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ORIGINAL ARTICLE

Effect of thermal indices on yield of pearl millet (*Pennisetum glaucum* L.) varieties under variable weather conditions of south Saurashtra Agro-climatic zone of Gujarat

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ABSTRACT
An experiment was conducted during summer season of year 2019 at Junagadh, Gujarat to study the thermal requirement of pearl millet (Pennisetum glaucum L.)varieties under different weather conditions. The experiment was conducted in split plot design with four sowing dates and three varieties. Results revealed that sowing between 25thJanuary to 15th February produced significantly higher growth due to fulfillment of optimum thermal requirement for various plant processes. Timely sown pearl millet crop recorded significantly higher GDD (growing degree days), HTU (helio-thermal units), PTU (photo-thermal units)and HUE (Heat use efficiency). Delay in sowing (after 15thFebruary) reduced the crop duration. GHB - 732 variety was found more conducive for growth and higher thermal unit.
Keywords: *Growing degree days, heat use efficiency, helio-thermal units, pearl millet,photo-thermal units.*

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INTRODUCTION

Pearl millet (*Pennisetum glaucum* L.) is one of the most important millet crop grown in India.Pearl millet belongs to family Poaceae and genus Pennisetum. The pearl millet growing countries are India, China, Nigeria, Pakistan, Sudan, Egypt, Arabia, and Russia. India is the largest producer of pearl millet in the world. In India major producing states are Rajasthan (46 %), Maharashtra (19 %), Gujarat (11 %), Uttar Pradesh (8 %) and Haryana (6 %). Nutritionally, the pearl millet grains are rich source of protein, fat, carbohydrates, mineral matters, high energy value and high Fe, Zn and Ca compared to other cereals. It is rich in vitamin-A and B, thiamine and riboflavin content and imparts substantial energy to the body with easy digestibility. It is gluten free and has also low glycine index. Apart from grain, dry fodder is an important secondary product in low resource agriculture for animal feed and fuel.

Temperature play a key role in influencing crop production. The occurrence of different phenological events during crop growth period in relation to temperature can be estimated by using accumulated heat units or growing degree days (GDD). Knowledge of accumulated GDD can provide an estimate of harvest date as well as crop development stage. Heat use efficiency(HUE), *i.e.*, efficiency of utilization of heat in terms of dry matter accumulation, depends on crop type, genetic factors and sowing time.Air temperature-based heat indices, *viz.*, growing degree days (GDD), photothermal units (PTU), and helio-thermal units (HTU) have been used to describe changes in phenological behaviour and growth parameters. The values of accumulated GDD, HTU and PTU for each phenophase are relatively constant and independent of sowing date but vary in a crop from variety to variety.

MATERIAL AND METHODS

The field experiment was conducted during summer season of year 2019 at Instructional Farm, Department of Agronomy, JAU, Junagadh (Gujarat). Geographically the experimental site was situated at 21.51° N latitude and 70.55° E longitude at an altitude of 83 m above mean sea level. The experiment was laid out in split plot design, consisting 36 treatment combinations comprised of four sowing dates were 25th January (D_1), 5th February (D_2), 15th February (D_3) and 25th February (D_4) and three varieties were GHB-538 (V_1), GHB-558 (V_2) and GHB-732 (V_3) with three replications. Observations of the yield and yield attributes such as germination percentage, plant height at maturity, number of total tillers per plant, number of effective tillers per plant, length of earhead, diameter of earhead, grain yield, stover yield, harvest index and test weight were taken. The daily meteorological observations recorded at the Agrometeorological observatory near Instructional Farm.

Several Agrometeorological indices expressed as,

Growing degree days can be mathematically expressed as under.

$$GDD = \sum_{ds}^{dp} [(Tmax + Tmin)/2 - Tb]$$

Where, GDD = Growing degree days
ds = Dates of sowing
dp = Dates of different phenological stages
T_{max} = Daily maximum temperature (°C)
T_{min} = Daily minimum temperature (°C)
T_b = Base temperature

The base temperature is taken as 12 °C, below this temperature growth cannot occur [5].

