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Assessing the impacts of planting dates and organic mulches on Ginger (*Zingiber officinale*) yield using agrometeorological indices

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Abstract

Ginger production remains highly sensitive to weather variables, especially temperature, which plays a critical role in phenological development, growth and yield. This study was carried out to assess the impact of varying planting dates and organic mulches using agrometeorologicalindicesacross phenological stages.A field experiment was laid out in split plot designat College of Agriculture, KAU, Vellanikkara, Thrissur district. Ginger variety, *Maran* was cultivated with four dates of planting *viz.* 1st June (D1), 15th June (D2) and 1st July (D3) and 15th July (D4)as main plot treatments and with three organic mulches *viz.* green leaves (M1), paddy straw (M2) and dry coconut leaves (M3) as sub plot treatments. The accumulated agrometeorological indices *viz.*Growing Degree Days (AGDD), Heliothermal Units (AHTU), Photothermal Units (APTU) and Hydrothermal Units (AHYTU)were calculated at different phenophases of the crop *viz.*planting to 50% germination (P1), 50% germination to active tillering (P2), active tillering to bulking (P3), bulking to physiological maturity (P4).The crop duration varied across different planting dates, which had a significant impact on yield.The June 1st planted crop took a longest duration (217 days) with higher fresh rhizome yield of 19958kg ha^{-1} followed by the second planting on June 15th (203 days) with 18273kg ha^{-1}, followed by third planting on July 1st(198 days) with 15347 kg ha^{-1} and fourth planting on July 15th(187 days) with 8520kg ha^{-1}.The ginger crop mulched with paddy straw produced high fresh rhizome yield of 16941kg ha^{-1}, which was on par with green leaves mulch yield of 15798kg ha^{-1}. The dry coconut leaves mulched ginger gave less yield of 13835kg ha^{-1}. Accumulated Growing Degree Days (AGDD), Accumulated Heliothermal Units (AHTU), Accumulated Photothermal Units (APTU) and Accumulated Hydrothermal Units (AHYTU) at four phenophases showed a positive correlation with Ginger yield.The selection of suitable organic mulching materials is also important in combination with optimal planting windows to maximize ginger productivity.

Keywords: Ginger, Growing degree days, Heliothermal units, Photothermal units

Introduction

Ginger (*Zingiber officinale* Rosc.), a key member of the Zingiberaceae family, is a tropical horticultural crop valued for its pungent rhizomes, widely used in culinary, pharmaceutical, and industrial applications. Its distinct aroma and flavor are mainly due to the presence of gingerols, a class of bioactive ketones (Ansari, 2021). Believed to have originated in the tropical forests of the Indian subcontinent. Ginger was one of the earliest spices exported to the West and has grown to become the second most traded spice globally after black pepper (Nair, 2014).

India is currently the world's leading producer of ginger, cultivating 2224.84 metric tonnes from 204,840 hectares, with Kerala contributing significantly through its higher-than-average productivity of 20.83 MT/ha against the national average of 10.86 MT/ha (Indiastat, 2022). Since ginger is cultivated as a rainfed crop, it's production remains highly sensitive to climatic variables, especially temperature, which plays a critical role in phenological development, growth, and yield (Kandiannan et al., 2002; Puthuma, 2020).In regions like Kerala, where microclimatic variability is high, the selection of planting dates significantly alters the thermal environment experienced by the crop, impacting its growth and productivity (Parashar et al., 2014; Chatte, 2021). The objective of this study is to evaluate the thermal and moisture related - agrometeorological indices across phenological stages of ginger crop under varying planting dates and organic mulches in order to improve the yield potential of ginger in agroclimatic conditions of Kerala.

Material and methods

Experimental location

The experimental site is located at 10.54 °N, 76.27 °E at

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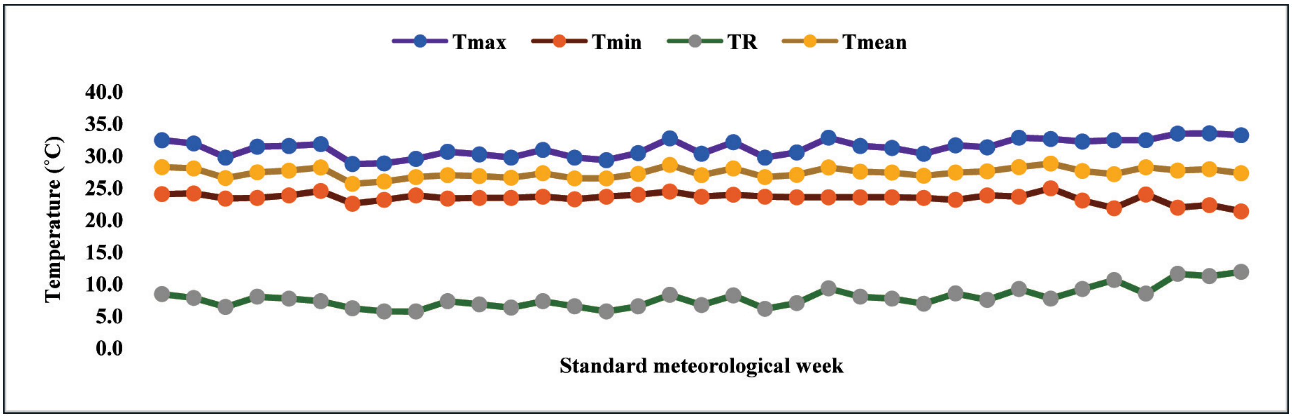


Figure 1. Temperature experienced during by ginger crop at Vellanikkara during 2020-2021Tmax – Maximum temperature, Tmin-Minimum temperatureTR – Temperature Range, Tmean- Mean temperature

Kerala Agricultural University, Thrissur with an elevation of 22 AMSL (Above Mean Sea Level). The climate of this region is monsoon-influenced humid tropical climate. Weather data in Fig. 1 illustrated that the maximum and minimum temperatures recorded during the crop season were 31.2°C and 23.4°C, respectively. The bright sunshine hours recorded during the crop period was 4.3 hrs. The rainfed ginger was benefitted from a cumulative rainfall of 2775 mmduring its lifecycle. Highest amount of rainfall was received in August and September. The mean relative humidity was 80.65 percentage.

