

# Heat Unit Accumulation, Heat Use Efficiency, Yield, and Sweetness of Sweet Corn (*Zea mays saccharata* Sturt L.) under Tropical Lowland Conditions

Affan Prasetya, Dulbari\*, Zulkarnain

Applied Master's Program in Food Security, Politeknik Negeri Lampung, Bandar Lampung,  
Jl. Soekarno Hatta No. 10, Rajabasa Raya, Kec. Rajabasa, Kota Bandar Lampung, Lampung 35141, Indonesia.

Corresponding author\*

dulbari@polinela.ac.id

Manuscript received: 26 June 2026. Revision accepted: 30 September 2026, Published: 13 October 2026.

## Abstract

Temperature is an important environmental factor influencing phenological development and productivity of sweet corn through heat unit accumulation. This study evaluated heat unit accumulation, heat use efficiency (HUE), yield components, and sweetness of seven commercial sweet corn cultivars grown under tropical lowland conditions during one growing season. The experiment was arranged in a randomized complete block design with seven cultivars and three replications. Heat unit accumulation was calculated using growing degree days (GDD) with a base temperature of 10°C. Phenological stages, plant height, cob yield components, total soluble solids (°Brix), and HUE were recorded. Significant differences among cultivars were observed in GDD required to reach vegetative emergence, tasseling, and silking, whereas GDD at the milk stage and HUE did not differ significantly. Exsotic F1 produced the highest cob weight with husk (354.88 g), cob weight without husk (264.16 g), cob length (20.37 cm), and cob diameter (60.27 mm), while Hibrix 72 F1 exhibited the highest total soluble solids (15.11 °Brix). Pcobson correlation analysis showed that HUE was positively associated with cob weight and cob size, whereas °Brix was negatively correlated with cob yield components. Principal component analysis separated cultivars according to phenological, yield, and quality traits. Under the environmental conditions of this study, commercial sweet corn cultivars differed in thermal requirements, yield characteristics, and sweetness, providing comparative information on cultivar performance under tropical lowland conditions.

**Keywords:** growing degree days; heat use efficiency; phenology; sweet corn; tropical lowland.

**Abbreviations:** CSI: Corn Sweetness Index; DAP: Days After Planting; GDD: Growing Degree Days; HEW: Husked Cob Weight; HUE: Heat Use Efficiency; R1: Silking Stage; R3: Milk Stage; UEW: Unhusked Cob Weight; VE: Vegetative Emergence; VT: Tasseling Stage.

## INTRODUCTION

*Zea mays saccharata* Sturt L.) is one of the most economically important horticultural crops because of its high nutritional value, desirable taste, and wide utilization in both fresh and processed food industries. The increasing demand for fresh vegetables and processed sweet corn products has encouraged the expansion of sweet corn cultivation in Indonesia, where it has become an important commodity in several major production regions (Paranhos et al. 2023; Sudjarmiko & Chozin 2024). However, sweet corn productivity remains highly dependent on environmental conditions, particularly air temperature, which regulates plant growth, phenological development, and yield formation (Liu et al. 2025).

Temperature controls crop development through the accumulation of thermal time, commonly expressed as Growing Degree Days (GDD). The GDD approach

describes the relationship between daily temperature and plant developmental rate, allowing accurate prediction of phenological stages, flowering time, and physiological maturity (Wang et al. 2025). In addition, Heat Use Efficiency (HUE) has been widely used to evaluate the ability of plants to convert accumulated thermal energy into biomass and economic yield, making it an important indicator of varietal adaptation and productivity under different climatic conditions.

The thermal requirement of sweet corn varies among cultivars due to differences in genetic characteristics and physiological adaptation to environmental conditions (Radočaj et al., 2025). Cultivars with lower thermal requirements generally reach developmental stages more rapidly, whereas those requiring greater heat accumulation often exhibit longer growth duration and may be exposed to greater environmental stress during the growing season (Li et al., 2022). Consequently, understanding varietal differences in heat unit

accumulation is essential for selecting suitable cultivars and improving crop management under specific agroecological conditions.

Several studies have demonstrated that temperature variation significantly affects flowering time, crop duration, and yield performance of maize and sweet corn. Under tropical conditions, differences in temperature have been reported to alter heat accumulation and consequently influence crop productivity (Paranhos et al. 2023; Sudjarmiko & Chozin 2024). Furthermore, projected increases in global temperature are expected to accelerate crop development, shorten vegetative growth, and shift planting calendars in many maize-producing regions (Franch et al. 2022; Wang et al. 2025).

