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Effect of Intra-Row Spacing and Potassium Fertilizer on Growth and Yield of Potato (*Solanum tuberosum* L.)

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ABSTRACT

This study investigated the effects of various plant spacings and potassium fertilizer on the growth and yield of potato (cv. Santa) in Nangarhar Province, Afghanistan during the summer of 2024.A factorial experiment was conducted at the research farm of the Agriculture Faculty, Nangarhar University. The experiment comprised 12 treatments with three levels of intra-row spacing (20, 25, and 30 cm) and four levels of potassium fertilizer (0, 100, 150, and 200 kg/ha). The experimental design utilized a randomized complete block design (RCBD) with three replicates. The results revealed that both plant spacing and potassium fertilizer significantly influenced growth and yield parameters. The closest spacing (20 cm) resulted in the highest values for plant height (58.55 cm), number of branches per plant (3.72) and number of leaves per plant (50.68).The application of 150 kg/ha of potassium (F3) resulted in significant increases in plant height (59.53 cm), number of branches per plant (4.12), and number of leaves per plant (54.21). The best interaction between plant spacing and potassium was observed with treatment S1F3 (20 cm + 150 kg/ha), which yielded the highest values for plant height (63.50 cm) and number of leaves per plant (56.87). Yield parameters indicated that the closest spacing and potassium application of 150 kg/ha maximized tuber weight per plant (500.86 g) and total tuber yield per hectare (32.06 t). Economic analysis revealed that S1F3 achieved the highest gross (AF 700,407/ha) and net returns (AF 455,437.3/ha).This study recommends that farmers adopt a spacing of 20 cm between potato plants and apply 150 kg/ha of potassium fertilizer to optimize potato growth, yield, and profit.

Keywords: Potato, Intra Row Spacing, Potassium Fertilization

INTRODUCTION

Potatoes (*Solanum tuberosum* L.) are among the most widely consumed vegetables worldwide and play a crucial role in agriculture.

Originating from the Andes Mountains of Peru and Bolivia, potatoes are cultivated at various altitudes and are distinguished by their starchy tubers and unique growth conditions (Kumar & Chandra, 2018; Levy & Veilleux, 2007). While global cultivation thrives in temperate climates with high yields, Afghanistan faces significant challenges that result in notably lower potato production (FAO, 2022). As the fourth most important food crop globally, potatoes serve as a staple food and provide essential nutritional benefits, including vitamins C and B6, and potassium (Patel et al., 2023). Nutritional attributes play a crucial role in ensuring food security, especially in areas such as Afghanistan, where there are significant dietary deficiencies (Shailbala, 2008).

Extensive research has been conducted on potato cultivation, including genetics, propagation methods, and management practices that influence yield (Olivier et al., 2006; Kushwah & Singh, 2008). In addition, farmers in Afghanistan face many challenges in growing potatoes. Many are still using old farming techniques, which are not as effective, and they often struggle with poor soil nutrients. Additionally, various social and economic problems make it difficult for farmers to improve their practices and grow healthy crops. These difficulties make it challenging for Afghan farmers to succeed and improve their livelihoods through potato farming (World Bank 2021) While numerous studies emphasize the role of factors such as the spacing between plant rows and potassium fertilizer, there is a scarcity of research focusing on how these elements influence potato cultivation, specifically within Afghanistan's distinct environmental conditions (Kadian et al., 2003). The existing literature often reflects diverging results regarding the impact of these factors on growth and yield, highlighting the need for localized research to address these discrepancies.

Enhancing potato yields in Afghanistan is crucial, as it has the potential to bolster food security and improve the livelihoods of farmers who primarily rely on subsistence agriculture (Kadian et al., 2003). This study aims to offer practical advice tailored to meet the requirements of local farmers. The principal research question guiding this study is as follow: What are the effects of varying intra-row spacing and potassium fertilization rates on potato growth and yield in Afghanistan? Additionally, in what ways do these elements interact to affect the production results?

The objectives of this study were as follows: (1) to examine the impact of varying intra-row spacing on potato growth and yield, (2) to assess the effects of different levels of K fertilization on the growth and yield of potatoes and (3) to explore the interaction between spacing and fertilizer application rates. It is hypothesized that optimal intra-row spacing, combined with appropriate potassium fertilization would significantly enhance potato growth and yield, leading to improved productivity and economic viability for Afghan farmers.

