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Effect of intra-row spacing, gibberellic acid concentration and $N:P_2O_5:K_2O$ ratio on growth and yield of potato variety Royal

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Abstract

The potato variety Royal is suitable to make French fries due to its frying qualities. However, the tubers lack the long-oval shape which is preferred in processing of French fries. Despite the lower nitrogen (N) requirement of variety Royal, farmers apply same recommendation ignoring the variety-specific needs. Thus, two experiments were conducted to (a) evaluate the possibility of changing tuber shape by manipulating intra-row spacing and gibberellic acid (GA_3) application and to (b) identify the best $N:P_2O_5:K_2O$ ratio to optimize growth and yield. The first experiment was conducted with 45 cm inter-row spacing, as a two-factor factorial RCBD. Factors one and two were intra-row spacing (15, 20, 25, 30, and 35 cm) and foliar-applied GA_3 concentration (0, 150, 200, and 250 ppm), respectively. In the second

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experiment, recommended $N:P_2O_5:K_2O$ ratio, 8.0:3.5:8.5, (Department of Agriculture, Sri Lanka) with organic manure (control) and the same without organic manure were compared with three other $N:P_2O_5:K_2O$ ratios. Each treatment had 4 replicates, with 12 plants per replicate in both experiments. Data were analysed with Two-Way ANOVA in the first experiment and One-Way ANOVA in the second, using Minitab 17. Tukey's mean comparison test was used to compare the mean values of both experiments. Intra-row spacing and GA_3 interaction did not significantly ($P>0.05$) affect the tuber yield and shape. By increasing IRS, yield per plant increased, but yield per unit land area (YPL) decreased. The effect of GA_3 on tuber yield was not significant ($P>0.05$). GA_3 at 200 ppm recorded the highest number of long-oval tubers (62% increment). $N:P_2O_5:K_2O$ ratio had no significant ($P>0.05$) effect on growth, yield, and quality. Therefore, a fertilizer ratio with low nutrient input will be more sustainable and cost-effective for potato variety Royal with lower nutrient needs. Closer intra-row spacing (15 cm) with 200 ppm GA_3 can be recommended for higher YPL with higher number of long-oval tubers.

Keywords: Fertilizer, GA_3, growth hormone, long-oval shape, plant density.

Introduction

Potato (*Solanum tuberosum* L.) is an economically important tuber crop which belongs to the family Solanaceae. It is a staple food in many countries and contributes greatly towards food security with high nutrition (Naik, 2005; Marwaha *et al*., 2010). Use of potato both in processed and fresh food forms is progressively increasing (Brown, 2005). While there are a number of potato varieties available in the world with diverse characteristics, all varieties are not suitable for processing. Potato processing industry requires tubers with specific qualities such as shape, size and depth of eyes, tuber dry matter content, reducing sugar content, phenolic compounds and glycoalkaloids (Marwaha *et al*., 2010). Despite the increasing demand for specific potato varieties suitable for processing industry, agronomic requirements of such varieties to achieve acceptable yield and processing qualities have not been adequately examined (Marwaha *et al*., 2010).

Potato variety Royal was introduced to Sri Lanka in 2021 as a French fries variety because of its good frying qualities and suitability for long-term storage

(Danespo, 2021). To minimize wastage during processing of French fries, varieties with long-oval shaped tubers are preferred (Abong *et al.,* 2009). Royal variety produces mostly big oval and rather square tubers (Danespo, 2021) but lacks long-oval shape tubers, as required. Although, the shape of a tuber is controlled by genetic factors, environment and management practices may also affect it to a certain extent (Abbas *et al.,* 2012). Thus, possible alterations in tuber shape through different management practices such as manipulating intra-row spacing and application of plant growth hormones such as Gibberellic Acid (GA_3) need to be explored. GA_3 can promote tuber misshaping (Myhre and Eddins, 1957; MacLeod and Howatt, 1958) and elongation, *i.e.*, longer tubers (Lovell and Booth, 1967), in addition to reducing tuber production. Overall, GA_3 can affect potato tuberization and yield (Lovell and Booth, 1967; Kumar and Wareing, 1974; Xu *et al*., 1998; Alexopoulos *et al*., 2017) but limited recent scientific evidence is available on its impact on tuber shape (Bodlaender and Van de Waart, 1989; Alexopoulos *et al*., 2017), especially for variety Royal.