Experimental details

The ginger cultivar used in the study was *Maran*. The experiment was carried out in a split plot design, with main plot treatments consisting of four distinct planting dates and with sub plot treatments consisting of three different types of organic mulches. Consecutive dates of plantings at fortnight interval were chosen *viz.* 1st June (D1), 15th June (D2), 1st July (D3) and 15th July (D4). Organic mulches likegreen leaves (M1), paddy straw (M2) and dry coconut leaves (M3) were used. All seven treatments were set with three replications.The package of practice recommendations of Kerala Agricultural University was followed. The agrometeorological indices were calculated for various phenophases of ginger viz., Planting to 50% germination (P1), 50% germination to active tillering (P2), Active tillering to bulking (P3), Bulking to physiological maturity (P4).

Agrometeorological indices

a. Growing Degree Days (GDD) is a metric for measuring the amount of heat accumulated over a period of time. It was computed by deducting the base temperature from the average daily temperature, then adding the results together over a period of time (phenophase).

GDD was calculated using following formula.

GDD = ((Tmax + Tmin/2) - Tb)

Where: Tmax. and Tmin. are the daily maximum and minimum temperature respectively for particular phenophase, while Tb is the base temperature (ºC) which is equal to 13ºC for ginger (Evenson et al., 1978).

b. Helio Thermal Unit (HTU) was calculated using following formula

HTU = GDD * Sunshine Hours

Where: Sunshine Hours = Actual bright sunshine hours in a day

c. Photo Thermal Unit (PTU) was calculated using following formula

PTU = GDD * Day Length

Day Length = Number of hours of daylight

[Day length is the maximum possible sunshine hours calculated for the latitude and longitude of the study area from the NOAA (National Oceanic and Atmospheric Administration) solar calculation.]

d. Hydro Thermal Unit (HYTU)was calculated using following formula

HYTU = GDD * Average Relative Humidity (%)

Where: Average Relative Humidity = Average relative humidity for a given day

Results and discussion

Days taken for physiological maturity of ginger crop under different planting dates

The crop duration varied across different planting dates, which had a significant impact on yield. First planting on June 1sttook longest duration of 217 days for physiological maturity and was harvested on January 4th. Second planting on June 15th attained physiological maturity in 203 days and

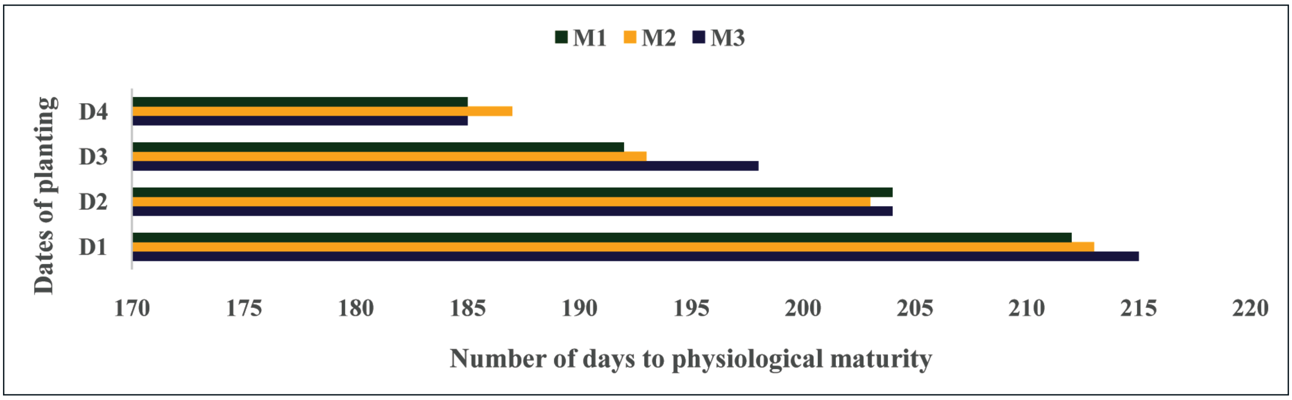


Figure 2. Days to physiological maturity under different date of plantingand organic mulches

Date of planting	**D1** 1st June 2021	**D2** 15th June 2021	**D3** 1st July 2021	**D4** 5th July 2021
Organic Mulches	**M1** Green leaves	**M2** Paddy straw	**M3** Dry coconut leaves	

