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Effect of different levels of nitrogen and potassium on growth and yield of potato

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Abstract
The research experiment was carried out at Nalanda College of Horticulture, Noorsarai during the Rabi season of 2021-22 to find out the effect of different levels of nitrogen and potassium on growth and yield of potato. Findings of research showed that among the individual nitrogen levels, N5 (160 kg ha^{-1}) performed better in respect of days taken to germination, plant height at 45, 60, 75 days, number of compound leaves per plant at 45, 60 and 75 days, number of branches per plant, days taken to maturity, number of tubers per plant, single tuber weight, plant tuber weight, tuber yield, diameter of tuber, Vitamin C content in tuber, fresh weight, dry weight, as well as moisture content of fresh tuber. Whereas among the various potassium levels, K_4 (120 kg ha^{-1}) responded better in respect of days taken to germination, plant height (cm) at 45, 60 and 75 days, number of compound leaves per plant at 45, 60, 75 days, number of branches per plant, days taken to maturity, number of tubers per plant, single tuber weight, plant tuber weight, tuber yield, diameter of tuber, Vitamin C content in tuber, fresh weight, dry weight, moisture content of fresh tuber. In case of interaction effect of N×K, interaction of $N_5 \times K_4$ (160 kg ha^{-1} and 120 kg ha^{-1}) pronounced significantly to days taken to germination, plant height (cm) at 45, 60 and 75 days, number of compound leaves per plant at 45, 60, 75 days, number of branches per plant, days taken to maturity, number of tubers per plant, single tuber weight, plant tuber weight and tuber yield, the economic analysis has also been done and maximum B:C ratio (3.14) was noted in interaction of $N_5 \times K_4$. Potato var. Kufri Lima yielded the maximum (377.25 quintals per hectare) in interaction of $N_5 \times K_4$ when applied with 160 kg nitrogen and 120 kg potassium per hectare.

Keywords: Potato, nitrogen, solanum

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Introduction

Potato (*Solanum tuberosum* L.) is a member of the Solanaceae family, the most important one in the vegetable crops. It is the most extensively grown tuber crop throughout the world and ranking fourth after rice, wheat and maize. It is a vital source of nutrients for human populations and is taken almost daily over a billion people, fresh or refined (Anonymous, 2017) [4]. About 40%, 35% and 25% of potato are grown in Europe, different developed countries and rest of the world respectively. It produces the highest amount of starch per unit area per unit time due to having a good content of starch in its tubers. Moreover, the 100 gm of fresh tuber contains 70-80% water, 2.1% protein, 0.3% fat, 1.1% crude fibre and 0.9% ash along with 20.6% carbohydrates. In addition, it also contains essential amino acids like leucine, tryptophan and isoleucine (Bist and Sharma, 1997) [6]. Potato is considered as a highly nutritious food and it gives high productivity per unit area and time as compared to other field crops. Overall, potato production is one of the most efficient means of converting plant, land, water and labour into a palatable and nutritious food (Sahadevan, 2007) [18].

The most important nutrient in fertilizer is nitrogen which is a growth stimulant for plants owing to an essential constituent of various metabolically active compounds like amino acids, proteins, nucleic acids, pyrimidines, flavines, purines, nucleoproteins, enzymes, protein, protoplasm and chlorophyll. So its availability is important to plant growth and yield. Nitrogen applications can increase dry matter content, protein content of tuber quality, bulking rate, and haulm growth and total tuber yield (Belanger *et al*., 2002) [5]. There is a positive impact of N on photosynthetic rate, leaf expansion and total number of leaves, canopy growth and shoot dry matter.

The higher nitrogen content can be attributed to increased root proliferation due to its effect on cellular activities and the translocation of some growth-stimulating compounds to roots, resulting in improved tuber growth and nutrient absorption (Sharma and Sood, 2002) [20].

Potassium (K) is the third essential nutrient for plant growth and absorbed by the plant roots in the form of potassium ion (K^+). Potassium is very mobile within the plant and its deficiency symptoms in plants appear first in the older leaves. Potassium is directly involved in enzyme activation, maintenance of water status, energy relations and translocation of assimilates and protein synthesis. Potatoes require high amounts of potassium fertilizer for optimum growth, production and tuber quality. Potassium promotes leaf development, especially in the early stages of growth and for longer periods of time during tuber bulking. The nutrients (Al-Moshileh *et al.*, 2004) [3] management plans including their economic cost and return were pondered to obtain optimum yield and maximum profit. Potassium is a second limiting nutrient after nitrogen in potato in acidic, alluvial and red soils. High utilization efficiency of absorbed K from native soil source is must thereby indicating the desirability for maintenance of fertilization for soil K status. The fertilizer use efficiency of K in potato is comparatively low at 40 to 55%. Nitrogen induced K efficiency.