Effect of plant spacing on tuber yield and other yield parameters such as number of tubers per plant, tuber weight per plant and marketable tuber size is reported regularly (Arsenault *et al*., 2001; Bohl *et al*., 2011; Arega *et al*., 2018; Getaneh and Laekemariam, 2021). However, only a few studies have reported shape changes in potato tubers under different plant spacing. According to Tsegaye *et al*. (2019), at narrower plant spacing, potato produces small-sized tubers which are more or less spherical in shape, as compared to wider spacing. Conversely, the tubers produced at wider spacing are large in size and oval in shape. Therefore, the optimum plant spacing to get higher tuber yield with desired quality attributes may be variety specific and requires further investigations.

Improper management of nutrients, particularly nitrogen (N), may not only reduce crop yield (Jan *et al*. 2011; Carvalho *et al*. 2016; Ladha *et al*. 2016) but also lead to losses through leaching, run-off, volatilization or denitrification causing environmental issues (Tabak *et al*. 2020). Nutrient management with proper fertilizer ratio and amount is thus critical for improving yield of potato both in quantity and quality. It also minimizes negative impact on soil fertility. Nitrogen is a critical element for plant growth and development and is also the key yield-determining element (Kolodziejczyk, 2014). However, several studies have demonstrated low effectiveness of applied N doses (Kolodziejczyk, 2014; Tabak *et al*., 2016). For instance, Zebarth et al. (2004) found that excessive N application did not significantly increase tuber yield, suggesting that optimal N levels depend on the cultivar, with early-maturing cultivars exhibiting lower N use efficiency compared to mid-season and late-maturing varieties. Additionally, factors such as application method (single or split), timing, and climatic conditions, including heavy rainfall, can significantly affect N uptake and utilization in potato plants (Errebhi et al., 1998; Muleta and Aga, 2019). Potato is classified as a plant with high fertilizer requirements but with low N utilization (Goffart *et al*., 2008). According to Vos (2009), N fertilizer recovery is 45% in potato and it is relatively lower than that of some other crops such as maize and other cereals which have a recovery range of 50-60% (Krupnik et al., 2004; Dobermann, 2007).

Similar to N, phosphorous (P) and potassium (K) also contribute for overall plant growth, yield potential and tuber quality (Allison et al., 2001; Rosen and Bierman, 2008; Birtukan, 2016; Firew *et al*., 2016; Girma *et al*., 2017; Torabian *et al*., 2021). Adequate P nutrition is essential for many physiological processes including photosynthesis, respiration and root growth (Rosen *et al*., 2014; Brady and Weil, 2017). Positive impacts of P fertilizer application on growth and tuber yield are apparent (Allison *et al*., 2001; Rosen and Bierman, 2008; Birtukan, 2016; Firew *et al*., 2016; Girma *et al*., 2017). It is critical to identify the optimum rate of P application as both excess and deficient conditions cause negative impact on tuber yield. There is a possibility to develop zinc (Zn) deficiency symptoms under excessive P applications (Boawn and Leggett, 1963). Moreover, there may be an increased risk of P loss through runoff due to over-fertilization of potato cultivations with P (Ruark *et al*., 2014).

Although K fertilization is required to gain higher marketable tuber yield, excessive or improper application can have a negative impact on potato growth, tuber yield and quality (Khan *et al*., 2010, 2012). The yield reduction due to excessive K may be mainly due to nutrient imbalances caused due to antagonistic relationships with N, magnesium (Mg), and calcium (Ca) (Malvi, 2011). Except N, P and K, Mg is considered as the other key element which can affect the yield of potato (Djeugap *et al*., 2014).Mg supply during fertilization is often neglected despite its key functions in growth and physiology of crops

(Cakmak and Yazici, 2010; Yakimenko and Naumova, 2021). Importantly, nutrient requirement may vary between potato varieties, but farmers tend to apply the same amount of fertilizer for all varieties ignoring the variety-specific needs. Certain varieties may require low nutrient inputs compared to others. All these facts highlight the need of identifying variety-specific need of fertilizer input with correct $N:P_2O_5:K_2O$ ratio in order to increase fertilizer use efficiency resulting in greater yield and avoiding wastage and environmental damage.

