



Effect of Planting Dates on Growth and Yield of Potato (*Solanum tuberosum* L.) Varieties at Rampur, Chitwan

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Received: April 25, 2025
Revised: August 10, 2025
Published: December 31, 2025

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Publisher: Agronomy Society of Nepal (ASoN)



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ABSTRACT

Potato productivity in Nepal is highly influenced by planting time and varietal adaptability to local agro-climatic conditions. A field experiment was conducted at the Horticulture Farm of Agriculture and Forestry University, Rampur, Chitwan, from September 2021 to February 2022 to evaluate the effect of different planting dates on the growth and yield performance of two potato varieties, Cardinal and MS 42.3. The experiment was laid out in a two-factor factorial randomized complete block design with three replications, comprising four planting dates (September 30, October 15, October 30, and November 15). Growth parameters including emergence, stem number, plant height, leaf number, canopy diameter, and days to physiological maturity, along with yield attributes such as number of tubers per plant, marketable and unmarketable yield, total yield, tuber grading, and dry matter content were recorded and analyzed. Planting date significantly ($p < 0.05$) influenced most growth and yield parameters, with mid-October planting producing superior vegetative growth and the highest marketable (30.45 mt/ha) and total tuber yield (31.62 Mt ha⁻¹), followed by late October planting, while early and late plantings resulted in comparatively lower performance. Among the varieties, Cardinal produced significantly ($p < 0.001$) higher marketable (30.14 Mt ha⁻¹) and total yield (31.51 Mt ha⁻¹), whereas MS 42.3 produced more tubers per plant (10.62). The study suggests that planting potato around mid-October using the variety Cardinal is most suitable for achieving higher yield under the agro-climatic conditions of Rampur, Chitwan.

Keywords: Growth performance, planting date, potato, tuber yield, variety

How to cite this article:

Gurung M and HN Giri. 2025. Effects of Planting Dates on Growth and Yield of Potato (*Solanum tuberosum* L.) Varieties at Rampur, Chitwan. *Agronomy Journal of Nepal* 9(1): 30-43. DOI: <https://doi.org/10.3126/ajnl.v9i1.90902>

INTRODUCTION

Potato (*Solanum tuberosum* L.), a member of the Solanaceae family, native to Peruvian - Bolivian Andes, is one of the highly commercialized crops globally. Most of the common cultivars of potatoes are tetraploid ($2n = 4x = 48$) with a basic chromosome number of 12. However, there are cultivated species belonging to diploid ($2n = 2x = 24$) to pentaploid ($2n = 5x = 60$) levels (Watanabe, 2015). Potato is a wholesome food containing starch (16.1 g 100 g⁻¹), protein (2.1 g 100 g⁻¹), vitamin C (17.1 mg 100 g⁻¹), potassium (443 mg 100 g⁻¹) and essential amino acids (lysine, methionine, and cysteine). It also contains a good amount of niacin, thiamin, potassium, phosphorous, iron, and calcium (McGill et al 2013, Bártová et al 2015). Because of its exceptional nutritional quality and its contribution to the world food transition, it was declared as Food of the Future in 2008 also referred to as Food Security Crop by FAO (Devaux et al 2014, Hussain 2016). In Nepal, 3,487,816 mt of potatoes are produced in 203,812 ha with the productivity of 17.11 Mt ha⁻¹ (MoALD 2024).

Nepal is a landlocked country with large environmental variation. Either early planting or late planting can result in lower yield because the probability exists that unfavorable climatic conditions or stress can occur after planting or during the growing season (Sandhu et al 2013). Temperature stress and drought stress affect the vegetative growth and tuber production in three ways by affecting the rate of photosynthesis, by affecting the source: sink relationship, and by increasing the amount of reactive oxygen species (Finkel and Holbrook 2000, Muthoni and Kabira 2016). In addition, low temperature during the cropping period increases the outbreak of late blight of potatoes caused by *Phytophthora infestans* causing more than 75% yield loss in hills and 50-90% loss in terai region (Shrestha 2000, Sharma and KC 2004).

Such environmental stresses cannot be manipulated under field conditions but optimization of planting date and selection of appropriate varieties adaptable to the environment helps to escape such stress and support meeting

the optimum thermal requirements of the crop at various phenological stages to avoid any adverse effects on the yield and quality (Gupta et al 2017). However, the selection of planting date is highly location specific and the planting date suitable to one region may not be suitable for another region due to the variation in weather conditions from place to place (Haile et al 2015). Another strategy to cope with the stress is the selection of the appropriate variety at the particular location as per their adaptability (Dash et al 2018).

It is necessary to find out location-specific variety and appropriate planting time to efficiently utilize moisture, nutrient and solar radiation (Adhikari et al 2020). Since limited work has been done to find suitable variety and planting time under the Rampur, Chitwan condition, the research was conducted from September 2021 to February 2022 to find out the suitable variety and planting date for potato cultivation to find out the suitable variety and planting date for potato cultivation.

MATERIALS AND METHODS

Experimental site description

The field experiment was conducted at the Horticulture Farm of Agriculture and Forestry University, Rampur, Chitwan from September 2021 to February 2022. The experimental site is located at 228 masl. Geographically, it is located at 27°40' N latitude and 84°19' E longitude.

Physico-chemical properties of the experimental soils

Composite soil samples of tillage layer (24 cm depth) of experimental plots were taken before planting seed tubers to analyze soil organic matter, pH, soil texture, total nitrogen, available phosphorous, and available potassium. The samples were air-dried and sieved through a 2 mm sieve for analysis. For the analysis, the sample was sent to Lumbini Agro-Environment Lab Pvt. Ltd. located at Sunwal-12, Nawalparasi-West. Total nitrogen, available phosphorous, and available potassium were analyzed by Kjeldahl method (1883), Modified Olsen's bicarbonate method (1954), and flame photometer (1993) method respectively. Soil organic matter was analysed by Walkley and Black (1934) method and soil p^H by electrometric method.

The soil of the experimental field was sandy loam with the p^H value of 6.5, 3.52% organic matter, 0.091% total nitrogen, 24.47 kg ha⁻¹ available phosphorus, and 376.32 kg ha⁻¹ available potassium. The physico-chemical properties of soils before establishing the field experiment are presented in table 1.

Table 1. Physico-chemical properties of soil before establishing the field experiment

S.N.	Properties	Test method	Value
1	p ^H	Electrometric method	6.5
2	Soil organic matter (%)	Walkley and Black (1934)	3.52
3	Total nitrogen (%)	Kjeldhal (1883)	0.091
4	Available phosphorous (kg ha ⁻¹)	Modified Olsen's bicarbonate (1954)	24.47
5	Available potassium (kg ha ⁻¹)	Flame-photometer (1993)	376.32
7	Textural class	Feel	Sandy loam

(Source: Lumbini Agro-Environment Lab Pvt. Ltd., 2021)

Agro-meteorological data of an experimental site

The data on maximum temperature, minimum temperature, precipitation, and relative humidity (RH) were collected from the weather station of the National Maize Research Program (NMRP), Rampur, Chitwan. In September 2021, the maximum temperature of 33.4°C, minimum temperature of 24.6°C, rainfall of 105.5 mm, and relative humidity of 85.7% were recorded. Similarly, the maximum temperature of 31.74°C, minimum temperature of 24.1°C, 162.3 mm rainfall, and 85.8% relative humidity were recorded in October 2021. Likewise, the maximum temperature of 27.7°C, minimum temperature of 16.3°C, no rainfall, and 84.7% relative humidity were recorded in November 2021. Similarly, the maximum temperature of 23.8°C, minimum temperature of 11.6°C, 29.2 mm rainfall, and 95% relative humidity were recorded in December 2021. In consideration of January 2022, the maximum temperature of 28.05°C, the minimum temperature of 16.13°C, and 84.7% relative humidity were recorded. Similarly, in February 2022, the maximum temperature of 23.5°C, minimum temperature of 11.7°C, 51.2 mm rainfall, and 78.4% relative humidity were recorded. During the experimental period, a total rainfall of 348.2 mm was recorded.

