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# Optimizing Brussels sprout *(Brassica oleracea var. geminifera* L.*)* yield through strategic sowing dates and environmental parameters across various growth stages

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## ABSTRACT

The important exotic vegetable crop in nutritive and cultivation concern had been planted on different dates to study the environmental effect on Brussels sprout growth and yield.The experiment was conducted during 2018 and 2019 at Punjab Agricultural University, Regional Research Station, Gurdaspur. The findings revealed that yield increased significantly with rising maximum, minimum, and mean temperatures. Plant height also showed a positive response to temperature increases. Temperature exhibited a strong and significant correlation with key growth parameters such as the number of leaves, ten-fruit weight, and fruit diameter. Heat use efficiency demonstrated a positive and significant relationship with yield, plant height, number of leaves, ten-fruit weight, and fruit diameter, highlighting its relevance in predicting crop performance. The highest yield was observed when planting done on October 20, while the lowest yield was recorded for the November 10 planting. Similarly, growth attributes, including plant height, number of leaves, ten-fruit weight, and fruit diameter, improved significantly with earlier planting dates. These findings underscore the importance of optimizing planting dates and understanding environmental interactions to maximize Brussels sprout productivity and growth.

## Introduction

Brussels sprout (*Brassica oleracea var. gemmifera*) is an important exotic vegetable of brassica family. It is a highly nutritious and known for exceptional nutritive value. Among cole crops, its demand is increasingly day-by-day particularly in metropolitan cities. Brussels sprout is a leading source of protein (4.4% by weight), total carbohydrates (8.9% by weight), and calories (58 per 100 grams) (Brown and Hutchison, 1949). Helm (1963) traced the origin of Brussels sprout to Belgium, suggesting they evolved from the older variety var. ramose (thousand head kale) into var. gemmifera. The crop's stem exhibits longitudinal growth, often exceeding one meter in some cultivars. The axillary buds of the petiolate leaves develop into miniature heads, just a few centimeters in diameter, which hold commercial value. Early planting has been consistently associated with higher yields (Krieghoff, 1988; Abuzeid and Wilcockson, 1989; Gaye and Maurer, 1991; Babik, 1994).

Keeping in view, the importance of Brussels sprout the present study explores the impact of varying planting dates on the growth and marketable yield of Brussels sprout, with

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particular attention to their correlation with environmental conditions, aiming to provide insights for improved cultivation practices.

## Material and Methods

The experiment was carried out during 2018 and 2019 at Punjab Agricultural University-Regional Research Station, Gurdaspur on sandy loam, using Brussels sprout cv. Hills Ideal. In each year the crop was planted at three planting dates with three replications. The experiment was laid out in 2 m x 3 m sized plots. The plot consisting of two rows at a distance of 75 cm x 50 cm from row to row and plant to plant each row consisting 6 plants where total plant per plot was 12. The planting was done on 20th October ($D_1$), 30th October ($D_2$) and 10th November ($D_3$) during 2018 and 2019. The marketable yield (excluding unmarketable buds due to quality defects) of the crop was determine for each planting dates at the same time number of days after planting (Table 3) by mechanical harvesting. The date of harvesting coincided with the three to four latest measurements of the total crop. At the same time each observation was also recorded like plant height (cm), number of leaves, weight per plant (g), ten sprout weight (g), fruit length (cm), fruit diameter (cm) to compare the yield quintal per acre with each character. The analysis of variance was carried out with the R statistical package.

## Results and Discussion

The yield is a complex polygenic character and the improvement in yield depends on the knowledge and extent of its association with various component characters. An understanding of the association among the different pairs of component characters and their relative association with yield is necessary for improvement in the desired traits. In the present investigation also, the phenotypic correlation coefficients were worked out. The estimates of correlation coefficients among different pairs of characters at phenotypic showed a close resemblance to each other.

Yield demonstrated (Table 1) a positive and significant correlation with maximum temperature during early growth (0.69) and the overall season (0.82), indicating that as temperature increases, both vegetative and reproductive growth improve. However, being a cool-season crop, Brussels sprout exhibited a negative and non-significant correlation with fruiting (-0.44), as temperature had limited influence on this stage. Similarly, yield showed a positive and significant correlation with minimum temperature during early growth (0.88) and the overall season (0.73), but a negative and non-significant relationship with fruiting (-0.32). Mean temperature displayed the strongest positive and significant correlation with early growth (0.90) and the overall season (0.97), while also having a negative and non-significant relationship with fruiting (-0.40). The intensity, duration, and rate of temperature changes collectively influence plant development and physiology (Wahid *et al.*, 2007).