Beyond phenological prediction, GDD has practical applications in determining optimum planting dates, fertilizer scheduling, irrigation management, and harvest timing (Vellidis et al., 2025). Recent studies have also integrated thermal time models into crop productivity forecasting across diverse agroecosystems (Menendez-Coccoz et al. 2025); Liu et al. 2025). Nevertheless, information regarding the thermal requirements of commercial sweet corn cultivars under tropical lowland conditions in Indonesia remains limited. Previous studies have primarily focused on phenological development or yield performance, whereas studies integrating heat accumulation at each phenological stage, heat use efficiency, and yield characteristics among commercial sweet corn cultivars are still limited.

Therefore, this study was conducted to evaluate heat unit accumulation at each phenological stage and to analyze the effects of varietal differences on heat use efficiency, yield, and cob quality of several commercial sweet corn cultivars grown under tropical lowland conditions during one growing season. The results are expected to provide additional information on varietal differences in thermal requirements and heat use efficiency under the environmental conditions of this study, which may serve as a reference for further research under different locations and growing seasons.

## MATERIALS AND METHODS

### Study area

The experiment was conducted from February to May 2026 in Untoro Village, Trimurjo District, Central Lampung Regency, Indonesia (Figure 1). The experimental site was located at 5°05'27.49" S and 105°14'58.37" E, at an altitude of 54 m above sea level, on Podzolic Red-Yellow soil. During the experimental period, the average daily air temperature ranged from 25.3 to 28.7 °C, total rainfall was 566.8 mm, and relative humidity ranged from 68% to 93%. The experiment was arranged in a randomized complete block design (RCBD) with a single factor consisting of seven commercial sweet corn (*Zea mays saccharata* L.) variety (Table 1) and three replications, resulting in 21 experimental plots.

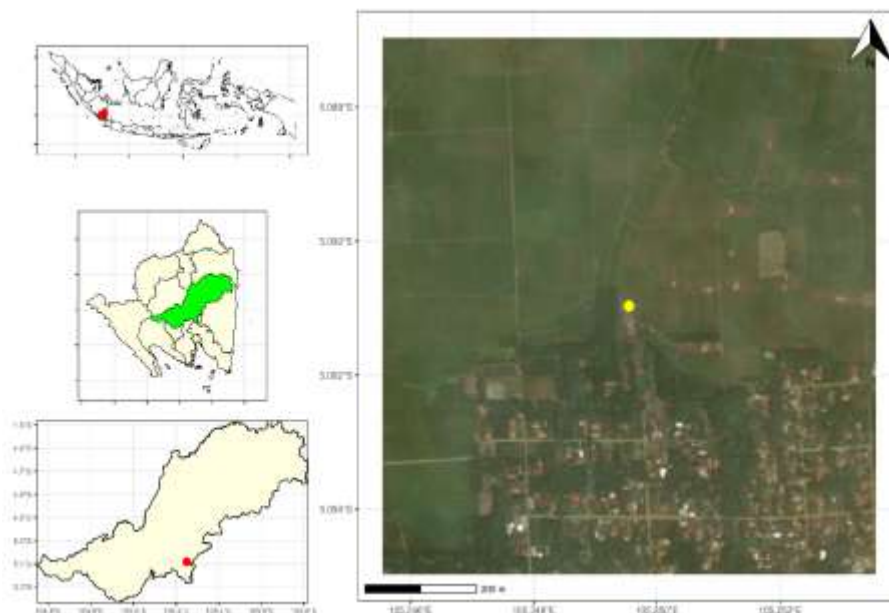


Figure 1. Research Location.

## MATERIALS AND EQUIPMENT

The materials used in this study consisted of sweet corn (*Zea mays saccharata* Sturt L.) seeds of seven commercial cultivars, namely NB Super F1, Romanza

F1, Exsotic F1, Paragon F1, Madu 59 F1, Hibrix 72 F1, and Fresty F1. Other materials included cattle manure, NPK fertilizer (15-10-12), urea, synthetic herbicides containing ammonium glufosinate, atrazine, mesotrione, and carfentrazone-ethyl as active ingredients, as well as

pesticides containing *imidacloprid*, *emamectin benzoate*, *dimethomorph*, *metalaxyl*, and *pyraclostrobin*. The equipment used in this study included hoes, sickles, watering cans, measuring tapes, a 16-L knapsack sprayer, an analytical balance, a digital refractometer, and a digital caliper.

### Experimental Design and Treatments

The experiment was arranged in a Randomized Complete Block Design (RCBD) with a single factor consisting of seven commercial sweet corn cultivars: NB Super F1 (V1), Romanza F1 (V2), Exsotic F1 (V3), Paragon F1 (V4), Madu 59 F1 (V5), Hibrix 72 F1 (V6), and Freesty F1 (V7). Each treatment was replicated three times, resulting in a total of 21 experimental plots. Each experimental plot measured 2.5 m × 2.8 m and was planted at a spacing of 0.7 m × 0.25 m. Each plot consisted of four planting rows with a total of 40 plants. Data were collected from 10 sample plants located in the two central rows (second and third rows) of each plot to minimize border effects. In total, the experiment consisted of 840 plants, of which 210 plants were selected as observation samples.