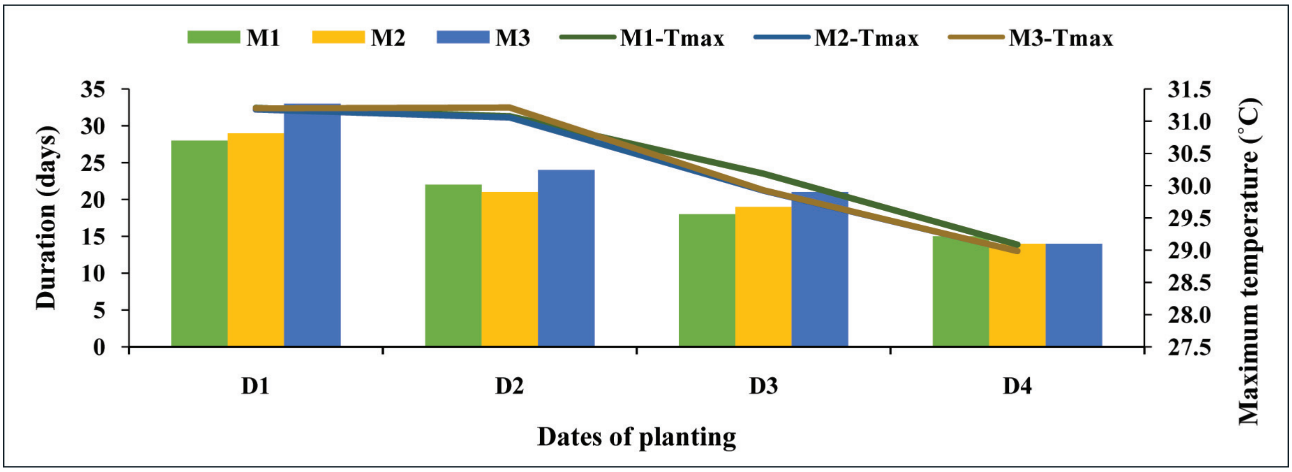


Figure 3. Maximum temperature and duration of planting to 50% germination (P1)

was harvested on January 4th. Third planting on July 1st took 198 days and was harvested on January 15th. Fourth planting on July 15th took187 days and was harvested on January 18th.

Influence of maximum temperature on phenophase duration of ginger crop

The number of days taken for physiological maturity varied significantly across treatments due to temperature differences experienced under different planting dates.

Fig.3 shows that the earliest planting date (D1) experienced both the highest maximum temperature and the longest

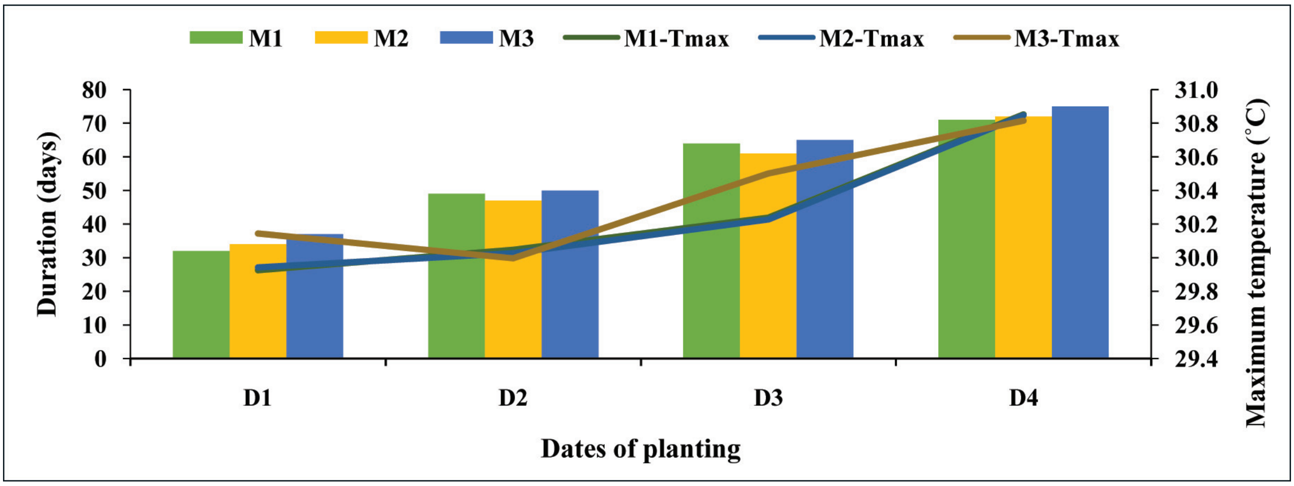


Figure 4. Maximum temperature and duration of 50% germination to active tillering (P2)

duration in the first phenophase. On the crop sown on June 1st, a longer heat period was needed to achieve 50% germination in first phenophase (P1). In contrast, it was less in the planting that followed on June 15th, July 1st and July 15th. These observations align with earlier research by Kandiannan and Chandragiri (2008), who found that thermal accumulation was influenced by temperature and germination timing. Higher thermal time was needed for 50% germination in the May 15th planted crop, whereas crops planted on June 15th and July 15th required less thermal accumulation.

Similarly, Fig.4 shows that the latest planting (D4) also exhibited a relatively high maximum temperature and longer duration in the second phenophase (P2). This could be attributed to delayed development caused by suboptimal initial establishment conditions or increased temperature stress in later stages, necessitating longer adaptation periods.

As time progresses, the maximum temperature begins to rise, shortening the third and fourth phenophases (Fig. 5 and Fig. 6). This result is in accordance with the findings of Kandiannan and Chandragiri (2008). Five improved cultivars of ginger varieties *viz.* Varada, Maran, Mahima, Rejatha, and Himachal were planted in a split-plot design experiment conducted in Kerala, with three replicationsat 15 days intervals from April 30th to June 15th. The accumulated heat sums (GDD) for the lifecycle events showed a positive and significant relationship with yield (Kandiannan et al., 2013).