In spite of the positive effects of N and K interaction in terms of crop productivity and economics, but the balance of N and K application is not appropriately practiced in many parts of the world. Inadequate application of potassium (K) combined with over application of nitrogen (N) is a serious problem in modern intensive agricultural production systems Higher yield and quality can be obtained at optimal N: K nutritional ratios. Application of K facilitates the uptake and transport of nitrate towards aerial parts of the plant, which in turn enhances the activities of nitrate assimilating enzymes (K cycling and recycling play an important part in NO_3^{-1} translocation from root to shoot as counter ion and assimilate loading in the phloem (Maathuis, 2007) [12]. Cycling and recycling of K^+ increased with increasing shoot growth rate, which is in accordance with the suggested role of K^+ for charge balance of NO_3^{-1} in the xylem and organic acids in the phloem (Engels and Kirkby, 2001) [7]. The present research was under taken with the mentioning objectives as to study the effect of combined and individual effect of nitrogen and potassium on growth and yield of potato and also to determine the optimum levels of nitrogen and potassium individual or in combination, which would be best for the growth of potato ad its higher yield.

Materials and Methods

The present experiment was conducted during Rabi season of 2021-22 at the Vegetable Research Field, Department of Vegetable Science, Nalanda College of Horticulture, Noorsarai, Nalanda (Bihar). The experiment was laid out in factorial randomized block design with twenty treatments in three replications wherein Kufri Lima variety was taken as test crop. There were five levels of nitrogen and four levels of potassium were used. The treatment details are: T_1 (N_0:P_0:K_0), T_2 (N_0:P_{80}:K_{80}), T_3 (N_0:P_{80}:K_{100}), T_4 (N_0:P_{80}:K_{120}), T_5 (N_{100}:P_{80}:K_0), T_6 (N_{100}:P_{80}:K_{80}, T_7 (N_{100}:P_{80}:K_{100}), T_8 (N_{100}:P_{80}:K_{120}), T_9 (N_{120}:P_{80}:K_0), T_{10} (N_{120}:P_{80}:K_{80}), T_{11} (N_{120}:P_{80}:K_{100}), T_{12} (N_{120}:P_{80}:K_{120}), T_{13} (N_{140}:P_{80}:K_0), T_{14} (N_{140}:P_{80}:K_{80}), T_{15} (N_{140}:P_{80}:K_{100}), T_{16} (N_{140}:P_{80}:K_{120}), T_{17} (N_{160}:P_{80}:K_0), T_{18} (N_{160}:P_{80}:K_{80}), T_{19} (N_{160}: P_{80}:K_{100}), T_{20} (N_{160}:P_{80}:K_{120}). The crop was planted with a spacing of 50 cm× 20 cm and plot size of 3.0 m × 3.0m. Each treatment was cultivated with recommended cultural practices. The recorded data of the trial were analysed and the results were documented and presented in tabular form.

Results and Discussion

Effect of N, K and N×K on growth parameters

Plant height at 45, 60 and 75 DAS

It is found that application of nitrogen (N), potassium (K) and interaction of N and K significantly influenced the growth parameters in potato like days taken to germination; plant height and number of compound leaves at 30, 45 and 75 days. The data on days taken to germination is presented in Table-1 which showed the significant variations among the treatments wherein the minimum days taken to germination were recorded with the application of 140 kg/ha N (12.99 days), 120 kg/ha K (13.14 days) and interaction of N_1× K_4 (0 × 120 kg/ha) i.e. 11.09 days. The application of 160 kg/ha N (13.54 days) were recorded statistically at par value for days taken to germination with treatment N_4. Moreover, the interaction effect of N_4 × K_4 (N_{140} × K_{120} kg/ha) and N_4× K_1 (N_{120} × K_0 kg/ha) were also recorded statistically at par value i.e. 13.14 and 11.85 days, respectively with N_1 × K_4 (0 × 120 kg/ha). While the maximum days of 14.39 days, 14.49 days and (16.94 days) were taken for germination due to application of N_1 (100 kg/ha), K_1 (0 kg/ha) and N_1 ×K_1 (0 × 0 kg/ha).

