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Effect of potassium and sowing time on potato yield and quality

[a] Mujeeb Ur Rehman, [b] Muhammad Jamal Khan, [c] Mujib Ur Rehman, [d] Hanif Khan, [e] Ihsan Muhammad, Irfan Ullahe, [f] Hafiz Ullah, [d] Umar Zeb*
[a] Department of Soil and Environmental Sciences, the University of Agriculture, Peshawar Pakistan,
[b] Department of Soil and Environmental Sciences, the University of Agriculture, Peshawar Pakistan,
[c] College of Resource and Environment Science, Sichuan Agricultural University , Sichuan, China,
[d] Key Laboratory of Resource Biology and Biotechnology, College of Life Sciences, Northwest University, China,
[e] College of Urban and Environmental Sciences,Northwest University, Xi'an China,
[f] Department of Botany University of Chitral, Pakistan.

Authors' Contribution	**M. Rehman, M. J. Khan, M. Rehman** and **H. Khan** conducted the research; **I. Muhammad, I Ullahe, H. Ullah** and **U. Zeb** procced the data analysis and wrot the manuscript.
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ABSTRACT

The current study was conducted the effect of sowing time and different doses of a potassium supplement on yield attributes of potato at Gollen valley Chitral, the Northern Pakistan during summer 2018. Sowing Potato (cv. Roko) commenced from 5thMay and continued till 5thJune keeping an interval of 15 days among sowing times. Potassium (K) was applied at the rate of 100, 150, 200 and 250 kg ha^{-1} as potassium chloride. Basal doses of nitrogen (N) and phosphorus (P) were applied at the rate 120 and 100 kg ha^{-1} respectively, as urea and DAP. All yield attributes like number of leaves per plant, plant height, the number of tubers per plant, tuber volume and yield of potato were higher for May 5th (early sowing date) with potassium dose of 200 kg ha^{-1}. Interaction of sowing dates and Potassium (SD×K) for yield, tuber volume and soil potassium content was statistically significant (P≤0.05). The study showed that by delaying the sowing season, yield traits and yield of potato decreased significantly; hence early cultivation and K fertilization of 200 kg ha^{-1} resulted in maximum production of potato as well as improved soil properties under agroclimatic conditions of the region which is a dry temperate zone of Pakistan.

Keywords: Potassium levels, sowing time, potato yield, Chitral, Pakistan.

INTRODUCTION: The appearance of the potato (*Solanum tuberosum* L) belongs to family *Solanaceae*, generally considered being an index of quality and often determines consumer choice. Great efforts have recently been focused in producing good appearance and quality of potato through the utilization of inexpensive and environ-mentally friendly resources. However, Pakistan is an agro-economy based country of Asia, depending on cash crops to meet the demands of the fast-growing population. Cultivating vegetables is not only a reliable source of essential nutrients but it also creates more livelihood opportunities than cereals (Ali and Tsou, 2000; AbdelGadir *et al.*, 2003). Among these vegetable crops potato occupies a significant position in revenue generation and food production. The yield of potat crop in Pakistan is very low due to several biotic and abiotic factors (Abbas *et al.*, 2012; Abbas *et al.*, 2014; Abbas and Madadi, 2016; Qamar *et al.*, 2016; Urooj *et al.*, 2016). Production of good quality fruits is controlled by the interaction of genetic diversity, environmental factors, including plant nutrients. Among significant plant nutrients, potassium (P) is the one that is absorbed by the potato plant in the major amounts and it is considered being the key to production of quality vegetables. Potato is one of the cash crops of Pakistan containing a large amount of starch and higher production per unit area. It occupies a prime position among all underground crops. This is the rich source of carbohydrates, vitamins B, C and minerals. Potato tubers contain 20.6% carbohydrates, 70-80% water, 2.1% proteins, 1.1% crude fibers, 0.3% fat and 0.9% ash (Banu *et al.*, 2007). Among the major crop's potato produces the highest biological yield and more edible protein per unit area, about 3-4 times more than cereals for the same productivity area. Pakistan has the low yield of potato about 10 tons ha^{-1} as compared to the other developing countries which needs improvement to meet the rapidly increasing demand (Singh *et al.*, 2019). Unavailability of quality seed, sowing time, application of fertilizers and climatic conditions are some major factors which determine yield per unit area. The NPK fertilizers govern its growth and development and required for the production of the higher yield of potato crops. The rates of NPK fertilizers are directly proportional to the yield of potato and quality of certain levels of application beyond which the yield decreases (Aggarwal *et al.*, 1976).