The vegetative phases were longer in early plantings, causing them to mature slowly. Consequently, these plants spent more time in the field for growth and development. The June 1st planting had a later physiological maturity than the other planting dates because of this. The results of Kandiannan et al. (2010) revealed that ginger crops planted on April 30, May 15, June 15, and June 30 required 275, 260, 245, and 230 days, respectively, to reach maturity.

The maximum temperature correlated positively with the first and second phenophases planting to 50% germination and 50% germination to active tillering), but negatively with the

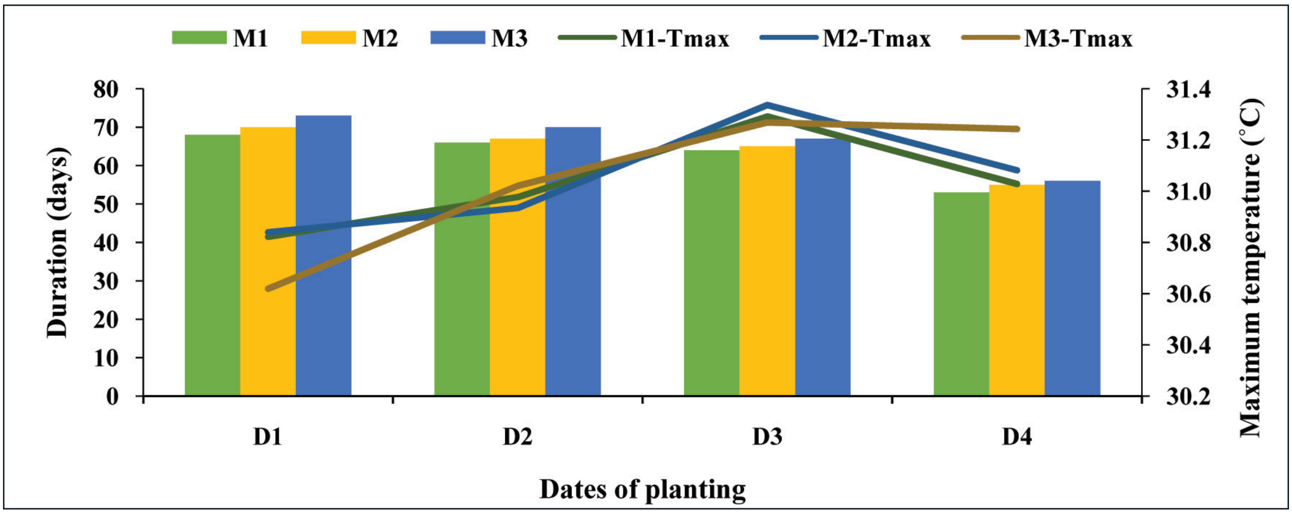


Figure 5. Maximum temperature and duration of active tillering to bulking (P3)

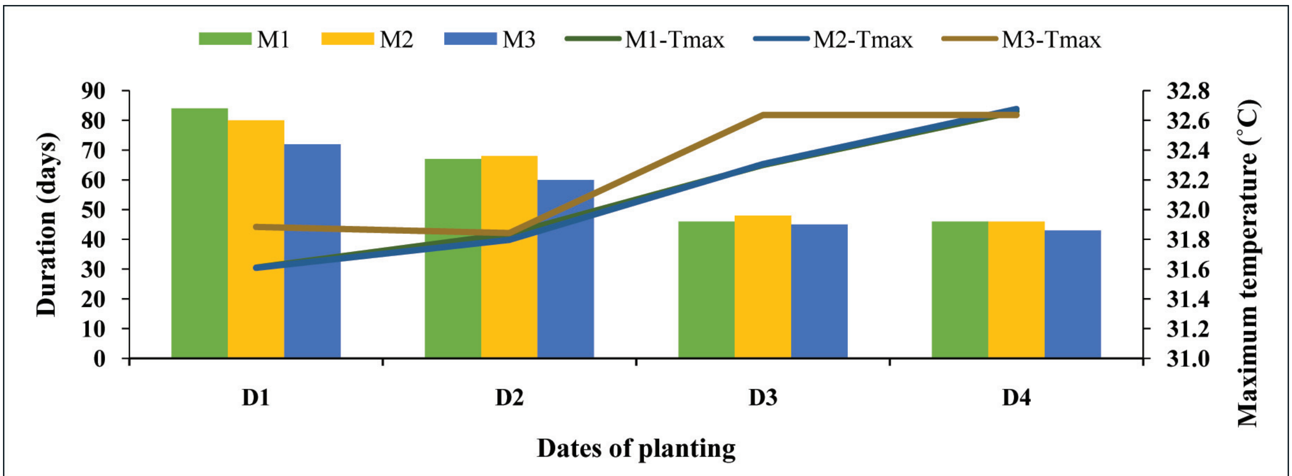


Figure 6. Maximum temperature and duration of Bulking to physiological maturity (P4)

third and fourth phenophases (active tillering to bulking and bulking to physiological maturity). The maximum temperature in the first two phenophases decreases from early planting dates to late planting dates as a result of the intensification of the southwest monsoon, which lessens the optimum temperature conditions for early vegetative phases of the plants and prolong their duration. However, as time progresses, the maximum temperature begins to rise, which shortens the phenophase at the third and fourth phenophases. This result was in accordance with that of Kandiannan and Chandragiri (2008).