Photo-thermal unit formula given by Wang [6].

PTU = GDD x N

Where,

N = Maximum possible sunshine hours

Helio-thermal unit formula given by Wang [6].

HTU = GDD x n

Where,

n = Actual duration of bright sunshine hours

Heat use efficiency

$$HUE = \frac{\text{Total grain yield (kg/ha)}}{\text{Summation of Accumulated GDD (degree days)}}$$

RESULTS AND DISCUSSION

Effect of sowing dates:

Thermal indices during different phenophases

First date of sowing (25thJanuary) have a highest thermal indices like GDD, HTU and PTU in all the phenophases and lowest was observed in last date of sowing (25thFebruary) (Table 1 and Fig. 1,2 and 3). All the phenophses had a highest thermal indices in first date of sowing. The maximum GDD to reach maturity was recorded at 25thJanuary followed by other date of sowing which indicated that the crop exposed sub-optimal thermal regime with delay in sowing [1]. Helio-thermal and photo-thermal unit was recorded highest in 25thJanuary followed by 5th February due to higher growing degree days [2], while lowest value was recorded at 25thFebruary. Maturity stage have a highest thermal indices compare to the other phenophases because maturity stage have more growth days compare to other phenophases.

First date of sowing had days to taken for maturity was 112 days and Less days (89 days) to taken for maturity was observed in last date of sowing. The results indicated that the crop attain the highest heat use efficiency (2.76 kg/ha °C day) showed in third date of sowing (D_3). Whereas it was more or less in the second and fourth dates of sowing. It was lowest (1.96 kg/ha °C day) in the first date of sowing (D_1). These results are in conformity with the findings of Kulwinder *et al.* [3] and Mohammad *et al.* [4]. (Table 2 and Fig. 4).

Table 1: Accumulated thermal indices during different phenophases of pearl millet as affected by various treatments.

Treatments	Thermal indices	P_1	P_2	P_3	P_4	P_5	P_6	P_7
Sowing dates								
25th January (D_1)	GDD	66	211	309	96	219	76	805
	HTU	598	1748	2541	979	2185	761	8278
	PTU	730	2422	3656	1157	2645	957	10308
5th February (D_2)	GDD	61	225	302	101	212	78	770
	HTU	438	1752	2856	1006	2107	797	7931
	PTU	697	2591	3623	1209	2628	982	9892
15th February (D_3)	GDD	56	227	329	97	193	63	708
	HTU	478	1810	3203	965	1940	589	7333
	PTU	647	2662	3944	1183	2436	794	9116
25th February (D_4)	GDD	64	223	355	76	159	56	701
	HTU	371	2054	3566	742	1486	615	7365
	PTU	737	2681	4314	956	2003	706	9086
Varieties								
GHB 538 (V_1)	GDD	52	209	292	86	216	81	706
	HTU	395	1736	2745	861	2122	822	7306
	PTU	586	2442	3507	1051	2671	1023	9078
GHB 558 (V_2)	GDD	62	234	339	86	196	62	746
	HTU	471	1946	3190	861	1930	625	7727
	PTU	703	2736	4073	1051	2428	778	9601
GHB 732 (V_3)	GDD	72	222	339	105	176	62	787
	HTU	548	1841	3190	1047	1737	625	8148
	PTU	820	2589	4073	1278	2185	778	10123

P_1: Emergence P_2: Tillering P_3: Panicle initiation
P_4: Earhead emergence P_5: Flowering initiation P_6: 50 % Flowering P_7: Maturity