### Heat Unit Calculation

Daily maximum and minimum air temperature data were obtained from the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) Radin Inten II Meteorological Station, the ncobest weather station to the experimental site. Daily mean temperature was calculated as:

$$T = \frac{T_x + T_n}{2}$$

Heat unit (HU), expressed as Growing Degree Days (GDD), was calculated using the following equation:

$$HU = \sum (T - T_0)$$

where HU is the accumulated heat unit (°C day), T is the daily mean air temperature (°C),  $T_x$  and  $T_n$  are the daily maximum and minimum air temperatures (°C), respectively, and  $T_0$  is the base temperature. A base temperature of 10°C was used for all calculations, as it is widely accepted for maize and sweet corn phenological studies (McMaster et al. 1997; Paredes et al. 2025; Vellidis et al. 2025).

### Observed Parameters

Phenological observations were conducted at the vegetative emergence (VE), tasseling (VT), silking (R1),

and milk (R3) stages. The VE stage was recorded when the coleoptile emerged above the soil surface, VT when the last branch of the tassel was visible, R1 when silks emerged from the cob, and R3 at 20 days after silking. Heat unit accumulation was calculated from planting to each phenological stage (Sholikah, 2020). Plant height (cm) was measured from the soil surface to the highest growing point at 14, 28, and 42 days after planting (DAP). At harvest, cob weight with husk (g), cob weight without husk (g), cob length (cm), cob diameter (mm), and total soluble solids (°Brix) were determined using a digital balance, ruler, digital caliper, and handheld refractometer, respectively.

Heat use efficiency (HUE) was calculated according to Sankar et al. (2023) and Hussain et al. (2023) using the following equation:

$$HUE = \frac{Y}{GDD}$$

where HUE is heat use efficiency (g °C<sup>-1</sup> day<sup>-1</sup>), Y is cob yield per plant (g plant<sup>-1</sup>), and GDD is the accumulated growing degree days from planting to harvest.

### Data Analysis

Prior to the analysis of variance (ANOVA), the data were tested for normality using the Shapiro-Wilk test and for the homogeneity of the variance using the Levene test. The data were then ANOVA tested at a significance level of  $p \leq 0.05$ , followed by Duncan's Multiple Range Test (DMRT) for mean separation when significant differences occurred. Pcobson correlation analysis was performed to evaluate the relationship between heat accumulation, heat use efficiency, yield components, and corn sweetness index variables. Statistical analysis was conducted using STAR version 2.0.1 and Microsoft Excel LTSC Professional Plus 2021. Data visualization, including key component analysis (PCA) and correlation heatmap construction, was performed using RStudio version 2025.09.1+401 with *ggplot2* and *corrplot* packages.

## RESULTS AND DISCUSSION

### Heat Unit Accumulation Across Phenological Stages

Accumulated heat units significantly influenced the phenological development of sweet corn throughout the growing cycle. Significant differences among cultivar were observed at the VE, VT, and R1 stages, indicating variation in heat units requirements under tropical conditions.

**Table 1.** Heat unit accumulation at each phenological stage.

| Cultivar     | VE (°C day)      | VT (°C day)       | R1 (°C day)       | R3 (°C day)     |
|--------------|------------------|-------------------|-------------------|-----------------|
| NB Super F1  | 84.65 ± 0.00 c   | 694.32 ± 18.33 b  | 742.51 ± 19.61 c  | 1046.78 ± 18.31 |
| Romanza F1   | 102.30 ± 0.00 a  | 699.55 ± 27.40 b  | 753.68 ± 38.95 bc | 1125.50 ± 32.22 |
| Exsotic F1   | 90.53 ± 10.19 bc | 720.72 ± 9.06 a   | 770.66 ± 9.53 b   | 1030.01 ± 10.74 |
| Paragon F1   | 96.42 ± 10.19 ab | 710.14 ± 24.18 ab | 759.34 ± 25.73 bc | 1104.25 ± 62.90 |
| Madu 59 F1   | 102.30 ± 0.00 a  | 720.72 ± 9.06 a   | 770.66 ± 9.53 b   | 1135.73 ± 38.88 |
| Hibrix 72 F1 | 102.30 ± 0.00 a  | 725.96 ± 9.06 a   | 798.93 ± 17.40 a  | 1119.94 ± 49.98 |
| Fresty F1    | 90.53 ± 10.19 bc | 699.64 ± 15.88 b  | 748.01 ± 29.14 bc | 1083.71 ± 41.87 |
| Sig.         | *                | *                 | **                | ns              |
| CV %         | 6.16             | 1.39              | 1.65              | 3.73            |

Note: Values are mean ± SE (n = 3). Means followed by different letters within the same column differ significantly according to DMRT at  $p \leq 0.05$ . ns = non-significant; \*  $p \leq 0.05$ ; \*\*  $p \leq 0.01$ . CV (%) = coefficient of variation