The twisted and extreme use of N and P fertilizer might heighten the situation in different cropping system because of insignificant K use in the country and continuous use of N and P would hasten drainage of soil natural K reserves (Akhtar and Khan, 2002; Khan *et al.*, 2014) It not only changes soil K level but also adversely affects crop yield. Planting dates influences leaf area index trend as well as an amount of absorbed radiation in crop population and is ultimately an important factor for determining potato yield. Delayed planting dates cause yield reduction (Chapagain *et al.*, 2003). Short-duration potatoes in temperate regions where the objective is to maximize sellable tuber yield, is significantly affected by frost action resulting in a reduction of the number of tubers per plant and decline of leaves (Krishnappa, 1993; Arab *et al.*, 2011). Among the fertilizer potassium fertilizer is considered most important for the growth and yield of potato crops. Increasing the doses of potassium also increase the tuber size and a number of tubers and ultimately the yield of potato (El-Gamal, 1985). The application of K either increases the tuber yield or increases the size of tubers per plant or both which ultimately increases the

production of potato crops (Humadi, 1986). Potassium is essential for photosynthesis, increasing enzymes activities, improving a synthesis of fats, carbohydrates and proteins and also translocation of photosynthesis which enable their ability to resist against pests and diseases (Jamro *et al.*, 2015). Potassium is sometime recorded as in indicator crop for K++ availability because of its high requirements (Humadi, 1986; Arab *et al.*, 2011).

Chitral is considered as a rich producing region of potato in Pakistan. It is the main cash crop of rural areas of Chitral like Garam Chashma and Gollen. More than 80% of the farmers grow potato as their main crop. Being off season, potatoes give much better financial returns in these areas. Moreover, the soil and climatic conditions are favorable for potato production and the average yield in these areas is greater than other parts of the country. These potato growing areas are single cropping regions and farmers can grow only one crop in a year. Due to climatic change in terms of global warming during recent years, the snowfall has considerably decreased. Low snowfall has encouraged an increase in temperature during spring season. According to meteorological department's forecast winter rains would further decrease in the next twenty years which could further increase the temperature in spring and summer seasons in these areas.

These single cropping zones could be converted into double cropping zones as summer will be prolonged with the increase in spring and autumn temperatures and could be a great opportunity for livelihood improvement of the poor people of these remote areas in terms of cultivation of a second crop in the same season. In this connection two experiments were laid out in Borbonu and Lohok villages of lower Goboor valley Chitral to determine the suitable sowing and harvesting dates for a potato crop which could provide sufficient space for a second crop without compromising on potato yield and income. The seed of Paramount and Roko cultivers stored by ARS Chitral was utilized in these experiments.

OBJECTIVES: The objectives of this study were as follows: (1) to study the effect of different sowing time on growth yield and quality of potato (2) to study the effect of potassium source and rate of application on potato yield. (3) To evaluate the combined effect of fertilizer application and harvest time on unit area production.

MATERIALS AND METHODS: Research description: Field experiment was conducted in village Ashgoor of Gollen valley, Chitral during summer 2018. The research experiment was planned in Randomized Complete Block design (RCB) in a split plot arrangement each in three replicas. The plot size was kept 5 m x 3 m ($15m^2$) and *S. tuberosum* was sown at three different dates with an interval of 15 days. Each plot was divided into six sub plots. Experiments were conducted in three different sowing times which were assigned to main plot while five potassium levels were applied to subplots. Potatoes were sown on ridges (30-40 cm high) and fertilizer was mixed before the formation of ridges. All P, K and half N of the recommended doses were applied at the time of sowing while the remaining half of N was applied 30 days after sowing. Regular irrigation was done according to the crop demand through spring water. Potassium was applied at the rate of 0, 100,150, 200 and 250 kg ha^{-1} as KCl whereas all other cultural practices, including weeding, insect control and irrigation were uniformly carried out for all plots.

Soil analysis of the experimental site: A composite soil samples comprising ten randomly collected soil cores (0–15 cm) each was collected at pre-sowing stage. The collected samples were then passed through a 2 mm sieve size to clean the soil from other trash, leaves and plant roots. After cleaning plant and soil samples were brought to Soil and Environmental Science laboratory, The University of Agriculture, Peshawar and were analyzed for various physcio-chemicals properties like soil texture, electrical conductivity (EC), pH, organic matter, lime content and AB-DTPA extractable P and K. Beside this soil and plant samples were also collected from the subplots at flowering and post-harvest stage for the P and K analysis.

Statistical analysis: In this experiment the data obtained from a randomized complete block design was analyzed using analysis of variance. The means were compared by using LSD test at 5% level of significance.

Physico-chemical properties of soil before sowing of potato crop: The physico-chemical properties of composite soil sample are given in the (Table 1).

Table 1: Physico-chemical properties of soil before sowing of potato crop

S. No	Soil Property	Units	Value
1	Soil pH	----	7.4
2	Electrical Conductivity	dSm^{-1}	0.9
3	Soil Texture	-----	Sandy loam
4	Organic Matter	%	2.5
5	Lime Content	%	10.5
6	Total Nitrogen	mg kg^{-1}	0.5
7	Potassium	mg kg^{-1}	74
8	Phosphorous	mg kg^{-1}	11.0

The soil of the experimental site was a sandy loam (Koehler *et al.*, 1984), with the slightly alkaline pH 7.4 (Page *et al.*, 1982), and sufficient organic content (Nelson and Sommers, 1982). The soil was non-saline and slightly calcareous. Both P and K are deficient.