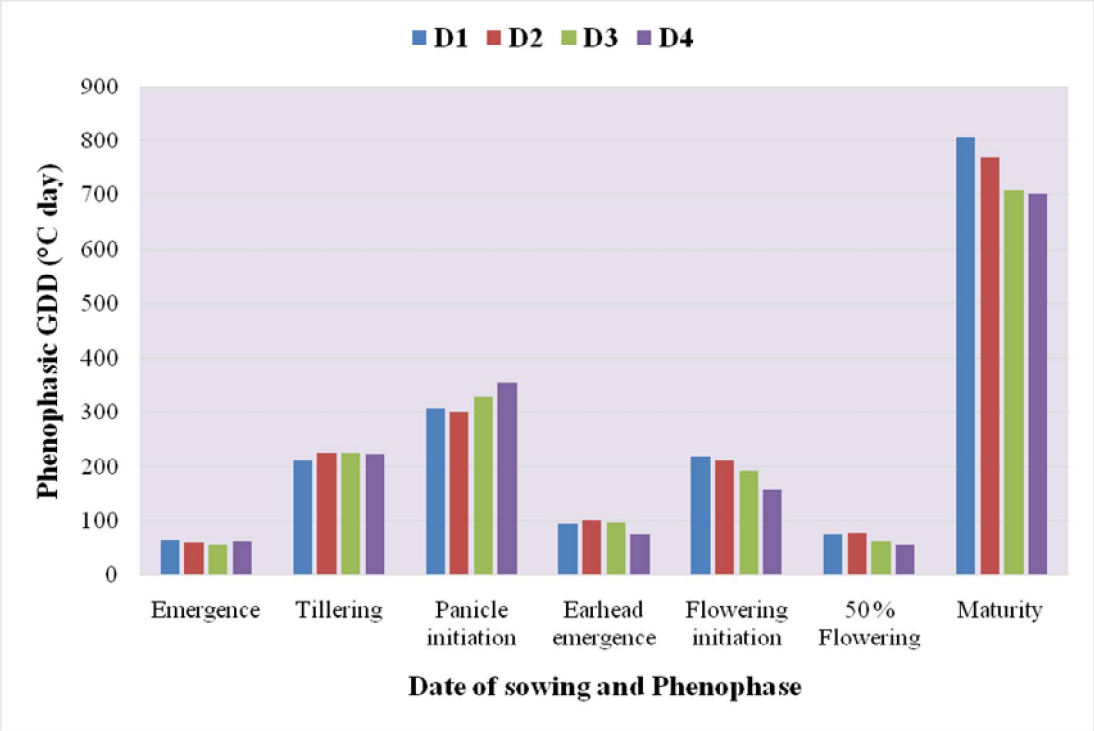

Fig.1 Phenophasic growing degree days as influenced by date of sowing

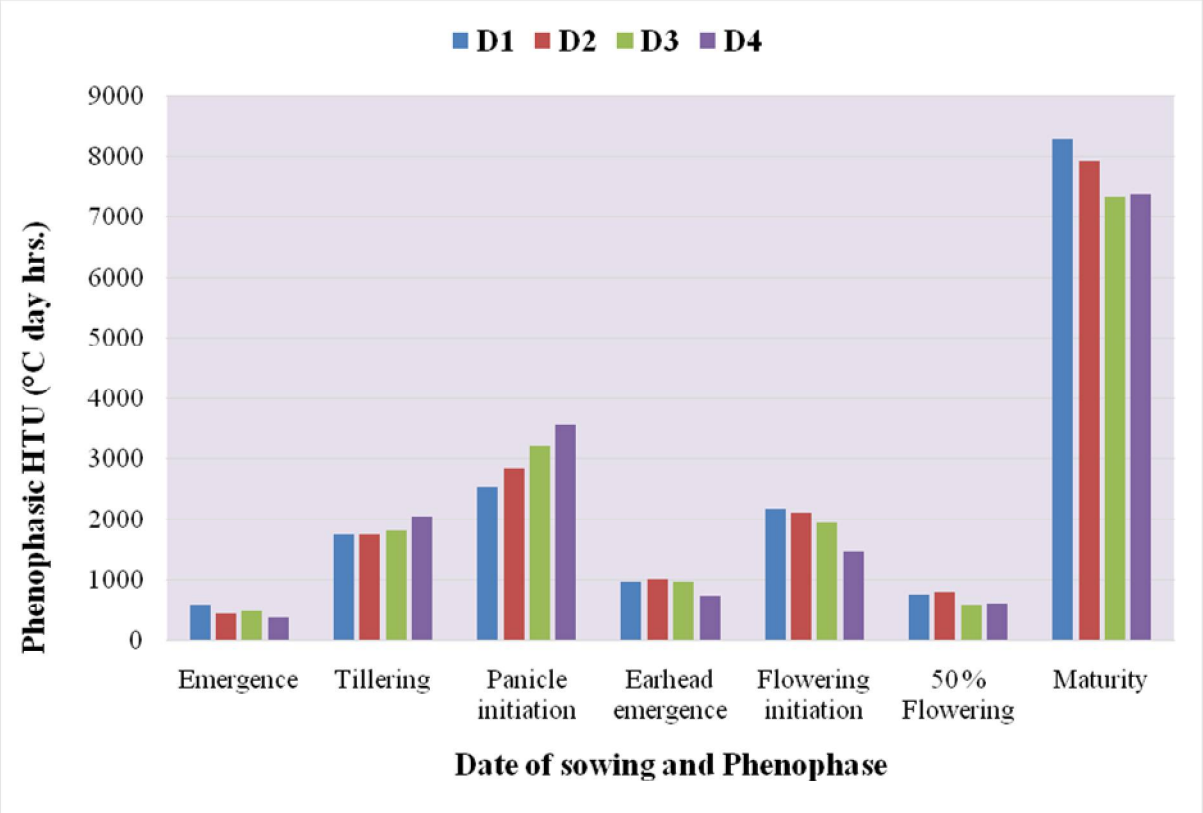