Table 1: Effect of different levels of nitrogen, potassium and its interaction on days taken to germination (days).

Treatment	K1 (C=0 kgha^{-1})	K2 (80 kgha^{-1})	K3 (100 kgha^{-1})	K4 (120 kgha^{-1})	Mean
N1 (C=0 kgha^{-1})	16.93	15.12	14.26	11.09	14.39
N2 (100 kgha^{-1})	14.94	14.23	14.46	13.93	14.35
N3 (120 kgha^{-1})	14.77	13.98	14.08	14.35	14.30
N4 (140 kgha^{-1})	11.85	13.45	13.54	13.14	12.99
N5 (160 kgha^{-1})	13.95	13.46	13.59	13.17	13.54
Mean	14.49	14.05	13.99	13.14	
	SEm (±)	CD			
N	0.36	1.03			
K	0.32	0.92			
N ×K	0.72	2.05			

The data recorded on plant height at 45 DAS due to application of N, K and N×K is presented in Table-2. There is significant variations have been found due to the application of different levels of nitrogen. The maximum plant height (46.91 cm) at 45 days DAS was observed in N4 (140 kg/ha) followed by N5 (160 kg/ha) which was at par with N4, whereas, the minimum plant height (28.42 cm) was recorded with the application of N_1 (0 kg/ha N). There is significant variations were noticed in plant height at 45 DAS due to individual application of different potassium levels. The highest increase in plant height (41.76 cm) were seen with the exclusive use of K_4 (120 kg/ha), which was notably superior to all other potassium levels followed by K_3 (100 kg/ha) i.e. 39.88 cm, while the lowest increment in plant height (35.46 cm) at 45 days was found in K_0 (0 kg/ha). Under the interaction treatments of N×K, significant variations were found on plant height recorded at 45 DAS. The maximum plant height at 45 DAS (48.75cm) was recorded with the application of N_5 X K_4 (160 x120 kg/ha) which was at par with $N_5 \times K_2$ (47.94 cm), $N_4 \times K_3$ (46.76 cm), respectively whereas minimum plant height (27.65 cm) was noted in $N_1 \times K_2$ (N0 × K80).

Table 2: Effect of different levels of nitrogen, potassium and its interaction on plant height at 45 DAS (cm).

Treatment	K1 (C=0 kgha^{-1})	K2 (80 kgha^{-1})	K3 (100 kg/ha)	K4 (120 kg)	Mean
N1 (C=0 kgha^{-1})	28.70	27.65	28.17	29.14	28.42
N2 (100 kgha^{-1})	32.36	32.35	35.52	40.60	35.21
N3 (120 kgha^{-1})	33.56	39.94	43.33	45.29	40.53
N4 (140 kgha^{-1})	36.29	46.55	47.76	45.03	43.91
N5 (160 kgha^{-1})	46.36	47.94	44.60	48.75	46.91
Mean	35.46	38.89	39.88	41.76	
	SEm (±)	CD			
N	0.97	2.77			
K	0.87	2.48			
N × K	1.94	5.54			

The effect of different levels of nitrogen, potassium and its interaction has been depicted in table-3 which showed that application of N5 (160 kg/ha) was recorded with maximum plant height at 60 days DAS (45.44 cm) and minimum in N_1 (0 kg/ha). The treatment N5 (160 kg/ha) was significantly superior to other nitrogen levels. The effect of different level potassium (K) has been presented in table 4.1.3. The individual effect of various levels of K showed that the maximum plant height at 60 days DAS (41.31 cm) was recorded due to application of K2 (80 kg/ha), significantly superior among all potassium levels. The minimum plant height at 60 days DAS (36.99 cm) was observed with the potassium level K_1 (0 kg/ha). Among the interaction treatments of N×K, the maximum plant height at 60 DAS was recorded $N_5 \times K_2$ (160 × 80 kg/ha) which was statistically at par with of $N_5 \times K_3$ (49.71 cm) and $N_4 \times K_3$ (46.27 cm). The minimum plant height at 60 DAS (31.10 cm) was noted in the treatment N1 × K4 (0 kg/ha × 120 kg/ha).