Accumulated agrometeorological indices across phenophases of ginger crop

The agrometeorological indices like accumulated GDD, accumulated HTU, accumulated PTU, accumulated HYTU were calculated for different phenophases and were presented in Table 1-5.

a. Accumulated Growing Degree Days (AGDD): The accumulation of Growing Degree Days (AGDD) exhibited a consistent decline with delayed planting across all three replications (M1, M2, and M3) (Table 1). The earliest planting date (D1) recorded the highest AGDD, with values ranging from 3024 (M1) to 3070 (M3), and a mean of 3044. As the planting was delayed to D4, the AGDD decreased significantly, ranging from 2648 (M1) to 2692 (M3), with a mean of 2672. Among the phenophases, P3 and P4 contributed the highest AGDD across all treatments, indicating a higher thermal requirement during the reproductive and maturity stages.

b. Accumulated Heliothermal Units (AHTU): The trend in Accumulated Heliothermal Units (AHTU) was consistent with AGDD, showing a decreasing pattern from early to late planting (Table 2). The highest AHTU was observed in D1, with a mean of 12,387, while the lowest was recorded in D3 (11,620 in M1). P3 and P4 phenophases accounted for a major

Table 1. Accumulated GDD experienced by the crop in different phenophases

Date of	M1					M2					M3				
Planting	P1	P2	P3	P4	**Total**	P1	P2	P3	P4	**Total**	P1	P2	P3	P4	**Total**
D1	404	439	967	1215	**3024**	417	467	997	1158	**3038**	476	511	1030	1054	**3070**
D2	316	672	944	979	**2911**	301	644	957	993	**2896**	348	682	1003	878	**2911**
D3	248	890	921	684	**2744**	259	847	938	714	**2759**	287	914	960	670	**2831**
D4	198	1011	754	685	**2648**	185	1024	784	684	**2677**	185	1066	803	638	**2692**

Table 2. Accumulated HTU experienced by the crop in different phenophases

Date of	M1					M2					M3				
planting	P1	P2	P3	P4	**Total**	P1	P2	P3	P4	**Total**	P1	P2	P3	P4	**Total**
D1	1815	1256	3233	5889	**12192**	1873	1319	3406	5733	**12331**	2165	1243	3532	5699	**12639**
D2	1265	1451	3732	5459	**11907**	1198	1405	3764	5392	**11760**	1483	1470	3708	5247	**11907**
D3	812	2294	3459	5055	**11620**	812	2149	3514	5270	**11745**	915	2685	3143	5663	**12406**
D4	299	3476	2192	5800	**11768**	261	3515	2378	5876	**12030**	261	3612	2704	5602	**12179**

Table 3. Accumulated PTU experienced by the crop in different phenophases

Date of	M1					M2					M3				
planting	P1	P2	P3	P4	**Total**	P1	P2	P3	P4	**Total**	P1	P2	P3	P4	**Total**
D1	5138	5565	11899	14205	**36807**	5316	5914	12234	13512	**36975**	6060	6456	12563	12263	**37342**
D2	4027	8452	11416	11368	**35263**	3837	8115	11595	11540	**35086**	4433	8570	12084	10176	**35263**
D3	3155	11068	10931	7908	**33063**	3297	10538	11147	8253	**33235**	3647	11332	11345	7746	**34071**
D4	2509	12435	8870	7912	**31726**	2335	12609	9216	7902	**32062**	2335	13110	9420	7378	**32243**

Table 4. Accumulated HYTUexperienced by the crop at forenoon in different phenophases

Date of	M1					M2					M3				
planting	P1	P2	P3	P4	**Total**	P1	P2	P3	P4	**Total**	P1	P2	P3	P4	**Total**
D1	38012	41944	93064	107591	**280611**	39263	44757	95848	101570	**281438**	44689	49250	99043	90868	**283851**
D2	29931	64781	90495	82784	**267991**	28466	62200	91723	84550	**266939**	32839	65812	95869	73471	**267991**
D3	23792	85971	87152	54375	**251290**	24896	81876	88836	56885	**252493**	27593	88003	89674	53427	**258697**
D4	19212	97153	70109	54699	**241173**	17901	98464	72745	54404	**243514**	17901	102552	74429	49693	**244575**

Table 5. Accumulated HYTU experienced by the crop at afternoon in different phenophases

Date of	M1					M2					M3				
planting	P1	P2	P3	P4	Total	P1	P2	P3	P4	Total	P1	P2	P3	P4	Total
D1	30133	33645	70961	81697	216436	31079	35664	73767	76666	217175	35595	38611	77680	66987	218873
D2	22877	51386	70515	60784	205562	21905	49174	71619	62285	204983	24954	52885	74137	53586	205562
D3	19323	67166	67590	38032	192111	20148	64421	68575	39725	192869	22153	67916	70528	35642	196239
D4	15887	74156	55800	36386	182228	14893	75149	57594	35863	183499	14893	78775	58003	32437	184108

share of AHTU, especially in early planting dates, suggesting that increased sunlight hours and temperature during these phases supported better thermal energy use efficiency. Maximum AHTU (12,639) was observed in D1-M3, and minimum (11,620) in D3-M1.

c. Accumulated Photothermal Units (APTU): Accumulated Photothermal Units (APTU) followed a similar trend as AGDD and AHTU, with a gradual reduction from D1 to D4 (Table 3). The mean APTU for D1 was 37,041, while the lowest was observed in D4 (32,010). Across replications, the highest APTU was recorded in D1-M3 (37,342). Phenophases P2 and P3 contributed significantly to APTU accumulation, suggesting their sensitivity to photoperiod and temperature interactions. Delayed sowing significantly reduced photothermal accumulation, which may affect crop duration and biomass partitioning.

