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# ASSESSING THE EFFECT OF DIFFERENT AGRONOMIC PRACTICES ON POTATO (*SOLANUM TUBEROSUM* L.) GROWTH, YIELD, AND QUALITY FOR CHIPPING INDUSTRY

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**Abstract**

Cultural techniques such as planting time, ridge width, and fertilizer use influence potato tuber growth, yield, and quality. Additionally, the potato rate for the chipping sector is reduced by climate change. Three factors—sowing windows, ridge sizes, and three doses of potash fertilizer—were combined in a two-year study to evaluate the yield and quality of potatoes in progressive farmer fields in Punjab's Kasur area in the fall of 2017 and 2019. In comparison to early sowing in the middle of September, it was observed that sowing on October 15 and September 30 showed statistically significant increases in the following areas: germination percentage (90.0% & 89.24%), number of leaves per plant (45.84 & 53.35), plant vigor (3.13, 3.95), plant height (34.2 cm, 38.29 cm), large tuber weight (126.11 g, 153.79 g), average weight (61.43 g, 73.6 g), marketable yield (23.99, 24.26 t/ha), yield (27.82 t/ha), total solid (22.06%), specific gravity (1.03%), and less green tuber per plant (3.22%). There were notable results in agronomic and qualitative criteria for 95 cm and 115 cm ridge sizes. In contrast to the usual ridge size of 75 cm, which gave maximum green tubers per plant because of the break in the ridge that caused the tubers to become green, the treatments with ridge sizes of 115 cm and 95 cm displayed less green tubers per plant. Treatments with 125 kg ha-1 of potash produced the highest yield (21.91 t/ha) and greatly improved growth characteristics. Due to specific climatic conditions, a more vigorous reaction was seen in 2018 for agronomic qualities and quality traits compared to 2019. The results of this study indicate that, in the context of a changing environment, planting potatoes on September 30 at ridges spaced 95 cm apart and applying potassium fertilizer at a rate of 125 kg K ha-1 will result in the highest yield and highest quality of potatoes.

**Keywords:** Marketable Yield, Plant Vigor, Planting Window, Ridge Sizes, and Tuber Greening.

## 1. INTRODUCTION

With an annual production of almost 300 million tons, potatoes rank fourth in the world's food crops, behind rice, wheat, and corn (Chakraborty et al., 2010; Ali et al., 2015). It is a typical food in Europe, an inexpensive source of calories and starch content (SC) (Maikhuri et al., 1996; Zaheer & Akhtar, 2016). A potato tuber comprises about 75–80% water, while the remaining 16–20%, 2.5–3.2%, and 0.6% contribute to essential carbohydrates, crude protein, and vitamins crucial for human health (FAOSTAT, 2017).

In 2022, 374.777 million tonnes of potatoes were produced globally (FAOSTAT, 2022). China is the world's leading potato producer, with China and India collectively contributing to about one-third of global potato production (Ali et al., 2015). In Pakistan, potatoes are

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cultivated on 341 thousand hectares, yielding 8.32 million tons annually. According to the Pakistan Economic Survey for 2022–23, potato production experienced a 4.8% increase as compared to the previous year's 7.94 million tons. In Pakistan, the annual per-capita consumption of potatoes has risen from 4 to 15 kilograms (Anonymous, 2017). Average annual production of potatoes is lower in Pakistan than developed potato-growing regions like Europe and the US. Owing to post-harvest losses, its profitability falls by another 20–40%.

The potato is a weather-sensitive crop. The planting time, ridge size, and cultivation/management techniques including weed control, tamping, irrigation, fertilizer management, plant protection measures, the manner and time of harvest, etc. all have a significant impact on the quality of potato tubers. The timing of planting is one of these aspects that has a significant impact on potato yield since it allows for some degree of control over temperature and light. The potato crop requires long days during growth and short days during tuberization in order to produce the optimum yields. The night time temperature and day duration are the primary climatic variables influencing tuber development (Chadha, 2009). The yield and quality of the crop is also impacted by the size and shape of the ridges. In Pakistan, potato crop is mostly grown on ridges of 75 cm and as the tuber matures, cracks appear in the ridges. This causes the tuber to turn green due to light penetration, which is thought to be a bad quality (carcinogenic) trait of the potato.