Treatments details

Two factors were used in the field experiment. Varieties were used as first factor and planting dates as the second factor. The first factor had two levels: Cardinal and MS 42.3 whereas the second factor had four levels: September 30, October 15, October 30, and November 15. The detail about the factors used in the experiment is given in Table 2.

Table 2. Factors and their levels used in the experiment at Rampur, Chitwan, 2021/022

Varieties	Planting dates
Cardinal	September 30
MS 42.3	October 15
	October 30
	November 15

Treatment combinations

Treatment combinations were made by using two levels of varieties and four levels of planting dates. Altogether eight different treatment combinations were made by combining each level of varieties with every other level of planting dates. The details of the treatment combinations and treatments are given in Table 3.

Table 3. Treatment combinations and treatments details of the experiment at Rampur, Chitwan, 2021/022

Treatments	Treatment combinations
T ₁	Cardinal × September 30
T ₂	Cardinal × October 15
T ₃	Cardinal × October 30
T ₄	Cardinal × November 15
T ₅	MS 42.3 × September 30
T ₆	MS 42.3 × October 15
T ₇	MS 42.3 × October 30
T ₈	MS 42.3 × November 15

Experimental design and layout of the experiment

The experiment was laid out in two factor-factorial Randomized Complete Block Design (Factorial-RCBD) with eight treatments and three replications. The total area of the experimental field was 224.75 m² which were divided into three equal blocks. Each block was divided into eight plots where eight treatment combinations were allotted randomly. There were twenty-four-unit plots and the size of each plot was 3.5 m × 1.25 m. The distance between the blocks and plots were 1.0 m and 0.5 m respectively. The area of each individual plot was 4.38 m². In each plot, twenty-five plants were planted at the spacing of 70 cm × 25 cm. Among twenty-five plants, middle five plants were selected as sample plants.

Plant materials

Undamaged and bruise-free potato seed tubers (41-50 g) of Cardinal and MS 42.3 were purchased from Kiran Enterprises located in Saheedchowk, Chitwan. The seed tubers were kept in a clean and well-ventilated room for sprouting until the final planting was done.

Cultural practices**Land preparation and field layout**

The field was harrowed thrice until the land became suitable for planting seed tubers. Primary tillage was done on September 20, 2021. The weed residues were removed from the experimental field after tillage. In addition, the weeds present in the periphery of the field (up to 1 m outside the field) were removed manually. For layout, the initial demarcation was done before the land preparation but the final layout of the experimental plot was done after the land preparation on September 25, 2021. Undamaged and bruise-free seed tubers of 41-50 g were planted on raised beds. Five rows of about 10 cm deep were made on each plot and the seed tubers were planted at the spacing of 70 cm × 25 cm. Potatoes were planted at their respective planting dates. The recommended dose of urea, DAP, and MOP fertilizer for potatoes is 7:11:5 kg ropani⁻¹ and compost at the rate of 1500 kg ropani⁻¹ was applied during the field preparation and also in different two split doses (MoALD 2021). Hoeing, weeding and irrigation activities was also done throughout the growing period as per need. Tubers were harvested when 70% of the plants turned yellow. Careful digging was done with the help of a hoe to prevent any damage to the tubers. The tubers of sample plants were kept in separate trays to prevent mix-up. After harvesting, tubers were graded on the basis of weight and dimension.

Data collection

Various growth parameters such as days to tuber emergence, stem diameter, plant height, canopy diameter, and days to physical maturity were recorded throughout the experiment period. Similarly, various yield parameters like marketable yield (Mt ha⁻¹), unmarketable yield (Mt ha⁻¹), and total yield (Mt ha⁻¹) were calculated during the harvesting of the potato tubers. Similarly, dry matter content and grading on the basis of weight was calculated as per followings:

Dry matter content of the tubers

At first 200 g of the tubers were selected, cut into pieces, and dried under sunshine for a day. After sun drying, the cut pieces of tubers were kept in the paper bag and kept in the oven for drying at 70°C. Tuber pieces were dried in an oven until the constant weight was obtained. The final weight of the sample was measured after the constant weight was achieved. The dry matter content of potato tubers was computed by the formula given below:

$$\text{Dry matter content of the tubers (\%)} = \frac{\text{Dry weight of potato tubers (g)}}{\text{Fresh weight of potato tubers (g)}} \times 100 \dots\dots\dots(\text{Eq.1})$$

Grading on the basis of weight

Tubers from the sample plants were graded into three groups considering the weight of the tubers: <25 g (small), 25-50 g (medium), and >50 g (large) (Adhikari et al 2020, Lamsal et al 2022). The weight of the tubers was measured with the help of weighing balance.

Statistical analysis

The collected data were processed by MS Excel 2016 and analyzed by using R-studio software version 3.4.5. All the recorded data were subjected to analysis of variance (ANOVA) and Duncan's multiple Range Test (DMRT) at 5 % level of significance was used for mean comparison (Gomez and Gomez 1984).

RESULTS

Growth parameters

Days to tuber emergence

The days to 50% tuber emergence did not differ significantly between varieties while the days to 50% emergence of tuber differed significantly at $p < 0.001$ among planting dates (Table 4).

Table 4. Effect of varieties and planting dates on days to emergence of potato (*Solanum tuberosum* L.) tuber at Rampur, Chitwan, 2021/022

Treatments	Days to 50% emergence of tuber
Varieties	
Cardinal	16.75
MS 42.3	17.25
SEm (\pm)	0.41
F-test	ns
Planting dates	
September 30	19.83 ^a
October 15	17.67 ^b
October 30	16.50 ^b
November 15	14.00 ^c
SEm (\pm)	0.58
F-test	***
LSD _{0.05}	1.76
CV, %	8.35
Grand mean	17.00
Varieties \times Planting dates	ns

Means with same letter in column are not significantly different at $p = 0.05$ by DMRT. ns and *** indicate not significant at 5% ($p > 0.05$) and significant at 0.1% ($p < 0.001$) respectively. LSD = Least significant difference, CV = Coefficient of variation, and SEm (\pm) = Standard error of mean.

The maximum of 19.83 days were required for 50% tuber emergence when planted on September 30 which was followed by October 15 and October 30. However, significantly minimum of 14.00 days were required for 50% tuber emergence when planted on November 15. However, the interaction effect between varieties and planting dates on days to 50% tuber emergence was found statistically non-significant.

Stem diameter

The stem diameter did not differ significantly between the varieties at different growth stages of the potato (Table 5). The stem diameter differed significantly at $p < 0.05$ at all growth stages of potatoes among planting dates (Table 5). At 30 DAP, 45 DAP, 60 DAP, 75 DAP, and 90 DAP, the significantly thickest stem diameter of 8.34 mm, 8.56 mm, 8.81 mm, 9.53 mm, and 9.62 mm respectively was recorded on October 15 which was statistically at par with September 30 and October 30. However, significantly thinnest stem diameter of 6.80 mm, 7.04 mm, 7.34 mm, 8.13 mm, and 8.20 mm was recorded at 30 DAP, 45 DAP, 60 DAP, 75 DAP, and 90

DAP respectively on November 15. However, the interaction effect between varieties and planting dates on stem diameter was found statistically non-significant at different growth stages of potato plants.

