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Thermal utilization of Rabi sorghum (*Sorghum bicolor*) under different sowing windows in western agro - climatic zone of Tamil Nadu

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Abstract
Sorghum is one of the major food crops it was consumed as flour, grains and fodder for animals. A field experiment was carried out at Tamil Nadu Agricultural University, Coimbatore to optimize the sowing window for *Rabi* sorghum 2019 based on thermal indices. The treatment comprises of three sowing dates viz., First sowing (D_1 – 15th September), Second sowing (D_2 – 30th September) and Third sowing (D_3 – 22nd October). Growing degree days, Helio thermal units, Photo thermal index, Heat use efficiency, Helio thermal use efficiency was calculated for different phenophases of sorghum viz., germination, vegetative, flowering, physiological maturity. The results indicated that first sowing (first fortnight of September) accumulated growing degree days, Helio thermal units, Heat use efficiency, Helio thermal use efficiency and also higher grain yield compared to other sowing dates.

Keywords: sorghum, different date of sowing, growing degree days, helio-thermal units, photo thermal units, photo thermal index heat use efficiency

Introduction
The rate of growth and development of plants depends on the temperature surrounding the plant, and each species has a minimum, maximum, and optimum specific temperature range for better growth and development (Hatfield *et al*., 2015) [6]. Thermal period is an independent variable for the description of plant growth. It can be used in various crops as a method for characterizing thermal responses. An estimation of the harvest date and the stage of crop production can be given with knowledge of accumulated GDD Sorghum (*Sorghum bicolor*) is important cereal crop in the world next to wheat, rice, corn and barely. It is a gluten free and source of higher protein & sugar as compared to other cereal crops. It is a drought tolerant crop and widely cultivated in the arid and semi- arid regions of Africa and Asian countries. In India the production of sorghum is about 4.733 million metric tones. The date of sowing major determining factors for yield improvement and also helpful to mitigate of impacts of climate change. According to Subramanyam *et al*., (2018) [15], the heat unit concepts were used to identify the best sowing time in sorghum. In the present study attempts were made to optimize the best sowing time for the *Rabi* sorghum by using thermal time approach in western agro-climatic zones of Tamil Nadu.

Materials and Methods
Afield experiment was conducted ineastern block farm of Tamil Nadu Agricultural University, Coimbatore during *Rabi* season 2019 – 2020 to study the thermal utilization pattern of *Rabi* sorghum under different sowing dates. The geographical location of the experimental site was 11 º N latitude, 77 º E longitude and mean sea level is 426.7 m. The soil type of the experimental field is sandy clay loamy soil with of pH 7.8. Annual average rainfall of the experimental site is 675 mm. A dual-purpose sorghum variety CO 30 have been used for the study and this was released by Tamil Nadu Agricultural University, Coimbatore (Ganesamurthy *et al*., 2011) [4]. It is a tall growing, non- lodging type with duration of 100-105 days. The average yield of the variety is 2805 kg/ ha under rainfed condition. The experiment was conducted in split plot design with three sowing dates and three nitrogen levels (75%, 100%, 125% RDF) replicated thrice. The 50% of N, 100% P & K were applied as basal and remaining 50% N was split equally as 25%, applied on 15 and 30 days after sowing (DAS). The required weather data for calculation were obtained from Agromet observatory of the Agro - Climate Research Centre, Coimbatore. Thermal indices namely Helio-thermal units (HTU), Heat use efficiency (HUE), Helio-thermal efficiency, growing degree days (GDD) and Photo Thermal Index (PTI) were calculated by using the daily weather data. The base temperature of 10 ^{0}C is fixed for the above calculation (Leong and Ong 1983) [10] for different stages of crop growth *viz*., emergence, vegetative stage, flowering and physiological maturity. The grain yields recorded for different date of sowings were documented. The formulae adopted for calculation of different thermal indices were furnished in Table No. 1

Table 1: The thermal indices and their formulae

S.No	Thermal Indices	Formula	Refernces
1	Growing Degree Days	$GDD = \frac{Tmax + Tmin}{2} - Tb$	(Iwata *et al*., 1984) [8]
2	Helio-thermal units	$HTU = GDD \times$ Bright Sunshine hours	(Rajput *et al.*, 1980) [14]
3	Heat use efficiency	$HUE = \frac{Grain\ Yield\ (Kg)}{GDD}$	(Haider *et al.*, 2003) [7]
4	Helio-thermal use efficiency	$HTUE = Grain\ Yield\ (Kg)/\ HTU$	(Puniya *et al*., 2017) [13]
5	Photo thermal Index	$PTI = \frac{GDD}{Growth\ Days}$	(Haider *et al.*, 2003) [17]

Results and Discussion

Growing Degree Days (GDD)

Growing degree days accumulated by plants to attain individual growth stages were varied under different date of sowing (Table 2).At germination stage, the plants sown on 30th September (Second sowing D_2)observed higher (87.5) GDD followed by first sowing (D_1) (84.8) and D_3 (77.8). First sowing (D_1) recorded higher accumulated GDD (601.5) during vegetative stage and Flowering stages (480.7) than other date of sowings. During maturity stage, third (D_3) recorded more GDD (389.3) compared to other sowings. However, the overall total accumulated GDD during entire crop growth period was higher in D_1 (1537.6) than D_2 (1497.6) and D_3 (1458.7). The delay sowing has been significantly declined GDD was observed. The similar type of result finding was reported in, Subramanyam *et al.* (2018) [15], Poornima *et al.* (2010) [11]

Table 2: Influence of date of sowing on Growing degree days, Helio thermal units, Photo thermal index at different growth stages of sorghum

