50 kg K_2O ha^{-1} increased vitamin C content, 100 kg K_2O ha^{-1} had no effect, while 150 and 300 kg K_2O ha^{-1} reduced it. Imas (1999) also showed that applying K to potato significantly increased the vitamin C contents and decreased weight losses from the tubers after harvest.

Table 4. Effect of source and level of K on quality of potato (average of two years).

Treatment	Dry matter	Specific gravity	Vit. C (mg $100g^{-1}$)	Starch contents	Sugar contents	Ash contents
				----------	%	----------
Control (N alone @ 250)	17.36	1.069	17.12	10.88	1.24	6.90
N and P @ 250 125 kg ha-1)	18.07	1.074	17.72	11.85	1.26	8.66
K_2O @ 150 kg ha^{-1} as SOP	19.60	1.081	19.61	12.80	1.40	9.72
K_2O @ 225 kg ha^{-1} as SOP	20.57	1.092	19.57	13.55	1.48	9.09
K_2O @ 150 kg ha^{-1} as MOP	19.49	1.087	20.33	12.23	1.37	8.64
K_2O @ 225 kg ha^{-1} as MOP	19.66	1.086	19.40	12.78	1.41	8.42
K_2O @ 150 kg ha^{-1} soil + 1% K_2O foliar SOP	20.48	1.086	19.54	13.33	1.87	9.24
K_2O @ 150 kg ha^{-1} soil + 1% K_2O foliar MOP	20.20	1.086	19.44	12.60	1.27	8.81

Sugar contents of potato tubers were also affected with P and K application. Sugar content was relatively higher in tubers treated with K as compared to N and NP treatments. The difference between K levels was narrow in case of MOP treatment, while in case of SOP treatment, the difference between K levels was more pronounced, which was 0.15 g 100 g^{-1} between applied K levels (Table 4). The difference between applied K levels was significant that indicates that use of higher rates of K in potato would tend to enhance sugar contents in potatoes. Similarly, Kamal *et al*., (1974 b) reported increased sugar content in potato tubers with K application. As regards the relationship between potassium source and starch production, Buchner (1951) reported that in chloride-treated plants the reducing sugar content was less than that with sulphate.

Ash content of potato tubers increased significantly with P treatment over N (control) (Table 4). The result indicated that ash content increased with K application at 150 kg K_2O ha^{-1} from both of the sources but at higher rate i.e., application at 225 kg K_2O ha^{-1}, ash contents decreased in potato tubers. The difference between sources of K was significant and SOP treated potato tubers had more ash contents than that of MOP treated ones. This might be due to physiological effect of chloride and sulphate ions which through fertilizer had on the enzyme activity of plants. Latzko *et al*., (1966; 1968) reported that chloride fertilizer reduced the hydrolytic activity of sacchrase and β glucose both in leaves and in the tubers of potato, whereas no such reduction in activity was observed with sulphate nutrition. At higher level of K, decrease in ash contents may be due to corresponding increase in starch content in tubers because K application in sufficient quantities had positive effect on enhancing starch contents.

The specific gravity is a measure of quality in potato tuber which is related to the dry matter contents in the tubers. This was positively affected with P as well as K fertilization. The specific gravity was more in potato tubers harvested from plots treated with SOP than those treated with MOP ones. The potato tubers obtained from the plants treated with foliar K had specific gravity at par with those from the plants treated with soil applied K_2O at 150 kg ha^{-1} from both the sources (Table 4). There are many factors that affects the specific gravity like potato variety, location and fertilizer used etc., (Malik 1995). The specific gravity is also associated with starch content, total solids and mealiness of potato tubers (Teich & Menzres 1964). They also reported a reduction in specific gravity due to fertilizer treatment and its influence on crop quality. Higher the specific gravity the higher will be the quantity of dry matter and the greater the yield of produce. Potatoes with high specific gravity are preferred for preparation of chips and French fries. Potatoes with low specific gravity are used for canning. However, potatoes with very high specific gravity (1.10) may not be suitable for French fries production because they become hard or biscuit like. So purpose of growing potato should be kept in mind.

Conclusion

The study revealed that potassium enhanced potato tuber yield and also improved the quality of produce. Plant nutritional status, tuber quality were positively affected by K application. There was no significant difference in response of potato regarding the yield amongst both the applied K sources and levels but tuber yield was relatively higher in MOP treatments than that of SOP. This meant that both the sources are equally effective as far as yield is concerned. Foliar application of K increased potato tuber yield upto 11% over that of applied soil K at 150 kg ha^{-1} from both sources of K which indicated that K application in latter crop growth stage can compensate in optimizing the potato yield

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