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Predicting optimum harvest time in baby corn using accumulated heat units under different sowing dates

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Abstract

Temperature plays a decisive role in shaping the growth dynamics, phenology, and productivity of baby corn. A field experiment conducted during the 2022–2023 summer season in Meghalaya assessed the impact of seven sowing dates on thermal accumulation, growth parameters, yield attributes, and harvest prediction. Results revealed that early planting, particularly on 2nd April (S_1), provided more favourable thermal and light conditions, leading to greater plant height, higher dry matter accumulation, improved heat use efficiency, and a 54% increase in cob yield over the latest sowing date (20th April; S_7). Thermal indices such as GDD, PTI, and HUE were closely linked with crop development and yield performance, underscoring their predictive relevance. A linear regression model was successfully developed to estimate the optimal harvesting window, indicating that 153.499°C day of heat accumulation after tasseling (≈ 10 –11 days) is required for achieving optimum cob maturity. These findings demonstrate that integrating temperature-based metrics with appropriate sowing windows can significantly enhance production planning, yield stability, and harvest accuracy in baby corn cultivation.

Keywords: Baby corn, growing degree days, heat use efficiency, harvest prediction, photo-thermal index, sowing window

1. Introduction

Maize stands out as a highly versatile and well-researched crop, cultivated extensively across tropical, subtropical, and temperate zones following rice and wheat in terms of global cultivation. One approach to diversifying its use and enhancing its economic value is by cultivating it for vegetable purposes in the form of baby corn (Singh & Singh, 2019) [30]. Baby corn (*Zea mays* L.), commonly referred to as mini corn or candle corn, is grown for its unfertilized small ears, which are plucked as soon as the silks turn pinkish, shortly after emergence. Dehusked, young baby corn ears are eaten as a vegetable and are highly prized for their exquisite sweetness and crispness. Key traits relevant to baby corn include early maturation, prolificacy, synchronised ear emergence, and yellow kernels (Kumar & Kalloo, 1998) [15].

Market favours baby corn ears with a diameter of 1.0 to 1.5 cm, light yellow in hue, regularly aligned in rows, and 10 to 12 cm long (Golada *et al.*, 2013) [7]. The crop enters its reproductive stage around 45 to 55 days after sowing and reaches maturity within 60 to 70 days (Lone *et al.*, 2013) [18]. In India, baby corn is cultivated throughout the year as a dual-purpose crop, valued for both its tender cobs and green fodder. Its high potential for processing and export has made it popular among both domestic and international consumers (Kumar *et al.*, 2015) [14]. Countries such as Thailand, Taiwan, Sri Lanka, and Myanmar have found notable success with baby corn cultivation, while China and Thailand currently lead global production (Kheibari *et al.*, 2012) [13]. In the Indian context, states like Uttar Pradesh, Haryana, Meghalaya, Andhra Pradesh, Maharashtra, and Karnataka have emerged as major producers of baby corn (Ranjan and Sow, 2021) [25].

Owing to its short duration, baby corn allows for the cultivation of three to four crops annually, subject to regional agro-climatic conditions. It also provides a considerable quantity of green fodder per unit area, reinforcing its role as a dual-purpose crop (Nataraj *et al.*, 2011) [20]. With

increasing demands for both vegetables and livestock feed, driven by a rapidly growing population, scaling up baby corn production has become imperative to ensure food and fodder security (Sankar *et al.*, 2023) [27].

Baby corn is a thermally sensitive crop whose productivity is closely tied to seasonal patterns. A range of biotic and abiotic factors are primarily responsible for its reduced productivity. Rising temperatures have been repeatedly shown to depress yield, highlighting the importance of thermal conditions during crop growth (Hatfield & Prueger, 2015) [9]. Typically, plants need a specific Growing Degree Day (GDD), which is determined by the daily average temperature starting from the date of planting (Dahmardeh, 2012) [3]. The growing degree day (GDD) or heating unit idea assumes that there is a direct and linear link between plant growth and temperature.

Accurate forecasting of harvest dates has become increasingly important for ensuring a steady supply of raw material to the processing industry. Efficient scheduling of sowing and harvesting requires understanding how environmental conditions interact with crop physiology and phenology (Lass *et al.*, 1993) [17]. In baby corn, precise estimation of the ideal harvest window is critical for maintaining quality and maximizing yield.