Yield comparisons with diurnal temperature range revealed a negative and significant relationship with fruiting (-0.49). Evening relative humidity showed a positive but non-significant correlation with fruiting (0.35) and negative correlations with early growth (-0.43) and the overall season (-0.50), the latter being significant. Mean relative humidity exhibited a negative and significant relationship with early growth (-0.59) and the overall season (-0.84), while showing a positive but non-significant correlation with fruiting. Rainfall displayed a negative and non-significant correlation with yield, while bright sunshine hours showed no relation. Wind speed negatively correlated with all growth stages, significantly with fruiting (-0.53). Finally, yield demonstrated a positive response to reference evapotranspiration across all stages, significantly correlating with fruiting (0.73). Most crops experience adverse effects when exposed to high temperatures during the vegetative growth period, a phenomenon well-documented for cool-season annuals such as wheat (Porter and Gawith, 1999) and *Brassica juncea* (Hayat *et al.*, 2009).

Plant height exhibited a significant and positive correlation with yield (0.63). When compared with maximum temperature, plant height showed a positive and significant correlation during early growth (0.51) and the overall season (0.58) but a negative and non-significant correlation with fruiting (-0.37). Similarly, plant height compared with minimum temperature displayed a mix of positive and negative non-significant results. In relation to mean temperature, plant height showed a positive and significant correlation with early growth (0.55) and the overall season (0.53), but a negative and non-significant correlation with fruiting (-0.37). The increase in plant height with rising temperatures highlights the significant influence of temperature on vegetative growth, while its relationship with fruiting remained non-significant. Plant height did not show a significant relationship with the diurnal temperature range. Comparisons with relative humidity in the morning showed a positive but non-significant correlation, while relative humidity in the evening exhibited a negative and significant correlation with plant height during the season (-0.50). Mean relative humidity had a negative and significant correlation with plant height during early growth (-0.51) and the overall season (-0.61), but a positive and non-significant correlation with fruiting (0.33). Rainfall, sunshine hours, wind speed, and evapotranspiration did not significantly affect plant height.

The number of leaves per plant showed a strong positive and significant correlation with yield (0.93). When compared with maximum temperature, leaves per plant exhibited a positive and significant correlation during early growth (0.68) and the overall season (0.79), but a negative and significant correlation with fruiting (-0.49). Similarly, comparisons with minimum temperature revealed a positive and significant relationship during early growth (0.79) and the overall season (0.64), while the correlation with fruiting was negative and non-significant (-0.35). When compared with mean temperature, leaves per plant displayed a positive and significant correlation during early growth (0.86) and the overall season (0.89), but a negative and non-significant correlation with fruiting (-0.45). Leaves per plant showed no significant correlations when compared with diurnal temperature range, relative humidity (morning, evening, or mean), rainfall, bright sunshine hours, wind speed, or reference evapotranspiration. These factors appeared to have no measurable impact on the number of leaves per plant.

The ten-fruit weight showed a strong positive and significant correlation with yield (0.86). When compared with maximum temperature, ten-fruit weight exhibited a positive and significant relationship during early growth (0.60) and the overall season (0.75), but a negative and non-significant relationship with fruiting (-0.34). Comparisons with minimum temperature revealed a positive and significant correlation with early growth (0.83) and the overall season (0.70), while the correlation with fruiting was negative and non-significant (-0.27). Similarly, ten-fruit weight showed a positive and significant response to mean temperature during early growth (0.82) and the overall season (0.91), but a negative and non-significant relationship with fruiting (-0.32). Factors such as diurnal temperature range, relative humidity (morning, evening, or mean), rainfall, bright sunshine hours, wind speed, and reference evapotranspiration did not have any significant effect on ten-fruit weight.

