Effect of Potassium Levels on Growth, Yield and Quality of Potato (*Solanum tuberosum* L.)

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Abstract

This experiment assessed the influence of potassium (K) levels on the growth, yield and quality of potato with a focus on determining the optimal potassium application rate. The experiment was conducted in a randomized complete block design in JICA, Tsukuba International Center, Ibaraki, Japan, from March 4, 2024, to July 12, 2024, on the Kitakari variety. There were four different levels (0, 75, 150 and 225 kg/ha) of potassium treatment with three replications. The result showed a significant difference in plant height, stem number, marketable yield, dry matter and starch level based on potassium level. The highest marketable yield (4.1 kg/m^2) and highest dry matter were observed at 150 kg/ha of potassium. Conversely, potassium levels of 225 kg/ha resulted in larger tubers but decreased overall quality. The study concluded that 150 kg/ha of potassium optimizes potato yield and quality. This finding recommended an application rate of 150 kg/ha for optimal growth and yield in potato cultivation. Further research is suggested to validate these results across various geographical conditions.

Keywords: Dry Matter, Nutrient Management, Potassium, Potato Yield, Tuber Quality

Introduction

Potato (*Solanum tuberosum* L.) is an herbaceous annual plant, belonging to the Solanaceae family and is widely recognized as a staple food and vegetable. Ranking as the third most consumed food globally, following rice and wheat, potatoes are the leading non-grain food commodity. Over one billion people consume potatoes, which are cultivated in more than 100 countries. In 2022, global potato production reached an impressive 375 million tons (FAOSTAT 2022).

Potato is important for food security, as it is a rich source of energy, nutrients, and protein. It is a major crop due to their rich content of starch, vitamins B and C, and minerals. Nutritionally, potato is made up of about 20.6% carbohydrates, 2.1% protein, 0.3% fat, 1% fiber, and 0.9% ash. They also provide essential amino acids like leucine, tryptophan, and isoleucine (Khurana and Naik, 2003).

Potato is one of the major vegetable crops in Nepal, grown from tropical terai areas to high mountain regions. It is consumed as stable food in the high Himalayan region. Currently, the area of potato is 198,256 ha and production is 3,410,829 mt., and it ranks first in productivity, second in production, and fifth in area in comparison to cereal crops cultivated in Nepal. It contributes 6.35% to AGDP (MoALD 2023). However, the incidence of disease and insects, low soil fertility, unavailability of quality seed, and lack of improved technology for potato cultivation results in lower productivity of Nepalese potato compared to global scenario.

Potassium (K) is an essential nutrient for all plants and has a major effect on the yield and quality of potato and the crop's general health and vigor. It is involved in regulating the amount of water in the plant; in the absence of sufficient potassium, crops cannot use water efficiently. Also, adequate K levels in the plant helps to withstand water stress during periods of drought. Potassium also plays a vital role in maintaining the turgidity (rigidity) of plant cells. Because of its importance in turgor maintenance, potassium is essential for obtaining maximum leaf extension and stem elongation.

Another need to ensure an adequate supply of K is that it plays a vital role in the movement of sugars produced in the leaf by photosynthesis, to the tubers, where the sugars are converted to starch. Potassium also contributes to various aspects of tuber quality that are vital for marketing. The balance between nitrogen (N) and K supply is of particular importance for this crop. Insufficiency of potassium makes the plant susceptible to disease and pests, poor marketable quality, weaker stems, lower starch content of the tubers, increasing susceptibility to brushing and mechanical damage, greater susceptibility to adverse effects of drought, and lack of response to nitrogen and consequently reduces yield and quality of potato (Umar and Moinuddin, 2002).

The nutrient recommendation dose in Nepal for potato crops is 100:100:60 NPK kg/ha along with 20 mt Farmyard Manure (FYM) (Khatri and Shrestha, 1998). Most Nepalese farmers apply Nitrogen and Phosphorus to a greater extent and the application of Potassium is usually ignored (Pervez et al., 2013). Potassium deficiency is majorly seen in acidic soil where there is high rainfall that causes leaching of K (Getachew et al., 2009)

Therefore, there is a pressing need to understand the effect of K application on growth, yield and quality of potato. This study aims to determine appropriate amount of K to bridge existing knowledge gaps and contribute to the advancement of understanding in this critical area.