Table 4 presents the accumulated growing degree days (GDD) required by each variety to reach vegetative emergence (VE), tasseling (VT), silking (R1), and milk stage (R3). At the VE stage, NB Super F1 showed the lowest GDD requirement (84.65 °C day), whereas Romanza F1, Madu 59 F1, and Hibrix 72 F1 required significantly higher heat accumulation (102.30 °C day). At the VT stage, Hibrix 72 F1 exhibited the highest accumulated GDD (725.96 °C day), followed by Exsotic F1 and Madu 59 F1 (720.72 °C day). In contrast, NB Super F1 showed lower heat accumulation at tasseling (694.32 °C day). Similar trends were observed at the R1 stage, where Hibrix 72 F1 required the highest GDD (798.93 °C day), while NB Super F1 required the lowest (742.51 °C day). Although differences at the R3 stage were not statistically significant, variation among variety

remained apparent. Exsotic F1 and NB Super F1 reached the milk stage with relatively lower GDD values, whereas Hibrix 72 F1 and Madu 59 F1 showed higher heat accumulation.

#### Yield Components and Cobs Characteristics

Yield components and cobs characteristics are important indicators for evaluating the agronomic performance and market quality of sweet corn variety. Parameters such as cob weight, cob length, and cob diameter reflect the efficiency of assimilate partitioning and kernel development during the generative stage. Variations in these traits among variety indicate differences in genetic potential and physiological responses to accumulated heat units under tropical growing conditions

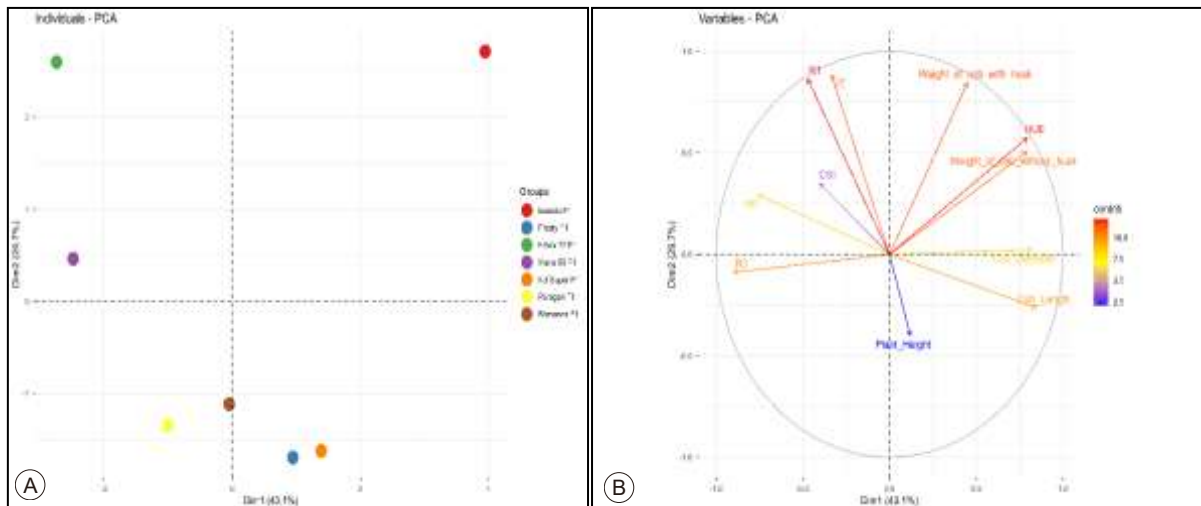
**Table 2.** Yield, cob characteristics, and heat use efficiency.

| Cultivar     | Plant height (cm) | Weight of cob with husk (g) | Weight of cob without husk (g) | Cob length (cm) | Cob diameter (mm) |
|--------------|-------------------|-----------------------------|--------------------------------|-----------------|-------------------|
| NB Super F1  | 163.82 ± 29.64    | 314.58 ± 24.23              | 230.69 ± 21.85                 | 19.61 ± 0.59 ab | 53.06 ± 9.51 bcd  |
| Romanza F1   | 174.93 ± 14.86    | 325.80 ± 41.70              | 227.56 ± 33.84                 | 19.71 ± 1.36 ab | 58.17 ± 2.09 ab   |
| Exsotic F1   | 164.88 ± 5.03     | 354.88 ± 54.75              | 264.16 ± 38.06                 | 20.37 ± 0.83 a  | 60.27 ± 2.37 a    |
| Paragon F1   | 161.73 ± 18.68    | 309.76 ± 25.64              | 215.13 ± 10.26                 | 18.91 ± 0.20 b  | 52.76 ± 1.60 bcd  |
| Madu 59 F1   | 167.30 ± 28.86    | 323.95 ± 51.40              | 217.79 ± 38.14                 | 18.63 ± 0.85 b  | 46.88 ± 2.56 d    |
| Hibrix 72 F1 | 163.73 ± 9.11     | 331.47 ± 65.33              | 232.96 ± 43.98                 | 17.04 ± 1.13 c  | 51.07 ± 3.37 cd   |
| Fresty F1    | 177.57 ± 13.23    | 316.06 ± 56.63              | 241.29 ± 45.02                 | 19.03 ± 1.01 b  | 56.01 ± 4.73 abc  |
| Sig.         | ns                | ns                          | ns                             | **              | **                |
| CV %         | 6.57              | 6.57                        | 9.95                           | 3.55            | 6.45              |