The present study reports the results of two field experiments. The Experiment I examined the possibility of altering tuber shape of potato variety Royal into long-oval shape, while maximizing the yield by changing intra-row spacing and applying GA_3. The Experiment II aimed to identify the best $N:P_2O_5:K_2O$ ratio for higher growth and yield performances of potato variety Royal.

Methodology

Experiment site

Two field experiments were carried out in a farmer field (6°56'41.0" N 80°46'40.6" E) in Nuwara-Eliya district, Sri Lanka where the elevation is 1,889 m above mean sea level. Average annual temperature and annual rainfall of the area are 19.1 °C and 2,550 mm, respectively. Major soil type was Red Yellow Podzolic (RYP).

Planting material

Potato variety Royal was cultivated in *Maha* season of 2021. The entire land was prepared following primary and secondary tillage practices.

Soil sampling

Representative soil samples were collected up to cm depths from 10-15 places in the field and analyzed for available N, available P, and exchangeable K contents before planting.

Agronomic practices

The optimal pH range for growing potatoes is 5.5-6.5 (Department of Agriculture, Sri Lanka, 2021). Therefore, lime was added to the soil in order increase pH value up to pH 5.5-6.5. Thereafter, the land was demarcated into two blocks to carry out two experiments: Experiment I and Experiment II, as described below. In both experiments, seeds were treated with a fungicide solution (2 g L^{-1} Carbendazim) prior to planting with the purpose of avoiding fungal attacks. Planting was carried out on a sunny day. Fungicide solutions were added once in five days to avoid fungal diseases such as late blight. Water was applied by considering moisture level of the soil. Fertilizer was applied according to Table 1 for Experiment II. All treatments of Experiment I received fertilizer based on the recommendation of the Agriculture Research Station, Seetha-Eliya, Sri Lanka (T1: Control; Table1).

Table 1. Treatments and their respective $N:P_2O_5:K_2O:MgO$ ratios applied as basal dressing (753.6 kg ha^{-1}) and the total amounts of N, P_2O_5, K_2O and MgO received by each treatment as basal + top dressings.

Treatment	Inorganic fertilizer (Basal dressing)		Organic manure (t ha^{-1})	Total amount (Basal + top dressing*) (kg ha^{-1})			
	N: P_2O_5: K_2O: MgO ratio	Rate (kg ha^{-1})		N	P_2O_5	K_2O	MgO
T1 (Control)	8:3.5:8.5:0	753.6	25	201.6	137.1	192.3	0.0
T2	8:3.5:8.5:0	753.6	0	201.6	137.1	192.3	0.0
T3	12.5:21:12:0	753.6	25	144.6	194.0	156.8	0.0
T4	9:19:12:0	753.6	25	119.7	180.2	157.8	0.0
T5	9:10:16:1	753.6	25	119.7	112.4	187.8	7.4

**Top dressing was applied uniformly for all the treatments at a rate of 372.2 kg ha^{-1} ($N:P_2O_5$: K_2O: MgO; 14: 10: 18:0)*

Experimental design

Experiment I: Assessing the effect of intra-row spacing and GA_3, concentration on growth, yield, tuber shape and other quality attributes of potato variety Royal

Treatments were arranged according to two-factor factorial randomized complete block design (RCBD): Factor 1 was intra-row spacing (15, 20, 25, 30, and 35 cm) and factor 2 was GA_3 concentration (0, 150, 200, and 250 ppm; foliar-applied at bulking stage). Inter-row spacing was kept at constant distance of 45 cm. There were 4 replicates for each treatment combination and each replicate consisted with 12 plants. 25 x 45 cm plant spacing without GA_3 application was the control.