Fruit diameter showed a significant and positive correlation with yield (0.80), indicating that an increase in fruit diameter is associated with a higher yield. When compared with maximum temperature, fruit diameter exhibited a positive and significant correlation during early growth (0.58) and the overall season (0.69), but a negative and non-significant correlation with fruiting (-0.39). Comparisons with minimum temperature revealed a positive and significant relationship during early growth (0.82) and the overall season (0.67), while the correlation with fruiting was negative and non-significant (-0.29). Similarly, mean temperature showed a positive and significant correlation with fruit diameter during early growth (0.79) and the overall season (0.85), but a negative and non-significant correlation with fruiting (-0.37). Fruit diameter also demonstrated a positive and significant correlation with reference evapotranspiration during early growth (0.30), fruiting (0.77), and the overall season (0.36). Other factors, including diurnal temperature range, relative humidity (morning, evening, or mean), rainfall, bright sunshine hours, and wind speed, did not show a significant correlation with fruit diameter.

The data presented in Table 2 demonstrate the correlation between Brussels sprout and growing days, as well as thermal growing indices. Yield, when compared with crop stage duration, showed a positive and significant correlation with early growth (0.88), fruiting (0.67), and the entire season (0.93). Yield also exhibited a positive and significant relationship with both growing degree-days and photo-thermal units during early growth (0.97). The yield showed a positive and significant correlation with heliothermal units during early growth (0.69) and the overall season (0.77). Additionally, the photo-thermal index demonstrated a positive and significant correlation with yield during early growth (0.91) and the entire season (0.97). Plant height, compared with crop stage duration, showed a positive and significant correlation with the overall season (0.41), and a positive and significant relationship with growing degree-days during early growth (0.54). Plant height also exhibited a positive and significant correlation with heliothermal units during early growth (0.58) and the entire season (0.62). The photo-thermal index had a positive and significant correlation with plant height during early growth (0.56) and the overall season (0.51). Heat use efficiency showed a positive and significant correlation with yield (1.00), plant height (0.62), number of leaves (0.92), ten-fruit weight (0.86), and fruit diameter (0.82). Crop stage duration was positively and significantly correlated with the number of leaves during early growth (0.80), fruiting (0.56), and the overall season (0.83), as well as with ten-fruit weight during early growth (0.82), fruiting (0.55), and the entire season (0.84), and fruit diameter during early growth (0.78), fruiting (0.81), and the overall season (0.86).

The data presented in Table 3 highlight the significant differences in yield (quintals per acre) across different sowing dates. The maximum yield was recorded in $D_1$ (61.35), while the minimum yield was observed in $D_3$ (9.81). $D_1$ showed no significant difference compared to $D_2$, and $D_2$ was significantly at par with $D_3$; however, $D_1$ was significantly different from $D_3$. The highest recorded yield per acre was 70.2, while the lowest was 7.8. Everaarts and De Moel (1998) also reported that combinations of high plant density and late planting resulted in fewer sprouts per plant.

Table 3 also demonstrates significant differences in plant height (cm) across the three sowing dates. The tallest plants were observed in $D_1$ (36.4 cm), while the shortest plants were observed in $D_2$ (14.6 cm). Early planting led to taller plants compared to late planting. Bravo *et al.* (1986) suggested that the period from transplanting to harvest was shorter for later planting dates. The number of leaves per plant showed a significant difference among the sowing dates. The highest number of leaves was observed in $D_1$ (31.5), while the lowest was in $D_3$ (20.5). Early sown plants produced more leaves, directly impacting yield. Abuzeid and Wilcockson (1989) noted that early-sown plants produce more buds than late ones due to a longer growing season.

A significant difference in ten-sprout weight (g) was also observed across sowing dates. The maximum ten-sprout weight was recorded in $D_1$ (151.83 g), while the minimum was observed in $D_3$ (75 g), with an overall mean of 111.44 g. Early sowing showed better performance in sprout weight, positively influencing yield, as higher temperatures during early planting promote vegetative growth, while cooler temperatures are essential for bud formation. Vural *et al.* (2000) also reported that Brussels sprout require a period of low temperatures (12-17°C) for proper bud initiation. The data on sprout diameter (cm) showed significant differences across sowing dates. $D_1$ (3.28 cm) exhibited the largest sprout diameter, while $D_3$ (2.11 cm) had the smallest. The overall mean diameter was 2.83 cm. No significant effect on sprout diameter was found between $D_1$ and $D_2$, as cooler temperatures are needed for sprout formation, as reported by Grevsen and Olesen (1994).