MATERIALS AND METHODS

The experiment was conducted at the Research Farm of the Agriculture Faculty of Nangarhar University in 2024. Three intra-row spacings (20, 25, and 30 cm) and four potassium fertilizer levels (0, 100, 150, and 200 kg/ha, K_2O) were studied for various growth and yield parameters. A Factorial Randomized Complete Block Design (FRCBD) was employed, and each treatment was replicated thrice. Each replicate included an examination of 12 treatments, resulting in a total of 36 treatments. The plot size was 7.5 m^2 (2.5 m × 3 m), and the total net area was 270 m^2. Potato tubers of the Santa variety, chosen for their medium size, were selected because their suitability for thriving in local conditions. The experimental field was fertilized with 100 kg/ha nitrogen and 100 kg/ha phosphorus during land preparation, potassium (K_2SO_4) fertilizer was applied as per treatment levels, and the remaining 100 kg of nitrogen fertilizer was added during earthing-up, 40 days after sowing. The experimental site has a semi-arid climate with hot, dry summers and mild winters, with an annual rainfall of 426.5 mm. April had the highest precipitation (239 mm). From September to December, the rainfall totaled 10 mm, averaging 2.5 mm monthly (Afghanistan Meteorological Department, 2024). The experimental site soil is clay loam, with pH 8.6, showing low nitrogen (18.75 kg/ha) and potassium (201.6 kg/ha), while phosphorus is optimal at 79.83 kg/ha (Soil Laboratory of Sheshambagh Agriculture Research Station, Jalalabad). Potato tubers were harvested at full maturity when 70% of the plants turned yellow. All standard cultural practices were performed according to crop requirements.

Data Collection: Data on the growth and yield parameters were systematically collected. For growth observations, plant height, number of branches per plant, and number of leaves per plant were measured 30 and 60 days after sowing. The yield parameters included the number of tubers per plant, total tuber weight per plant, and total tuber yield per hectare.

Statistical Analysis: The experimental data were analyzed using Analysis of Variance (ANOVA) with the assistance of SPSS software (version 25). Results were considered statistically significant at the 0.05 probability threshold. Means were separated using the Least Significant Difference (LSD) test to determine the differences among the treatment effects.

RESULTS

Growth Parameters

1.1. Plant height (cm)

Plant height was measured at 30 and 60 (DAS), as shown in Tables 1 and 2. Analysis of variance revealed that plant height was affected by plant spacing, potassium fertilizer levels ($p < 0.05$), and their interactions. At 30 days after sowing, the tallest height (27.56 cm) was recorded in closer spacing S1 (75 × 20 cm), while the shortest height (23.80 cm) was recorded with S3 (75 × 30 cm). Plant height was maximum (28.53 cm) with F3 (150 kg/ha) of K2O fertilizer, comparable with F4 (200 kg/ha), and minimum (22.00 cm) with F1 (no K fertilizer). The interaction between spacing and potassium levels was significant ($P<0.05$). Maximum plant height (33.51 cm) was observed in S1F3 (20 cm +150 kg/ha), while the lowest (21.07) was observed in S3F1 (30 cm + 0 kg /ha). At 60 DAS, both spacing and K fertilizer levels significantly affected plant height. The tallest plants (58.55 cm) were at S1 (20 cm), whereas the shortest (53.76 cm) were recorded at S3 (30 cm). The highest plant height (59.53 cm) was achieved with F3 (150 kg/ha K2O), and the lowest (51.44 cm) with F1 (no K fertilizer). Maximum plant height (63.5 cm.)

was observed with S1F3 (20 cm + 150 kg/ha) and minimum (49.733 cm) in S3F1.

1.2. Number of branches/plants

The ANOVA results showed that K fertilizer significantly affected the number of branches per plant ($p<0.05$) at 30 and 60 DAS, whereas intra-row spacing and its interaction with K fertilizer were not significant ($p> 0.05$). The results are presented in Tables 1 and 2 respectively. At 30 DAS, although the effect of intra-row distance was not statistically significant, the maximum number of branches per plant (3.32) was recorded at closer spacing (20 cm), followed by 25 cm and 30 cm. For K fertilizer levels, F3 (150 kg/ha, K2O) recorded the highest branches/plant (3.45), which was statistically comparable with F4 (200 kg/ha, K2O) (3.43). The Minimum branch count (3.03) was observed in F1 (no K fertilizer). At 60 DAS, intra-row plant distance did not significantly affect the number of branches per plant. The greatest number of branches (4.00) was observed at 30 cm spacing, followed by 25 cm and 20 cm spacing. For K fertilizer, the maximum branch count (4.12) was recorded in F3 (150 kg/ha K_2O), which was statistically similar to that of F4 (200 kg/ha K_2O) (4.08). The minimum branch values (3.39) were observed in F1.