Experiment II: Assessing the growth and yield responses of potato variety Royal to different ratios of N: P_2O_5: K_2O fertilizer

Different ratios of N:P_2O_5:K_2O:MgO (basal dressing) were used as treatments and they were arranged according to RCBD (Table 1). The fertilizer recommendation for potato given by the Agriculture Research Station, Seetha-Eliya, Sri Lanka was the control (T1). All treatments except T2 received organic manure at a rate of 25 t ha^{-1}.

Measurements

Experiment 1

Growth parameters such as plant height, number of compound leaves, and stems per plant were recorded. Leaf greenness was measured using a SPAD meter, and the number of stolons was also recorded. These parameters were assessed 45 days after planting. Tuber yield per plant, tuber yield per unit land area, number of long-oval shaped tubers per plant (Figure 1), and tuber dry weight were measured as yield and quality parameters at harvest (120 days after planting).

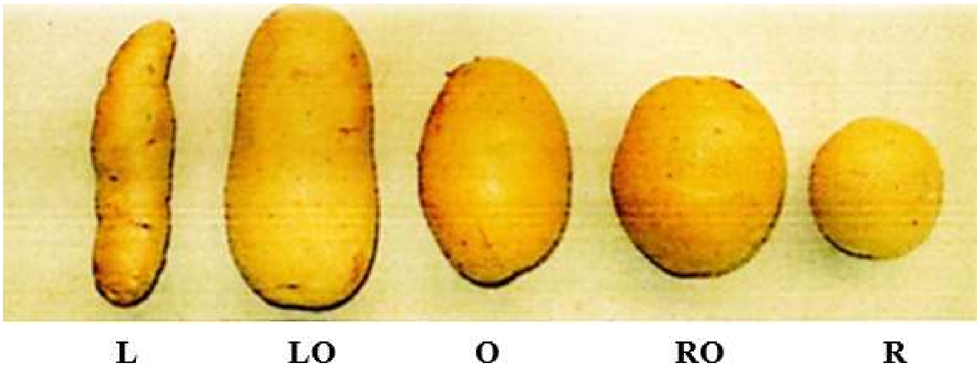

Figure 1. Categorization of potato tuber based on their shape. L: Long; LO: Long-oval; O: Oval; RO: Round-oval; R: Round. Long-oval shape is preferred for the processing industry (Source: Den Hartigh Potatoes, Screening Evaluation: Evaluation Protocol, 2021).

Experiment II

Total yield per unit land area, total number of tubers per plant and number of marketable tubers (excluding rotten, cracked and deformed tubers) per plant were measured at harvest (120 days after planting). A cost analysis was conducted for each fertilizer treatment to compare the application costs across the different treatments.

Data Analysis

Data were analysed according to two-way Analysis of Variance (ANOVA) in Experiment I and one-way ANOVA in Experiment II using Minitab 17 statistical software. The Tukey's mean comparison test was used to compare mean values in both experiments.

Results and discussion

Experiment 1: Assessing the effect of intra-row spacing and GA3 concentration on growth, yield, tuber shape and other quality attributes of potato variety Royal

Yield and tuber shape

Only the main effects of intra-row spacing and GA_3 application had a significant *(P<0.05)* effect on number of long-oval shaped tubers per plant (Table 2). However, their interaction effect was not significant *(P>0.05).* Higher number of long-oval shaped potato tubers were found in 25, 30, 35 cm intra-row spacing and it was statistically similar to 15 cm intra-row spacing. Application of 200 ppm GA_3 recorded the highest number of long-oval shaped tubers per plant; it is a 62% increment compared to the non-applied control (0 ppm GA_3). Tuber shape is known to impact peeling and trimming efficiency during processing (Abong *et al*., 2010). Tuber shape influences the length of French fries where long-oval shape is preferred by processors due to less wastage during processing. Tuber shape influences the length of French fries, with processors preferring long-oval shapes due to less wastage during processing. This shape produces long, desirable fries (Abong *et al*., 2009).

Figure 2. Deformed or misshapen tubers of plants treated with GA_3 at a concentration of 250 ppm

Table 2. Effect of intra-row spacing (IRS) and GA_3 application on tuber yield and number of long-oval shaped tubers of potato variety Royal. Inter-row spacing; constant as 45 cm.