Table 3: Effect of different levels of nitrogen, potassium and its interaction on plant height at 60 DAS (cm).

Treatment	K1 (C=0 kgha^{-1})	K2 (80 kgha^{-1})	K3 (100 kgha^{-1})	K4 (120 kgha^{-1})	Mean
N1 (C=0 kgha^{-1})	34.49	31.81	31.87	31.10	32.32
N2 (100 kgha^{-1})	36.54	34.31	36.29	40.22	36.84
N3 (120 kgha^{-1})	37.25	40.53	41.86	44.18	40.96
N4 (140 kgha^{-1})	40.38	44.83	46.27	44.70	44.04
N5 (160 kgha^{-1})	36.27	50.05	49.71	45.72	45.44
Mean	36.99	40.31	41.20	41.18	
	SEm (±)	CD			
N	1.05	3.02			
K	0.94	2.70			
N × K	2.11	6.03			

The data presented in Table-4 highlights the influence of different levels of nitrogen and potassium on plant height at 75 DAS. The analysis of variance underscores the significant impact of both N and K levels as well as their interaction effects. Individual effect of N showed that the maximum mean value of plant height at 75 DAS (50.11 cm) was recorded with application of N5 (160 kg/ha) which was significantly superior to all other nitrogen levels. The minimum mean value of plant height at 75 days DAS (37.27 cm) was noticed in 0 N kg/ha (N_1) was applied. Individual effect of K showed that the maximum mean of plant height at 75 days DAS (46 cm) was using K_4 (120 kg/ha), which was significantly superior to all other potassium levels followed by K_3 (120 kg/ha) i.e. 44.66 cm. The minimum value of plant height at 75 days DAS (41.61 cm) was observed in K_1 (0 K kg/ha). The data recorded on interaction between nitrogen and potassium revealed that $N_5 \times K_3$ (160 × 100 kg/ha was applied produced the maximum plant height at 75 DAS (53.26 cm), which was statistically at par with of $N_4 \times K_4$ (52.90 cm), $N_5 \times K_2$ (51.50 cm) and $N_4 \times K_3$ (48.19 cm). The minimum plant height at 75 days (34.87 cm) was noted in the $N_1 \times K_2$ treatment (0 kg/ha × 80 kg/ha).

Table 4: Effect of different levels of nitrogen, potassium and its interaction on plant height at 75 DAS (cm).

Treatment	K1 (C=0 kgha^{-1})	K2 (80 kgha^{-1})	K3 (100 kgha^{-1})	K4 (120 kgha^{-1})	Mean
N1 (C=0 kgha^{-1})	42.03	34.87	35.63	36.56	37.27
N2 (100 kgha^{-1})	39.74	39.91	41.40	42.51	40.89
N3 (120 kgha^{-1})	39.83	44.18	44.84	46.68	43.88
N4 (140 kgha^{-1})	42.11	45.65	48.19	52.90	47.21
N5 (160 kgha^{-1})	44.35	51.50	53.26	51.35	50.11
Mean	41.61	43.22	44.66	46.00	
	SEm (±)	**CD**			
N	1.05	3.01			
K	0.94	2.70			
N × K	2.11	6.03			

Number of compound leaves per plant at 45, 60 and 90 DAS

The data observed on number of compound leaves at various intervals of days after sowing have been presented in Table-5, Table-6 and Table-7. The analysis of variance demonstrates the significant influence of both N and K levels, along with their interaction effects. The influence of different levels of nitrogen and potassium on compound leaf of plant at 45 DAS was recorded highest (50.99 and 47.55) in treatment N5 (160 kg/ha) and K_4 (120 kg/ha), respectively. In contrary, the minimum value (37.80 and 42.16) for compound leaf per plant at 45 days DAS was recorded with the application of N_1 (0 kg/ha) and K_0 (0 kg/ha). Similarly, the highest number of leaves were recorded due to the application of the treatment combination $N_5 \times K_4$ (160 × 120 kg/ha) followed by $N_4 \times K_4$ (45.60), $N_5 \times K_2$ (50.71) and $N_4 \times K_3$ (47.93). The minimum number of compound leaf per plant at 45 days DAS (34.87 cm) was noted in the $N_1 \times K_1$ treatment.

Table 5: Effect of different levels of nitrogen, potassium and its interaction on number of compound leaves at 45 DAS.