Potash (K) fertilizers, such as potassium sulfate (SOP), potassium muriate (MOP), and potassium chloride (KCl), are among the main chemical fertilizers and are thought to be the most crucial for optimum plant growth and productivity (Cutter, 1992). The tuber size and number of tubers of plant$^{-1}$ were both greatly increased, and eventually the tuber yield, by increasing the doses of K to the ideal level (Struik & Ewing, 1995). Temperature changes cause the potato planting season to move from September to October. Potato cultivation requires an ideal temperature range of 30°C during the day and 15-20°C at night for healthy growth and development (El-Gamal, 1985; Humadi, 1986). Based on the above research and temperature fluctuations, a study was designed to examine the impact of planting dates and other cultivation techniques, such as bed size and potash fertilizer application rate. The current research study's objectives are to (i) compare early and late sowing cultivars of potatoes to the standard/recommended planting time for yield and quality and (ii) compare elevated beds of 95 cm and 115cm to conventional sowing.

## 2. METHODOLOGY

### 2.1 Experimental Site and Climatic Conditions:

The field trials were conducted at the farmer's field in Kasur, Punjab, Pakistan (31°72′ N, 74°28 E), under sub-humid and subtropical climatic conditions. The average annual rainfall during the research period (2017–2019) was 585 mm, mostly falling between July and September during the monsoon season and the remaining 35–40 mm during the winter. During that period, the average yearly maximum temperature ranged between 36

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and 42°C, with summer peaks reaching 48°C and winter lows dropping to 4-6°C. Figure 1 displays the average temperature and precipitation data for the study period.