Main effect	Yield per plant (g plant^{-1})	Yield per unit land area (kg m^{-2})	No. of long-oval shaped tubers
Intra-row spacing (IRS; cm)			
15	590.6±41.7^{b}	8.7±5.8^{a}	1.1±0.1^{a}
20	688.1±40.1^{ab}	7.6±4.7^{ab}	0.6±0.1^{b}
25	700.2±36.4^{ab}	6.2±3.2^{bc}	1.2±0.1^{a}
30	715.1±35.4^{ab}	5.2±2.9^{cd}	1.2±0.1^{a}
35	739.4±33.0^{a}	4.6±2.9^{d}	1.2±0.1^{a}
GA_3concentration (ppm)			
0	735.0±32.0	7.1±4.5	0.8±0.1^{c}
150	638.0±39.1	6.0±3.1	0.8±0.1^{bc}
200	672.5±38.1	6.2±3.2	1.3±0.1^{a}
250	701.1±36.8	6.6±3.8	1.2±0.1^{ab}
P value			
IRS	0.033	0.001	0.008
GA_3	0.150	0.142	0.001
IRS x GA_3	0.068	0.288	0.068

Values are means ± standard error of mean. Means followed by different letters within each column are significantly different at P = 0.05

Tuber shape response to GA_3 is consistent with the findings of Alexopoulos *et al*. (2017) who reported GA_3 induced changes in tuber shape. According to their study, GA_3 application during early growth stage resulted in more elongated tubers. However, GA_3 did not affect tuber shape when applied during later stages of growth. Bodlaender and Van de Waart (1989) found that plants applied with low dosage of GA_3 during stolon growth produce slightly elongated tubers and those applied with high dosage during tuber initiation produce long and curved tubers. Similar deformations have been reported previously by Sharma et al. (1998) and Caliskan *et al*. (2021). We also found significantly *(P<*0.05*)* higher number of deformed tubers with 250 ppm GA_3. In our study, GA_3 was applied at the bulking stage, a time when tubers were already initiated. This may be a possible reason for the shape abnormalities observed in some tubers especially at 250 ppm. The findings thus emphasize the importance of applying the correct GA_3 dosage at correct time for obtaining desired quality attributes, particularly the tuber shape. Further investigation is needed to identify the correct time of GA_3 application.

Interaction effect between intra-row spacing and GA_3 for tuber yield per plant and per unit land area were not significant (*P>0.05*) (Table 2). Tuber yield per plant increased as intra-row spacing increased but yield per unit land area decreased with increasing plant spacing due to low plant density. For example, tuber yield per unit land area decreased by 47% and yield per plant increased by 25% as intra-row spacing increased from 15 cm to 35 cm. These results are consistent with previously reported plant spacing responses of potato by Masarirambi *et al*. (2012) who reported an increase in tuber yield per unit land area with increasing density (closer plant spacing). This effect may be due to the increased inter-plant competition for water, light and nutrients and less room for root or tuber development at closer plant spacing (Masarirambi *et al*., 2012). GA_3 application had no significant *(P>*0.05*)* effect on tuber yield which is consistent with previous findings by Alexopoulos *et al*. (2017) where foliar-applied GA_3 has no significant effect on total weight (yield) of tubers per plant despite a reduction in mean tuber weight. This is in contrast to some other previous studies which have demonstrated inhibition of tuberization (Lovell and Booth, 1967; Kumar and Wareing, 1974; Mensel, 1980; Hannapel, 1985) and reduction of potato yield (Sharma *et al*., 1998; Alexopoulos *et al*., 2006) in response to exogenous application of GA_3.

Table 3: Effect of intra-row spacing and GA_3 application on growth parameters of potato variety Royal as at 45 days after planting (DAP). Inter-row spacing; constant as 45 cm.