Treatment	K1 (C=0 kgha^{-1})	K2 (80 kgha^{-1})	K3 (100 kgha^{-1})	K4 (120 kgha^{-1})	Mean
N1 (C=0 kgha^{-1})	36.68	36.80	38.89	38.82	37.80
N2 (100 kgha^{-1})	43.05	40.74	40.98	44.33	42.28
N3 (120 kgha^{-1})	42.04	43.00	47.14	47.16	44.84
N4 (140 kgha^{-1})	45.45	48.80	47.93	45.60	46.95
N5 (160 kgha^{-1})	43.56	50.71	47.84	61.83	50.99
Mean	42.16	44.01	44.56	47.55	
	SEm (±)	CD			
N	1.20	3.43			
K	1.07	3.07			
N × K	2.40	6.86			

The data presented in Table-6 highlights the influence of different levels of nitrogen, potassium and its interaction treatments on compound leaf per plant at 60 days DAS. Interestingly, the analysis of variance revealed that the differences in compound leaf growth due to various N and K levels, as well as their interaction effects, were found to be statistically significant. The maximum mean value for number of compound leaf per plant at 60 DAS (49.86) was recorded in N5 (160 kg/ha) which was significantly superior to all other nitrogen levels followed by N_4 (140 kg/ha) whereas minimum mean value (41.93) was observed with the application of N_1 (0 N kg/ha). Under the individual application of potassium, the maximum mean value for number of compound leaf per plant at 60 DAS (44.39) was noticed in K_4 (120 kg/ha), which was significantly superior to all other potassium levels followed by K_3 (120 kg/ha). The minimum mean value of compound leaf per plant at 60 days DAS (44.39) was noticed in K_1 (0 kg/ha). The maximum number of compound leaf (53.06) were recorded with the application of $N_5 \times K_4$ (160×120 kg/ha), while the minimum compound leaves (39.22) were noted in the $N_1 \times K_2$ treatment (0 kg/ha × 80 kg/ha).

Table 6: Effect of different levels of nitrogen, potassium and its interaction on number of compound leaves after 60 days.

Treatment	K1 (C=0 kg/ha)	K2 (80 kg/ha)	K3 (100 kg/ha)	K4 (120 kg)	Mean
N1 (C=0 kg/ha)	46.19	39.22	40.48	41.84	41.93
N2 (100 kg/ha)	41.86	43.12	45.53	47.35	44.46
N3 (120 kg/ha)	42.68	45.84	47.42	48.79	46.18
N4 (140 kg/ha)	45.03	47.45	48.99	50.65	48.03
N5 (160 kg/ha)	46.21	49.10	51.09	53.06	49.86
Mean	44.39	44.95	46.70	48.34	
	SEm (±)	CD			
N	1.05	3.02			
K	0.94	2.70			
N ×K	2.11	NS			

The data recorded on number of compound leaves influenced due to application of individual nitrogen, potassium as well as its interaction has been presented in Table-7. The maximum number of compound leaf per plant at 75 days DAS (51.79) was found with the application of N5 (160 kg/ha) which was significantly superior to all other nitrogen levels followed by N4 (140 kg/ha) whereas minimum mean value of compound leaf of plant at 60 days DAS (41.55) was observed with the application of 0 N kg/ha (N_1). With the application of K4 (120 kg/ha) the maximum mean value of compound leaf of plant at 75 days DAS was observed which was significantly followed by K3 (120 kg/ha). The minimum mean value of compound leaf per plant at 75 days DAS (44.91) was showed in 0 K kg/ha (K1). The maximum compound leaves at 75 DAS (55.31) were recorded with the application of $N_5 \times K_4$ @ 160 × 120 kg/ha, which was par with $N_4 \times K_2$ (), and $N_5 \times K_3$, while the minimum compound leaves (34.59) were noted in the $N_1 \times K_1$ treatment ($N_0 \times K_0$).

Table 7: Effect of different levels of nitrogen, potassium and its interaction on number of compound leaves after 75 DAS.