**Table 1.** Correlation of yield and related characters of Brussels sprout with growing environ parameters at different growth stages

| | Yield | p-Value | Plant height | p-Value | Leaves/ plant | p-Value | Ten fruits weight | p-Value | Fruit diameter | p-Value |
|---|---|---|---|---|---|---|---|---|---|---|
| Yield | 1.00 | <0.001 | 0.63 | 0.005 | 0.93 | <0.001 | 0.86 | <0.001 | 0.80 | <0.001 |
| Maximum Temperature | | | | | | | | | | |
| **Early growth** | **0.69** | **0.002** | **0.51** | **0.029** | **0.68** | **0.002** | **0.60** | **0.008** | **0.58** | **0.012** |
| Fruiting | -0.44 | 0.069 | -0.37 | 0.128 | -0.49 | 0.037 | -0.34 | 0.172 | -0.39 | 0.107 |
| Seasonal | **0.82** | **<0.001** | **0.58** | **0.011** | **0.79** | **<0.001** | **0.75** | **<0.001** | **0.69** | **0.002** |
| Minimum Temperature | | | | | | | | | | |
| Early growth | **0.88** | **<0.001** | 0.36 | 0.140 | **0.79** | **<0.001** | **0.83** | **<0.001** | **0.82** | **<0.001** |
| Fruiting | -0.32 | 0.196 | -0.35 | 0.156 | -0.35 | 0.159 | -0.27 | 0.280 | -0.29 | 0.239 |
| Seasonal | **0.73** | **<0.001** | 0.27 | 0.288 | **0.64** | **0.004** | **0.70** | **0.001** | **0.67** | **0.002** |
| Mean Temperature | | | | | | | | | | |
| Early growth | **0.90** | **<0.001** | **0.55** | **0.019** | **0.86** | **<0.001** | **0.82** | **<0.001** | **0.79** | **<0.001** |
| Fruiting | -0.40 | 0.102 | -0.37 | 0.136 | -0.45 | 0.063 | -0.32 | 0.201 | -0.37 | 0.135 |
| Seasonal | **0.97** | **<0.001** | **0.53** | **0.025** | **0.89** | **<0.001** | **0.91** | **<0.001** | **0.85** | **<0.001** |
| Diurnal Temperature Range | | | | | | | | | | |
| Early growth | 0.21 | 0.411 | 0.33 | 0.183 | 0.25 | 0.311 | 0.14 | 0.569 | 0.13 | 0.618 |
| Fruiting | **-0.49** | **0.037** | -0.31 | 0.212 | **-0.56** | **0.015** | -0.36 | 0.142 | -0.43 | 0.076 |
| Seasonal | 0.16 | 0.534 | 0.31 | 0.212 | 0.20 | 0.422 | 0.11 | 0.657 | 0.09 | 0.736 |
| Relative Humidity (Morning) | | | | | | | | | | |
| Early growth | -0.17 | 0.501 | 0.13 | 0.611 | -0.12 | 0.634 | -0.15 | 0.540 | -0.24 | 0.344 |
| Fruiting | 0.18 | 0.473 | 0.35 | 0.156 | 0.22 | 0.379 | 0.12 | 0.627 | 0.13 | 0.610 |
| Seasonal | -0.03 | 0.903 | 0.20 | 0.435 | 0.02 | 0.929 | -0.06 | 0.821 | -0.07 | 0.783 |
| Relative Humidity (Evening) | | | | | | | | | | |
| Early growth | -0.43 | 0.073 | -0.44 | 0.068 | -0.45 | 0.060 | -0.38 | 0.119 | -0.34 | 0.174 |
| Fruiting | 0.35 | 0.156 | 0.38 | 0.117 | 0.40 | 0.102 | 0.26 | 0.307 | 0.28 | 0.263 |
| Seasonal | **-0.50** | **0.035** | **-0.50** | **0.037** | **-0.49** | **0.040** | -0.46 | 0.055 | -0.38 | 0.116 |
| Relative Humidity (Mean) | | | | | | | | | | |
| Early growth | **-0.59** | **0.011** | **-0.51** | **0.031** | **-0.58** | **0.012** | **-0.53** | **0.023** | -0.46 | 0.056 |
| Fruiting | 0.29 | 0.248 | 0.33 | 0.175 | 0.34 | 0.171 | 0.20 | 0.421 | 0.24 | 0.333 |
| Seasonal | **-0.84** | **<0.001** | **-0.61** | **0.008** | **-0.77** | **<0.001** | **-0.81** | **<0.001** | **-0.67** | **0.003** |
| Rainfall | | | | | | | | | | |
| Early growth | -0.01 | 0.960 | -0.26 | 0.305 | -0.05 | 0.835 | 0.01 | 0.960 | 0.06 | 0.813 |
| Fruiting | -0.05 | 0.845 | 0.16 | 0.533 | 0.01 | 0.964 | -0.09 | 0.714 | -0.09 | 0.712 |
| Seasonal | -0.32 | 0.196 | -0.09 | 0.734 | -0.25 | 0.318 | -0.38 | 0.124 | -0.26 | 0.293 |
| Bright Sunshine Hours | | | | | | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Early growth | 0.23 | 0.363 | 0.37 | 0.130 | 0.27 | 0.284 | 0.17 | 0.501 | 0.13 | 0.619 |
| Fruiting | -0.46 | 0.056 | -0.40 | 0.102 | **-0.52** | **0.026** | -0.29 | 0.237 | -0.43 | 0.077 |
| Seasonal | 0.18 | 0.479 | 0.35 | 0.160 | 0.22 | 0.379 | 0.15 | 0.552 | 0.08 | 0.763 |
| Wind Speed | | | | | | | | | | |
| Early growth | -0.15 | 0.558 | -0.33 | 0.184 | -0.20 | 0.432 | -0.10 | 0.685 | -0.03 | 0.902 |
| Fruiting | **-0.53** | **0.023** | -0.05 | 0.848 | -0.41 | 0.092 | **-0.49** | **0.040** | **-0.50** | **0.033** |
| Seasonal | -0.40 | 0.099 | -0.41 | 0.091 | -0.42 | 0.084 | -0.38 | 0.119 | -0.23 | 0.353 |
| Reference Evapotranspiration | | | | | | | | | | |
| Early growth | 0.41 | 0.088 | 0.44 | 0.068 | 0.43 | 0.077 | 0.36 | 0.142 | **0.30** | **0.219** |
| Fruiting | **0.73** | **<0.001** | 0.42 | 0.086 | **0.65** | **0.003** | **0.63** | **0.005** | **0.77** | **<0.001** |
| Seasonal | 0.46 | 0.055 | 0.45 | 0.063 | 0.47 | 0.051 | 0.40 | 0.101 | **0.36** | **0.14** |