Table 5. Effect of varieties and planting dates on stem diameter of potato (*Solanum tuberosum* L.) at Rampur, Chitwan, 2021/022

Treatments	Stem diameter (mm)				
	30 DAP	45DAP	60 DAP	75 DAP	90 DAP
Varieties					
Cardinal	7.99	8.23	8.49	9.17	9.32
MS 42.3	7.72	8.01	8.18	8.63	8.76
SEm (\pm)	0.22	0.27	0.26	0.20	0.21
F-test	ns	ns	ns	ns	ns
Planting dates					
September 30	8.17 ^a	8.51 ^a	8.61 ^a	9.10 ^a	9.32 ^a
October 15	8.34 ^a	8.56 ^a	8.81 ^a	9.53 ^a	9.62 ^a
October 30	8.11 ^a	8.35 ^a	8.57 ^a	8.83 ^{ab}	9.03 ^{ab}
November 15	6.80 ^b	7.04 ^b	7.34 ^b	8.13 ^b	8.20 ^b
SEm (\pm)	0.32	0.38	0.36	0.29	0.30
F-test	*	*	*	*	*
LSD _{0.05}	0.96	1.15	1.09	0.88	0.90
CV, %	9.84	11.53	10.61	7.96	8.00
Grand mean	7.86	8.12	8.33	8.90	9.04
Varieties \times Planting dates	ns	ns	ns	ns	ns

Means with same letter in column are not significantly different at $p = 0.05$ by DMRT. ns and * indicate not significant at 5% ($p > 0.05$) and significant at 5% ($p < 0.05$) respectively. LSD = Least significant difference, CV = Coefficient of variation, SEm (\pm) = Standard error of mean, and DAP = Days after planting

Plant height

The plant height did not differ significantly between the potato varieties but the plant height differed significantly among planting dates (Table 6).

Table 6. Effect of varieties and planting dates on plant height of potato (*Solanum tuberosum* L.) at Rampur, Chitwan, 2021/022

Treatments	Plant height (cm)				
	30 DAP	45DAP	60 DAP	75 DAP	90 DAP
Varieties					
Cardinal	26.74	35.81	42.22	47.54	50.16
MS 42.3	28.34	38.04	44.28	49.28	51.87
SEm (\pm)	1.23	1.31	1.43	1.66	1.59
F-test	ns	ns	ns	ns	ns
Planting dates					
September 30	29.35 ^{ab}	37.94 ^{ab}	44.20 ^b	48.39 ^b	51.39 ^b
October 15	32.36 ^a	43.32 ^a	50.58 ^a	57.31 ^a	59.31 ^a
October 30	25.09 ^{bc}	36.11 ^b	42.74 ^b	47.90 ^b	49.90 ^b
November 15	23.39 ^c	30.32 ^c	35.47 ^c	40.04 ^c	47.45 ^c
SEm (\pm)	1.74	1.85	2.02	2.35	2.25
F-test	*	**	**	**	**
LSD _{0.05}	5.27	5.61	6.13	7.11	6.81
CV, %	15.45	12.28	11.43	11.87	10.79
Grand mean	27.54	36.92	43.24	48.41	51.01
Varieties \times Planting dates	ns	ns	ns	ns	ns

Means with same letter in column are not significantly different at $p = 0.05$ by DMRT. ns, *, and ** indicate not significant at 5% ($p > 0.05$), significant at 5% ($p < 0.05$), and significant at 1% ($p < 0.01$) respectively. LSD = Least significant difference, CV = Coefficient of variation, SEm (\pm) = Standard error of mean, and DAP = Days after planting

The plant height of potatoes differed significantly at $p < 0.05$ among planting dates at 30 DAP whereas the plant height differed significantly at $p < 0.01$ at 45 DAP, 60 DAP, 75 DAP, and 90 DAP (Table 6). At 30 DAP, the significantly tallest plant height of 32.36 cm was recorded on October 15 which was statistically similar to September 30. At 45 DAP, the significantly tallest plant height of 43.32 cm was recorded on October 15 which was statistically similar to September 30. At 60 DAP and 75 DAP, the significantly tallest plant height of 50.58 cm and 57.31 cm respectively was recorded on October 15. Likewise, at 90 DAP, the significantly tallest plant height of 59.31 cm was recorded on October 15 as compared to other planting dates. However, the interaction effect between varieties and planting dates on plant height was found statistically non-significant at different growth stages of potato plants.

Canopy diameter

The canopy diameter differed significantly at $p < 0.05$ at all growth stages between varieties (Table 7). At 30 DAP, 45 DAP, 60 DAP, 75 DAP, and 90 DAP, the significantly widest canopy diameter was recorded on Cardinal as compared to MS 42.3. With the advancement in growth stages, the canopy diameter was increased. At 90 DAP, the widest canopy diameter of 58.43 cm was recorded on Cardinal whereas the narrowest canopy diameter of 53.56 cm was recorded on MS 42.3.

Table 7. Effect of varieties and planting dates on canopy diameter of potato (*Solanum tuberosum* L.) at Rampur, Chitwan, 2021/022

Treatments	Canopy diameter (cm)				
	30 DAP	45DAP	60 DAP	75 DAP	90 DAP
Varieties					
Cardinal	31.19 ^a	40.68 ^a	47.60 ^a	54.17 ^a	58.43 ^a
MS 42.3	26.97 ^b	36.49 ^b	42.36 ^b	49.35 ^b	53.56 ^b
SEm (\pm)	1.24	1.30	1.47	1.42	1.61
F-test	*	*	*	*	*
LSD _{0.05}	3.75	3.94	4.46	4.30	4.90
Planting dates					
September 30	31.13 ^{ab}	41.24 ^{ab}	47.67 ^{ab}	55.15 ^a	59.15 ^a
October 15	33.74 ^a	44.62 ^a	52.62 ^a	58.59 ^a	62.88 ^a
October 30	27.36 ^{bc}	37.22 ^b	42.67 ^{bc}	48.79 ^b	52.08 ^b
November 15	24.09 ^c	31.28 ^c	36.98 ^c	44.51 ^b	49.96 ^b
SEm (\pm)	1.75	1.84	2.08	2.00	2.28
F-test	**	***	***	***	**
LSD _{0.05}	5.30	5.57	6.31	6.07	6.92
CV, %	14.73	11.65	11.33	9.49	9.98
Grand mean	29.08	38.59	44.98	51.76	56.02
Varieties \times Planting dates	ns	ns	ns	ns	ns

Means with same letter in column are not significantly different at $p = 0.05$ by DMRT. ns, *, **, and *** indicate not significant at 5% ($p > 0.05$), significant at 5% ($p < 0.05$), significant at 1% ($p < 0.01$), and significant at 0.1% ($p < 0.001$) respectively. LSD = Least significant difference, CV = Coefficient of variation, SEm (\pm) = Standard error of mean, and DAP = Days after planting

The canopy diameter of potatoes differed significantly at $p < 0.01$ among planting dates at 30 DAP (Table 7). At 30 DAP, the significantly widest canopy diameter of 33.74 cm was recorded on October 15 as compared to other planting dates and was statistically similar to September 30. The canopy diameter differed significantly at $p < 0.001$ among planting dates at 45 DAP, 60 DAP, and 75 DAP (Table 7).

The significantly widest canopy diameter of 44.62 cm, 52.62 cm, and 58.59 cm was recorded at 45 DAP, 60 DAP, and 75 DAP respectively when planted on October 15 which was statistically similar to September 30. Similarly, the canopy diameter varied significantly at $p < 0.01$ among the planting dates at 90 DAP. At 90 DAP, the widest canopy diameter of 62.88 cm was recorded on October 15 which was statistically similar to September 30. However, the interaction effect between varieties and planting dates on canopy diameter was found statistically non-significant at different growth stages of potato plants.