d. Accumulated Hydrothermal Units – Forenoon (AHYTU1): The AHYTU1 values also showed a declining trend with delay in planting. The highest values were recorded in D1 (mean: 281,967), while the lowest was in D4 (mean: 243,087) (Table 4). Within phenophases, P3 and P4 consistently contributed the most to AHYTU1, indicating a greater combination of temperature and humidity during the mid and late crop stages. The maximum AHYTU1 was observed in D1-M3 (283,851), and the minimum in D4-M1 (241,173).

e. Accumulated Hydrothermal Units – Afternoon (AHYTU2): AHYTU2 followed the same trend as AHYTU1, with earlier planting (D1) accumulating higher values. The mean AHYTU2 decreased from 217,496 in D1 to 183,278 in D4. The highest value was noted in D1-M3 (218,873) and the lowest in D4-M1 (182,228). Afternoon thermal and moisture conditions were less favourable in later planting dates, reducing total hydrothermal accumulation during critical growth stages (Table 5).

Analysis of accumulated agrometeorological indices across phenophases revealed that the reproductive phase (P3) consistently contributed the highest accumulation of AGDD, AHTU, APTU, and both AHYTU1 and AHYTU2. This indicates the critical importance of thermal and hydrothermal conditions during flowering and rhizome development. The early sowing (D1) allowed the crop to exploit favourable thermal and radiative environments, while late sowing (D4) coincided with suboptimal conditions, thereby reducing total accumulation and potentially affecting growth and yield (Yada et al., 2014).

Fresh rhizome yield of ginger crop in seven treatments

The sharp decline in yield observed in late sowing (8,520 kg/ha on July 15th) compared to early sowing (19,957 kg/ha on June 1st) can be attributed to multiple weather-induced constraints (Table 6). Ginger requires specific temperature conditions for optimal growth at each phenological stage: 25 to 30°C for sprouting and vegetative growth, 22 to 28°C for rhizome initiation and bulking, and a moderately warm, dry period during maturity (Kumar et al., 2018). Late planting exposed the crop to higher-than-optimal temperatures during critical rhizome development phases. Elevated temperatures and extended day lengths likely hastened phenological progression, shortening the bulking phase and reducing the duration available for assimilate accumulation in rhizomes.

Table 6. Fresh yield obtained during each date of planting

Date of planting	Fresh yield (kg ha^{-1}) M1	M2	M3	Average yield
1st June	19947^{a}	23116^{a}	16614.20^{a}	19958^{a}
15th June	19835^{a}	18370^{b}	11441.36^{b}	18273^{b}
1st July	15648^{ab}	17022^{b}	13372.43^{b}	15347^{c}
15th July	7762^{b}	9257^{c}	8541.152^{cb}	8520^{d}
CD		2903		1338

Additionally, high temperatures during the bulking stage may have impaired photosynthate translocation, resulting in poor rhizome filling. These physiological disruptions, compounded by reduced accumulation of GDD, PTU, and HTU due to shortened crop duration, contributed to the significant yield reduction observed in delayed sowing. These findings are consistent with those of Fumen et al. (2021), who reported strong links between thermal indices and crop productivity in tropical tuber crops.

Correlation analysis between agro-meteorological indices and rhizome yield

The variation in phenological stage durations across sowing dates in ginger resulted in different accumulations of agrometeorological indices. Correlation analysis (Table 7) showed a highly significant positive relationship ($p < 0.01$) between rhizome yield and growing degree days (GDD), photothermal units (PTU), and both forenoon and afternoon hydrothermal units (HTU). This indicates that higher thermal and hydrothermal accumulation during the growth period enhances yield potential.

GDD serves as an effective indicator for predicting crop growth and maturity, as it quantifies the heat and energy available for plant development. In this study, GDD was calculated for the major phenophases of ginger: planting to 50% germination, 50% germination to active tillering, active tillering to bulking, and bulking to physiological maturity. Late sowing exposed the crop to a rapid rise in maximum and minimum daily temperatures during later growth stages, shortening reproductive phases and accelerating maturity.