Among management practices, sowing date is a key non-monetary input that strongly influences productivity by altering the crop's thermal environment. Shifts in planting time modify the microclimate experienced by the crop, affecting growth rate, phenological progression, and final yield.

Considering these factors, the present field study was undertaken to assess how different sowing dates shape the thermal regime of baby corn, with the objective of identifying the most suitable sowing window and predicting the optimal harvest period.

2. Materials and Methods

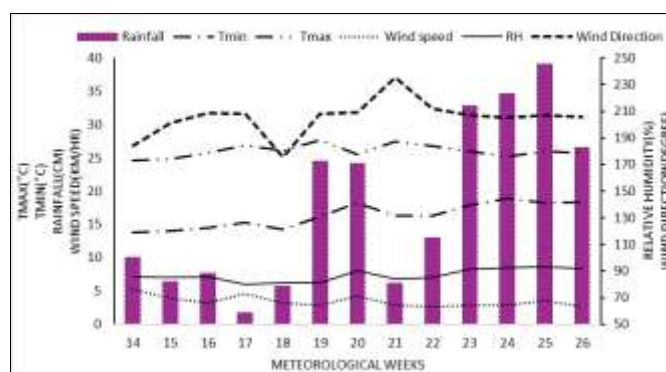
2.1. Experimental site description

To assess how different sowing dates influence the thermal requirements of baby corn, a field experiment was carried out during the *zaid* season of 2022–2023 at the Experimental Farm of the College of Post Graduate Studies in Agricultural Sciences (CAU, Imphal), located in Umiam, Ri-Bhoi district, Meghalaya. The experiment consisted of seven sowing dates namely 2 April (S₁), 5 April (S₂), 8 April (S₃), 11 April (S₄), 14 April (S₅), 17 April (S₆), and 20 April (S₇) arranged in a Randomized Block Design with three replications. The recommended nutrient dose of 100:50:40 kg ha⁻¹ N, P₂O₅, and K₂O was supplied through urea, SSP, and MOP, respectively. Half of the nitrogen and the full dose of phosphorus and potassium were applied as a basal dose at sowing, while the remaining nitrogen was top-dressed in two equal splits at 30 and 60 days after sowing. A seed rate of 25 kg ha⁻¹ and a spacing of 50 × 20 cm were maintained, using the hybrid variety CMVL-Baby Corn 2.

The experimental site lies at an elevation of 950 m above mean sea level, positioned between 91°18'–92°18' E longitude and 25°40'–26°20' N latitude. The region experiences the onset of monsoon rainfall in early June, which typically continues until late September. Monsoon withdrawal begins in the first week of October, with rainfall showing a declining trend from September onward. Pre-monsoon showers occur intermittently between March and May. The area receives an average annual rainfall of 2617.10 mm (Ray *et al.*, 2012) [26]. Standard meteorological conditions recorded during the experimental period are presented in Fig. 1.

Soil analysis revealed that the site was characterized by acidic soil (pH 4.78) with high organic carbon content (1.53%), but low levels of available nitrogen (215.40 kg ha⁻¹), phosphorus

(20.74 kg ha⁻¹ P₂O₅), and potassium (202.62 kg ha⁻¹ K₂O).



2.2. Data collection and analysis

Growth parameters including plant height and total dry matter accumulation were recorded at 20, 40, and 60 days after sowing (DAS) and at harvest. Yield attributes such as cob length, cob girth, cob weight, and the number of cobs per plant were assessed at harvest. Plant height was measured from base to the tip of the uppermost leaf on five randomly selected plants, and the average value was recorded in centimeters.

Cob length and girth, with and without husk, were measured in centimeters from the base to the tip. The number of cobs per plant was counted from five sampled plants, and fresh cob weight was recorded in grams per plant. Border plants were excluded from harvesting. Yield from the net plot was recorded in kilograms and converted to tonnes per hectare (t ha⁻¹).

Thermal indices including Growing Degree Days (GDD) and Heat Use Efficiency (HUE) were calculated for the main phenological stages: emergence, knee-high, tasseling, silking, and harvest. GDD was estimated using the equation:

$$GDD = \sum_{i=1}^n \left(\frac{(T_{max} + T_{min})}{2} - T_b \right)$$

where, Tmax (°C) is the daily maximum temperature, Tmin (°C) is the daily minimum temperature, Tb (°C) is the base temperature. The heat sum was calculated with Tb = 10°C (Davidson and Campbell, 1983; Gallagher, 1979) [5, 6].