RESULTS: Emergence m^{-2} and number of leaves $plant^{-1}$: The experimental data (table 1 and 2) showed that emergence $m^{-2}$and number of leaves per $plant^{-1}$of potato crop were significantly ($P \leq 0.05$) affected through showing dates while levels of potassium and their interaction with climate was found significant in case of a number of leaves per $plant^{-1}$. The mean values of the data reveal that maximum emergence 96.1% were recorded when the crop was sown on 5th May followed by sowing date 20thMay. Minimum emergence (69.7%) and leaves per $plant^{-1}$ were recorded when the crop was sown in early June (5th June). In case of potassium level maximum emergence 77.2% and leaves per $plant^{-1}$101.1% were noted from the application of 250 kg K ha^{-1} whereas low emergence of 75.8% was seen in the control plots, but they are statistically non-significant (NS) while found significant in case of leaves per $plant^{-1}$ (71.3%).

Plant height (cm) and number of tubers $plant^{-1}$: Analysis of the data regarding plant height, number of tuber $plant^{-1}$ showed that significant result for sowing dates and potassium rates presented in table 4. Interactions of sowing dates and potassium levels remained non-significant in plant height, while significant in case of number of tuber $plant^{-1}$ (figure 1). Taller plants were produced (25.1) cm after 60 days of emergence for May 5th sowing date, while dwarf plants were found (19.5 cm)

after 60 days of emergence from 20th May.

Table 2: Effect of potassium levels and sowing dates on emergence (%) and number of leaves plant^{-1} of potato Emergence Percentage (%) of potato crop

Potassium levels (kg ha^{-1})	Sowing Dates			Means
	5th May	20th May	5th June	
0	84.3	75.3	67.7	75.8
100	83.3	71.3	69.3	74.6
150	86.3	68.3	69.7	74.8
200	86.7	72.7	71.0	76.8
250	87.7	73.0	71.0	77.2
Means	85.7	72.1	69.7	
Number of leaves plant^{-1}of potato crop				
0	74.0	70.0	70.0	71.3 c
100	79.3	94.7	72.8	82.3 bc
150	100.0	101.0	69.3	90.1 ab
200	118.0	100.3	85.0	101.1a
250	109.3	102.7	84.7	98.9 a
Means	96.1	93.7	76.4 b	
LSD for Emergence % (0.05)			LSD for Leaves per plant $^{-1}$ (0.05)	
Sowing dates (S)	3.71		Sowing dates (S)	14.03
Potassium (K)	NS		Potassium (K)	16.87
S x K	NS		S x K	NS

Mean with different letters in the similar group are significantly varied from each other at ($p \leq 0.05$) by checking with LSD test.

Table 3: Effect of potassium and sowing dates on plant height (cm) and number of tuber plant^{-1}after 60 days plant height as influenced by sowing dates and K levels

Potassium (kg ha^{-1})	Sowing dates			Means
	5th May	20th May	5th June	
0	18.0	14.0	13.0	15.0 d
100	22.0	17.0	19.4	19.5 c
150	25.0	19.3	21.0	21.8 b
200	29.7	23.0	22.7	25.1 a
250	30.7	24.0	24.1	26.2 a
Means	25.1 a	19.5 b	20.0 b	
Number of tuber plant^{-1} as affected by sowing dates and K levels				
Potassium (kg ha^{-1})	Sowing dates			Means
	5th May	20th May	5th June	
0	7.7	9.3	7.3	8.1 d
100	12.3	13.0	10.7	12.0 c
150	13.0	12.3	11.7	12.3 c
200	15.0	13.7	12.0	13.6 b
250	16.0	14.3	13.7	14.7 a
Means	12.8 a	12.5 a	11.1 b	
LSD for plant height (0.05)			LSD for umber of tuber plant^{-1} (0.05)	
Sowing dates (S)	1.496		Sowing dates (S)	1.125
Potassium (K)	2.1469		Potassium (K)	0.845
S x K	NS		S x K	1.463

Means in the above with different subscripts differ significantly ($p \leq 0.05$) using LSD test.

Similarly, a greater number of tuber plant^{-1}(12.8) was verified from sowing date 5th May; while a smaller number of tuber plant^{-1} (12.5 and 11.1) was noted in 20th May and June 5th respectively. For potassium levels highest plant height (26.2 cm) was recorded for K fertilizer (250 kg K ha-1) which was statistically compared to 200 kg K ha-1 with plant height of (25.1 cm). Subsequently, maximum number of tuber plant-1 (14.7) was seen in the treatment of 250 kg K ha-1 while minimum plant height (15 cm) and number of tuber plant-1 (8.1) was recorded in control plots.

Volume of tuber (cm^3) and potato yield (ton ha^{-1}): Data analysis for tuber volume and yield of potato crop indicated that its volume and yield were considerably affected with potassium levels and sowing dates while the interaction of potassium and sowing date remained non-significant in case of tuber volume, and found significant for yield of potato (table 3 and 4). Maximum volume (114.7 cm^3) and tuber yield (38.3-ton ha^{-1}) were recorded from sowing date of 5th May, while sowing date 20th May and 5th June ranked 2nd and 3rd with tuber volume (110 and 108 cm^3) and tuber yield (37 and 36.9-ton ha^{-1}) respectively which were statistically similar to each other. With the increase in potassium levels, it was noted that the volume of tuber and tuber yield also increased significantly. Maximum volume of tuber (129 cm^3) was observed in the treatments of

250 kg K ha^{-1} which is statistically at level with 200 kg K ha^{-1} (127 cm^3), while in the case of potato yield, highest tuber weight (39.8 ton ha^{-1}) was noted in the plots receiving 200 kg K ha^{-1} which is statistically similar with 250 and 150 kg K ha^{-1} with tuber yield of 39.4 and 39.7 ton ha^{-1} respectively. The minimum tuber volume (83 cm^3) and tuber yield (32.7-ton ha^{-1}) were recorded from control plots.