Days to physiological maturity

The days to physiological maturity of potatoes differed significantly at $p < 0.001$ between the varieties (Table 8). Cardinal required significantly fewer days for physiological maturity as compared to MS 42.3. Cardinal required 101.77 days to reach the physiological maturity whereas MS 42.3 days required 109.83 days to reach the physiological maturity.

The days to physiological maturity of potato differed significantly at $p < 0.001$ among planting dates (Table 8). Potatoes planted on October 30 required 112.50 days to reach physiological maturity which was significantly maximum among other planting and statistically similar to October 15. However, significantly minimum days of 99.00 days were required to reach physiological maturity when planted on September 30. However, the interaction effect between varieties and planting dates on days to physiological maturity was found statistically non-significant.

Table 8. Effect of varieties and planting dates on days to physiological maturity of potato (*Solanum tuberosum* L.) at Rampur, Chitwan, 2021/022

Treatments	Days to physiological maturity
Varieties	
Cardinal	101.77 ^a
MS 42.3	109.83 ^b
SEm (\pm)	1.34
F-test	***
LSD _{0.05}	3.29
Planting dates	
September 30	99.00 ^c
October 15	107.87 ^{ab}
October 30	112.50 ^a
November 15	103.83 ^b
SEm (\pm)	1.90
F-test	***
LSD _{0.05}	4.65
CV, %	3.55
Grand mean	105.80
Varieties \times Planting dates	ns

Means with same letter(s) in column are not significantly different at $p = 0.05$ by DMRT. *** indicates significant at 0.1% ($p < 0.001$), LSD = Least significant difference, CV = Coefficient of variation, and SEm (\pm) = standard error of mean

Yield parameters

Different yield parameters such total marketable yield, total unmarketable yield, total yield, and dry matter content of tubers are recorded, presented in the tables, and discussed under the following specific headings.

Marketable yield

Marketable yield differed significantly at $p < 0.001$ between the varieties (Table 9). Cardinal produced significantly higher marketable yield as compared to MS 42.3. Cardinal produced 30.14 Mt ha⁻¹ marketable yield whereas MS 42.3 produced 23.64 Mt ha⁻¹ marketable yield. Marketable yield differed significantly at $p < 0.001$ among planting dates (Table 10). Significantly maximum marketable yield of 30.45 Mt ha⁻¹ was recorded when planted on October 15 which was statistically similar to October 30. However, significantly minimum marketable yield of 22.85 Mt ha⁻¹ was recorded when planted on September 30. However, the interaction effect of varieties and planting dates on marketable yield was found statistically non-significant.

Unmarketable yield

Unmarketable yield differed significantly at $p < 0.01$ between the varieties (Table 9). MS 42.3 produced significantly higher unmarketable yield as compared to Cardinal. MS 42.3 produced 1.80 Mt ha⁻¹ unmarketable yield whereas Cardinal produced 1.37 Mt ha⁻¹ unmarketable yield. Different planting dates varied significantly in terms of unmarketable yield at $p < 0.001$ (Table 9). The highest unmarketable yield of 2.05 Mt ha⁻¹ was recorded on September 30 which was statistically similar to November 15. Significantly lowest unmarketable yield of 1.16 Mt ha⁻¹ was recorded on October 15. However, the interaction effect of varieties and planting dates on unmarketable yield was found statistically non-significant.

Total yield

Total yield differed significantly at $p < 0.001$ between the varieties (Table 8). Cardinal produced significantly higher total yield as compared to MS 42.3. Cardinal produced total yield of 31.51 Mt ha⁻¹ whereas MS 42.3 produced total yield of 25.44 Mt ha⁻¹. Total yield differed significantly at $p < 0.05$ among the planting dates. The highest yield of 31.62 Mt ha⁻¹ was recorded on October 15 which was statistically similar to October 30. However, significantly lowest yield of 24.90 Mt ha⁻¹ was recorded when planted on September 30. However, the interaction effect between varieties and planting dates on total yield was found statistically non-significant.

Dry matter content of the tubers

The dry matter content of potato tubers varied significantly at $p < 0.001$ between varieties (Table 9). Cardinal produced significantly higher dry matter content of potato tubers as compared to MS 42.3. Cardinal produced 26.16% dry matter whereas MS 42.3 produced 24.58% dry matter. The dry matter content of the tubers varied significantly at $p < 0.05$ among different planting dates (Table 9). The maximum dry matter of 26.10% was recorded on October 15 which was statistically similar to October 30 and November 15. However, the minimum dry matter of 24.53% was recorded when planted on September 30. However, the interaction effect between varieties and planting dates was found statistically non-significant on the dry matter content of potato tubers.

Table 9. Effect of varieties and planting dates on marketable, unmarketable, total yield, and dry matter content of tubers of potato (*Solanum tuberosum* L.) at Rampur, Chitwan, 2021/022

Treatments	Unmarketable yield (Mt ha ⁻¹)	Marketable yield (Mt ha ⁻¹)	Total yield (Mt ha ⁻¹)	Dry matter content of tubers (%)
Varieties				
Cardinal	1.37 ^b	30.14 ^a	31.51 ^a	26.16 ^a
MS 42.3	1.80 ^a	23.64 ^b	25.44 ^b	24.58 ^b
SEm (±)	0.08	1.02	1.01	0.23
F-test	**	***	***	***
LSD _{0.05}	0.26	3.10	3.05	0.70
Planting dates				
September 30	2.05 ^a	22.85 ^c	24.90 ^c	24.53 ^b
October 15	1.16 ^b	30.45 ^a	31.62 ^a	26.10 ^a
October 30	1.36 ^b	28.96 ^{ab}	30.32 ^{ab}	25.48 ^{ab}
November 15	1.78 ^a	25.31 ^{bc}	27.09 ^{bc}	25.38 ^{ab}
SEm (±)	0.11	1.44	1.42	0.33
F-test	***	**	*	*
LSD _{0.05}	0.34	4.38	4.31	0.99
CV, %	18.46	13.15	12.23	3.16
Grand mean	1.59	26.89	28.48	25.37
Varieties × Planting dates	ns	Ns	ns	ns

Means with same letter in column are not significantly different at $p = 0.05$ by DMRT. ns, *, **, and *** indicate not significant at 5% ($p > 0.05$), significant at 5% ($p < 0.05$), significant at 1% ($p < 0.01$), and significant at 0.1% ($p < 0.001$) respectively. LSD = Least significant difference, CV = Coefficient of variation, and SEm (±) = Standard error of mean

Grading of potato tubers on the basis of tuber weight

The number of small tubers varied significantly at $p < 0.01$ between the varieties (Table 10). Cardinal produced significantly lower number of small tubers per plant as compared to MS 42.3. Cardinal produced 2.08 small tubers per plant whereas MS 42.3 produced 2.45 small tubers per plant. The number of small tubers varied significantly at $p < 0.001$ among planting dates (Table 10). The maximum number of small tubers per plant was recorded on November 15. Potatoes planted on November 15 produced 2.73 small tubers per plant which was statistically similar to September 30. However, the minimum number of small tubers per plant was recorded on October 15 which produced 1.67 small tubers per plant. However, the interaction effect between varieties and planting dates on the number of small tubers per plant was found statistically non-significant.