1.3. Number of leaves/plants

The ANOVA results showed that intra-row spacing, K fertilizer, and their combination significantly affected the amount of leaves/plant at 30 and 60 days after planting (Tables 1 and 2). At 30 DAS, the maximum number of leaves/plant (37.84) occurred at the closest spacing, S1 (20 cm), while the minimum (31.93) occurred at the widest spacing, S3 (30 cm). For K fertilizer, F3 (150 kg K/ha) produced the maximum number of leaves per plant (41.42), significantly higher than other treatments, while the lowest (26.81) was in F1 (no potassium). The combination effect was significant ($p<0.05$), with the maximum number of leaves (43.83) in the S1F3 treatment. At 60 DAS, S1 (20 cm) showed highest count of leaves/plant (50.68), followed by S2 (49.10). The minimum leaf count per plant (47.57) occurred at S3 (30 cm). For K fertilizer levels, F3 (150 kg/ha) produced the maximum number of leaves (54.21), followed by F4 (52.69), while the minimum (40.08) was observed in F1 (no K fertilizer). The interaction showed maximum leaves (56.87) in S1F3, whereas the minimum (38.30) was observed in S3F1.

Table 1. Main effect of intra row spacing and K fertilizer on plant height, number of branches/plant and numbers of leave/plant at 30 and 60 DAS.

Treatment	Plant Height		Number of braches/plant		Number of leaves/plants	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
Intra Row Spacing Levels (cm)						
S1	27.56	58.55	3.32	3.72	37.84	50.68
S2	25.91	56.00	3.29	3.79	36.28	49.10
S3	23.80	53.76	3.22	4.00	31.93	47.57
CV	13.73	6.87	7.69	10.76	18.18	12.00
SEM±	0.36	0.31	0.05	0.09	0.28	0.34
CD (P=0.05)	1.06	0.91	SN	SN	0.81	0.98
K_2O Levels (kg/ha)						
F1	22.00	51.44	3.03	3.39	26.81	40.08
F2	24.88	55.62	3.20	3.76	34.19	49.49
F3	28.53	59.53	3.45	4.12	40.47	54.21
F4	27.62	57.81	3.43	4.08	39.93	52.69
CV	13.73	6.87	7.69	10.76	18.15	12
SEM±	0.42	0.36	0.06	0.1	0.32	0.39
CD (P=0.05)	1.23	1.05	0.17	0.29	0.94	1.13

DAS (Days after sowing), NS (Non-significant), CV (Coefficient of variation), SEM (Standard error of means), CD (Critical differences).

Table 2. Interaction effect of intra row spacing and K fertilizer on plant height, number of branches/plant and numbers of leave /plant at 30 and 60 DAS.

Treatment	Plant Height		Number of branches/plants		Number of leaves/ plants	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
S1F1	22.43	53.13	2.92	3.14	27.47	42.53
S1F2	24.43	58.57	3.29	3.8	37.8	50.5
S1F3	33.51	63.5	3.53	3.99	43.83	56.87
S1F4	29.87	59	3.55	3.96	42.27	52.83
S2F1	22.49	51.47	3.01	3.48	28.2	39.41
S2F2	26.53	55.87	3.1	3.59	36.87	48.5
S2F3	27.15	58.37	3.55	4.09	42.27	54.9
S2F4	27.47	58.3	3.49	4.01	37.8	53.6
S3F1	21.07	49.73	3.16	3.57	24.77	38.3
S3F2	23.66	52.43	3.2	3.9	27.9	49.47
S3F3	24.93	56.73	3.28	4.27	36.87	50.87
S3F4	25.53	56.13	3.25	4.26	38.17	51.63
CV	13.73	6.87	7.69	10.76	18.15	12
SEM±	0.73	0.62	0.1	0.17	0.56	0.67
CD (P=0.05)	2.13	1.82	SN	SN	1.63	1.97

DAS (Days after sowing), NS (Non-significant), CV (Coefficient of variation), SEM (Standard error of means), CD (Critical differences).