Objective

The objective of this study is to determine the appropriate amount of potassium required for optimum growth, yield, and quality of potato.

Materials and Methods

1. Field experimentation

The experiment was conducted at the farm of Tsukuba International Training Center (TBIC), Ibaraki, Japan from 4th March to 12th July 2024. The experimental site is located at the temperate climatic zone of Japan. The experiment was conducted using a Randomized Block Design (RBD) to evaluate the performance of the crop variety *Kitakari* under different treatment conditions. The study comprised one factor with four treatment levels (**Table 1**), each replicated three times, resulting in a total of 12 experimental plots.

Table 1: The fertilizer treatments of the experiment

Treatments no	Nutrient Used (kg/ha)			Compost (t/ha)
	N	P_2O_5	K_2O	
T1	120	200	0	20
T2	120	200	75	20
T3	120	200	150	20
T4	120	200	225	20

Each plot measured 2.8m² (2m × 1.4m) (Figure1), and the total experimental area was 49.4m² (13.1m × 3.9m). A uniform number of 12 plants were maintained per plot, summing up to 144 plants in the entire experiment (Figure 2). From each plot, five representative plants were randomly selected for data collection, resulting in a total of 60 sample plants. This design ensured reliable comparisons among treatments by minimizing field variability.

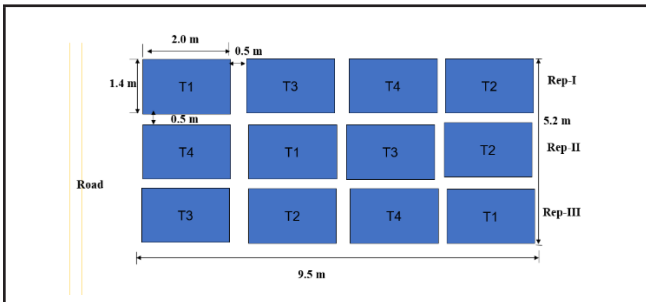

Figure 1: Layout of Experiment

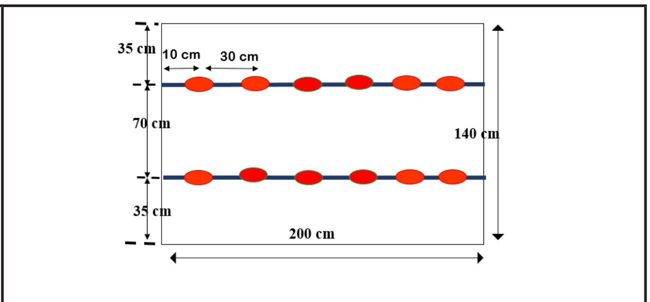

Figure 2: The individual Plot's layout

2. Soil analysis

The soil in the experimental site was tested for its P^H, carbon, nitrogen, available P and exchangeable K. The different parameters of soil chemical properties in the experimental site is presented in Table 2.

Table 2: Soil chemical properties of experimental plot

Experiment Field	Soil p^H (H_2O)	Total carbon g/kg	Total nitrogen g/kg	Available P (Bray No.2) mg/kg	Exchangeable K cmolc/kg
TBIC, Annex field	6.6	29.8	2.86	63.0	1.40

Source: JICA Tsukuba field (2024)

3. Seed tuber disinfection and seed tuber preparation

Potato seed tubers were disinfected by dipping in a 200 times dilution of validamycin (300 ml in 60 liters of water) for 10 seconds. The tubers were placed in a ventilated area to sprout. Seeds weighing less than 70 g were cut with a kitchen knife and then dipped in ashes to prevent contamination. The knife was disinfected with sodium hypochlorite after each cut to avoid spreading diseases. The tubers were placed in trays inside a greenhouse, away from direct sunlight, to promote sprouting.