The number of medium tubers per plant varied significantly at $p < 0.001$ between the varieties (Table 10). MS 42.3 produced significantly maximum number of medium tubers per plant as compared to Cardinal. Cardinal produced 3.08 medium tubers per plant whereas MS 42.3 produced 4.85 medium tubers per plant. The number of medium tubers per plant varied significantly at $p < 0.001$ among planting dates. The maximum number of medium tubers per plant was recorded when planted on October 15 as compared to other planting dates. Potatoes planted on October 15 produced 5.26 medium tubers per plant. However, the minimum number of medium tubers per plant was recorded when planted on November 15. Potatoes planted on November 15 produced 3.10 medium tubers per plant which was statistically similar to September 30. However, the interaction effect between varieties and planting dates on number of medium tubers per plant was found statistically non-significant.

The number of large tubers varied significantly at $p < 0.01$ between the varieties (Table 10). Cardinal produced significantly higher number of large tubers per plant as compared to MS 42.3. Cardinal produced 3.97 large tubers per plant whereas MS 42.3 produced 3.32 large tubers per plant. The number of large tubers per plant varied significantly at $p < 0.001$ among planting dates. The maximum number of large tubers per plant was recorded when planted on October 15. Potatoes planted on October 15 produced 4.66 large tubers per plant. However, the minimum number of large tubers per plant was recorded when planted on November 15 which produced 2.14 large tubers per plant. However, the interaction effect between varieties and planting dates on the number of large tubers per plant was found statistically non-significant.

Table 10. Effect of varieties and planting dates on grading of potato tubers on the basis of tuber weight per plant of potato (*Solanum tuberosum* L.) at Rampur, Chitwan, 2021/022

Treatments	Grading of tubers on the basis of weight per plant		
	<25 g (Small)	25-50 g (Medium)	>50 g (Large)
Varieties			
Cardinal	2.08 ^b	3.08 ^b	3.97 ^a
MS 42.3	2.45 ^a	4.85 ^a	3.32 ^b
SEm (±)	0.07	0.19	0.13
F-test	**	***	**
LSD _{0.05}	0.20	0.58	0.58
Planting dates			
September 30	2.73 ^a	3.11 ^c	2.14 ^d
October 15	1.67 ^c	5.26 ^a	4.66 ^a
October 30	2.06 ^b	4.38 ^b	4.17 ^b
November 15	2.60 ^a	3.10 ^c	3.62 ^c
SEm (±)	0.09	0.27	0.18
F-test	***	***	***
LSD _{0.05}	0.28	0.81	0.28
CV, %	10.13	16.67	6.30
Grand mean	2.27	3.96	3.64
Varieties × Planting dates	Ns	ns	ns

Means with same letter in column are not significantly different at $p = 0.05$ by DMRT. ns, **, and *** indicate not significant at 5% ($p > 0.05$), significant at 1% ($p < 0.01$), and significant at 0.1% ($p < 0.001$) respectively. LSD = Least significant difference, CV = Coefficient of variation, and SEm (±) = Standard error of mean

DISCUSSION

Growth parameters

Tuber emergence

The days required to 50% tuber emergence did not vary significantly between varieties (Table 4). The result was in agreement with the findings of Shrestha et al (2020). The mean value of days to 50% emergence was comparatively higher for Cardinal as compared to MS 42.3. Such variation in the days to 50% emergence might be due to the availability of genetic variability among the varieties (Abubaker et al 2011, Haile et al 2015).

Days required for 50% tuber emergence varied significantly among planting dates (Table 4). The early planted seed tubers required significantly higher days to 50% emergence as compared to late planted tubers. The maximum days to 50% emergence recorded when planted on September 30 might be due to the presence of growth inhibitors in the physiologically young seed tuber. The result was supported by the findings of Darabi (2013), Gomaa (2014), and Haile et al (2015). Burton and Meigh (1971) also reported the availability of inhibitors of sprout growth such as benzothiazole, 1,4-dimethyl naphthalene, and 1,6-dimethyl naphthalene in the physiologically young seed tubers. The seed tubers planted later became physiologically aged as compared to early planted seed tubers and the amount of such inhibitors became comparatively low which favoured sprout growth. This might be the reason behind the early emergence of seed tubers planted on November 15 as compared to other planting dates.

Stem diameter

The stem diameter did not vary significantly between the varieties (Table 5). However, thicker stem diameter was recorded in Cardinal as compared to MS 42.3 at all growth stages. The variation in stem diameter between the varieties grown under the same conditions might be due to genetic variability and their ability to exploit environmental conditions (Shrestha et al 2020, Keleta et al 2018).

The thickest stem diameter was recorded on potatoes planted on October 15 at all growth stages as compared to other planting dates (Table 5). Too early and too delayed planting caused reduction in the stem diameter. A similar finding was reported by Taha and Roshdy (2021) and Keleta et al (2018). The decrease in stem diameter in the late planted tubers might be due to the availability of low temperature, physiological aging of the seed tubers, and increased number of stems produced per seed tubers (Keleta et al 2018). The increase in the stem diameter in early planting as compared to late planting might be due to warmer temperatures which facilitated better absorption of nutrients and promoted carbohydrate partitioning to the above-ground vegetative parts (Lafta and Lorenzen 1995).

Plant height

The plant height did not vary significantly between the varieties at 30 DAP, 45 DAP, 60 DAP, 75 DAP, and 90 DAP. However, the height of MS 42.3 was higher as compared to Cardinal (Table 6). The difference in plant height under the same growing condition might be due to the genetic makeup of the variety and the greater capacity of plants to absorb nutrients from the soil (Eaton et al 2017, Khanal et al. 2017). Banjade et al (2019) also recorded a similar finding.

Among planting dates, significantly tallest plant height was recorded on October 15 and plant height was comparatively lower in late planting dates at all growth stages (Table 6). Thongam et al (2017), Kumar et al (2019), and Adhikari et al (2020) also recorded a reduction in the plant height with the delayed planting. The reduction in the plant height at the late planted tubers might be due to the occurrence of cooler temperature during the growth period as compared to the early planted ones. Such temperature stress caused poor vegetative growth due to reduced allocation of assimilates to the vegetative parts which ultimately reduced plant height (Adhikari et al 2020). However, the increment in the plant height at early plantings was due to the occurrence of comparatively high temperature at all growth stages. High temperature increases gibberellins content which promotes internodal elongation and ultimately increases the plant height (Pinthus et al 1989).

Canopy diameter

Significantly higher canopy diameter was found in Cardinal as compared to MS 42.3 at all growth stages (Table 7). The ability of plants to produce the number of leaves, size of the leaves, and stems per plant depends upon the genetic makeup and environmental condition which consequently affects canopy diameter (Thapa 2022). Banjade et al (2019) and Panthi et al (2019) also recorded similar finding.

The significantly widest canopy diameter was recorded when planted on October 15 at all growth stages as compared to other planting dates (Table 7). The maximum canopy diameter recorded on October 15 might be due to the congenial environment in terms of temperature and sunny days which might have influenced the vegetative growth influencing canopy diameter. Late planted potatoes experienced comparatively cooler temperature throughout the growing period as compared to other planting dates which created temperature stress. Low temperature stress during the vegetative growth reduced the number and size of leaves due to reduced photosynthesis and reduced photoassimilates partitioning to the vegetative portion which ultimately promoted lower canopy diameter in the late planted tubers (Tsoka et al 2012).

Days to physiological maturity

Significantly higher number of days to physiological maturity were recorded in MS 42.3 as compared to Cardinal (Table 8). The variation might be due to varietal characteristic which is governed by the genetic makeup of the varieties. Musa et al (2009), Zelelew et al (2016) and Asnake et al (2023) also recorded variation in the days to physiological maturity due to the genetic variability among the varieties.