Yield Performance

2.1. Number of tubers/plants

The ANOVA showed that plant spacing, K fertilizer levels, and their interactions had a significant ($p < 0.05$) effect on the number of tubers/plant parameter, as shown in Tables 3 and 4. The maximum number of tubers per plant (6.19) occurred in the closest spacing, S1 (20 cm), followed by S2 (25 cm), while the lowest number of tubers per plant (3.98) was in the widest spacing, S3 (30 cm). For K fertilizer, 150 kg/ha yielded the highest tuber counts (5.68) compared to other treatments. The interaction effect was also significant, with the greatest tuber count per plant (7.43) in the S1F3 treatment (20 cm spacing + 150 kg/ha) and the minimum (3.71) in the S3F1 treatment (30 cm spacing + no potassium).

2.2. Tuber weight/plant (g)

The results of ANOVA showed that plant spacing, K fertilizer levels, and their combination significantly ($p < 0.05$) influenced tuber weight/plant, as presented in Tables 3 and 4. The maximum tuber weight per plant (418.97 g) was observed at 20 cm spacing, followed by 25 cm spacing (393.20 g/plant), with the lowest tuber weight per plant (373.23 g) at the widest spacing. For K fertilizer, highest tuber weight per plant (453.21 g) was observed in F3 (150 kg/ha K2O), followed by F4 (200 kg/ha K2O) (430.02 g/plant), while the lowest tuber weight (299.98 g/plant) was observed in the control treatment F1. The interaction between spacing and K fertilizer significantly affected tuber weight per plant ($p < 0.05$). The highest tuber weight (500.86 g/plant) was achieved with S1F3 (20 cm spacing + 150 kg/ha), followed by S1F4 (449.54 g/plant), while the lowest (272.39 g/plant) was in S3F1 (30 cm spacing + no potassium).

2.3. Total tuber yield/ha (t)

The analysis of variance suggested that the factors intra-row spacing, potassium fertilizer levels, and the interaction between these factors had significant ($p < 0.05$) effects on total tuber yield/ha. The summary results are presented in Tables 3 and 4. The highest tuber yield (26.81 t/ha) was observed at the closest spacing, S1 (20 cm), followed by S2 (25 cm) with a yield of 20.97 t/ha, and the lowest tuber yield (15.92 t/ha) was at S3 (30 cm). The highest tuber yield (24.44 t/ha) was observed for F3 (150 kg/ha K2O), followed by F4 (200 kg/ha K2O) and F2 (100 kg/ha, K2O) with yields of 23.08 t/ha and 21.28 t/ha, respectively. The control treatment, F1 (no K fertilizer), provided the lowest yield (16.14 t/ha). The interaction between the factors also had significant ($p < 0.05$) effects on the yield. The highest production (32.06 t/ha) was in S1F3 (20 cm + 150 kg/ha K2O) treatment with narrowest spacing and highest rate of K, followed by S1F4 (20 cm + 200 kg/ha K2O) and S1F2 (20 cm + 100 kg/ha K2O) with yields of 28.77 t/ha and 26.45 t/ha, respectively. The lowest yield (11.62 t/ha) was in S3F1 treatment (30 cm spacing + no K fertilizer

Table 3. Main effect of intra row spacing and K fertilizer on number of tuber/plants, tuber weight/plant and total tuber yield/ha.

Treatment	Number of tubers/plants	Tuber weight/ plant (g)	Total tuber yield/ha(t)
Intra Row Spacing Levels (cm)			
S1	6.19	418.97	26.81
S2	4.81	393.2	20.97
S3	3.98	373.23	15.92
CV	24.13	16.37	26.69
SEM±	0.17	4.64	0.27
CD (P=0.05)	0.51	13.55	0.79
K_2O Levels (kg/ha)			
F1	4.51	299.98	16.14
F2	4.83	397.32	21.28
F3	5.68	453.21	24.44
F4	4.95	430.02	23.08
CV	24.13	16.37	26.69
SEM±	0.2	5.36	0.31
CD (P=0.05)	0.59	15.65	0.91

DAS (Days after sowing), NS (Non-significant), CV (Coefficient of variation), SEM (Standard error of means), CD (Critical differences)

Table 4. Interaction effect of intra row spacing and K fertilizer on number of tuber/plants, tuber weight/plant and total tuber yield/ha.

Treatment	Number of tubers/plants	Tuber weight/ plant (g)	Total tuber yield/ha(t)
S1F1	5.17	312.15	19.98
S1F2	5.67	413.31	26.45
S1F3	7.43	500.86	32.06
S1F4	6.50	449.54	28.77
S2F1	4.67	315.4	16.82
S2F2	4.47	391.71	20.89
S2F3	5.60	434.57	23.18
S2F4	4.50	431.13	23.00
S3F1	3.71	272.39	11.62
S3F2	4.37	386.94	16.51
S3F3	4.00	424.19	18.10
S3F4	3.86	409.39	17.47
CV	24.13	16.37	26.69
SEM±	0.35	9.29	0.54
CD (P=0.05)	1.02	27.11	1.57

DAS (Days after sowing), NS (Non-significant), CV (Coefficient of variation), SEM (Standard error of means), CD (Critical differences).