Heat Use Efficiency (HUE) = Yield ÷ GDD (Haider *et al.*, 2003) [8].

3. Results and Discussion

3.1 Growth parameters

The study demonstrated that selecting an appropriate sowing date is crucial for optimizing the growth and yield of baby corn. Growth parameters such as plant height and dry matter accumulation, recorded at regular intervals, were significantly affected by the different dates of sowing. Plant height is an important indicator of overall growth because it reflects the plant's ability to accumulate dry matter, maintain proper leaf orientation, and develop an efficient canopy structure. These characteristics collectively influence how effectively the plant captures sunlight and conducts photosynthesis.

During the first 20 days after sowing (DAS), the rate of increase in plant height was relatively slow, corresponding to the crop's early emergence phase. Between 20 and 40 DAS, plant height increased most rapidly, coinciding with active vegetative growth. After this period, the rate of increase declined steadily until harvest. Early sowing consistently produced taller plants, whereas delayed sowing resulted in shorter plants. The maximum plant height was obtained with the 2 April sowing

(S₁), while the minimum was recorded in the 20 April sowing (S₇). Early sown plants benefited from a longer growing period to utilize available growth resources and more favorable environmental conditions, particularly temperature, which supported enhanced vegetative growth. These results are consistent with the findings of Shirzadi (2009)^[8] and Zarei *et al.* (2013)^[32], who also reported greater plant height under earlier planting dates.

Dry matter accumulation increased progressively throughout the crop's growth cycle. The accumulation was minimal during the first 20 DAS due to slow seedling establishment. A pronounced increase was observed from 60 DAS until harvest, a period characterized by greater leaf area development, enhanced photosynthetic activity, and cob formation. Sowing date had a highly significant influence on dry matter production. The highest dry matter accumulation occurred in the 2 April sowing (S₁), with substantial reductions of 14, 34, 50, 64, 70, and 76 percent recorded for sowings on S₂, S₃, S₄, S₅, S₆, and S₇, respectively. The superior performance of S₁ can be attributed to ambient conditions that promoted better growth and biomass accumulation. Early sowing allowed the crop to exploit optimal temperature conditions, resulting in higher net photosynthate gain. In contrast, delayed sowing coincided with increased temperatures that accelerated phenological development and raised respiration rates, thereby lowering the net accumulation of dry matter. These findings support the observations of Oktem *et al.* (2004)^[22], who reported comparable effects of planting time

on dry matter production.

Overall, the results clearly indicate that early sowing, particularly on 2 April, provides the most favorable conditions for growth and biomass production in baby corn. Both plant height and dry matter accumulation benefit significantly from timely sowing, highlighting the importance of selecting an optimal planting window for achieving higher productivity.

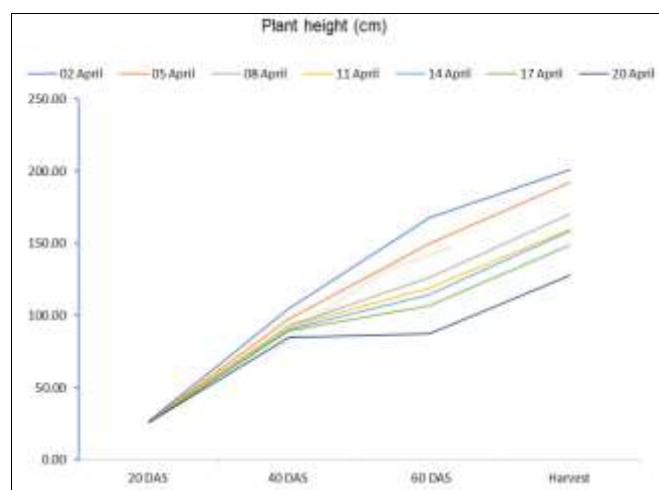


Fig 1: Effect of different sowing dates on plant height (cm) at different growth stages