Correlation values in bold faces are significant at $p \leq 0.05$

**Table 2.** Correlation of yield and related characters of Brussels sprout with growing days and thermal growing indices

| | Yield | p-Value | Plant height | p-Value | Leaves/ plant | p-Value | Ten fruits weight | p-Value | Fruit diameter | p-Value |
|---|---|---|---|---|---|---|---|---|---|---|
| Crop stage duration days | | | | | | | | | | |
| Early growth | **0.88** | **<0.001** | 0.37 | 0.127 | **0.80** | **<0.001** | **0.82** | **<0.001** | **0.78** | **<0.001** |
| Fruiting | **0.67** | **0.002** | 0.21 | 0.402 | **0.56** | **0.015** | **0.55** | **0.017** | **0.81** | **<0.001** |
| Seasonal | **0.93** | **<0.001** | **0.41** | **0.091** | **0.83** | **<0.001** | **0.84** | **<0.001** | **0.86** | **<0.001** |
| Growing Degree Days (GDD) | | | | | | | | | | |
| Early growth | **0.97** | **<0.001** | **0.54** | **0.022** | **0.91** | **<0.001** | **0.89** | **<0.001** | 0.85 | <0.001 |
| Fruiting | **-0.14** | **0.579** | -0.30 | 0.226 | **-0.25** | **0.325** | **-0.10** | **0.693** | **-0.03** | **0.910** |
| Seasonal | 0.96 | <0.001 | 0.49 | 0.041 | 0.88 | <0.001 | 0.89 | <0.001 | 0.86 | <0.001 |
| Photo-thermal unit (PTU) | | | | | | | | | | |
| Early growth | **0.97** | **<0.001** | 0.54 | 0.021 | **0.91** | **<0.001** | **0.89** | **<0.001** | 0.85 | <0.001 |
| Fruiting | **-0.20** | **0.432** | **-0.32** | **0.191** | **-0.30** | **0.233** | **-0.15** | **0.543** | **-0.09** | **0.735** |
| Seasonal | 0.96 | <0.001 | 0.48 | 0.042 | 0.88 | <0.001 | 0.89 | <0.001 | 0.85 | <0.001 |
| Helio-thermal unit (HTU) | | | | | | | | | | |
| Early growth | **0.69** | **0.001** | **0.58** | **0.011** | **0.68** | **0.002** | **0.62** | **0.007** | 0.53 | 0.025 |
| Fruiting | -0.27 | 0.280 | -0.33 | 0.183 | -0.36 | 0.146 | -0.16 | 0.517 | **-0.20** | **0.421** |
| Seasonal | **0.77** | **<0.001** | **0.62** | **0.006** | **0.74** | **<0.001** | **0.71** | **0.001** | **0.58** | **0.011** |
| Photo-thermal index (PTI) | | | | | | | | | | |
| Early growth | **0.91** | **<0.001** | **0.56** | **0.016** | **0.86** | **<0.001** | **0.82** | **<0.001** | **0.79** | **<0.001** |
| Fruiting | -0.35 | 0.157 | -0.33 | 0.179 | -0.41 | 0.093 | -0.26 | 0.293 | -0.31 | 0.213 |
| Seasonal | **0.97** | **<0.001** | **0.51** | **0.032** | **0.89** | **<0.001** | **0.91** | **<0.001** | **0.86** | **<0.001** |
| Heat use efficiency (HTU) | | | | | | | | | | |
| **Seasonal** | **1.00** | **<0.001** | **0.62** | **0.006** | **0.92** | **<0.001** | **0.86** | **<0.001** | **0.82** | **<0.001** |