4. Seed tuber selection

The seed tubers were kept in the greenhouse for 20 days at an optimal temperature of 15–20 °C to develop sprouting eyes of 3–5 mm diameter. This sprouting process ensured that the sprouts germinated uniformly and became dark green and robust. To avoid uneven germination, the positions of the potato seeds were upside down weekly during the treatment period. Weak and non-sprouted seeds were discarded, and only strong and healthy seeds were selected for planting.

5. Seed tuber planting

Seed potato were planted in the field at 70 cm row-to-row and 30 cm plant-to-plant distance. The depth of sowing was 10-12 cm from the surface. There were 6 seeds in a row and 2 rows per plot. The details of the field activities are presented in Table 3.

Table 3: Details of field activities

Date	Activities
March 4	Tuber exposed for sprouting
March 19	Field Layout
March 25	Cutting seed tubers used ash
April 11	Basal dose fertilizer application (50 % N and K_2O and 100 % P_2O_5).
April 11	Tuber planting
May 11	Top dressing 50 % of N and K_2O
May 20	First growth data collection (40 DAP)
June 4	Spray of Jiman daisen (mancozeb) fungicide
June 9	Second-time growth data collection (60 DAP)
June 11	Spray of Jiman daisen (mancozeb) fungicide
June 20	Spray of Kasumin Boardeaux fungicide
July 9	Third-time data collection (90 DAP)
July 12	Harvesting and yield data collection

6. Disease control

Different agrochemicals were applied to treat potato disease in the experimental site. The details of agrochemical applications are presented in Table 4.

Table 4: Agrochemical application

Date	Brand Name	Active ingredient	Target disease
4th June, 2024	Jiman daisen	Mancozeb	Late blight, Alternaria leaf spot
11th June, 2024	Jiman daisen	Mancozeb	Late blight, Alternaria leaf spot
22nd June, 2024	Kasumin Bordex	Copper oxychloride	Late blight

7. Data collection

7.1. Growth parameter

Plant growth of potato plants was measured three times in 60 DAP (Days after Transplant), 80 DAP and 100 DAP. During these times the data regarding the number of stems, plant height, and leaf color (SPAD value) were measured. Plant height was measured using measuring tape and SPAD value was measured using SPAD meter.

27.2 Yield data

After harvesting, tubers were categorized into different grades according to their weight and number. The tuber weighing less than 20 g was considered unmarketable, and more than 20 g were categorized into marketable tubers. The marketable tubers were further categorized into 20-60 g, 71-100 g, and more than 100 g and unmarketable (disease-infected, deformed size and less than 20 g weight).

7.3. Dry matter analysis

Dry matter was analyzed by chopping 200 g tubers into small pieces about 2 X 2 cm cubes and putting them in a hot air oven at 80^{0}C for 72 hrs. After completion of this time dried potato cubes were weighed again and dry matter was calculated using equation 1.

Dry Matter (%) =(W_i/W_f) ×100 ----- (1)

Where, W_i is the initial weight of the fresh sample, and W_f is the final weight of the dried sample.

7.4 Specific gravity (SG) and starch content

The potato gauge method is a practical approach to measuring the specific gravity of potato. The following method was used (Kleinkopf, Westermann, Wille, and Kleinschmidt, 1987). The potato was weighed in the air and reweighed in water using a potato gauge. The specific gravity was determined using equation 3.

Specific gravity (SG) = Weight of potato in air/ (weight of potato in air-weight of potato in water) ---- (3)

The starch content was calculated using equation 2.

Starch Contents (%) = 214.5 X (Specific gravity (SG) -1.05) + 7.5 ---- (3)

8. Organoleptic evaluation of potato tubers

An organoleptic test was conducted using a structured approach to assess the sensory attributes of different potato tuber treatments. The test aimed to evaluate the potato based on four key criteria- testiness, sweetness, flakiness, and flavor. In this test, potato tubers were boiled separately for 20 minutes to ensure each treatment was prepared under consistent conditions to avoid any bias in the results. A total of 20 participants were involved in the evaluation. They were asked to evaluate each sample against the given criteria and provide their range (1 to 4) accordingly. Twenty evaluators tasted the boiled potato pieces and rated them on a scale of 1 to 4, where 4 is very good, 3 is good, 2 is medium and 1 is very poor. The total score from all participants was calculated.