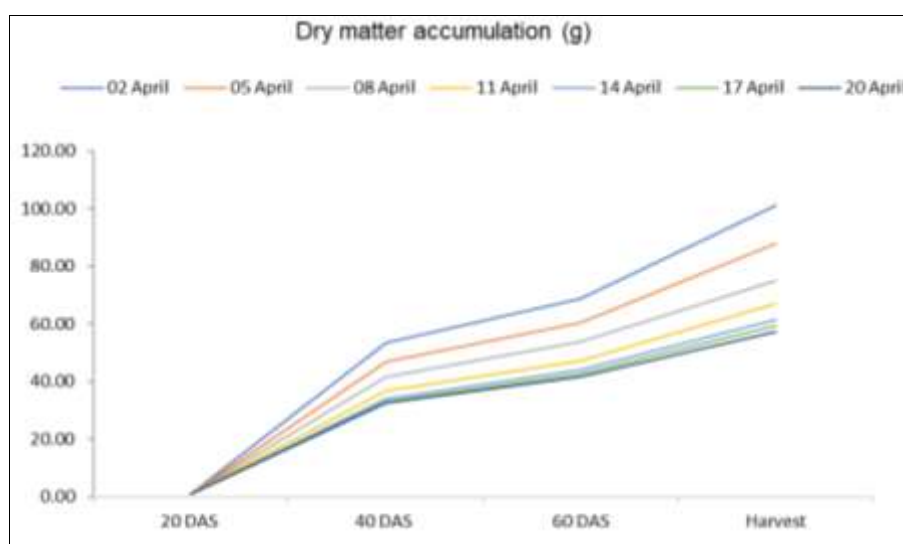


Fig 2: Dry matter accumulation (g plant⁻¹) of Baby corn as influenced by different sowing dates

3.2. Yield Attributes and Yield of Baby Corn

Planting dates had a marked effect on yield attributes and cob yield. As shown in Table 1, early sowing improved all yield parameters, including cob length, cob girth (with and without husk), number of cobs per plant, and cob weight. The 2 April sowing (S₁) recorded the highest values, whereas the 20 April sowing (S₇) showed the lowest.

The improved performance under early sowing can be linked to the longer growth period, which allowed better use of light, nutrients, and moisture. This supported greater assimilate production and more effective distribution to reproductive parts, resulting in higher yield components. In contrast, delayed sowing exposed the crop to higher temperatures and reduced soil

moisture during the reproductive phase, limiting dry matter accumulation and weakening yield-contributing traits. Similar observations were reported by Arash *et al.* (2011)^[1].

Previous research aligns with these findings. Shrestha *et al.* (2016)^[9] noted that maize yield consistently responds well to earlier sowing across environments. Hemalatha *et al.* (2013)^[10] also highlighted that increased heat-unit accumulation enhances maize productivity. Naveen *et al.* (2020)^[21] reported that early sowing extended the phenophase duration in green gram, resulting in higher yields. These results confirm that early planting provides more favorable growing conditions for baby corn, contributing to improved yield attributes and cob yield.

Table 1: Length (cm), Girth (cm), No. of cobs per plant, Cob Weight (g) and Cob yield (tha⁻¹) of Baby Corn as influenced periodically by different sowing dates

	Cob length		Cob Girth		No. of cobs per plant	Cob Weight	Cob Yield	
	with husk	without husk	with husk	without husk			with husk	without husk
S ₁	24.18a	8.46a	2.85a	1.47a	2.71a	8.56a	7.88a	1.86a
S ₂	21.75ab	7.98ab	2.17b	1.34b	2.36ab	8.30ab	7.57ab	1.56b
S ₃	20.60ab	7.58bc	1.84c	1.22bc	2.10bc	8.06abc	7.27bc	1.42bc
S ₄	19.55b	7.33c	1.61cd	1.13cd	1.93cd	7.86bc	7.03bcd	1.29bc
S ₅	18.69b	7.20c	1.46de	1.06d	1.80cd	7.70bc	6.88cd	1.25bc
S ₆	18.03b	7.08c	1.36de	1.03d	1.70d	7.60c	6.77cd	1.22c
S ₇	17.72b	7.03c	1.30e	1.00d	1.63d	7.53c	6.68d	1.21c
SE(m)±	1.22	0.18	0.09	0.04	0.12	0.20	0.17	0.10
CD (p=0.05)	3.75	0.55	0.28	0.13	0.36	0.63	0.53	0.30

3.3. Growing Degree Days (GDD) of Baby Corn

The accumulation of Growing Degree Days (GDD) differed notably among the sowing dates and had a clear influence on the pace of crop development. The crop planted on 5 April (S₂) accumulated the highest heat units across all phenological stages, recording 97.27 °C day at emergence, 547.54 °C day at the knee-high stage, 923.56 °C day at tasseling, 995.06 °C day at silking, and 1069.98 °C day by harvest. These values were very similar to those observed in the 2 April sowing (S₁), indicating that early planting provided the most favorable thermal environment.