The maximum number of days to reach physiological maturity was recorded when planted on October 30 whereas the minimum was recorded when planted on September 30 (Table 8). The variation might be due to the impact of temperature on the days required for the completion of vegetative and reproductive stages. Potatoes planted on September 30 experienced comparatively higher temperature throughout the growth period which might have caused accelerated photosynthetic and metabolic activities causing a shorter period required for physiological maturity. Thongam et al (2017) also reported accelerated growth and maturity during long days and at high temperature conditions. Haile et al (2015) observed that phenological stages rapidly advanced due to the availability of higher thermal units over a short period of time causing early maturity of the potatoes planted at high temperature. However, the potato planted on October 30 received comparatively cooler temperature as compared to other planting dates which might have retarded the photosynthetic as well as metabolic activities resulting in increasing the period required for completion of the vegetative phase and reproductive phase. Haile et al (2015) and Thongam et al (2017) also reported a similar pattern in the completion of the crop cycle of potatoes under the influence of high and low temperature.

Yield parameters

Tuber yield

The significantly higher yield was recorded in Cardinal as compared to MS 42.3 which might be due to excellent foliage growth which increased canopy diameter and promoted interception of more PAR causing increased photosynthesis and allocation of photosynthates to tubers during tuber initiation and tuber bulking period. Oliveira et al (2016), Giri et al (2023) and Eaton et al (2017) also recorded variability among the varieties in terms of tuber yield.

The significantly highest yield was recorded on October 15 due to the prevalence of suitable temperature and sunshine hours which increased the number of leaves and canopy diameter. The excellent vegetative growth might have promoted interception of more PAR causing increased photosynthesis and availability of low temperature during tuber initiation and bulking promotes allocation of photosynthates to tubers (Meena et al 2023). Khan et al (2011) and Adhikari et al (2020) also recorded higher yield due to increased photosynthesis facilitated by excellent vegetative growth. However, the minimum yield recorded on September 30 might be due to higher temperature experienced as compared to other planting dates. Higher temperature might reduce tuber yield by reducing the photosynthesis rate, affecting the source-sink relationship by promoting photosynthates partitioning towards above-ground vegetative portions, and increasing the generation of reactive oxygen species which cause oxidative stress to the cells (Lafta and Lorenzen 1995, Finkel and Holbrook 2000, Muthoni and Kabira 2016).

Marketable yield

Significantly higher marketable yield was recorded in Cardinal as compared to MS 42.3 which might be due to excellent foliage growth which promoted interception of more PAR causing increased photosynthesis and allocation of photosynthates towards tuber initiation and tuber bulking period. Thapa (2022) and Haile et al (2015) also recorded variability among the varieties in terms of marketable yield.

Significantly highest marketable yield was recorded on October 15 (Table 9) due to the prevalence of favourable temperature and sunshine hours and longer maturation period which increased the number of leaves and canopy diameter. High temperature during vegetative growth period produces higher canopy diameter due to excellent vegetative growth which promotes interception of more PAR causing increased photosynthesis. Similarly, cooler temperature during the tuber initiation and bulking period promotes the allocation of photosynthates towards tubers as compared to above-ground vegetative parts. Greater allocation of photosynthates towards the tuber promoted better bulking of tubers increasing the weight of tubers. A similar finding was reported by Haile et al (2015). However, early planted (September 30) potatoes produced lower marketable yield due to higher temperature experienced throughout the growth period as compared to other planting dates. Higher temperature reduces the marketable yield by reducing the photosynthesis rate, affecting the source-sink relationship by promoting photosynthates partitioning towards leaves and increasing the generation of reactive oxygen species which cause oxidative stress to the cells (Lafta and Lorenzen 1995, Finkel and Holbrook 2000, Muthoni and Kabira 2016). Eventually, high temperature stress lowers the yield by limiting bulking of the tubers. High temperature also caused pre-harvest sprouting, and secondary-chain formation by increasing the amount of gibberellins during tuberization, and the irregular shaping of the tubers due to interruption of longitudinal and diametric growth during the bulking stage (Menzel 1980, Rykaczewska 2015, Momčilović, 2019).

Unmarketable yield

The significant variation in unmarketable yield (Table 9) between varieties might be due to the genetic variation which affects the tuberization efficiency of the varieties. Haile et al (2015) and Adhikari et al (2020) also recorded variability among the varieties in terms of unmarketable yield governed by genetic makeup.

The significantly lowest unmarketable yield (Table 9) was recorded on October 15 as compared to other planting dates which might be due to the prevalence of congenial temperature and moisture favoring tuber bulking and increasing the size of the tubers. However, potatoes planted on September 30 produced the highest unmarketable tuber yield (Table 9). This might be due to the higher temperature experienced during tuber initiation and bulking period as compared to other planting dates. The higher temperature might have affected the unmarketable yield by reducing the photosynthesis rate, increasing the respiration rate, affecting the source-sink relationship by promoting photosynthates partitioning towards leaves as compared to tubers and increasing the generation of reactive oxygen species which cause oxidative stress to the cells (Finkel and Holbrook 2000, Muthoni and Kabira 2016). Eventually, high temperature stress lowered the unmarketable yield by reducing bulking of the tubers. Limited bulking of the tubers and short maturity period reduced the weight of the tubers producing unmarketable tuber yield. High temperature also caused the irregular shape of the tubers due to the interruption of longitudinal and diametric growth during the bulking stage, pre-harvest sprouting, and secondary tuberization by increasing the number of gibberellins (Menzel 1980, Rykaczewska 2015, Momčilović 2019).

Dry matter content of the tubers

The higher dry matter content of the tubers of Cardinal (Table 9) might be due to the higher canopy diameter. Higher canopy diameter might have facilitated higher interception of photosynthetically active radiations (PAR) and increased photosynthesis and partitioning of photoassimilates towards the tubers (Meena et al 2023). Dhakal et al (2011) and Tessema et al (2020) also reported variability in the dry matter content of the tubers due to genetic variability.

The maximum dry matter content of the tubers was obtained on October 15 among other planting dates (Table 9). This might be due to the maximum period of optimal temperature and sunshine hours for crop development which resulted in a longer crop cycle, greater uptake of nutrients from the soil, excellent foliage growth, and greater canopy diameter which ultimately promoted higher interception of photosynthetically active radiations (PAR), improved photosynthesis and increased allocation of photo assimilates to the tubers (Sandhu et al 2014, Haile et al 2015, Alam et al 2017). However, significantly lowest dry matter content was recorded on September 30 as compared to other planting dates (Table 9). This might be due to the comparatively higher temperature experienced during the growth period as compared to other planting dates. Higher temperature reduces photosynthesis rate, promotes photosynthates partitioning towards leaves and reduces photosynthates partitioning towards tubers, increases respiration rate which burns off solids accumulated from photosynthesis much faster than they are generated, and generates reactive oxygen species which cause oxidative stress to the cells (Finkel and Holbrook 2000, Khan et al 2011, Muthoni and Kabira 2016). In addition, because of the early physiological maturity of the potato planted on September 30, it received less time to collect assimilates ultimately reducing the weight of tubers (Naz et al 2022). Rab et al (2013), Haile et al (2015), Alam et al (2017), and Taha and Roshdy (2021) also recorded similar findings in terms of the dry matter content of the tubers.