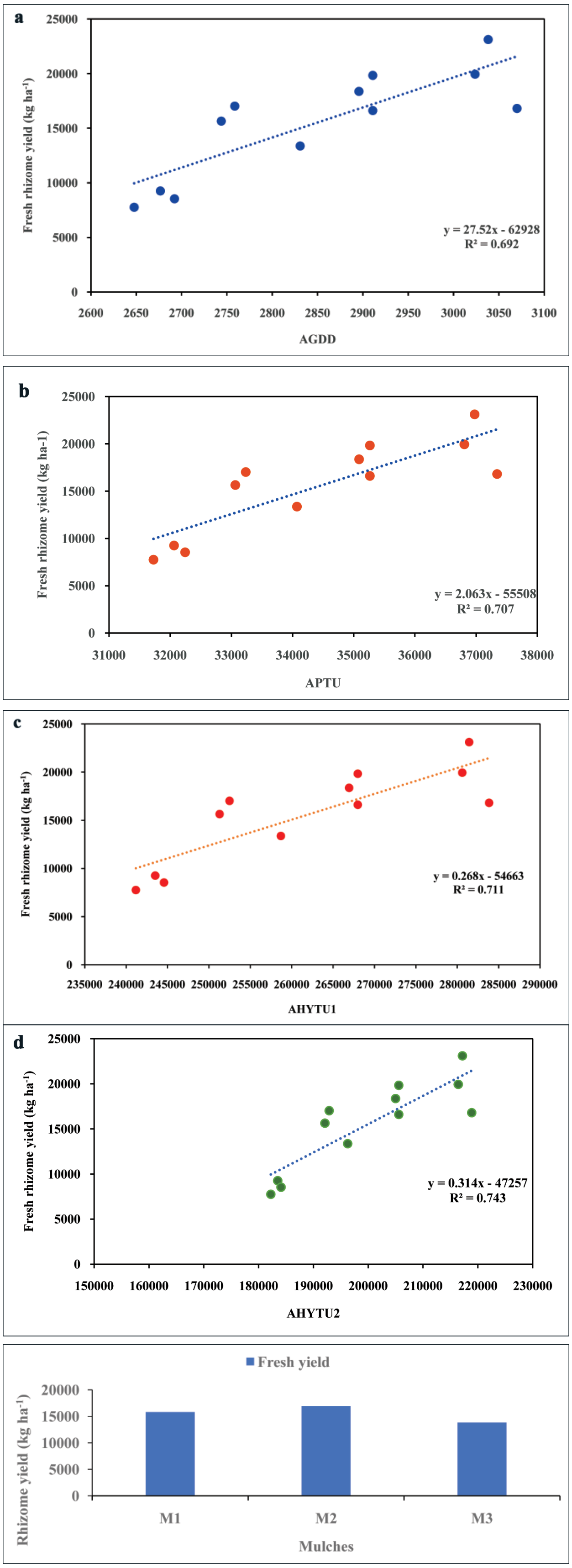


Figure7. (a-d). Relationship between the fresh rhizome yield of ginger and accumulated GDD, accumulated photothermal units, accumulated hydrothermal unit at forenoon and accumulated hydrothermal unit at afternoon

Consequently, the crop sown on June 1st accumulated the highest GDD, heliothermal units (HTU), PTU, and hydrothermal units (HYTU), followed by the July 1, June 15, and July 15 sowings. Delayed planting resulted in progressively lower GDD, PTU, and HTU values due to reduced heat unit accumulation.

Mulching also influenced thermal accumulation. Higher GDD, PTU, HTU, and HYTU values under dry coconut leaf mulch indicate its lower efficiency in thermal energy utilization, as crops required more time to transition between phenophases, signifying slower growth under prevailing conditions. In contrast, mulches that required lower heat units to reach each phenophase were more thermally efficient and better suited to similar climatic conditions.

These findings align with Kandiannan and Chandragiri (2008), who reported that compared to May planting, the thermal time required for 50% germination decreased for June and July plantings, with a similar trend in later phenophases. Crops planted earlier required longer thermal time to reach each stage because they had a longer period to complete phenophases without reducing the actual growth duration.

Table 7. Correlation between accumulated agrometeorological indices and yield of ginger

Agrometeorological index	Correlation coefficient
AGDD	0.83**
APTU	0.84**
AHYTU1	0.84**
AHYTU2	0.86**

Effect of mulches on yield of ginger

Mulching had a significant influence on ginger yield, with paddy straw and green leaf mulches outperforming dry coconut leaf mulch. The highest fresh rhizome yield was recorded under paddy straw mulch (16941kg ha^{-1}), followed closely by green leaf mulch (15,798 kg ha^{-1}). In contrast,

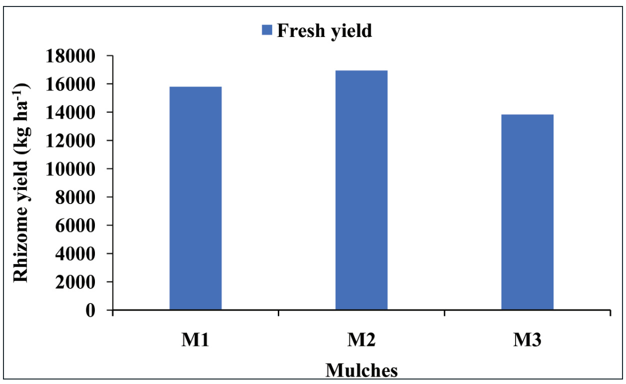
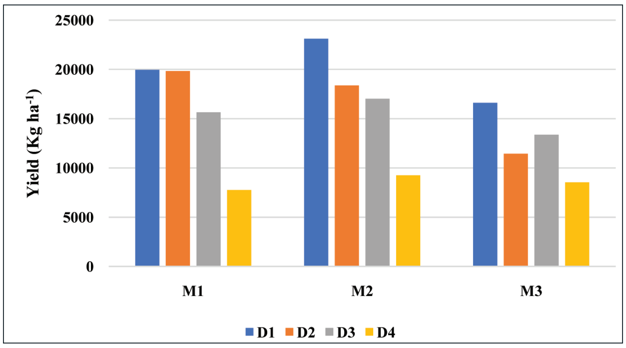


Figure 8. Effect of mulches on yield of ginger



M1: Green leaf mulch, M2 : Paddy straw mulch, M3: Coconut leaf much
Figure 9. Interaction effect of date of planting and mulches on yield of ginger

dry coconut leaf mulch resulted in a comparatively lower yield of 13,835 kg ha^{-1}.