Results and Discussion

1. Growth parameters

1.1 Plant height

The result of the plant height measurement is presented in Figure 3. The results revealed that the plant height was not significantly different in 40 DAP (Days after planting) and 60 DAP. However, there was a significant difference at 90 DAP. The highest plant height was observed in 150 kg /ha at 90 DAP. The similar results, the vegetative growth parameters like plant height were gradually and significantly increased by increasing the level of potassium application from up to 285 kg K_2O/ha (Asmaa, R.M. and Magda, M.H., 2010).

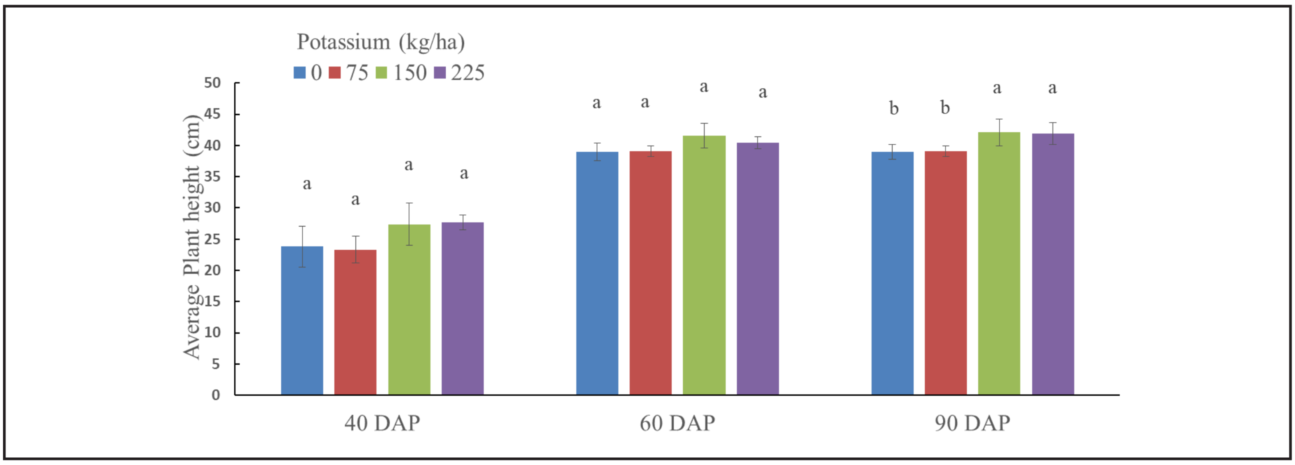

Figure 3: Effect of Potassium on the plant height of potato. The values of the graph are mean and standard deviation. The different alphabet in the figure shows a significant difference at p = 0.05 by LSD.

1.2 SPAD reading

The leaf color, as measured by SPAD values, provides an indirect estimation of chlorophyll content and nitrogen status in plants (Uddling et al., 2007). In the present study, SPAD readings at 40, 60, and 90 days after planting (DAP) showed no significant differences among treatments (Table 5). This suggests that the treatments did not substantially affect leaf chlorophyll content during the observed growth stages. Similar findings were reported by Hafez and El-Metwally (2007), who found that different fertilizer regimes had a minimal influence on SPAD values in maize, indicating a possible threshold beyond which additional inputs do not enhance chlorophyll concentration. Moreover, Zhao et al. (2016) argued that SPAD readings tend to stabilize under optimal growth conditions, with limited variation unless plants are exposed to significant nutrient stress or environmental changes. Therefore, the uniformity in SPAD values across treatments in this study may reflect comparable nitrogen availability and photosynthetic efficiency across the experimental plots.

Table 5: Effect of different levels of potassium on the leaf color of potato

(Mean ± SE)

K_2O (kg/ha)	40 DAP	60 DAP	90 DAP
0	48.0 ± 0.2 a	43.2 ± 1.0 a	35.2 ± 0.8 a
75	46.2 ± 0.2 a	44.1 ± 1.4 a	35.5 ± 0.5 a
150	47.5 ± 0.6 a	43.8 ± 1.0 a	36.3 ± 0.2 a
225	46.2 ± 0.0 a	42.8 ± 1.5 a	36.7 ± 1.2 a
p -value(%)	6.9	87.7	43.0

Note: The different alphabet in the figure shows significant difference by LSD; *p*- value =5%.