Note: Values are mean ± SE (n = 3). Means followed by different letters within the same column differ significantly according to DMRT at  $p \leq 0.05$ . ns = non-significant; \*  $p \leq 0.05$ ; \*\*  $p \leq 0.01$ . CV (%) = coefficient of variation

Heat use efficiency (HUE) ranged from 0.28 to 0.34 g °C<sup>-1</sup> day<sup>-1</sup> and was not significantly influenced by cultivar, indicating a relatively uniform ability among sweet corn cultivar to convert heat units into biomass under tropical lowland conditions. Exsotic F1 numerically exhibited higher HUE (0.34 g °C<sup>-1</sup> day<sup>-1</sup>), while Paragon F1 recorded the lowest (0.28 g °C<sup>-1</sup> day<sup>-1</sup>). In contrast, Corn Sweetness Index differed

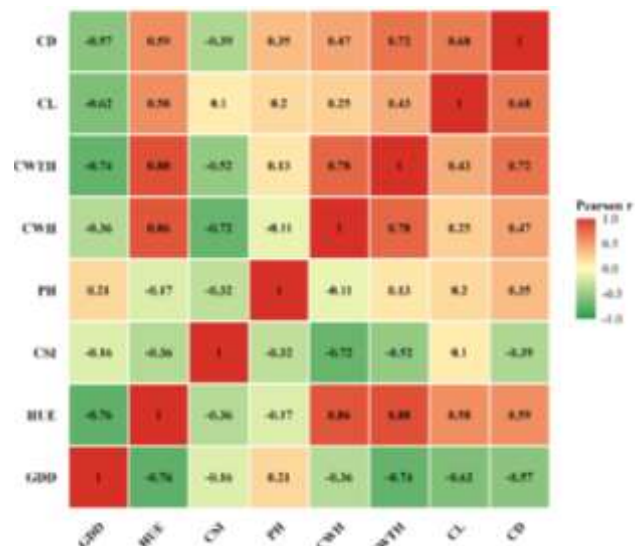
significantly among cultivar. Hibrix 72 F1 exhibited the highest °Brix value (15.11), followed by NB Super F1, Romanza F1, and Madu 59 F1 (13.47–13.85 °Brix), while Paragon F1 showed the lowest sweetness (11.05 °Brix). The results indicate that postharvest quality is strongly variety-dependent, despite similar although HUE values were statistically comparable among cultivars across cultivar.



**Figure 2.** Principal Component Analysis (PCA) of sweet corn cultivar and agronomic traits under tropical lowland conditions. (A) PCA score plot showing the distribution and clustering of sweet corn cultivar based on phenological, yield, and quality traits. (B) PCA loading plot illustrating the contribution and association of variables, whereas variables located in opposite directions indicate negative relationships.

The PCA analysis revealed substantial variation among sweet corn variety based on phenological, yield, and quality-related traits under tropical lowland conditions. Principal component 1 (Figure 2.a) explained 52.1% of the total variation and was mainly associated with yield-related variables, particularly husked cob weight (HEW), unhusked cob weight (UEW), cob diameter (ED), and heat use efficiency (HUE). This indicates that productivity differences among variety were primarily driven by generative sink strength and the efficiency of heat energy utilization. Exsotic F1 was positioned closer to the positive direction of these vectors, suggesting superior cob productivity and greater biomass accumulation compared with the other variety. In contrast, cultivar located farther from the main productivity axis exhibited relatively lower yield performance.

Principal component 2 (Figure 2.b), which accounted for 24.3% of the total variation, was more strongly related to phenological traits, including tasseling (VT), silking (R1), and vegetative emergence (VE), as well as corn sweetness index (CSI). The opposite orientation between CSI and several yield-related traits indicates a physiological trade-off between sweetness retention and biomass accumulation. Cultivar characterized by higher sweetness tended to exhibit lower cob productivity, whereas high-yielding cultivar were associated with stronger assimilate partitioning toward generative growth. The relatively isolated position of plant height (PH) suggests that vegetative growth contributed less to varietal differentiation compared with generative and quality traits under tropical environmental conditions.