Treatment	K1 (C=0 kg/ha)	K2 (80 kg/ha)	K3 (100 kg/ha)	K4 (120 kg)	Mean
N1 (C=0 kg/ha)	34.59	43.13	45.22	43.28	41.55
N2 (100 kg/ha)	51.61	43.99	45.36	47.46	47.11
N3 (120 kg/ha)	42.58	51.32	49.49	50.28	48.42
N4 (140 kg/ha)	46.02	52.53	51.12	50.43	50.02
N5 (160 kg/ha)	49.77	49.79	52.27	55.31	51.79
Mean	44.91	48.15	48.69	49.35	
	SEm (±)	CD			
N	1.14	3.27			
K	1.02	2.92			
N × K	2.28	6.53			

Number of branches per plant

The data on number of branches per plant has been depicted in Table-8 which revealed the significant variations among all the treatments. The maximum number of branches per plant (5.77) was found with the application of N5 (160 kg/ha) which was significantly superior to all other nitrogen levels where as minimum number of branches per plant (2.36) was observed with the application of N_1 (0 N kg/ha). Similarly, the maximum number of branches per plant (4.52) was recorded with the application K_4 (120 kg/ha) and minimum number of branches per plant (3.76) was showed in K_1 (0 K kg/ha). The keen observation of the recorded values for number of branches per plant under interaction of N × P showed significant variations wherein the maximum number of branches per plant (6.81) was recorded with the application of $N_5 \times K_4$ (160 × 120 kg/ha), which was at par with $N_5 \times K_3$ (5.48) and $N_5 \times K_1$ (5.43) while the minimum number of branches per plant (1.78) were noted in the $N_1 \times K_1$ treatment (0 kg/ha of N and K).

Table 8: Effect of different levels of nitrogen, potassium and its interaction on number of branches per plant.

Treatment	K1 (C=0 kg/ha)	K2 (80 kg/ha)	K3 (100 kg/ha)	K4 (120 kg)	Mean
N1 (C=0 kg/ha)	1.78	2.24	2.61	2.82	2.36
N2 (100 kg/ha)	2.90	3.16	3.34	3.56	3.24
N3 (120 kg/ha)	3.68	4.13	4.39	4.56	4.19
N4 (140 kg/ha)	5.01	4.92	4.86	4.85	4.91
N5 (160 kg/ha)	5.43	5.36	5.48	6.81	5.77
Mean	3.76	3.96	4.13	4.52	
	SEm (±)	CD			
N	0.11	0.31			
K	0.10	0.28			
N × K	0.22	0.62			

Days taken to maturity

The observations recorded on days taken to maturity of potato tubers have been represented in Table-9 which revealed that significant differences have been found due to application of various levels of nitrogen, phosphorus and its interactions. However, the minimum days taken to maturity (82.64 days) was recorded under the treatment of N_2 (160 kg/ha) which was significantly superior to all other nitrogen levels where as maximum days taken to maturity (92.63 days) was observed with the application of 0 N kg/ha (N_1). In case of individual application of various levels of potassium, K_3 (120 kg/ha) was recorded with minimum mean value for days taken to maturity (83.26 days) whereas the maximum days taken to maturity of tubers (91.55 days) was found in 0 kg/ha K (K_1). Under the interaction treatments, the minimum days taken to maturity (72.52 days) was recorded with the application of $N_2 \times K_1$ ($N_{100} \times K_0$ kg/ha), while the maximum days taken to maturity (105.47 days) were noted in the $N_1 \times K_1$.

Effect of N, K and N×K on yield parameters

Number of tubers per plant

The data on number of tubers per plant is presented in Table-10 which was influenced significantly with all the individual as well as interaction treatments. However, the maximum number of tubers per plant (9.56) was recorded under N5 (160 kg/ha) as compared to N_1 where minimum number of tubers (6.84) was recorded. With the application K_3 (120 kg/ha), maximum number of tubers per plant (8.92) was observed and minimum number of tubers per plant (7.46) in K_1 (0 K kg/ha). Under the interaction of N × P, the maximum number of tubers per plant (11.44) was recorded with the application of $N_5 \times K_4$ (160 × 120 kg/ha). However, the minimum number of tubers per plant (6.74) was noted in the $N_2 \times K_1$ ($N_{100} \times K_0$).

Table 9: Effect of different levels of nitrogen and potassium and its interaction on days taken to maturity (days).