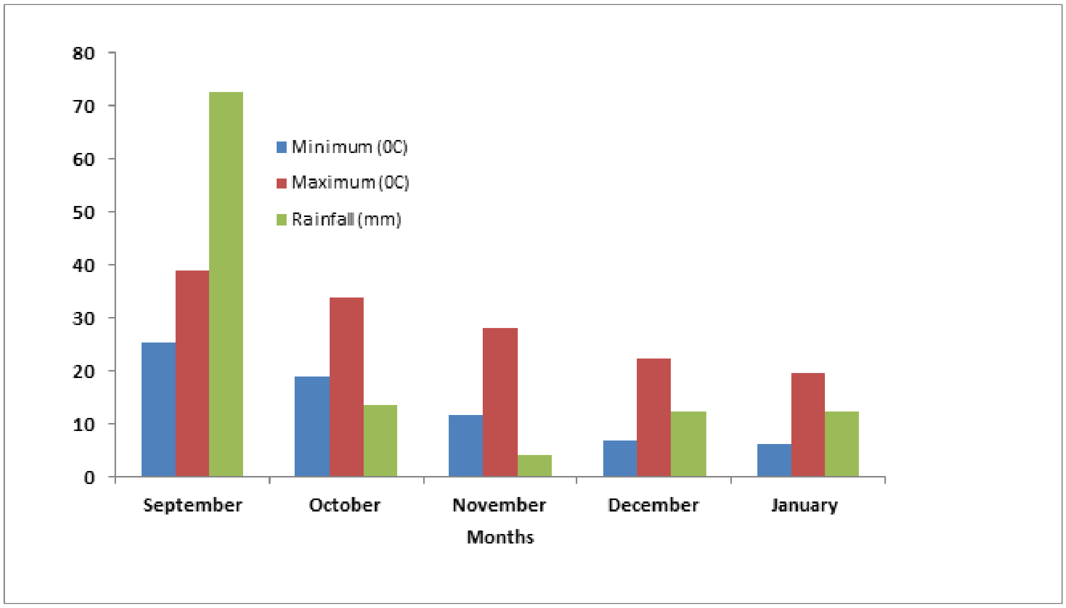


**Fig 1: Average weather data of experimental location during 2017-2019**

## 2.2 Soil Description:

The soil type described for the Central Punjab research region is Bahalike loam. The United States Department of Agriculture (USDA) recognises the hyperthermic haplargids of Ustalfico as research soils, but the Food and Agriculture Organisation of the United Nations (FAO, 2014) identifies the existing soil as Haplic Yermosols. Traditionally, the potato crop and the summer maize harvest are alternated. In every experimental year, the maize was sown at the end of February and harvested in mid-May or early June. On the other hand, potatoes are harvested during the final week of January after being sowed in September.

**Table 1. Experimental site physio-chemical properties of soil during 2017-2019.**

| Soil Properties | Soil Depth | |
|---|---|---|
| | 0–15 cm | 15–30 cm |
| Texture | Clay loam | Clay loam |
| pH | 8.4 | 8.3 |
| EC (mS cm$^{-1}$) | 1.4 | 1.3 |
| Organic matter (%) | 0.52 | 0.48 |
| Bulk density (gcm$^{-3}$) | 1.18 | 1.18 |
| Saturation (%) | 62 | 60 |
| Available P (mgkg$^{-1}$) | 6.5 | 5.8 |
| Available K (mgkg$^{-1}$) | 135 | 128 |

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## 2.3 Agronomic management

The field trial was conducted using a split plot design replicated thrice with mounds spacing of 75, 95, and 115 cm. Potassium was applied at 100, 125, and 150 kg ha $^{-1}$ to sub-plots (experimental unit of size 1.30 x 1.40 $m^2$) following the treatment plan. Each experimental sub-plot includes two rows of size 1.30 m x 0.70 m. The main plots (11.00 $m^2$) have variable sowing periods (15 and 30 September and 15 October. The experimental field was plowed two times 14 days before seeding. The tested potato variety Lady Rosetta's seeds were taken from healthy tubers weighing 20 to 30 kg, which were sown 15 cm below the soil's surface. Seeds were sown in each unit plot at a distance of 70 cm by 25 cm. Using band placement, phosphorus and nitrogen were applied at the suggested rates of 120 and 100 kg ha-1, respectively. Half of the nitrogen was sprayed at sowing and the other half six weeks later. The first watering was given to the middle of the mounds after the seeds were placed in order to avoid the formation of hard crusts that would allow soil microbes to escape.

## 2.4 Experimental Design and Layout

An investigation in the field assessed how tuber growth, yield, and quality were affected by varying sowing timings, ridge spacing, and K fertilisation. Treatment variables for the study included three distinct sowing dates (September 15, 30, and October 15), three ridge spacings (75, 95, and 115 cm), and three K rates (100, 125, and 150 kg/ha). A Split Plot Design (SPD) with three replicates was used to create the field trial. The main plots, which occupied 11.00 $m^2$, were planted at different times, and the subplots, which were experimental units of 1.30 m x 1.40 $m^2$, received treatment plan-recommended ridge spacing and K fertiliser levels. With dimensions of 1.30 m × 0.70 m, each experiment subplot contained two rows.

## 2.5 Parameters studied

### 2.5.1 Agronomic attributes

#### 2.5.1.1 Emergence (%)

After six weeks of seeding, the number of sprouted tubers from a chosen 15 m2 area for each treatment was counted to determine the emergence percentage.

#### 2.5.1.2 Plant vigour

Plant vigour was measured by visual observation after 6 weeks of sowing using a 1 to 4 scale where 1: Poor (small size tubers and stunted growth), 2: Moderate, 3: Good, and 4: Excellent (large size tubers with several leaves) (Wooster & Farooq, 1995).

#### 2.5.1.3 Plant height (cm)

After 6 weeks of sowing, 15 plants were randomly selected from each treatment, height was measured, and means were calculated.