DISCUSSION

This study observed that planting potatoes with an intra-row spacing of 20 cm, along with applying an optimal potassium fertilizer of 150 kg/ha, significantly improved various growth aspects and yield in the potato plants. The findings on plant height indicated that closer intra-row spacing (20 cm) resulted in significantly taller plants than wider spacing (30 cm). This is consistent with the notion that a higher plant density increases competition for sunlight, which stimulates plants to grow taller as they compete for light (Saifullah et al., 2024; Kumar et al., 2021). Likewise, applying the optimal potassium level of 150 kg/ha resulted in the tallest plants, supporting earlier findings by Nxumalo et al. (2020) and Dhakal et al. (2019), which showed that K fertilization enhanced vegetative growth. The role of K in chlorophyll synthesis and cell elongation likely contributed to the increased plant height (Razaq, 2015; Brady, 2004). At the optimal potassium level, the number of branches per plant was significantly increased, reinforcing the results reported by Nxumalo et al. (2020) and Sturz et al. (2007), who reported that potassium enhances meristematic activity, promoting more branches through its involvement in energy metabolism and enzyme activation (Kushwah & Singh, 2008). Potassium serves a critical physiological function by promoting higher branch density, which in turn facilitates improved tuber development. The number of leaves per plant was significantly affected by both closer spacing and optimal K fertilization. Plants grown with 20 cm spacing and 150 kg/ha K fertilizer recorded maximum leaf numbers, in agreement with Thakur et al. (2022), Yadav (2021), and Nxumalo et al. (2020). More leaves facilitate greater photosynthetic capacity, contributing to overall plant vigor and yield (Zelelew et al., 2016; Malviya, 2018). The significant interaction effect showed that tighter plant spacing, when paired with ideal fertilizer application, led to the highest leaf yield. In terms of yield parameters, the number of tubers per plant and their weight were highest under closer spacing (20 cm) combined with 150 kg/ha of K fertilizer. These results are in line with the findings of Thakur et al. (2022), Arega et al. (2018), and Kumar et al. (2007), who reported increased tuber numbers and weights with optimal plant density and fertilization. The synergistic effect of closer spacing and potassium fertilization boosted tuber development by optimizing nutrient utilization and enhancing water absorption. Finally, tuber yield per hectare was maximized at closer spacing with 150 kg/ha K fertilizer, emphasizing the importance of optimizing both plant density and nutrient levels for enhancing production. The improved yield attributes are attributable to better resource utilization, increased photosynthesis, and efficient starch accumulation facilitated by adequate potassium, consistent with earlier reports by Saifullah et al. (2024), Wani (2023), and Harnet et al. (2014). Collectively, these findings demonstrate that the strategic optimization of inter-row spacing and potassium application significantly improves both canopy growth and tuber yield in potato production systems.

CONCLUSION

The present study concluded that different plant spacings and potassium fertilizer levels in potato cultivation had a significant impact on growth, yield parameters, and overall profitability. Among the various intra-row spacings examined, a closer spacing of 20 cm demonstrated excellent performance in terms of both growth and yield compared with wider spacings. Additionally, the application of 150 kg/ha of potassium fertilizer proved to be the most suitable choice when evaluated against higher (200 kg/ha) and reduced (100 kg/ha) doses. This optimal potassium level positively influenced the growth and yield parameters. The results indicated that the treatment S1F3, combining a 20 cm spacing with 150 kg/ha of potassium, achieved a significantly maximum total tuber yield of 32.06 t/ha. Based on the findings of this study, farmers should adopt 20 cm intra-row spacing combined with 150 kg/ha of K fertilizer for potato cultivation. This approach can significantly enhance growth and yield parameters, achieving a maximum tuber yield of 32.06 t/ha.

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CONFLICT OF INTEREST

All authors express no conflict of interest in any part of the research.

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AUTHORS CONTRIBUTIONS

Conceived and designed the experiments: Dr. Asmatullah Durani & Associate Prof. Noor Ali Noor, Performed the experiments, Analyzed the data and wrote the paper: Abdul Wasi Hanifi, Review and Edit: Dr. Sajidullah Safi, and Dr. Azizullah Khalili.

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