In contrast, later sowing dates accumulated fewer heat units. The 17 April sowing (S₆) recorded the lowest GDD at tasseling (899.53 °C day), silking (957.68 °C day), and harvest (1033.89 °C day), while the 20 April sowing (S₇) showed the minimum values at emergence (66.38 °C day) and knee-high stage (523.74 °C day). The reduced GDD in these treatments can be attributed to shorter crop duration and exposure to higher temperatures early in the season, which accelerated developmental processes. Total heat accumulation from sowing to harvest followed a similar pattern. The highest GDD was recorded in S₂ (1069.98 °C day), followed closely by S₄, S₁, and S₃, all of which exhibited comparable values. The lowest cumulative GDD occurred in the 20 April sowing (S₇). Higher ambient temperatures in late sowings hastened crop maturity, thereby reducing the total heat units accumulated.

These observations are consistent with earlier reports by Thavaprakash *et al.* (2007) [31] and Shrestha *et al.* (2016) [9], who noted that warmer conditions hasten the attainment of phenophases and reduce crop duration under delayed sowing. Similar trends of declining GDD with later planting have also been reported by Khavse *et al.* (2015) [12], Praveen *et al.* (2018) [23], and Dar *et al.* (2018) [4].

Table 2: Growing Degree Days (GDD) (°C Day) of Baby Corn at different phenological stages as influenced by different sowing dates

	Emergence	Knee High	Tasseling	Silking	Harvest
S ₁	94.45a	534.77ab	911.85ab	988.78ab	1065.97a
S ₂	97.27a	547.54a	923.56a	995.06a	1069.97a
S ₃	89.94ab	551.51a	911.21ab	988.40ab	1060.91ab
S ₄	85.76ab	543.11ab	919.61ab	994.52a	1068.71a
S ₅	92.59a	533.40ab	912.03ab	969.88cd	1044.82bc
S ₆	72.55bc	535.95ab	899.53b	957.68d	1033.89c
S ₇	66.38c	523.74b	900.83b	976.43bc	1038.45c
SE(m)±	5.67	6.55	6.49	5.38	5.29
CD (p=0.05)	17.46	20.17	20.01	16.58	16.30

*Within the same column figures sharing the same letters do not differ significantly at p≤0.05

3.4. Heat Use Efficiency (HUE) of Baby Corn

Heat Use Efficiency (HUE) was markedly influenced by the

sowing dates. As shown in Table 3, HUE values ranged from 1.17 to 1.75 kg ha⁻¹ °C day⁻¹ across treatments. A clear decline in HUE was observed with delayed sowing. The highest HUE was recorded in the 2 April sowing (S₁), which achieved 1.75 kg ha⁻¹ °C day⁻¹, followed by the 5 April sowing (S₂). The lowest value of 1.17 kg ha⁻¹ °C day⁻¹ occurred in the 20 April sowing (S₇). The superior HUE in S₁ corresponds with the highest baby corn yield in this treatment, indicating that the early-sown crop benefitted from more favorable temperature conditions that promoted efficient conversion of accumulated heat into yield. Similar observations were made by Basu *et al.* (2009) [2], who reported higher productivity in summer-sown baby corn.

The reduced HUE under delayed sowing can be attributed to limited biomass accumulation and lower effective utilization of heat units, as high temperatures during later planting tend to shorten crop duration and suppress yield. Comparable findings were reported by Sankar *et al.* (2023) [27], who noted higher HUE under early sowing (21 January) and reduced HUE in later sowing (20 February) due to heat-induced yield decline. Overall, the results indicate that early planting enhances heat utilization efficiency in baby corn, while delayed sowing restricts the crop's capacity to convert thermal time into economic yield.