1.3 Stem number

The number of stems per plant increased progressively with potassium levels, reaching a maximum (4.8) at 225 kg K_2O/ha and a minimum (3.6) at 0 kg/ha at 90 DAP. This suggests that potassium promotes stem development, likely by enhancing cell division and bud activation. Potassium plays a key role in physiological functions such as enzyme activation and carbohydrate translocation, which support vegetative growth (Marschner, 2012). Consistent with this, Abay and Sheleme (2011) also observed increased stem numbers in potatoes with potassium fertilisation.

Table 6: Effect of different levels of potassium on the stem number of the potato

(Mean ± SE)

K_2O (kg/ha)	40 DAP	60 DAP	90 DAP
0	3.0 ± 0.3 a	3.3 ± 0.2 b	3.6 ± 0.2 b
75	2.6 ± 0.5 a	3.5 ± 0.3 b	3.6 ± 0.1 b
150	3.4 ± 0.4 a	4.3 ± 0.0 a	4.5 ± 0.1 a
225	4.2 ± 0.1 a	4.6 ± 0.2 a	4.8 ± 0.2 a
p-values (%)	15.6	3.4	0.8

Note: The different alphabet in the Figure shows significant difference by LSD; *p*- value =5%.

2. Yield data

2.1 Marketable and unmarketable tuber weight/number

Figure 4 revealed that there was significant effect of potassium treatment on the marketable yield. The highest marketable yield (4.1kg/m^2) was recorded at 150 kg/ha followed by 225 kg/ha of potassium. The lowest marketable tuber yield (2.7 kg/m^2) was recorded in 0 kg/ha of potassium.

The highest unmarketable yield was observed at 0 kg/ha of potassium and the lowest in 225 kg/ha. This might be the role of potassium in the transformation of photosynthate from leaf to tubers (Romheld and Kirkby, 2010).

Figure 5 revealed that there was a significant difference in marketable numbers within treatments. The higher tuber number was observed at 150 kg/ha, and the lowest was at 0 kg/ha of potassium. There was no significant difference in unmarketable tuber number within treatments.

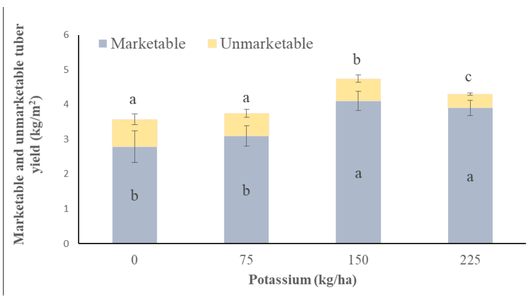

Figure 4: Effect of different levels of K on marketable/unmarketable tuber yield (kg)/m^2.

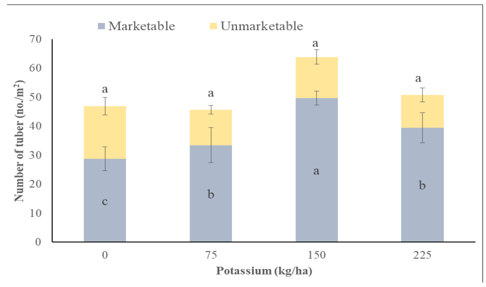

Figure 5: Effect of different levels of potassium marketability of tuber(no/ m^2).

Note: The different alphabet in the Figure shows a significant difference by LSD; *p*- value =5%.

2.2 Grade of marketable tuber

Table 7 revealed that the potassium level increases the tuber size. The largest size marketable tuber number and weight were significantly different among different levels of potassium, the highest > 100 g tuber number was found in 150 kg/ha and weight was found in 225 K_2O kg/ha followed by 150 kg/ha.