Soil and leaf potassium after 60 days of emergence (mg kg^{-1}): The results of K content in the soil and leaf after 60 days of emergence as influenced by applied K level and sowing dates is shown in (table 5). The analyzed data revealed sowing dates and applied potassium levels were significant at ($p \leq 0.05$), while their interaction was found also significant (figure 2) in case of soil K, while non-significant in the case of leaf K after 60 days of emergence. More K concentration (112 mg kg^{-1}) was recorded from sowing date 20th May, while lower K content (109 mg kg^{-1}) was noted when crop was planted on early May and June. Maximum leaf K concentration (1%) was given by the sowing date 5th May, while leaf K concentration (0.8% and 0.8%) was recorded for May 20th and June 5th sowing dates respectively. In case of different levels of K fertilizer significantly higher soil and leaf K content (149 mg kg^{-1} and 1%) were recorded when 250 kg K ha^{-1} was delivered to the potato crop. While lower soil and leaf K was observed in control plots after 60 days of emergence of the potato crop (table 6).

Potassium concentration in post-harvest soil: Effect of potassium and sowing dates on the potassium content after harvest is shown in Table 9. The data showed statistically that potassium content after harvest was significantly ($p \leq 0.05$) effected by applied potassium level along with sowing dates and their interaction (figure 4). Maximum potassium content in soil post-harvest was observed in plots receiving 250 kg K ha^{-1} followed by the treatments 200 and 150 kg K ha^{-1} with post-harvest potassium level of 127 and 108 mg kg^{-1} respectively. Minimum post-harvest potassium level (57.4mg kg^{-1}) was observed in the control plot.

DISCUSSION: The highest yield was noted in 5th May sowing date, because the climate of Chitral offers favorable growth conditions for potato vegetable is the month of May. Early sowing showed maximum emergence of seedlings, maximum number of leaves and tubers per plant. Similar fallouts were also stated by Jamro *et al.* (2015), who found that early sowing gives maximum return in comparison with late sowing. The results were also in judgment with Jamro *et al.* (2015) who recorded that highest emergence occurs in timely sowing as compared to late sowing.

The early sowing of the potato crop was found more efficient as compared to late sowing of potato crop due to the environmental condition, particularly temperature which has paramount effect on number of tubers per plant, volume of tuber and hence the yield (Khan *et al.*, 2010; Yenagi *et al.*, 2010). According to the judgments of, who reported maximum number of tubers when temperature is favorable, because during this month temperature of the area is low as temperature goes up growth of potato is also affected thus a decrease in volume of tubers results. Increase in temperature above optimum reduces growth of tubers and ultimately results in the minimum yield. Delayed sowing time from May to June decreased the plant height and other yield and growth parameter of the crop.

Our study findings are also in association with the results of (Putra *et al.*, 2019), who reported that, the application of the highest level of K i.e 300 kg K_2O ha^{-1}improved the numbers of tubers per plant. The increasing levels of K did not affect the emergence of potato because K is mainly involved in activation of enzyme and regulation of plant water (El-Latif *et al.*, 2011; Manolov *et al.*, 2015). Potassium plays a vital role in the photosynthetic action and regulation of the process due to which gives maximum energy which facilitated more number of leaves also regulating the conductance in leaves, water absorption and translocation assimilate in plants (Grzebisz *et al.*, 2013). Furthermore, K involved in various functions of plants including health of plants, resistant of plant against diseases and promoting the number of leaves (Chapagain and Wiesman, 2004; Misskire *et al.*, 2019).

Similarly, increasing levels of K also increased the plant height of the potato crop. Potassium maintains the nutrient balance in plants which in turn promote vegetative growth of the plants. Our results are comparable with (Pregno and Armour, 1992), who reported that application of K increase the efficiency of N which ultimately increase the plant growth of the crop because of more uptake of nitrogen. Similar results were also reported by Al-Moshileh and Errebi (2004) that increasing K levels increased the plant height of potato crop, chlorophyll content in plants, leaf area, K concentration and carbohydrate (Khan *et al.*, 2010).

Likewise, K significantly increased the volume of tuber as K play an important role in size, yield and tuber weight of potato. The results were also in the agreement of Hailu *et al.* (2017) who reported that by increasing K levels improved the total yield, the highest being 200 kg K_2O ha^{-1} ultimately increased the size of large and medium sized tubers and was significantly higher as compared to lower levels of K_2O. These results were also supported by (Adhikari and Karki, 2006) who reported that increase in tuber size requires maximum K as function of K is to transform sugars from leaves to tubers resulting in an increase in the volume of tuber.

These results showed similarity with Winsor and (Nilson and Abrahamson, 2018), who reported that plant reared sufficient K may produce much more yield even in stress conditions. The findings were in the line with the results which suggested that at the maximum K application rates, the successive crop might be benefited from a positive residual K, instead of the more effectiveness of potato production at that particular combination. It is notable; however, that potassium convenience in the soil was limited to a depth of 60 cm only (Grzebisz *et al.*, 2013).