**Figure 3.** Pcobson correlation heatmap showing the relationships among growing degree days (GDD), heat use efficiency (HUE), corn sweetness index (CSI), plant height (PH), cobs weight with husk (CWTH), cobs weight without husk (CWH), cobs length (CL), and cobs diameter (CD) of sweet corn cultivars under tropical lowland conditions. Positive correlation coefficients indicate direct relationships among variables, whereas negative coefficients indicate inverse relationships. Color intensity represents the strength of the correlation coefficient (r).

The Pcobson correlation heatmap revealed strong associations among heat accumulation, heat use efficiency, yield traits, and kernel sweetness of sweet corn under tropical lowland conditions. Growing degree days (GDD) showed negative correlations with heat use efficiency (HUE), cob weight, cob length, and cob diameter, indicating that variety requiring greater heat accumulation tended to exhibit lower productivity and reduced heat efficiency. In contrast, HUE was strongly and positively associated with cob weight traits and cob size variables, suggesting that efficient utilization of accumulated heat units contributed directly to generative biomass formation and yield improvement. Strong

positive relationships among cob weight, cob length, and cob diameter further indicate that larger cob morphology was closely related to increased productivity.

Corn sweetness index (CSI) exhibited negative correlations with most yield-related traits, particularly cob weight variables, indicating a physiological trade-off between sweetness retention and biomass accumulation. Cultivar with higher sweetness tended to produce smaller cobs and lower yield performance, whereas high-yielding variety were associated with stronger assimilate allocation toward structural biomass and kernel filling. Plant height showed relatively weak correlations with yield and heat efficiency variables, suggesting that vegetative growth contributed less to productivity variation than generative sink strength and assimilate partitioning efficiency under tropical conditions

## Discussion

Phenological development differed among the evaluated sweet corn cultivars, as reflected by variation in accumulated growing degree days (GDD) required to reach each developmental stage. These differences indicate variation in thermal requirements among cultivars under the environmental conditions of this study. Previous studies have shown that temperature influences maize developmental rate by regulating heat accumulation and phenological progression (M. Liu et al., 2022). Therefore, differences in GDD observed in the present study may reflect cultivar-specific responses to thermal conditions.

Differences in heat requirements were accompanied by variation in yield performance among cultivars. Cultivars with shorter growth duration reached physiological maturity earlier, whereas others required greater heat accumulation before harvest. Similar observations have been reported in maize, where crop duration may influence biomass production and yield formation depending on environmental conditions (Wang et al. 2022a; El-Sappah et al., 2022). However, because this study was conducted during a single growing season, these relationships should be interpreted within the conditions of the present experiment.

Variation in cob weight and cob size among cultivars suggests differences in assimilate allocation during the reproductive stage. Higher-yielding cultivars tended to produce larger cobs, indicating greater assimilate accumulation during grain filling. Previous studies have reported that post-silking assimilate availability contributes to kernel development and final yield, particularly under favorable growing conditions (Bheemanahalli et al., 2022). Nevertheless, the present study did not directly measure assimilate partitioning or physiological processes; therefore, this interpretation is based on observed yield characteristics and supporting literature.

Temperature during the reproductive stage has been reported to influence pollen viability, silk emergence,

and grain filling in maize (El-Sappah et al. 2022; Tas 2022). Although the present study did not evaluate heat stress responses directly, differences in phenological duration among cultivars may indicate differences in the timing of reproductive development under the prevailing temperature conditions.

Heat use efficiency (HUE) did not differ significantly among cultivars, although numerical differences were observed. These results suggest that the evaluated cultivars exhibited relatively similar efficiency in converting accumulated heat units into yield under the environmental conditions of this experiment. Similar findings have been reported in maize, where HUE may vary with genotype and environmental conditions (Wang et al. 2022b; Ru et al. 2022).

Differences in total soluble solids ( $^{\circ}$ Brix) among cultivars indicate variation in sugar accumulation during kernel development. Cultivars with higher  $^{\circ}$ Brix values may have retained a greater proportion of soluble sugars at harvest, whereas cultivars with higher yield tended to show relatively lower  $^{\circ}$ Brix values. Similar relationships between sugar accumulation and grain filling have been reported in sweet corn (Yousaf et al., 2022). Although additional physiological measurements would be required to confirm the underlying mechanisms. Overall, the evaluated cultivars showed differences in phenological development, heat unit accumulation, yield components, and sweetness under tropical lowland conditions during one growing season. These results provide comparative information on cultivar performance under the environmental conditions of this study and may serve as a basis for further evaluation across different locations and growing seasons.

## CONCLUSIONS

The evaluated sweet corn cultivars showed differences in phenological development, heat unit accumulation, yield components, and sweetness under tropical lowland conditions during one growing season. Differences in growing degree days (GDD) among cultivars indicated variation in thermal requirements during crop development.