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#### 2.5.1.4 No. of leaves plant$^{-1}$

At maximum crop growth, 15 plants were randomly selected from each treatment, and the leaves on each plant were counted.

#### 2.5.1.5 Leaf Area Index

According to Radford's (1967) formula, the Leaf Area Index (LAI) is the ratio of the leaf area to the crop's ground area, measured from one side.

$$\text{Leaf Area Index (LAI)} = LA/GA$$

### 2.5.2 Yield Parameters

#### 2.5.2.1 Number and weight (g) of tubers

Tubers were weighed and counted from a 15-square-meter area during harvest.

#### 2.5.2.2 Tuber sizes

Tubers from a 15 $m^2$ area were graded into three groups considering the size of tubers viz. >45 mm, <45 mm and < 45 mm.

#### 2.5.2.3 Marketable and Non-marketable yield

Marketable yield was calculated based on the weight of tubers with a size larger than 45mm diameter collected from a 15$m^2$ area. Non-marketable yield was calculated based on the weight of tubers with a size smaller than 35mm.

### 2.5.3 Quality Parameters

#### 2.5.3.1 Total Solid (%)

By first drying finely chopped tuber pieces in an oven at 80°C for six hours, and then again at 65°C until they reached a uniform weight, the dry matter content of the tubers was ascertained (Kumar & Ezekiel, 2004).

#### 2.5.3.2 Mini fry defect

Mini fry defect was determined by following the procedure of Martin's (1979), reported in the Manual of Food Quality Control (FAO).

#### 2.5.3.3 Specific gravity

Specific gravity was determined using the weight in air and the weight in water method. The samples were weighed twice, once in the air and once in water. The following formula was used to calculate the specific gravity:

$$\text{Specific gravity (SG)} = \text{Dry weight} / (\text{Dry weight} - \text{Wet weight}).$$

#### 2.5.3.4 Green tubers per plant

The colour of tubers, either green or yellow, is identified by using the procedure described by Wooster & Farooq (1995).

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### 2.6 Statistical Analysis

The data of field trials was subjected to analysis of variance (ANOVA), and means were compared by using the least significant test (LSD) at $p < 0.05$ using Statistix-8.1 software.

## 3. RESULTS

### 3.1 Agronomic attributes

**3.1.1 Germination percentage:** There was a relationship between planting dates and K-fertilizer treatment and emergence rate, however there was no discernible relationship between ridge size and harvest year, except 15 September sowing, which had the lowest emergence rate (75.15%) (Table 2).

**3.1.2 Number of leaves per plant:** Table 2 clearly shows the impact of fertilizer treatment, crest size, and planting dates on the number of leaves per plant. On September 30 the highest number of leaves per plant$^{-1}$ (53.24) were observed, followed by October 15 sowing dates (46.23), and the fewest leaves plant$^{-1}$ (40.56) on early sowing (September 15).

**3.1.3 Plant Height (cm):** It was observed significant association ($p \leq 0.05\%$) between planting dates, bed size, and potash application regarding their effect on plant height (table 2). Early planting (September 15) showed the smallest plant height (32.14 cm), while 30 September sowing showed the maximum plant height (38.29 cm), followed by (34.24 cm) sowing date of 15 October.

**3.1.4 Plant vigor:** Results for data on plant height (cm) between planting dates, bed size, and potash fertilizer application were significant ($p \leq 0.05\%$) (Table 2). Early planting (September 15) showed the smallest plant height (32.14 cm), while late sowing (October 15) showed the maximum plant height (38.29 cm), followed by sowing dates (34.24 cm).

**3.1.5 Leaf Area Index (LAI):** The LAI data revealed significant relationships ($p \leq 0.05\%$) among the sowing dates, bed size, and application of potash fertilizer (table 2). The sowing dates for 15 October exhibited the lowest leaf area indexes (1.39), whereas the sowing dates for 30 September showed the greatest leaf area indexes (3.22) and (2.26), respectively.