Conclusions

In this study, we concluded that emergence m^{-2}, leaves $plant^{-1}$, plant height, volume of tuber, tuber yield and number of tubes per plant are significantly influenced by early sowing date i.e 5th May. The number of leaves $plant^{-1}$, plant height, and volume of tuber, tuber yield and number of tubes per plant significantly increased with the application of 250 and 200 kg K ha^{-1}. Maximum soil and plant potassium at post-harvest and sixty days after emergence was increased by application of 250 and 200 kg K ha^{-1} and similarly leaf P and K concentration was also found more at the same levels of K while sowing dates produced non-significant result on soil and leaf P and K concentration. Among sowing dates, the early sowing of potato

Table: 4 Effects of potassium rates and sowing dates on volume of tubers (cm^3) and yield of potato (ton ha^{-1}) Volume of tubers (cm^3) as affected by potassium rates and sowing dates

Potassium (kg ha^{-1})	Sowing dates			Means
	5th May	20th May	5th June	
0	85.7	82.7	80.7	83.0 d
100	103.0	98.0	100.7	100.6 c
150	118.3	117.7	108.3	114.8 b
200	130.7	125.7	126.7	127.7 a
250	136.0	126.7	125.3	129.3 a
Means	114.7 a	110.1 b	108.3 b	
Potato Yield (ton ha^{-1}) as influenced by K levels and Sowing Dates				
0	34.7	31.8	31.8	32.7 c
100	36.8	34.8	34.4	35.3 b
150	40.0	39.2	39.7	39.7 a
200	40.3	39.8	39.2	39.8 a
250	39.5	39.3	39.3	39.4 a
Means	38.3 a	37.0 b	36.9 b	
LSD for volume of tuber (0.05)			LSD for yield of potato (0.05)	
Sowing dates (S)	2.027		Sowing dates (S)	0.480
Potassium (K)	6.815		Potassium (K)	0.984
S x K	NS		S x K	1.704

Means in the above with different subscripts are significantly different ($p \leq 0.05$) using LSD test.

Table: 5 Effect of potassium and sowing date on soil potassium after 60 days of emergence Soil K after 60 days of after emergence as affected by K levels and sowing dates

Potassium (kg ha^{-1})	Sowing dates			Means
	5th May	20th May	5th June	
0	82	77	79	80 e
100	90	89	91	90 d
150	102	102	99	101 c
200	128	138	125	130 b
250	141	155	150	149 a
Means	109 b	112 a	109 b	
Leaf potassium after 60 days of emergence of potato plants				
0	0.9	0.7	0.6	0.7 d
100	0.9	0.7	0.7	0.8 c
150	1.1	0.8	0.8	0.9 b
200	1.1	0.8	0.8	0.9 b
250	1.2	0.9	0.9	1.0 a
Means	1.0 a	0.8 b	0.8 b	
LSD for soil K(0.05)			LSD for leaf K (0.05)	
Sowing dates (S)	1.926		Sowing dates (S)	0.206
Potassium (K)	2.81		Potassium (K)	0.071
S x K	4.88		S x K	NS

Means in the above with different subscripts significantly different ($p \leq 0.05$) using LSD test.

Table 6: Effect of potassium and sowing date on potassium concentration in soil after harvest of potato plants

Potassium (kg ha^{-1})	Sowing dates			Means
	5th May	20th May	5th June	
0	59.1	54.7	58.4	57.4 e
100	68.2	66.6	67.8	67.5 d
150	83.5	82.3	76.3	80.7 c
200	106.3	114.7	103.0	108.0 b
250	117.5	136.5	128.6	127.5 a
Means	86.9	90.9	86.8	
LSD (0.05)				
Sowing dates (S)	3.03			
Potassium (K)	4.50			
S x K	7.79			

Means of the matching type followed by different letters are significantly different from each other at $p \leq 0.05$ using LSD test.