Among the evaluated cultivars, Exsotic F1 produced higher husked and dehusked cob weight, larger cob dimensions, and relatively higher heat use efficiency (HUE), whereas Hibrix 72 F1 recorded the highest total soluble solids ( $^{\circ}$ Brix). Pcobson's correlation analysis showed that HUE was positively correlated with cob yield components, while  $^{\circ}$ Brix was negatively correlated with cob weight and cob size.

Within the environmental conditions of this study, greater heat accumulation was not consistently associated with higher yield performance, suggesting that differences in thermal requirements among cultivars may influence yield and quality characteristics. These findings provide comparative information on the performance of

commercial sweet corn cultivars under the conditions of this experiment and may serve as a reference for future studies across different environments and growing seasons.

**Acknowledgements:** The authors sincerely thank the Graduate Program, Politeknik Negeri Lampung, for technical support throughout this study. The authors also express their appreciation to all individuals who assisted with the field experiment and data collection.

**Authors' Contributions:** Affan Prasetya conceived and designed the study, conducted the field experiment, collected and analyzed the data, and prepared the original manuscript. Dulbari contributed to the study design, supervised the rescobch, and critically reviewed and revised the manuscript. Zulkarnain contributed to data interpretation, supervised the rescobch, and reviewed and revised the manuscript. All authors read and approved the final version of the manuscript.

**Competing Interests:** The authors declare that there are no competing interests.

**Funding:** This rescobch received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

## REFERENCES

- Bheemanahalli, R., Vennam, R. R., Ramamoorthy, P., & Reddy, K. R. (2022). Effects of post-flowering heat and drought stresses on physiology, yield, and quality in maize (*Zea mays* L.). *Plant Stress*, 6, 100106. <https://doi.org/10.1016/j.plstress.2022.100106>
- El-Sappah, A. H., Rather, S. A., Wani, S. H., Elrys, A. S., Bilal, M., Huang, Q., Dar, Z. A., Elashokhy, M. M. A., Soaud, N., Koul, M., Mir, R. R., Yan, K., Li, J., El-Tarabily, K. A., & Abbas, M. (2022). Heat Stress-Mediated Constraints in Maize (*Zea mays*) Production: Challenges and Solutions. *Frontiers in Plant Science*, 13, 879366. <https://doi.org/10.3389/fpls.2022.879366/full>
- Franch, B., Cintas, J., Becker-Reshef, I., Sanchez-Torres, M. J., Roger, J., Skakun, S., Sobrino, J. A., Van Tricht, K., Degerickx, J., Gilliams, S., Koetz, B., Szantoi, Z., & Whitcraft, A. (2022). Global crop calendars of maize and wheat in the framework of the WorldCereal project. *GIScience & Remote Sensing*, 59(1), 885–913. <https://doi.org/10.1080/15481603.2022.2079273>
- Hussain, N., Hussain, A., Bhat, M. A., Wani, O. A., Hussain, A., Bhat, T. A., Mir, A. H., Wani, F. J., Kouser, S., Fatima, N., Hussain, M., & Hussain, S. (2023). Heat unit requirement of sweet corn under different planting methods and dates in temperate Kashmir, India. *Journal of Agrometeorology*, 25(3), 448–453. <https://doi.org/10.54386/jam.v25i3.2251>
- Li, T., ZHANG, X. peng, LIU, Q., LIU, J., CHEN, Y. quan, & SUI, P. (2022). Yield penalty of maize (*Zea mays* L.) under heat stress in different growth stages: A review. *Journal of Integrative Agriculture*, 21(9), 2465–2476. <https://doi.org/10.1016/j.jia.2022.07.013>
- Liu, M., Dong, X., Zhang, Y., Gu, M., Yu, Y., Xie, H., Yang, H., Yu, X., & Huang, S. (2022). Heat stress on maize with contrasting genetic background: Differences in flowering and yield formation. *Agricultural and Forest Meteorology*, 319, 108934. <https://doi.org/10.1016/j.agrformet.2022.108934>
- Liu, Y.-Y., Su, Y.-C., Sun, P.-W., Dai, H.-Y., & Kuo, B.-J. (2025). Stability of Maize Phenology Predictions by Using Calendar Days, Thermal Functions, and Photothermal Functions. *Agriculture*, 15(19), 1–22. <https://ideas.repec.org/a/gam/jagris/v15y2025i19p2020-d1759209.html>
- McMaster, Gregory, S., & Wilhelm, W. W. (1997). Growing degree-days: one equation, two interpretations. *Agricultural and Forest Meteorology*, 87(4), 291–300. <https://www.sciencedirect.com/science/article/pii/S0168192397000270>
- Menendez-Coccoz, M., Rotili, D. H., Otegui, M. E., Martini, G., Paolini, M., Di Bella, C., Piñeiro, G., & Oesterheld, M. (2025). Low-input, interpretable models to forecast maize yield at multiple scales based on absorbed radiation. *Agronomy Journal*, 117(3), e70089. <https://doi.org/10.1002/agi2.70089>
- Paranhos, J., Foshee, W., Coolong, T., Heyes, B., Salazar-Gutierrez, M., Kesheimer, K., & da Silva, A. L. B. R. (2023). Characterization of Sweet Corn Production in Subtropical Environmental Conditions. *Agriculture*, 13(6), 1156. <https://doi.org/10.3390/agriculture13061156>
- Paredes, P., López-Urrea, R., Martínez-Romero, Á., Petry, M. T., Cameira, M. do R., Montoya, F., Almeida, W., Salman, M., & Pereira, L. S. (2025). Base and upper temperature thresholds to support the calculation of growing degree days aiming at their use with the FAO56rev crop coefficients curve: A review. *Agricultural Water Management*, 319, 109755. <https://doi.org/10.1016/j.agwat.2025.109755>
- Radočaj, D., Plaščak, I., & Jurišić, M. (2025). Phenology-Based Maize and Soybean Yield Potential Prediction Using Machine Learning and Sentinel-2 Imagery Time-Series. *Applied Sciences*, 15(13), 7216. <https://doi.org/10.3390/app15137216>
- Ru, C., Hu, X., Chen, D., Wang, W., & Song, T. (2022). Heat and drought priming induce tolerance to subsequent heat and drought stress by regulating leaf photosynthesis, root morphology, and antioxidant defense in maize seedlings. *Environmental and Experimental Botany*, 202, 105010. <https://doi.org/10.1016/j.envexpbot.2022.105010>
- Sankar, T., Ramanathan, S. P., Kokilavani, S., Chandrakumar, K., & Kalarani, M. K. (2023). Evaluating the seasonal accumulation of Heat units as an agroclimatic indicator on Baby corn (*Zea mays* L.) under different sowing windows. *Journal of Applied and Natural Science*, 15(1), 340–348. <https://doi.org/10.31018/jans.v15i1.4273>
- Sholikah, Y. (2020). *Kajian Thermal Unit Varietas Jagung Manis (Zea mays var. saccharata) Pada Tingkat Kerapatan Tanam Yang Berbeda* [Skripsi, Universitas Brawijaya]. <https://repository.ub.ac.id/id/eprint/182374/1/yuliatius%20sholikah.pdf>
- Sudjatmiko, S., & Chozin, M. (2024). Phenological, growth, and yield responses of sweet corn to elevational air temperatures in the humid tropics. *Australian Journal of Crop Science*, 18(2), 92–98. <https://doi.org/10.21475/ajcs.24.18.02.pne4072>
- Tas, T. (2022). Physiological and biochemical responses of hybrid maize (*Zea mays* L.) varieties grown under heat stress conditions. *PeerJ*, 10, e14141. <https://doi.org/10.7717/peerj.14141/supp-1>