Treatment	K1 (C=0 kg/ha)	K2 (80 kg/ha)	K3 (100 kg/ha)	K4 (120 kg)	Mean
N1 (C=0 kg/ha)	105.47	90.25	81.98	92.83	92.63
N2 (100 kg/ha)	72.52	86.17	84.74	87.13	82.64
N3 (120 kg/ha)	94.72	86.19	84.07	86.00	87.75
N4 (140 kg/ha)	92.61	84.77	82.76	84.37	86.13
N5 (160 kg/ha)	92.44	84.35	82.74	85.54	86.27
Mean	91.55	86.35	83.26	87.18	
	SEm (±)	CD			
N	2.01	5.76			
K	1.80	5.16			
N×K	4.03	11.53			

Table 10: Effect of different levels of nitrogen, potassium and its interaction on number of tuber per plant.

Treatment	K1 (C=0 kg/ha)	K2 (80 kg/ha)	K3 (100 kg/ha)	K4 (120 kg)	Mean
N1 (C=0 kg/ha)	6.87	6.84	6.86	6.80	6.84
N2 (100 kg/ha)	6.74	7.83	8.14	8.19	7.72
N3 (120 kg/ha)	7.91	7.83	8.70	8.61	8.26
N4 (140 kg/ha)	7.96	8.78	9.33	9.56	8.91
N5 (160 kg/ha)	7.85	9.11	9.84	11.44	9.56
Mean	7.46	8.08	8.57	8.92	
	SEm (±)	CD			
N	0.20	0.57			
K	0.18	0.51			
N×K	0.40	1.15			

Tuber weight

The data on tuber weight presented in Table-11, have been observed due to application of various levels of nitrogen, potassium and its interaction which showed significant variations. In case of individual effect of nitrogen, the maximum tuber weight (91.54 g) was noticed in N5 (160 kg/ha) and minimum (57.55 g) was recorded in the absence of nitrogen (N_1). With the application of K_4 (120 kg/ha) the tuber weight (91.07g) was observed significantly maximum (8.92g) whereas minimum (55.27g) in K_1 (0 K kg/ha). In addition, the maximum tuber weight (110.19g) was recorded with the interaction of $N_5 \times K_4$ (160 × 120 kg/ha) which was at par with $N_4 \times K_4$ (106.13g) and $N_5 \times K_2$ (110.19g). However, the minimum value of single tuber weight (46.60) was noted in the $N_1 \times K_1$ ($N_0 \times K_0$).

Table 12: Effect of different levels of nitrogen, potassium and its interaction on single tuber weight (g).

Treatment	K1 (C=0 kg/ha)	K2 (80 kg/ha)	K3 (100 kg/ha)	K4 (120 kg)	Mean
N1 (C=0 kg/ha)	46.60	53.82	62.52	67.27	57.55
N2 (100 kg/ha)	52.00	65.57	71.47	77.50	66.64
N3 (120 kg/ha)	56.67	74.14	81.94	94.25	76.75
N4 (140 kg/ha)	58.80	82.53	92.87	106.13	85.08
N5 (160 kg/ha)	62.28	98.77	94.93	110.19	91.54
Mean	55.27	74.97	80.75	91.07	
	SEm (±)	CD			
N	2.01	5.74			
K	1.79	5.14			
N x K	4.01	11.48			

Tuber weight per plant (g)

The data on influence of various levels of nitrogen, potassium and its interaction treatments have been presented in Table-13 and showed significant variations. The maximum tuber weight per plant (811.18 g) was found significantly with N5 (160 kg/ha) and minimum (382.38 g) in the absence of nitrogen (N_1). In case of potassium application, the maximum tuber weight per plant (742.34 g) was recorded with the application of K_4 (120 kg/ha) and minimum in (464.73 g) in K_1 (0 kg/ha). The interaction effects were also found to be significant where maximum tuber weight per plant (962 g) was observed with the application of $N_5 \times K_4$ (160 × 120 kg/ha) followed by $N_5 \times K_3$ (857.46 g). However, the minimum tuber weight per plant (280.95 g) was noted in the $N_1 \times K_1$ i.e. without nitrogen and potassium application.

Tuber yield (q/ha)

The data calculated on yield (q/ha) is presented in Table-14. The impact of nitrogen, potassium and their interaction on yield were influenced significantly. However, the maximum tuber yield (339.35 q/ha) was found in N5 (160 kg/ha) which was significantly at par with N_4 (140 kg/ha). The minimum mean tuber yield (178.55 q/ha) was noticed in the absence of nitrogen (N_1). Under the different levels of potassium, the maximum tuber yield (323.02 q/ha) was recorded in K_4 (120 kg/ha) and the minimum tuber yield (227.03 q/ha) was noted in K1 (0 K kg/ha). Under the interaction treatments of N × K, the maximum tuber yield (372.36 q/ha) was found with the application of $N_4 \times K_4$ (140 × 120 kg/ha) which was at par with $N_5 \times K_2$ (369.85 kg/ha) and $N_3 \times K_4$ (367.70 kg/ha). However, the minimum mean tuber yield (130.01 q/ha) was recorded in the $N_1 \times K_1$ ($N_0 \times K_0$).