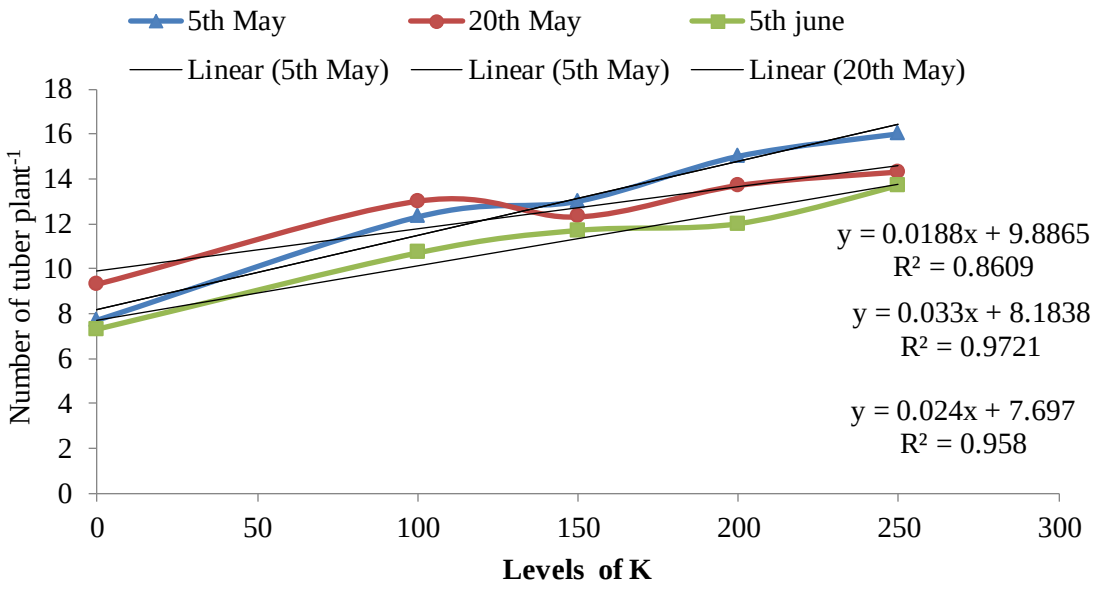

Figure 1: Effect of potassium and sowing date on number of tuber plant^{-1}

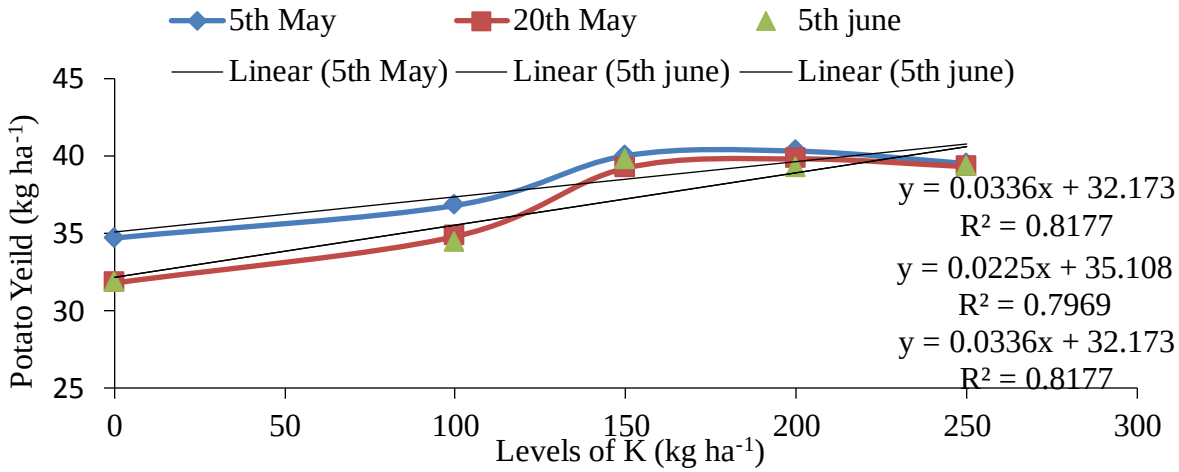

Figure 2: Effect of potassium and sowing date on crop yield (ton ha^{-1}) of potato.

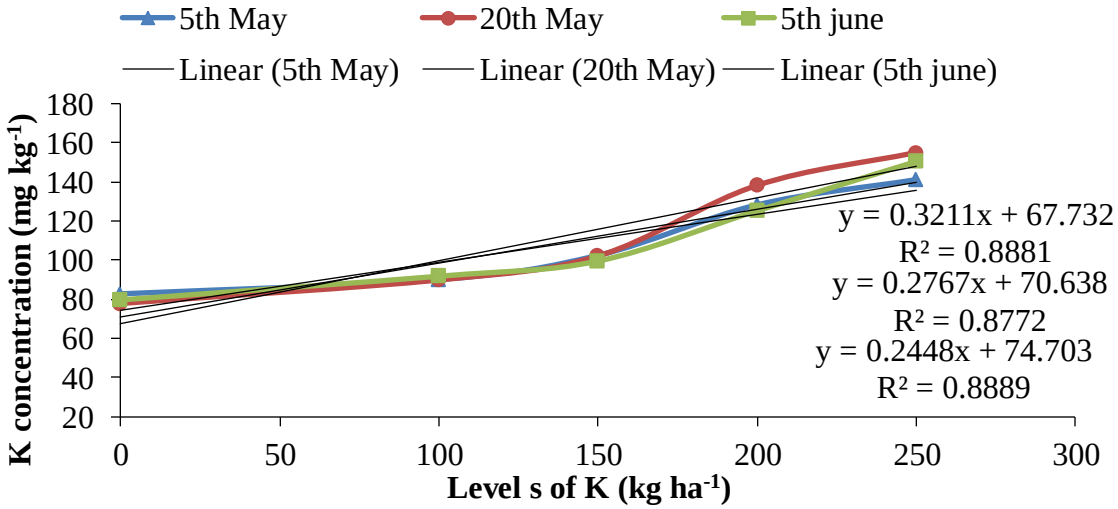

Fig. 3: Effect of potassium and sowing date on soil potassium after 60 days of emergence