Main effect	Plant height (cm)	No. of compound leaves per plant	No of stems	Greenness of leaves (SPAD value)
Intra-row spacing (IRS; cm)				
5	46.9±1	35±2	3±2	48.4±0.2
20	46.9±1	36±1	3±1	49.3±0.5
25	46.7±1	39±3	4±2	50.2±0.3
30	45.2±1	39±1	4±1	51.0±0.4
35	43.0±1	40±1	3±2	48.7±0.6
GA_3 concentration (ppm)				
0	47.5±1	40±1	3±1	51.0±0.8
150	42.8±1	33±2	3±1	49.4±0.8
200	44.2±1	38±1	3±2	50.7±0.5
250	46.4±1	38±3	4±2	51.0±0.6
P value				
IRS	0.681	0.745	0.359	0.916
GA_3	0.125	0.382	0.131	0.588
IRS x GA_3	0.752	0.587	0.543	0.665

Experiment II: Assessing the growth and yield responses of potato variety Royal to different ratios of $N:P_2O_5:K_2O$ fertilizer

Growth and yield parameters

$N:P_2O_5:K_2O$ ratio had no significant *(P>0.05)* effect on growth parameters such as plant height, number of compound leaves, number of shoots, number of stolons and leaf greenness (Table 4). None of the yield parameters were significantly *(P>0.05)* affected by the different fertilizer ratios (Table 5).

Table 4. Effect of different ratios of $N:P_2O_5:K_2O$ fertilizer on growth parameters of potato variety Royal as at 45 days after planting (DAP). Inter-row spacing; constant as 45 cm.

Treatment	Growth parameter				
	Plant height (cm)	No. of compound leaves	No. of stems	Greenness of leaves (SPAD value)	No. Of stolons
T1	49.7±1	40±3	4±1	46.8±0.6	9±1
T2	52.6±1	47±2	4±1	52.7±0.7	6±4
T3	53.2±1	43±4	4±2	52.0±0.3	2±3
T4	47.8±1	47±2	3±2	54.3±0.4	4±4
T5	46.0±1	39±4	4±1	52.4±0.5	3±2
P Value	0.115	0.229	970	0.825	0.724

Farmers tend to apply more than the recommended levels of N fertilizers ignoring the actual requirement of the crop (Lemaire et al., 1997). Certain varieties may require low N rates compared to other varieties. Nitrogen, when not absorbed by crops or microorganisms, undergoes various processes that result in a considerable amount of it being lost causing economic and environmental impacts (Kołodziejczyk et al., 2014). Moreover, excess N fertilizer applied at or before tuberization can extend the vegetative growth and delay tuber development, decreasing tuber yield. Too much N applied later in the season may delay tuber maturation, lowering yield and quality. On the other hand, low N application at any time during the season can decrease tuber yields and profitability (Rahemi et al., 2005). Therefore, application of variety-specific N rates is important to avoid over fertilization and to reduce the cost of N application. In our study, the T5 treatment used 41% less nitrogen (N), 18% less phosphorus (P_2O_5), and 2% less potassium (K_2O) compared to the control (Table 1), which follows the blanket fertilizer recommendation for potatoes provided by the Agriculture Research Station, Department of Agriculture, Seetha-Eliya, Sri Lanka. Despite the reduced inputs, T5 produced a yield similar to that of the control treatment. The T1 recommendation does not account for variety-specific fertilizer requirements.

Table 5. Potato tuber yield per unit land area, yield per plant, number of tubers per plant and number of marketable tubers per plant under different fertilizer ratios of $N:P_2O_5:K_2O$.

Treatment (N: P_2O_5: K_2O ratio)	Yield per unit land area(kg^{-2})	Yield per plant (g plant^{-1})	No. of tubers per plant	No. of marketable tubers per plant
T1	4.8±3.3	733.9±41.1	7.6±0.4	6.6±0.3
T2	4.1±3.5	731.1±38.2	8.5±0.3	7.6±0.3
T3	5.8±3.3	732.2±35.0	7.9±0.3	6.8±0.3
T4	4.4±3.2	667.0±29.4	7.4±0.2	6.1±0.2
T5	5.1±3.5	644.8±28.5	6.2±0.1	5.5±0.2
P value	0.204	0.753	0.170	0.172

According to a cost analysis based on the maximum retail prices of inorganic fertilizers in October 2024 (Table 5), the cost of the T5 treatment was approximately Rs. 169,537 per hectare, compared to Rs. 211,287 for the T1 (control). Accordingly, the T5 treatment was 29% less expensive in terms of fertilizer cost compared to the control. Thus. this lower nutrient input (T5) would be both cost-effective and environmentally friendly, particularly for potato varieties with lower nutrient demands, such as Royal.