Table 3: Heat Use Efficiency (HUE) (kg ha⁻¹ °C day⁻¹) of Baby Corn at different phenological stages as influenced by different sowing dates

	HUE
S ₁	1.75a
S ₂	1.46b
S ₃	1.33b
S ₄	1.21b
S ₅	1.20b
S ₆	1.18b
S ₇	1.17b
SE(m)±	0.09
CD (p=0.05)	0.28

*Within the same column figures sharing the same letters do not differ significantly at p≤0.05

3.5. Prediction of harvesting time of baby corn Using Accumulated Heat Units

A linear regression model was developed to estimate the harvest date of baby corn using the deviation in accumulated heat units and the number of days between tasseling and harvest (Figure 4.1). The graph presents the relationship between days elapsed after tasseling and the corresponding deviations in Growing Degree Days (GDD). The dotted line represents the fitted regression line, while the blue band indicates the 95% confidence interval for observed GDD. The orange and grey intervals show the 95% confidence limits for the minimum and maximum deviations from predicted values.

The regression equation and its validation statistics are provided

within the figure:

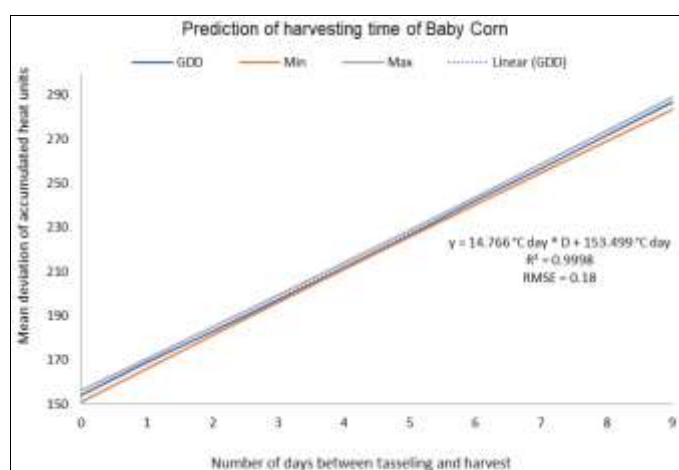
$$y = 14.766 \text{ }^{\circ}\text{C Day} * D + 153.499 \text{ }^{\circ}\text{C Day}$$

where, y= number of days of harvesting

D= Start day of tasseling after sowing

The model showed outstanding predictive strength, with an R^2 of 0.9998 and an RMSE of 0.18. Based on the regression, about 153.499°C day of heat accumulation from tasseling, at an average rate of 14.766°C day, is required to reach the ideal harvest stage. This corresponds to a harvest window of roughly 10–11 days after tasseling. For instance, the 2 April sowing (S_1) accumulated 169.365°C day by harvest, closely matching the predicted requirement.

Conventionally, harvest decisions rely on fixed calendar days or visual observations, which may result in premature or delayed harvests. Since temperature strongly governs crop development, monitoring daily temperatures and calculating GDD provides a more accurate indicator of physiological maturity. Reaching the threshold of 153.499°C day ensures timely harvest and better cob quality. Using GDD also improves decision-making across seasons, locations, and varieties by standardising harvest prediction despite variations in temperature. Such models help farmers plan operations with minimal uncertainty and support consistent quality. These findings are in agreement with Muñoz *et al.* (2012) [19], who demonstrated the effectiveness of GDD-based models for predicting baby corn harvest timing.



4. Conclusion

Temperature proved to be a key climatic determinant of baby corn growth, phenological progression, and yield. While higher maximum temperatures accelerated developmental stages, they simultaneously reduced yield potential. Early sowing enabled the crop to capitalize on favourable temperature and radiation conditions during critical early growth, thereby avoiding heat stress later in the season. As a result, baby corn sown on 2nd April (S_1) produced the highest yield, recording a 54% increase over the crop sown on 20th April (S_7).

Thermal indices like GDD and HUE showed strong positive relationships with crop growth and yield traits, confirming their value for assessing crop performance. The regression model developed for harvest prediction further demonstrated high accuracy, indicating that 153.499°C day of accumulated heat units (approximately 10–11 days after tasseling) marks the optimal harvest window. Adopting such GDD-based decision tools can enhance harvest precision, crop quality, and overall production efficiency in baby corn.

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Competing Interest

Author declare no competing interest

Image manipulation

NA (Self-generated)

Authors' contributions

This work was carried out in collaboration among all authors. Authors PR and VR Conceptualized the study. Author PR performed the methodology, investigated the study, curated the data. Authors PR, VK, VT conducted the formal analysis, wrote the original draft preparation. Authors PR, AS and VT reviewed and edited the manuscript. Authors PR and VR supervised the study. Authors PR, VR and VK visualised the study. Authors PR and AS pre-processed the data. All authors read and approved of the final manuscript.

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