Grading of potato tubers on the basis of tuber weight

The significantly ($p < 0.001$) higher number of medium tubers (25-50 g) and significantly ($p < 0.01$) higher number of large tubers (> 50 g) was found in Cardinal as compared to MS 42.3 (Table 10). Cardinal produced higher canopy diameter which promoted interception of more PAR causing increased photosynthesis and allocation of photosynthates towards tubers during tuber initiation and tuber bulking period. This reduced the number of low-weight tubers ultimately reducing the number of small tubers. The significant variation between varieties under the same growing conditions might be due to variations in tuberization efficiency governed by genetic makeup. Abbas et al (2012), Adhikari et al (2020), and Paudel et al (2023) also reported genetic differences responsible for variability in the number of small, medium, and large tubers per plant.

The significantly ($p < 0.001$) maximum number of small tubers (< 25 g) was obtained when planted on September 30 (Table 10). The higher number of small tubers on September 30 might be due to the higher temperature experienced during the tuber initiation and bulking period as compared to other planting dates. The higher temperature might have increased the number of small tubers by reducing the photosynthesis rate, increasing respiration rate, affecting the source-sink relationship, and increasing the generation of reactive oxygen species (Finkel and Holbrook 2000 and Muthoni and Kabira 2016). Because of the early physiological maturity of the potato planted on September 30, it received less time to collect assimilates ultimately reducing the weight of tubers (Naz et al 2022). The highest number of medium and large-sized tubers was obtained on October 15 might be due to the prevalence of congenial temperature for vegetative growth tuber initiation and tuber bulking. Congenial temperature favoured excellent foliage growth which ultimately increased the photosynthesis rate by higher interception of photosynthetically active radiation (PAR). The increased rate of photosynthesis, reduced rate of respiration, strong source-sink relationship promoting photoassimilates partitioning towards the tuber, and increased absorption of nutrients from the soil contribute to the higher number of medium (25- 50 g) and large tubers (> 50 g) (Finkel and Holbrook 2000, Sandhu et al 2014, Muthoni and Kabira 2016). The increment in number of medium and large tubers due to congenial temperature for vegetative growth and tuber bulking was also reported by Patel et al (2018) and Adhikari et al (2020).

CONCLUSION

Cardinal resulted in better vegetative growth and produced higher marketable yield, total yield, dry matter content of the tubers, number of large tubers, and matured earlier as compared to MS 42.3. Among planting dates, potatoes planted on October 15 produced significantly maximum number of leaves per plant, canopy diameter, and plant height. In addition, potatoes planted on October 15 produced the maximum number of tubers per plant, total yield, marketable yield, and dry matter content of the tubers as compared to other planting dates. The number and percentage of large tubers graded on the basis of tuber weight and tuber dimension were also recorded on October 15. The interaction effect of varieties and planting dates on growth and yield parameters was found statistically non-significant. From this experiment, it can be concluded that Cardinal variety and planting date of October 15 performed better growth and increased yield and are considered suitable for potato production under the growing condition of Rampur, Chitwan.

ACKNOWLEDGEMENTS

We would like to thank Department of Horticulture, Faculty of Agriculture, Agriculture and Forestry University, Rampur, Chitwan for providing the land and other necessary resources for the research.

AUTHORS' CONTRIBUTION

Maya Gurung: Conceptualization, Research conduction, Data Collection, Formal Analysis, Methodology, Software, Validation, Visualization, Writing Original draft and writing the manuscript. Hom Nath Giri, Writing the manuscript, Resources, Supervision, Visualization, Validation, Review and editing.

CONFLICT OF INTEREST

There is no conflict of interest.

REFERENCES

- Abbas G, IA Hafiz, NA Abbasi and A Hussain. 2012. Determination of processing and nutritional quality attributes of potato genotypes in Pakistan. *Pakistan Journal of Botany* **44**(1):201–208.
- Abubaker S, A AbuRayyan, A Amre, Y Alzubi and N Hadidi. 2011. Impact of cultivar and growing season on potato (*Solanum tuberosum* L.) under center pivot irrigation system. *World Journal of Agricultural Sciences* **7**(6):718–721.
- Adhikari S, AK Srivastava, M Sharma and AK Shrestha. 2020. Response of potato clones to planting dates in Pokhara, Kaski, Nepal. *Journal of Agriculture and Natural Resources* **3**(2):175–183.
- Ahmed B, M Sultana, MAH Chowdhury, S Akhter and MJ Alam. 2017. Growth and yield performance of potato varieties under different planting dates. *Bangladesh Agronomy Journal* **20**(1):25–29.
- Alam MS, N Islam, MJ Hossain, MSR Bhuiyan and MI Hossain. 2017. Effect of varied planting time and dehauling on the yield potential, processing quality and economic benefit in potato. *Bangladesh Journal of Agricultural Research* **42**(2):273–288.
- Asnake D, M Alemayehu and S Asredie. 2023. Growth and tuber yield responses of potato (*Solanum tuberosum* L.) varieties to seed tuber size in northwest highlands of Ethiopia. *Heliyon* **9**(3):e14586.
- Banjade S, SM Shrestha, N Pokharel, D Pandey and M Rana. 2019. Evaluation of growth and yield attributes of commonly grown potato (*Solanum tuberosum*) varieties at Kavre, Nepal. *International Journal of Scientific and Research Publications* **9**(11):134–139.
- Bártová V, J Bárta, A Brabcová, Z Zdráhal and V Horácková. 2015. Amino acid composition and nutritional value of four cultivated South American potato species. *Journal of Food Composition and Analysis* **40**:78–85.
- Burton WG and Meigh DF. 1971. The production of growth-suppressing volatile substances by stored potato tubers. *Potato Research* **14**(2): 96-101.
- Darabi A. 2013. Effect of planting date on total and marketable yield of potato cultivars in Khuzestan Province, Iran. *Seed and Plant Production Journal* **29**(3):369–386.
- Dash SN, S Behera and Y Pushpavathi. 2018. Effect of planting dates and varieties on potato yield. *International Journal of Current Microbiology and Applied Sciences* **7**(3):1868–1873.
- Devaux A, P Kromann and O Ortiz. 2014. Potatoes for sustainable global food security. *Potato Research* **57**:185–199.
- Dhakal R, SK Sah, SM Shakya and KB Basnet. 2011. Tuber yield and quality of potato chips as affected by mulch, variety and potash levels under western Terai, Nepal. *Agronomy Journal of Nepal* **2**:121–132.
- Eaton TE, AK Azad, H Kabir and AB Siddiq. 2017. Evaluation of six modern varieties of potatoes for yield, plant growth parameters and resistance to insects and diseases. *Agricultural Sciences* **8**(11):1315–1326.
- Finkel T and NJ Holbrook. 2000. Oxidants, oxidative stress and the biology of ageing. *Nature* **408**(6809):239–247.
- Giri RK, B Chalise, PB Paneru, GD Subedi, K Khadka, R Dhakal and S Gautam. 2023. Performance of potato genotypes at farmer's field in Jumla, Nepal. *Asian Research Journal of Agriculture* **16**(1):31-40
- Gomaa SS. 2014. Effect of planting dates and seed tuber sources on productivity of potato in Siwa Oasis. *Journal of Plant Production* **5**(12):2001–2016.
- Gomez KA and AA Gomez. 1984. *Statistical procedures for agricultural research*. John Wiley & sons.
- Gupta M, C Sharma, R Sharma, V Gupta and MK Khushu. 2017. Effect of sowing time on productivity and thermal utilization of mustard (*Brassica juncea*) under sub-tropical irrigated conditions of Jammu. *Journal of Agrometeorology* **19**(2):137–141.
- Haile B, A Mohammed and G Woldegiorgis. 2015. Effect of planting date on growth and tuber yield of potato (*Solanum tuberosum* L.) varieties at Anderacha District, southwestern Ethiopia. *International Journal of Research in Agriculture* **2**(6):272-280.
- Hussain T. 2016. Potatoes: ensuring food for the future. *Advances in Plants and Agriculture Research* **3**(6):178–182.
- Keleta BT, S Lal and SDY Naqvi. 2018. Effect of planting dates and varieties on growth and yield of potato (*Solanum tuberosum* L.) in Hamelmalo area. *Journal of Eco-friendly Agriculture* **13**(1):46–52.
- Khan AA, MS Jilani, MQ Khan and M Zubair. 2011. Effect of seasonal variation on tuber bulking rate of potato. *Journal of Animal and Plant Sciences* **21**(1):31–37.
- Khanal A, A Rijal, S Timilsina, RC Adhikari, KP Upadhyay and TB Pun. 2017. Selection of suitable potato genotypes in western high hills of Nepal. *Proceedings of the Ninth National Horticulture Workshop*, May 31- June 1 2017. NARC, HRD, Khumaltar, Lalitpur, Nepal; pp. 203-208.
- Kumar Y, R Singh, A Kumar and CS Dagar. 2019. Quantification of crop weather relationship and the effect of different planting dates on growth and yield of potato cultivars in a sub-tropical environment at Hisar. *Journal of Applied and Natural Science* **11**(1):17–22.
- Lafta AM and JH Lorenzen. 1995. Effect of high temperature on plant growth and carbohydrate metabolism in potato. *Plant Physiology* **109**(2):637–643.