Table 6. Cost analysis of inorganic fertilizers per hectare under different fertilizer treatments.

Treatment	Total Nutrients applied (kg/ha) (Basal+top dressing)				Total Fertilizer requirement (kg/ha)				Cost (Rs/ha)
	N	P_2O_5	K_2O	MgO	Urea (46% N)	TSP (46% P_2O_5)	MOP (60% K_2O)	Epsom Salt (16% MgO)	
T1	201.6	137.1	192.3	0	438.3	298.0	320.5	0	211,287.50
T2	201.6	137.1	192.3	0	438.3	298.0	320.5	0	211,287.50
T3	144.6	194	156.8	0	314.3	421.7	261.3	0	206,238.41
T4	119.7	180.2	157.8	0	260.2	391.7	263.0	0	189,374.35
T5	119.7	112.4	187.8	7.4	260.2	244.3	313.0	46.2	169,537.39

Note: The unit costs (Rs/kg) of urea, TSP, MOP, and Epsom salts are Rs. 187, 235, 185, and 120, respectively, based on the maximum retail prices as of October 2024.

Inclusion of MgO in T5 may have contributed for better yield performances even at low NPK levels. This confirms the previous findings indicating the positive impact of Mg supply during fertilization in potato (Wang *et al*., 2020; Yakimenko and Naumova, 2021). P is the second most limiting nutrient for potato crop after N (Mokrani *et al*., 2018). However, when the application of P exceeds the amount of P removed in harvested products, it can be accumulated in soil posing a long-term risk. Therefore, P should be managed carefully, due to the fact that P is directly associated with surface water pollution when runoff occurs. When considering K, T5 treatment had moderate amount of K_2O (187.84 kg ha^{-1} of K_2O) compared to other treatments. Potato requires relatively high amount of K to get ideal yield and quality (Li *et al*., 2015; Torabian *et al*., 2021). K is known to facilitate assimilate translocation to the tubers which could enhance tuber bulking capacity, tuber biomass and yield (Moinuddin and Bansal, 2005; Torabian *et al*., 2021). However, there is a controversy within the literature on the impact of K application on tuber yield. Some scientists found that K application does not always increase potato yield (Rosen *et al*., 2014; Kang *et al*., 2014). This implies that yield responses of potato to K fertilization may depend on many factors such as soil exchangeable K level, petiole K concentration, crop removal amount, soil conditions, management practices, climatic conditions, and potato variety (Locascio *et al*., 1992; Torabian *et al*., 2021). Therefore, these factors should be considered in making a rational K fertilizer recommendation for potato (Torabian *et al*., 2021).

Conclusion

The potato variety Royal is suitable for processing industry to make French fries and it requires long-oval shaped tubers to avoid wastages in the processing operations. When considering the required tuber shape *i.e*. the long oval shape, closer intra-row spacing (15 cm) along with 200 ppm foliar application of GA_3 can be recommended for potato variety Royal which also gives the highest yield per unit land area. With respect to nutrient requirement, $N:P_2O_5:K_2O:MgO$ ratio of 9:10:16:1 for basal (753.6 kg ha^{-1}) and 14:10:18:0 for top dressings (372.2 kg ha^{-1}) at 25 days after planting, supplemented with organic manure (25 t ha^{-1}), can be recommended for variety Royal based on the findings of our study. The selected fertilizer ratio with reduced inputs of N and P_2O_5, performed well without compromising yield, demonstrating that lower nutrient inputs can still achieve optimal results. This approach may have a positive environmental impact by reducing the risk of excess nutrient buildup in the soil and leaching, particularly for a potato variety like Royal, which has lower nutrient demands. Moreover, the selected fertilizer ratio is cost-effective in terms of inorganic fertilizer cost compared to the control. These findings will be useful for the potato growers to cater to the need of the potato processing industry.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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