Fig. 2 Phenophasic heliothermal units as influenced by date of sowing

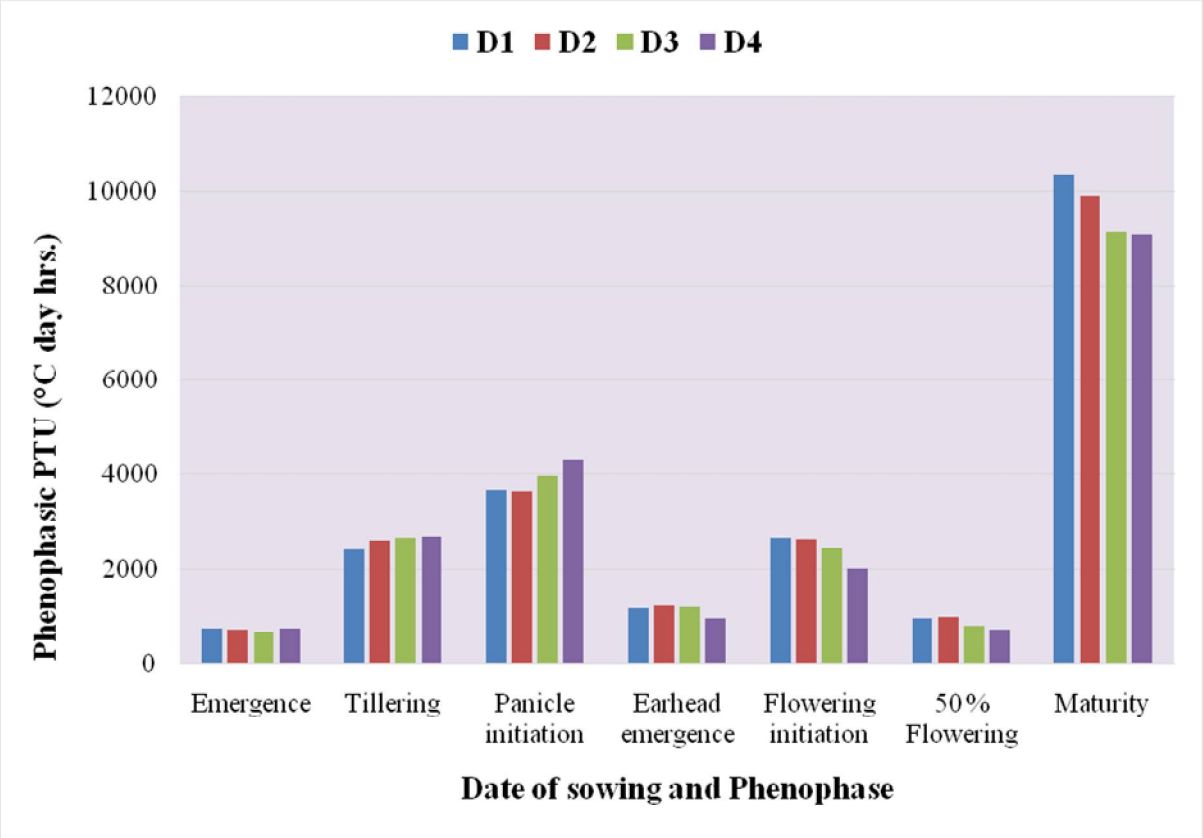

Fig.3 Phenophasic photothermal