- Lamsal G, A Khanal and LP Amgain. 2022. Growth and yield performance of potato clones under different planting dates. *Journal of Tikapur Multiple Campus* **5**:187–200.
- McGill CR, AC Kurilich and J Davignon. 2013. The role of potatoes and potato components in cardiometabolic health: a review. *Annals of Medicine* **45**(7):467–473.
- Meena AK, AKB Mohapatra, C Parhi, A Mishra, A Nanda, N Kumar and P Mohanty. 2023. Effect of planting dates and varieties on potato yield. *The Pharma Innovation Journal* **12**(6):3640–3643.
- Menzel CM. 1980. Tuberization in potato at high temperatures: responses to gibberellin and growth inhibitors. *Annals of Botany* **46**(3):259–265.
- MoALD. 2022. Statistical information on Nepalese agriculture. Monitoring, Evaluation and Statistics Division, Ministry of Agriculture and Livestock Development, Government of Nepal, Kathmandu.
- Momčilović I. 2019. Effects of heat stress on potato productivity and nutritive quality. *Hrana i Ishrana* **60**(2):43–48.
- Musa F, D Bericha, B Kelmendi, I Rusinovci, O Zhitia, R Bekqeli and I Lushi. 2009. Tuber yield and other relevant parameters of some Netherlands potato varieties in agro-climatic conditions of Kosova. *Proceedings of the 44th Croatian and 4th International Symposium on Agriculture*; pp.444–448.
- Muthoni J and JN Kabira. 2016. Potato production under drought conditions: identification of adaptive traits. *International Journal of Horticulture* **6**(12): 1-10
- Naz S, S Ahmad, G Abbas, Z Fatima, S Hussain, M Ahmed, MA Khan, A Khan, S Fahad, W Nasim, S Ercisli, CJ Wilkerson and G Hoogenboom. 2022. Modeling the impact of climate warming on potato phenology. *European Journal of Agronomy* **132**: 126404.
- Oliveira JS, HE Brown, A Gash and DJ Moot. 2016. An explanation of yield differences in three potato cultivars. *Agronomy Journal* **108**(4):1434–1446.
- Panthi U, S Bartaula, A Adhikari, K Timalsena, S Khanal and S Subedi. 2019. Effects of potassium levels on growth and productivity of potato varieties in inner Terai of Nepal. *Journal of Agriculture and Natural Resources* **2**(1):274–281.
- Patel CK, SK Chongtham and JK Patel. 2018. Growth, yield and productivity of potato as influenced by date of planting and genotypes. *International Journal of Agriculture Sciences* **10**(6):5500-5502.
- Paudel A, KR Pandey, YR Joshi and A Mahato. 2023. Performance of different potato varieties under plastic mulching conditions at Dailekh, Nepal. *Fundamental and Applied Agriculture* **8**(1–2):402–414.
- Pinthus MJ, MD Gale, NEJ Appleford and JR Lenton .1989. Effect of temperature on gibberellin (GA) responsiveness and on endogenous GA 1 content of tall and dwarf wheat genotypes. *Plant Physiology* **90**(3):854-859.
- Rab A, G Nabi, NU Amin, I Haq, M Sajid, K Nawab and N Ara. 2013. Influence of sowing time and potato propagules on yield and tuber quality. *Pakistan Journal of Botany* **45**(6):2013-2018.
- Rykaczewska K. 2015. The effect of high temperature occurring in subsequent stages of plant development on potato yield and tuber physiological defects. *American Journal of Potato Research* **92**(3):339–349.
- Sandhu AS, SP Sharma, RD Bhutani and SC Khurana. 2014. Effects of planting date and fertilizer dose on plant growth attributes and nutrient uptake of potato (*Solanum tuberosum* L.). *International Journal of Agricultural Sciences* **4**(5):196–202.
- Sandhu AS, SP Sharma, RD Bhutani and SC Khurana. 2013. Potato (*Solanum tuberosum* L.) tuber yield as affected by planting times and fertilizer doses under sandy loam soils. *Indian Journal of Agricultural Research* **47**(6):496–502.
- Sharma HB and HB KC. 2004. Participatory IDM research on potato late blight through farmers field school. In *Proceedings of the Fourth National Workshop on Horticulture 2004*. Horticulture Research Division, Nepal Agricultural Research Council, Kathmandu, Nepal. pp.205-210.
- Shrestha K, SK Sah, R Singh and YN Devkota. 2020. Performance of potato (*Solanum tuberosum* L.) varieties with and without straw mulch at Shankharapur, Kathmandu, Nepal. *Journal of Agriculture and Natural Resources* **3**(2):193–204.
- Shrestha SK. 2000. Late blight of potato: its magnitude, distribution, losses and approaches to management in Nepal. In *African Potato Association Conference Proceedings* **5**(1):303–307.
- Taha NM and AEDH Roshdy. 2021. Growth, chlorophyll, yield and tubers chemical composition and quality characters of potato cv. Spunta as affected by planting dates and irrigation regimes. *Alexandria Science Exchange Journal* **42**(3):657–664.
- Tessema L, W Mohammed and T Abebe. (2020). Evaluation of potato (*Solanum tuberosum* L.) varieties for yield and some agronomic traits. *Open Agriculture* **5**(1):63-74.
- Thapa S. 2022. Evaluation of performance of different varieties of potato (*Solanum tuberosum* L.) in Bajhang, Nepal. *International Journal of Applied Biology* **6**(2):115–125.
- Thongam B, AS Kadam, AA Singh and YH Singh. 2017. Influence of planting dates on growth and yield of potato (*Solanum tuberosum* L.). *Journal of Pharmacognosy and Phytochemistry* **6**(6):1243–1246.
- Tsoka O, P Demo, AB Nyende and K Ngamau. 2012. Potato seed tuber production from in vitro and apical stem cutting under aeroponic system. *African Journal of Biotechnology* **11**(63):12612-12618.
- Watanabe K. 2015. Potato genetics, genomics and applications. *Breeding Science* **65**(1):53–68.
- Zezelew DZ, S Lal, TT Kidane and BM Ghebreslassie. 2016. Effect of potassium levels on growth and productivity of potato varieties. *American Journal of Plant Sciences* **7**(12):1629–1638.