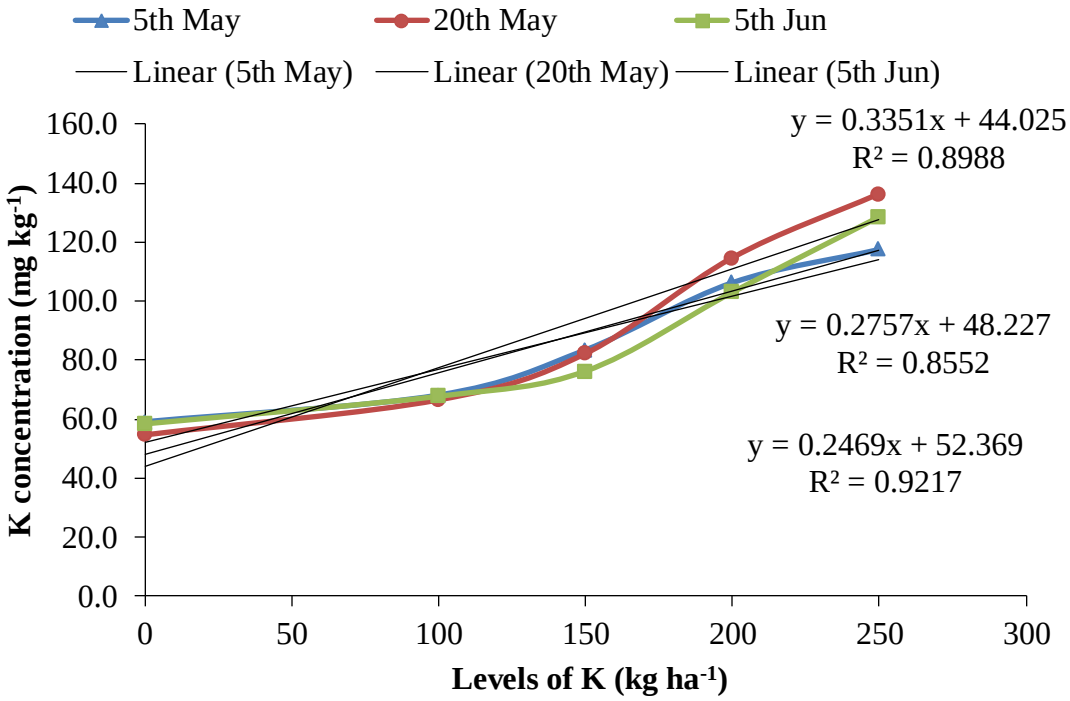

Figure 4: Effect of potassium and sowing date on potassium concentration in soil after harvest

crop was found more efficient as compared to late sowing so early sowing i.e 5th May is recommended for obtaining more yield. Similarly, the application of K at the rate 150 kg ha^{-1} is strongly recommended for the good yield of potato crop in the agro-climatic condition of Chitral. Further research work should be conducted to identify more sowing times as changing the climatic condition of the selected area.

CONFLICT OF INTEREST: Authors have no conflict of interest.

REFERENCES: Abbas, M. F., S. Hameed, A. Rauf, Q. Nosheen, A. Ghani, A. Qadir and S. Zakia, 2012. Incidence of six viruses in potato growing areas of Pakistan. Pakistan journal of phytopath, 24(1): 44-47.

Abbas, M. F., S. Hameed and C. A. Rauf, 2014. Presence of newstrain of potato virus Y in Pakistan. International journal of agriculture and biology, 16(5): 941-945.

Abbas, A. and M. Madadi, 2016. A review paper on potato mop-top virus (PMTV): Occurrence, properties and management. World journal of biology and biotechnology, 1(3): 129-134.

AbdelGadir, A., M. Errebhi, H. Al-Sarhan and M. Ibrahim, 2003. The effect of different levels of additional potassium on yield and industrial qualities of potato (*Solanum tuberosum* L.) in an irrigated arid region. American Journal of Potato Research, 80(3): 219-222.

Adhikari, B. and K. B. Karki, 2006. Effect of potassium on potato tuber production in acid soils of Malepatan, Pokhara. Nepal Agriculture Research Journal, 7: 42-48.

Aggarwal, R., J. Gupta, S. Saxena and K. Muthana, 1976. Studies on soil physico-chemical and ecological changes under twelve years old five desert tree species of Western Rajasthan. Indian Forester, 102(12): 863-872.

Akhtar, M. and M. Khan, 2002. Nutrient mining-a cause of soil degradation. Farming Outlook, 2: 22-24.

Al-Moshileh, A. and M. Errebi, 2004. Effect of various potassium sulfate rates on growth, yield and quality of potato grown under sandy soil and arid conditions. In: International Potash Institute. Regional workshop on potassium and fertigation development in West Asia and North Africa, Rabat, Morocco. pp: 24-28.

Ali, M. and S. Tsou, 2000. The integrated research approach of the asian vegetable research and development center (avrdc) to enhance micronutrient availability. Food Nutrition Bulletin, 21(4): 472-481.

Arab, H. R., H. Afshari, D. M. Sam, G. Laei and S. R. Toudar, 2011. The effect of planting date, depth and density on yield and yield components of potato in Shahrood (Iran). Journal of Research in Agricultural Science 7(2): 141-149.

Banu, S. S., T. M. Thiyagarajan and P. Malarvizhi, 2007. Effect of graded levels of fertilizers on quality aspects of potato. Potato Journal, 34(3-4).