- Vellidis, G., Mcavoy, T., & Bedwell, E. (2025). *Growing Degree Days for Sweet Corn in Southern Georgia* (Number 1320). UGA Cooperative Extension Circular.
- Wang, J., Zhao, L., Hao, M., Wang, N., Wen, Q. H., Mei, F. J., Khan, A., Wang, B. Z., Zhang, X. L., Wang, W., Yang, C. L., Mo, F., Tao, X. P., & Xiong, Y. C. (2025). Climate suitability determines optimal yielding of dryland maize: A validation on timely sowing as an ancient wisdom. *Field Crops Rescobch*, 328, 109920. <https://doi.org/10.1016/j.fcr.2025.109920>
- Wang, N., Liu, Q., Ming, B., Shang, W., Zhao, X., Wang, X., Wang, J., Zhang, J., Luo, Z., & Liao, Y. (2022). Impacts of Heat Stress around Flowering on Growth and Development Dynamic of Maize (*Zea mays* L.) Cob and Yield Formation. *Plants*, 11(24), 3515. <https://doi.org/10.3390/plants11243515>
- Wang, Z., Sun, W., Liu, X., Li, Y., Collins, B., Ullah, N., & Song, Y. (2022). Analysis on Heat Characteristics for Summer Maize Cropping in a Semi-Arid Region. *Agronomy*, 12(6), 1435. <https://doi.org/10.3390/agronomy12061435>
- Yousaf, M. I., Riaz, M. W., Jiang, Y., Yasir, M., Aslam, M. Z., Hussain, S., Sajid Shah, S. A., Shehzad, A., Riasat, G., Manzoor, M. A., & Akhtar, I. (2022). Concurrent Effects of Drought and Heat Stresses on Physio-Chemical Attributes, Antioxidant Status and Kernel Quality Traits in Maize (*Zea mays* L.) Hybrids. *Frontiers in Plant Science*, 13, 898823. <https://doi.org/10.3389/fpls.2022.898823/text>