**3.1.6 Tubers per Plant:** Plant vigor data for Tubers indicated significant results ($p \leq 0.05\%$) in relation to the various sowing dates, heap sizes, and potash fertilizer applications (table 02). The initial sowing period (15 September) revealed the lowest tubers plant$^{-1}$ (6.5), while the maximum tubers plant$^{-1}$ (8.56) was reported on 30 September, followed by (7.45) on the 15 October sowing dates.

**3.1.7 Number of small tubers per 15 m$^2$**: Based on the information in Table 2, there is a statistically significant difference ($p < 0.05\%$) in the number of small tubers per 15 m2 based on sowing dates, bed size, and potassium fertilizer application. The sowing dates of 15 September and 30 September both had the highest concentration of tiny tubers per 15 m$^2$ (161.27), whereas the sowing dates of 15 October had the lowest concentration (124.11) of small tubers per 15 m$^2$.

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**3.1.8 Small tubers weight (g):** Data for small tubers weight at various planting dates, bed sizes, and potash fertilizer treatment demonstrated significant results ($p \leq 0.05\%$) (Table 2). The 30 September planting time exhibited the heaviest lower weight of small tubers (17,46), while the 15 October sowing indicated the largest weight of small tubers (42.45 g), followed by (35.16 g).

**3.1.9 Number of tall tubers:** It is evident from Table 2 that the effect of various treatments of sowing date, bed size, and application of potash fertilizer on the number of large tubers was significant ($p \leq 0.05\%$). The 15 September planting period gave the fewest large tubers (86.4), while the 30 September planting period showed the maximum number of large tubers (92.90), followed by 15 October planting dates (90.51).

**3.1.10 Weight of large tubers (g)**: Sowing dates, bed size, and application of potash fertilizer significantly increased the weight of large tubers at $p \leq 0.05\%$ (Table 2). The sowing period on 15 September had the fewest large tubers (108.63 g), whereas the sowing period on 30 September had the largest tubers (153.79 g).

**3.1.11 Total Number of Tubers:** A significant interaction was observed between sowing dates, bed size, and potash fertilizer (table 2). Maximum tubers (248.01) were reported on October 15, followed by (230.28) on the September 30 planting dates, while the lowest number of tubers (216.5) were observed during the September 15 planting period.

**Table 2. Agronomics attributes under different sowing window, ridge geometry and potassium fertilizers application in potato cultivar**

| Sowing Dates (SD) | Germination (%age) | Number of leaves per plant | Plant Height (cm) | Plant Vigor | Tubers per plant | Leaf area index | Average Weight (g) |
|---|---|---|---|---|---|---|---|
| 15-Sep | 75.51C | 40.06C | 32.135C | 2.5C | 6.5C | 1.39C | 46.855C |
| 30-Sep | 89.24A | 53.35A | 38.29A | 3.955A | 8.56A | 3.22A | 73.645A |
| 15-Oct | 90.00A | 45.84B | 34.24B | 3.13B | 7.45B | 2.26B | 61.43B |
| **Ridge Size (cm)(RS)** | | | | | | | |
| 75.00 | 82.94A | 46.78B | 34.775B | 3.195AB | 6.94B | 2.31B | 58.B |
| 95.00 | 83.702A | 49.24A | 36.835A | 3.255A | 7.88A | 2.14C | 59.B |
| 115.00 | 82.255A | 43.24C | 33.06C | 3.14B | 7.66A | 2.4A | 64.A |
| **Potash Fertilizer (Kg/ha)** | | | | | | | |
| 100.00 | 79.46B | 47.15A | 33.67B | 2.77C | 7.39B | 2.15B | 58.3B |
| 125.00 | 84.17A | 48.38A | 37.44A | 3.57A | 7.78A | 2.57A | 61.A |
| 150.00 | 80.07A | 41.51B | 33.51B | 3.275B | 7.33B | 2.14B | 54.5C |
| **LSD 0.05)** | **1.84** | **1.33** | **0.88** | **0.09** | **0.22** | **0.068** | **1.74** |