Chapagain, B., Z. Wiesman, M. Zaccai, P. Imas and H. Magen, 2003. Potassium chloride enhances fruit appearance and improves quality of fertigated greenhouse tomato as compared to potassium nitrate. Journal of Plant Nutrition, 26(3): 643-658.

Chapagain, B. P. and Z. Wiesman, 2004. Effect of potassium magnesium chloride in the fertigation solution as partial source of potassium on growth, yield and quality of greenhouse tomato. Scientia Horticulturae, 99(3-4): 279-288.

El-Gamal, A., 1985. Effect of potassium level on potato yield and quality. Journal of Agriculture Sciences Mansoura University, 10(4): 1443-1476.

El-Latif, K. A., E. Osman, R. Abdullah and N. A. El Kader, 2011. Response of potato plants to potassium fertilizer rates and oil moisture deficit. Advances Applied Sciences Research, 2(2):

388-397.
Grzebisz, W., A. Gransee, W. Szczepaniak and J. Diatta, 2013. The effects of potassium fertilization on water-use efficiency in crop plants. Journal of Plant Nutrition Soil Science, 176(3): 355-374.
Hailu, G., D. Nigussie, M. Ali and B. Derbew, 2017. Nitrogen and phosphorus use efficiency in improved potato (Solanum tuberosum L.) cultivars in southern ethiopia. American Journal of Potato Research, 94(6): 617-631.
Humadi, F. J. Z., 1986. Influence of potassium rates on growth and yield of potato (*Solanum tuberosum*)(in Iraq).
Jamro, M. R., S. Tunio, U. Buriro and Q. Chachar, 2015. Effect of planting dates on growth and yield of true potato seed (tps) in nursery raising approach. ournal of Basic Applied Sciences, 11: 318-322.
Khan, I., M. Zaman, M. Khan, M. Iqbal, M. J. J. o. s. s. Babar and p. nutrition, 2014. How to improve yield and quality of potatoes: Effects of two rates of urea n, urease inhibitor and cytozyme nutritional program. 14(2): 268-276.
Khan, M. Z., M. E. Akhtar, M. N. Safdar, M. M. Mahmood, S. Ahmad and N. Ahmed, 2010. Effect of source and level of potash on yield and quality of potato tubers. Pakistan Journal of Botany, 42(5): 3137-3145.
Koehler, F., C. Moodie and B. McNeal, 1984. Laboratory manual for soil fertility, washington state uni. Pullman Washington.
Krishnappa, K., 1993. Effect of planting time on the yield and yield attributes of potato in eastern karnataka. Field Crop Absttract, 46(11).
Manolov, I., N. Neshev, V. Chalova and N. Yordanova, 2015. Influence of potassium fertilizer source on potato yield and quality. In: Proceedings. 50th Croatian and 10th International Symposium on Agriculture. Opatija. Croatia. pp: 363-367.
Misskire, Y., T. Mamo, A. M. Taddesse and U. Yermiyahu, 2019. The effect of potassium on yield, nutrient uptake and efficiency of teff (*Eragrostis tef zucc*. Trotter) on vertisols of North Western Ethiopian Highlands. Journal of Plant Nutrition, 42(4): 307-322.
Nelson, D. and L. E. Sommers, 1982. Total carbon, organic carbon, and organic matter 1. Methods of soil analysis. Part 2. Chemical Microbiological Properties(methodsofsoilan2): 539-579.
Nilson, M. A. and K. Abrahamson, 2018. Potato seed planting apparatus and method of planting potato seed using the apparatus. Google Patents.
Page, A., R. Miller and D. Keeney, 1982. Methods of soil analysis, part 2. Chemical Microbiological Properties, 2.
Pregno, L. and J. Armour, 1992. Boron deficiency and toxicity in potato cv. Sebago on an oxisol of the atherton tablelands, north queensland. Australian Journal of Experimental Agriculture, 32(2): 251-253.
Putra, F. P., S. Saparso, S. Rohadi and R. Ismoyojati, 2019. The response of potato plants (*Solanum tuberosum* L.) to various thicknesses of cocopeat media and sundstrom nutrition time. Jurnal Ilmiah Pertanian, 15(2): 57-66.
Qamar, M. I., S. Batool, W. Aurangzeb, R. Zainab and S. Menghwar, 2016. Different techniques for diagnostic of potato viruses: A brief review. World journal of biology and biotechnology, 1(3): 123-128.
Singh, V., B. Dwivedi, R. Mishra, A. Shukla, J. Timsina, P. Upadhyay, K. Shekhawat, K. Majumdar and A. Panwar, 2019. Yields, soil health and farm profits under a rice-wheat system: Long-term effect of fertilizers and organic manures applied alone and in combination. Agronomy, 9(1): 1-6.
Urooj, M., U. Arif and A. Intikhab, 2016. A brief review for identification and detection of potato viruses. World journal of biology and biotechnology, 1(1): 33-37.
Yenagi, B., S. Meli and S. Angadi, 2010. Effect of row spacing, planting date and nitrogen level on tuber grade, yield and economics of potato. Karnataka Journal of Agricultural Sciences, 17(2).