Table 7: Effect of different levels of potassium on grades of marketable tuber

(Mean ± SE)

K_2O (kg/ha)	Tuber Number (No./m^2)				Tuber Yield (kg/m^2)			
	Marketable				Marketable			
	20-60 g (S)	61-100 g (M)	>100 g (L)	Total	20-60 g (S)	61-100 g (M)	>100 g (L)	Total
0	6.2 ± 0.8 a	10.0 ± 2.2 a	12.5 ± 2.4 b	28.8 ± 4.1 b	0.3 ± 0.0 a	0.9 ± 0.1 a	1.7 ± 81.3 c	2.8 ± 0.5 b
75	12.8 ± 4.0 a	9.2 ± 2.1 a	11.9 ± 2.1 b	33.5 ± 6.0 a	0.5 ± 0.2 a	0.7 ± 0.2 a	2.0 ± 75.2 c	3.1 ± 0.3 b
150	19.1 ± 2.5 a	9.4 ± 1.6 a	21.3 ± 1.3 a	49.8 ± 2.4 a	0.8 ± 0.1 a	0.8 ± 0.1 a	2.6 ± 63.6 b	4.1 ± 0.3 a
225	11.3 ± 3.3 a	9.7 ± 2.1 a	18.5 ± 1.7 a	39.5 ± 5.2 a	0.5 ± 0.2 a	0.8 ± 0.2 a	2.7 ± 73.6 a	3.9 ± 0.2 a
p- value(%)	5.6	79.7	0.6	4.1	11.9	79.8	2.7	4.6

Note: The different alphabet in the Figure shows a significant difference by LSD; *p*- value = 5%.

3. Quality data

3.1 Dry matter and starch content

Dry matter refers to the portion of the potato that remains after moisture is removed, comprising structural compounds. It helps to determine the quality of processing. The high dry matter is associated with better texture and yield of processed food.

Figure 6 revealed that there was a significant difference in dry matter between the treatments. The highest dry matter % was observed at 150 kg/ha followed by 225 kg/ha. The lowest dry matter was observed in 0 kg/ha of potassium. The DM contents at a higher rate of K application were also reported by Dicking et al. (1962). This similar result is also observed by Khan, M.Z et al (2010) where the highest DM content was found in K_2O application at 150 kg/ha.

Figure 7 revealed that the highest starch content was found in 150 kg/ha, however the lowest starch content was found in 0 kg/ha of potassium treatment. Potassium sources could be important in promoting photosynthates, increasing the transport of their products to the tubers, and enhancing their conversion into starch, protein, and vitamins (Mengel and Kirkby, 1987). This finding is also similar to the specific gravity of potato tubers increased with an increase in K application up to 150 kg/ha and decreased at the higher rate of 225 kg/ha (Khan M.Z et al., 2010).

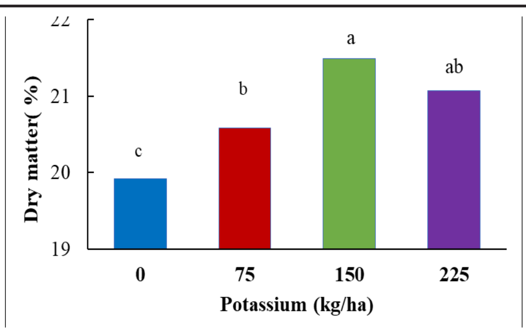

Figure 6: Effect of different levels of potassium on dry matter.

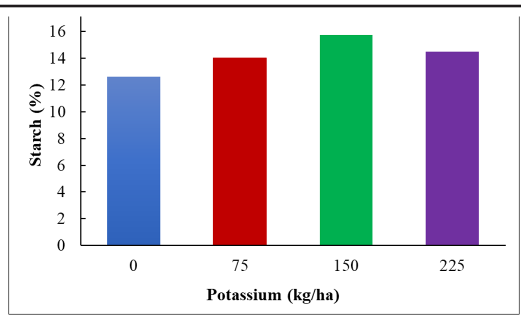

Figure 7: Effect of different levels of potassium on starch percentage.

Note: The different alphabet in the Figure shows a significant difference by LSD; p- value = 5%.