Means sharing common letter(s) in the column do not differ significantly at $p < 0.05$

## 3.2 Yield

**3.2.1 Marketable Tuber Yield (%):** The interactive effect of planting dates, bed size, and potash fertilizer on marketable tuber yield was significant ($p \leq 0.05\%$). It comprises plant 1's medium and large tubers (Table 03). The maximum marketable yield (24.26 t/ha) was reported on September 30, followed by (16.41 t/ha) on October 15, and the marketable yield (11.55 t/ha) was recorded during the sowing phase on September 15.

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**3.2.2 Non-Marketable Tuber Yield (%):** Table 3 revealed associations with planting dates, bed size, and potash fertilizer treatment that were statistically significant (p = 0.05%). The highest non-marketable yield (21.74 t/ha) was observed on September 15, and the lowest non-marketable yield (15.31 t/ha) was observed during the sowing period on September 30.

**3.2.3 Tuber yield (t/ha):** The data presented in Table 3 clearly shows the significant relationships ($p \leq 0.05\%$) between the sowing date, the size of the flower bed, and the potassium fertilization for their effect on tuber yield. The planting period on 15 September produced the lowest yield (13.37 t/ha), while the sowing period on 30 September produced the maximum yield (27.82 t/ha), followed by the treatment (20.66 t/ha), which was sown on 15 October. The appendix contained the ANOVA analysis table for the unmarketable yield (%).

### 3.3 Quality parameters

**3.3.1 Total Solid (%):** Data for total solids (%) in Table 03 reveals significant relationships ($p \leq 0.05\%$) between sowing dates, ridge size, and the use of potash fertilizer. The maximum solid total (22.06%) was observed on September 30, followed by (20.65%) on September 15 planting dates, while the lowest solid total (20.22%) was observed on October 15 planting days.

**3.3.2 Mini Fry Defect:** Results for mini fry defect were significant ($p \leq 0.05\%$) across planting dates, ridge size, and potash fertilizer treatment (Table 3). The planting time of September 30 had the fewest mini-fry defects (9.22), while October 15 had the highest number (11.41) and September 15 had the lowest number (10.38).

**3.3.3 Specific gravity (SG):** A non-significant interaction ($p \leq 0.05\%$) between potash fertilizer application, bed size, and sowing dates was observed (table 3).

**Table 3. Effect of sowing dates, ridge geometry and potassium fertilizers application on yield and quality of potato cultivar**

| Sowing Dates(SD) | Marketable Yield (t/ha) | Non-Marketable Yield (t/ha) | Yield (t/ha) | Total Solid (%) | Mini-Fry Defect | Specific Gravity(%) |
|---|---|---|---|---|---|---|
| 15-Sep | 16.42B | 21.74A | 13.37C | 20.65B | 10.38B | 1.039A |
| 30-Sep | 24.26A | 15.315C | 27.82A | 22.06A | 9.22C | 1.032A |
| 15-Oct | 23.99A | 18.945B | 20.67B | 20.22B | 11.41A | 1.02A |
| **Ridge Size (cm)(RS)** | | | | | | |
| 75.00 | 15.9B | 19.04B | 19.05B | 20.95A | 10.59A | 1.035A |
| 95.00 | 19.5A | 20.01B | 22.55A | 21.07A | 10.05B | 1.032A |
| 115.00 | 16.83B | 22.56A | 20.14C | 20.91A | 10.36A | 1.025A |
| **Potash Fertilizer (Kg/ha)** | | | | | | |
| 100.00 | 15.88B | 15.78A | 18.81B | 20.74B | 10.21B | 1.022A |
| 125.00 | 20.11A | 13.27B | 21.91A | 21.44A | 10B | 1.041A |
| 150.00 | 13.61C | 15.57A | 17.27C | 20.76B | 10.79A | 1.029A |
| **LSD (0.05)** | **0.34** | **1.31** | **0.88** | **0.068** | **0.28** | **0.068** |

Means sharing common letter(s) in the column do not differ significantly at $p < 0.05$

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## 4. DISCUSSION

The findings of Manolov et al., (2015) indicating a late planting date and an excessive amount of potash fertilizer treatment slowed potato emergence are supported by the study's results regarding emergence (%). The parameters that substantially affected emergence include soil temperature, water availability, and nutrient availability (Thornton et al., 2020).