Interaction effect of date of planting and mulches on yield of ginger

The interaction between sowing date and mulching treatment also revealed notable trends. Among crops planted in early June, paddy straw mulch produced the highest yield (19,958 kg ha^{-1}), significantly outperforming the other mulching treatments. This superior performance can be attributed to the mulch's ability to regulate soil temperature, conserve soil moisture, and suppress weed growth, thereby creating a more favorable microclimate for crop growth and rhizome development during the early crop stages.

Conclusion

The planting dates and mulches significantly influence rhizome yield by altering the crop's thermal and hydrothermal environment. Variations in accumulated agrometeorological indices such as growing degree days (GDD), hydrothermal units (HTU), photothermal units (PTU), and heliothermal units (HYTU) were closely associated with yield differences. The highest yield was recorded for the June 1st planting, followed by June 15th, July 1st and July 15thin paddy straw mulch.

Early planting (June 1stand 15th) enabled the crop to complete critical phenophases, such as sprouting, vegetative growth, and rhizome bulking under favorable thermal conditions, thereby allowing optimal accumulation of agrometeorological indices. This, in turn, promoted vigorous growth and enhanced assimilate partitioning toward rhizome development. In contrast, delayed planting reduced the length of growth phases and exposed the crop to optimal temperatures during key developmental stages, limiting the accumulation of thermal indices and ultimately reducing yield.

Paddy straw and green leaf mulches likely buffered daily temperature fluctuations and reduced evapotranspiration losses, contributing to enhanced physiological efficiency, particularly under optimal sowing conditions. These results underscore the importance of selecting suitable mulching materials in combination with optimal planting windows to maximize ginger productivity.

These findings underscore the importance of synchronizing crop phenology with favorable weather conditions to maximize productivity. Thus, early planting not only enhances yield but also improves resource use efficiency by optimizing thermal and hydrothermal inputs throughout the growing season.

References

Abhilash, D.C., Singh, R. and Premdeep, R.S., 2017. Agrometeorological indices and phenology of Basmati rice (Oryza sativa L.) under different dates of transplanting. *Int. J. Curr. Microbiol. App. Sci.*, 6(3): 212-222.

Ansari, F. R., Chodhary, K. A. and Ahad, M., 2021. A review on ginger (*Zingiber officinale*Rosc.) with unani perspective and modern pharmacology. *J. Med. Plants Stud.,* 9(3): 101-104.

Chatte, S. N., Jadhav, M. G., Dhekane, D. S., Mirza, I. A. B., Dakhore, K. K. and More, S. S., 2021. Agrometeorological indices, crop phenology and yield of pigeon pea as influenced by pigeon pea (*Cajanus cajan* L.) based intercropping system. Int. *J. Curr. Microbiol. Appl. Sci.,* 10(11): 387-396.

Evenson, J. P., Bryant, P. J., and Asher, C.J. 1978. Germination and early growth of ginger (*Zingiber officinale* Roscoe). I- Effects of constant and fluctuating soil temperature. *Trop. Agric*. 55(1): 23-28.

Fumen, K. S., Sawa, B. A., Fumen, G. A., & Kalu, G. 2021. Effect of variation in onset and cessation dates on ginger yield in Kachia area of Kaduna State. In *Proceedings of the 39th Annual Conference of the Horticultural Society of Nigeria (HORTSON) "CRIN 2021"* Horticultural Society of Nigeria, 1342p.

Indiastat. 2022. Area production, and productivity of ginger in India. [online] Available at: [Accessed 28 Oct. 2024].

Kandiannan, K. and Chandragiri, K. K., 2008. Phenology and dry matter distribution in turmeric (*Curcuma domestica Valeton*. syn. C. *longa* L.). J. *Med. Arom. Plant Sci.,* 30: 117.

Kandiannan, K., Chandaragiri, K.K., Sankaran, N., Balasubramanian, T.N. and Kailasam, C., 2002. Crop–weather model for turmeric yield forecasting for Coimbatore district, Tamil Nadu, India. *Agric. For. Meteorol.*, *112*(3-4): 133-137.

Kandiannan, K., Krishnamurthy, K. S., Ankegowda, S. J. and Anandaraj, M., 2014. Climate change and black pepper production. In Proceedings of the National Seminar on Soil,Water and Crop Management for Higher Productivity of Spices (pp. 11-12).

Kandiannan, K., Parthasarathy, U., Krishnamurthy, K. S. and Srinivasan, V., 2010. Ginger phenology and growing degree days—a tool to schedule cultural operations. In Proceedings of the National Seminar on Soil, Water and Crop Management for Higher Productivity of Spices, pp.11-12.

Kumar, A., Singh, R.K., Bharti, N., & Krishna, G. (2018). Performance and profitability study of different ginger-based cropping systems in Bokaro District of Jharkhand. *J. Curr. Microbiol. Appl. Sci.*, Special Issue-7: 2934–2939.

Nair, K. P., 2019. The agronomy and economy of ginger. In Turmeric (*Curcuma longa* L.) and Ginger (*Zingiber officinale*Rosc.) - World's invaluable medicinal spices, 245-315.

Nybe, E. V. and Raj, N. M., 2016. Ginger production in India and other South Asian countries. In Ginger, pp.231-260. CRC Press.

Puthuma, J., 2020. Challenges of climate change on spice crops in Kerala. *Int. J. Herbal Med.*, 8(3): 17-19.

Yadav, A., Khandekar, R., Korake, G., Haldankar, P., &Nawale,R. (2014). Effect of dates of planting on growth, yield and quality of ginger (*Zingiber officinale* Roscoe). *J. Spices Arom. Crops*, 23: 59-63.