Date of Sowing	GDD					HTU				
	GM	VG	FL	MT	Total	GM	VG	FL	MT	Total
D1	84.8	601.5	480.7	370.6	1537.6	1949.3	132390.2	89746.7	40951.3	265037.5
D2	87.5	576.4	466.9	366.8	1497.6	3185.0	127672.6	69754.9	40274.6	240887.1
D3	77.8	555.6	436.0	389.3	1458.7	1671.6	113276.7	49829.1	69403.3	234180.7

GM – Germination stage VG – Vegetative stage FL – Flowering stage MT – Maturity stage

Helio -Thermal Units (HTU)

Accumulated heat units are presented in Table 2. At germination stage, second sowing (D_2) recorded higher HTU (3185) followed by D_1 (1949) and D_3 (1671) and similarly third sowing (D3) registered more thermal units during physiological maturity., the total accumulated HTU during the cropping period was higher in first sowing (D_1-265037) followed by D_2 (240887) and D_3 (234180). The similar research findings also reported in Baviskar *et al*., (2017) [3]

Photo Thermal Index (PTI)

The PTI values were presented in figure 3. Higher PTI value of 64.98 was recorded in first sowing (D_1) and which was closely followed by second sowing (D_2) with a values of 64.20. The lowest PTI value of 61.52 was observed in third sowing (D_3). The similar type of research findings was reported in Prajapat *et al.*, (2018) [12], Akhter *et al.*, (2015) [1] and Alam *et al.*, (2007) [2].

Heat Use Efficiency (HUE) and Helio Thermal Use Efficiency (HTUE)

The HUE (grain yield per degree days) were calculated and presented in figure 1. The first sowing (D_1-13thSeptember) crop achieved higher HUE(1.95kg ha-1 °C day) followed by 1.88 kg ha-1 °C day and 1.66 kg ha-1°C day second sowing (D_2) and Third sowing (D_3) respectively. The optimum sowing window has accumulated higher HTU and HTUE than the late sowing of *Rabi* sorghum in the western agro climatic zone of Tamil Nadu.

The HTUE (grain yield per helio thermal units) were presented in figure 1. First sowing (D1) recorded higher helio thermal use efficiency (0.0113) and closely followed by (D_2) with a values of 0.0117 kg ha^{-1} °C day hr. The similar relationship was recorded in the Thavaprakash *et al*. (2007) [15], Kingra *et al. (*2012) [9], and Girijesh *et al.* (2011) [5].

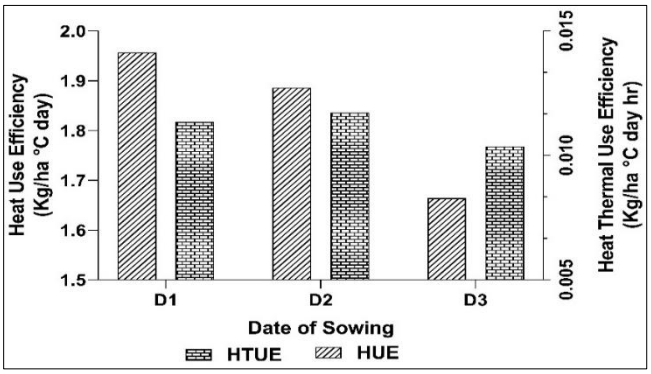

Fig 1: Heat use efficiency (kg ha-1°C day) and Helio thermal use efficiency (kg ha-1 °C day hr) of sorghum

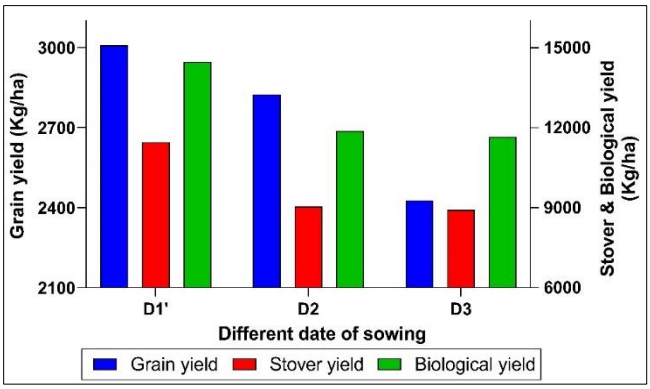

Fig 2: Yield attributes+ of sorghum

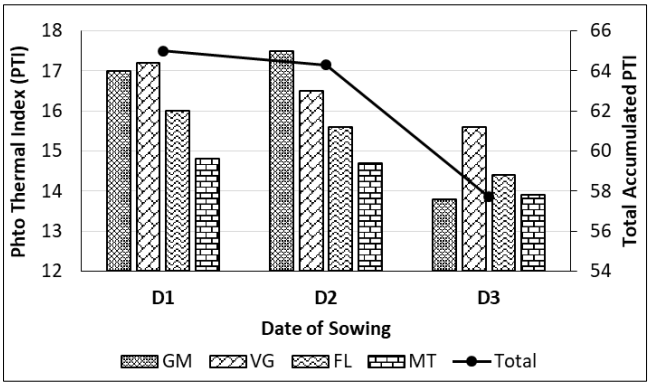

Fig 3: Photo thermal index

Conclusion

First sowing (first fortnight September) accumulated more GDD, HTU HUE, HTUE and also registered higher grain yield compared to other sowing dates. Therefore it can be concluded that first fortnight September (37th standard meteorological week) is the best time of sowing for getting higher yield in rabi sorghum in western agro climatic zone of Tamil Nadu.

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