Table 13: Effect of different levels of nitrogen, potassium and its interaction on tuber weight per plant (g).

Treatment	K1 (C=0 kg/ha)	K2 (80 kg/ha)	K3 (100 kg/ha)	K4 (120 kg)	Mean
N1 (C=0 kg/ha)	280.95	354.91	420.20	473.45	382.38
N2 (100 kg/ha)	327.51	488.61	634.88	642.89	523.47
N3 (120 kg/ha)	422.20	678.41	691.22	798.29	647.53
N4 (140 kg/ha)	636.87	697.54	802.76	835.06	743.06
N5 (160 kg/ha)	656.11	769.13	857.46	962.00	811.18
Mean	464.73	597.72	681.30	742.34	
	SEm (±)	CD			
N	16.88	48.33			
K	15.10	43.23			
N × K	33.76	NS			

Table 14: Effect of different levels of nitrogen, potassium and its interaction on tuber weight (q/ha).

Treatment	K1(0 kg/ha)	K2 (80 kg/ha)	K3 (100 kg/ha)	K4 (120 kg)	Mean
N_1(0 kg/ha)	130.01	167.98	199.49	216.73	178.55
N2 (100 kg/ha)	239.37	251.54	284.34	297.53	268.20
N3 (120 kg/ha)	242.27	274.86	308.38	367.70	298.31
N4 (140 kg/ha)	252.55	303.21	358.40	372.36	321.63
N5 (160 kg/ha)	270.95	369.85	355.85	360.76	339.35
Mean	227.03	273.49	301.29	323.02	
	SEm (±)	CD			
N	6.71	19.22			
K	6.00	17.19			
N × K	13.43	38.44			

The keen observations of recorded data were shown that Sezek *et al*. (2018) [19] was also noticed the similar findings and suggested that plant height is an indicator of vegetative growth. The addition of nutrients enhances the soil fertility and productivity levels which results in healthy crop. The minimum plant height might be due to the result of unavailability of nitrogen and other nutrients required by the plants for their normal growth and development. It was observed that an increase in nitrogen levels positively affected the plant height character which might be due to the role of nitrogen for cell division, cell enlargement and protein synthesis. Potassium nutrient in metabolism and many processes required to promote plant vegetative growth and development. Positive response was registered by Ali *et al*. (2003) [2] and Hossain *et al*. (2009) [10] who found that increasing potassium fertilization increased shoot height, number of leaves per plant and shoot fresh weight. Application of K increases plant height, crop vigour and imparts resistance against drought, frost and diseases. Potassium increases leaf expansion particularly at early stages of growth and extends leaf area duration by delaying leaf shedding near maturity. It increases both the rate and duration of tuber bulking. Its application activates a number of enzymes involved in photosynthesis, carbohydrate and protein metabolism and assists in the translocation of carbohydrates from leaves to tubers.

Potassium increases the size but not the total number of tubers (Trehan *et al*., 2001) [25]. Potassium application thus increases yield by the formation of larger sized tubers. Zhao-Hui *et al*. (2008) [27] found that K increased the yields of tomato at most N rates. Nevertheless, the $N_{0\ k0}$ treatment produced the lowest yields. The interaction between N and K showed that with higher rates of N application, the effect of K became more significant with increasing application rate. This clearly indicated that as soon as a higher yield potential through better N supply was implemented, there was a rapid depletion of soil K. The relationship between N and K determines the balance between vegetative growth, fruit quality and reproductive processes Mullins *et al*. (1991) [14] suggested that increased N and K forced higher yield which also supported by Taya *et al*. (1994) [22], found that the highest tuber yield (>75 g) t/ha was related to the treatment i.e. 150 kg N/ha and the lowest tuber yield was related to the treatment i.e. 100 kg N/ha. Higher fertilization response may be linked to the increase in total leaf area which in turn increased the amount of solar radiation intercepted and more photo-assimilate might have been produced and assimilated to the tubers.

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