The findings of present study regarding the number of leaves per plant are consistent with Ilyas et al., (2017), who found that sowing dates had an impact on plant leaves and late sowing decreased per plant leaf count. According to Thongam et al., (2017), the ideal temperature range enhanced number of leaves plant$^{-1}$ by increasing basal, apical, and lateral branches. While the lower leaves on plant during the late planting treatment may have been the result of oxidative damage having a cooling impact. The biochemical functions of plants, including photosynthesis, transpiration, nutrient transport, and respiration, as well as enzyme activity, are altered by oxidative stress brought on by the effect of frost.

Thornton et al. (2020) found that plants displayed maximum plant height and high vigor at high temperature (27/17 0 C) compared to low temperature (22/14 0 C), which is consistent with our findings on plant height. Similar to Thongam et al., (2017), it was claimed that raising P and K levels had no discernible impact on plant height at any growth stage. However, applying N causes a notable rise in plant height. Struik et al., (2019), claim that the plant's length is solely the sum of all its internodes, the number and length of which are related. Similar findings were reached by Stark et al., (2020), who found that altering the planting dates dramatically alters the number of tubers produced by plant 1. Small tubers result from lowering the assimilates to be stored in the tubers. However, because of the short growth season, the photosynthesis was unable to reach the tubers, resulting in their tiny size. The total quantity of tubers obtained is consistent with the findings of Gelaye et al., (2021), which found that early tuber planting increased tuber production in comparison to late planting.

The results of the leaf area index in this study are consistent with the findings of two previous studies (Duan et al., 2014; Roosjen et al., 2018). Even though the results for tuber weight are the same as those published in El-Sayed et al. (2015), the genotype (MF-1, Peru) was considered the stable preference genotype for stability performance for average tuber weight and is also mold resistant (15). Dingenen et al., (2019) noted that the average tuber weight of the cultivars varied across the seasons from 42.79 g to 49.96 g. The period of maximal growth (Jamro et al., 2015) and faster rate of photosynthesis (Crocco et al., 2018), which synthesizes the highest amount of assimilates, might be due to the early-sown potatoes' increased yield in small and large tubers. Variance in genotype, climatic conditions, increased emergence rate, variance in growth pattern (Khan et al., 2011), and variation in planting time (Zarzyńska et al., 2015) all contribute to the greatest production of marketable tubers. Stefaniak et al., (2021) further demonstrated that there were notable year effects on the total tuber yield. The reason for

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this diversity could be that various genotypes reacted differently to the same environmental conditions.

There was a negligible correlation between the planting dates, ridge size, and total solids (%). While early tuber planting improved dry matter (DM%), the opposite was observed with late tuber planting. The improvement in soluble solids (SS%) during the October 15 planting period, leading to a greater accumulation of MS through photosynthesis, may be attributed to a period of full growth, ideal meteorological circumstances, and early crop maturity (Mystkowska et al., 2021). Specific gravity (SG) in the tubercle decreased in conjunction with the decline in SG reported by Jain et al. (2019). Larger SG values are typically recommended when treating tubers (Figiel et al., 2019). Chang et al. (2016) found, while employing two different implant depths, that the percentage of green tubers in mounds 25 cm wide at the top was lower than in those 18 cm wide at the top.

## 5. CONCLUSION

Based on the results of our current research, we recommend planting the potato crop at the end of September, using a 95 cm bed, and fertilizing with 125 kg of potash per hectare as effective ways to increase potato development and yield.

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