Correlation values in bold faces are significant at $p \leq 0.05$

**Table 3.** Analysis of variance

| Planting Date | Yield (q/ ha) | | | Plant height (cm) | | | Leaves/ plant (no.) | | | Ten fruits weight (g) | | | Sprout diameter (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Min. | Max. | Mean | Min. | Max. | Mean | Min. | Max. | Mean | Min. | Max. | Mean | Min. | Max. |
| $D_1$ (20th Oct.) | 61.35± 7.62a | 52.2 | 70.2 | 30.77± 6.81a | 20.9 | 36.4 | 31.5± 2.16a | 29 | 35 | 151.83± 18.65a | 125 | 175 | 3.28± 0.23a | 3.0 | 3.6 |
| $D_2$ (30th Oct.) | 31.80± 2.26b | 28.3 | 34.2 | 22.10± 3.86b | 14.6 | 25.4 | 24.66± 1.86b | 22 | 27 | 107.50± 10.35b | 90 | 120 | 3.11± 0.27a | 2.8 | 3.6 |
| $D_3$ (10th Nov.) | 9.81± 1.43c | 7.8 | 11.3 | 23.36± 3.15b | 20.2 | 28.9 | 20.50± 2.25c | 18 | 24 | 75.00± 18.43c | 50 | 105 | 2.11± 0.19c | 1.8 | 2.3 |
| LSD | 5.74 | | | 5.64 | | | 2.58 | | | 20.04 | | | 0.29 | | |
| Grand Mean | 34.32 | | | 25.40 | | | 25.55 | | | 111.44 | | | 2.83 | | |

## Conclusion

This study reveals the intricate dynamics shaping the growth and yield of Brussels sprout in response to environmental conditions and sowing dates. The crop's yield displayed a positive correlation with maximum, minimum, and mean temperatures, demonstrating its sensitivity to temperature variations. Vegetative growth parameters such as plant height increased with rising temperatures, further highlighting temperature's role in development. Key growth attributes, including the number of leaves, ten-fruit weight, and fruit diameter, were positively influenced by temperature, reinforcing the importance of environmental factors in the plant's development. Heat use efficiency, a critical metric for evaluating plant performance, significantly correlated with traits like yield and growth parameters, validating its utility in assessing productivity.

Sowing dates emerged as a pivotal factor, with the highest yield recorded for planting on October 20. Early sowing improved critical growth characteristics, such as plant height, leaf count, fruit weight, and diameter, emphasizing the importance of optimal planting times for achieving maximum productivity. This research underscores the potential of Brussels sprout as a high-value crop with remarkable nutritional benefits. Understanding the interplay of environmental factors and cultivation practices enables growers to optimize yields, enhance nutritional value, and contribute to sustainable agricultural practices, paving the way for further advancements in this versatile crop.

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## Conflict of Interest

The authors have no conflict of interest.

## Data Sharing

All relevant data are within the manuscript.

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