4. Organoleptic test

4.1 Testiness test and sweetness test

On the organoleptic test of potato, the 75 kg/ha potassium treatment got the highest score 59 out of 80 followed by 150 kg/ha treatments. The 225 kg/ha treatment had got the lowest score 40 out of 80 (Figure 8). Whereas, on the sweetness test of potato, the 75 kg/ha potassium treatment had got highest score 60 out of 80 followed by 150 kg/ha treatments. The 0 kg/ha and 225 kg/ha treatments had got the lowest score 48 out of 80 (Figure 9).

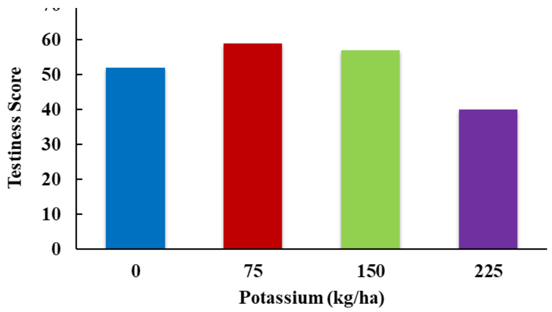

Figure 8: Effect of different levels of potassium on testiness test

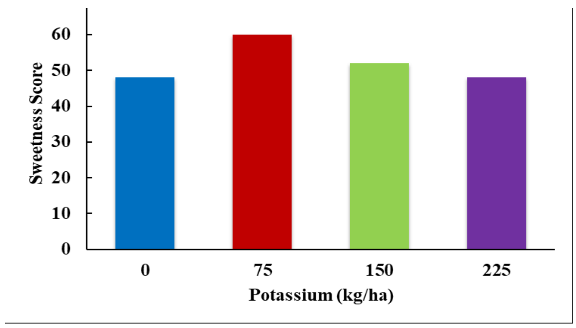

Figure 9: Effect of different levels of potassium on sweetness test

4.2 Flakiness and flavor test

On the flakiness test of potato, the 150 kg/ha potassium treatment had got highest score 66 out of 80 followed by 225 kg/ha treatments. The 0 kg/ha treatment had the lowest score of 40 out of 80. Whereas the flavor test of potato showed that the 150 kg/ha potassium treatment had got highest score 58 out of 80 followed by 0 kg/ha treatments. The 225 kg/ha treatment had the lowest score of 52 out of 80.

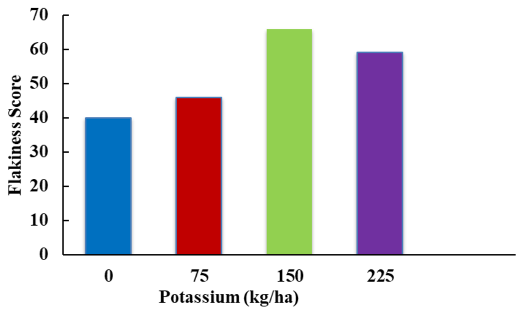

Figure 10: Effect of different levels of potassium on flakiness test

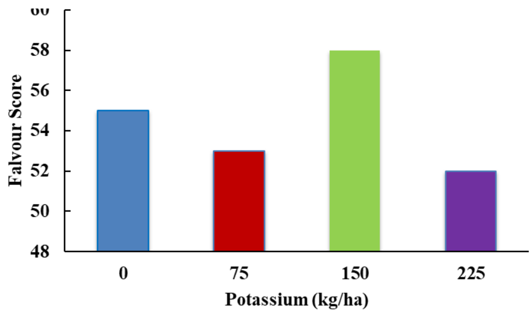

Figure 11: Effect of different levels of potassium on flavor test

Conclusion and Recommendation

This study concluded that the application of potassium has a significant and positive effect on the growth and yield of potato. For optimal growth and yield, 150 kg/ha of potassium appears to be the most effective, providing a balance of high marketable yield, dry matter, starch content, flakiness, and flavor. However, 225 kg/ha of potassium also enhances certain aspects such as large tuber yield and reduces unmarketable tuber yield.

It is recommended that farmers can use 150 kg/ha potassium for the best yield, dry matter and starch content. Both deficiency and excessive application can adversely affect the potato crop's dry matter and starch accumulation. Experiments should be conducted in different geographical conditions to find out the consistency of the results.

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Annex

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