units as influenced by date of sowing

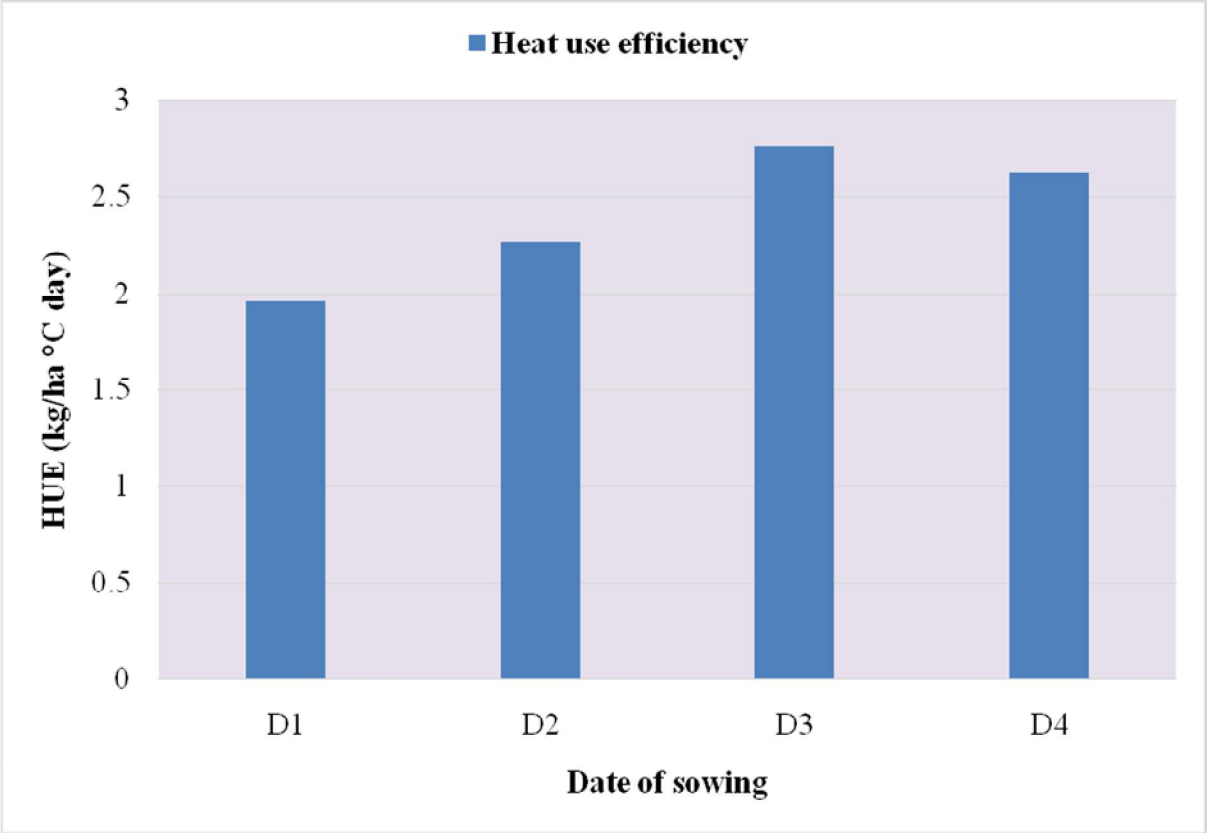

Fig. 4 Heat use efficiency as influenced by date of sowing

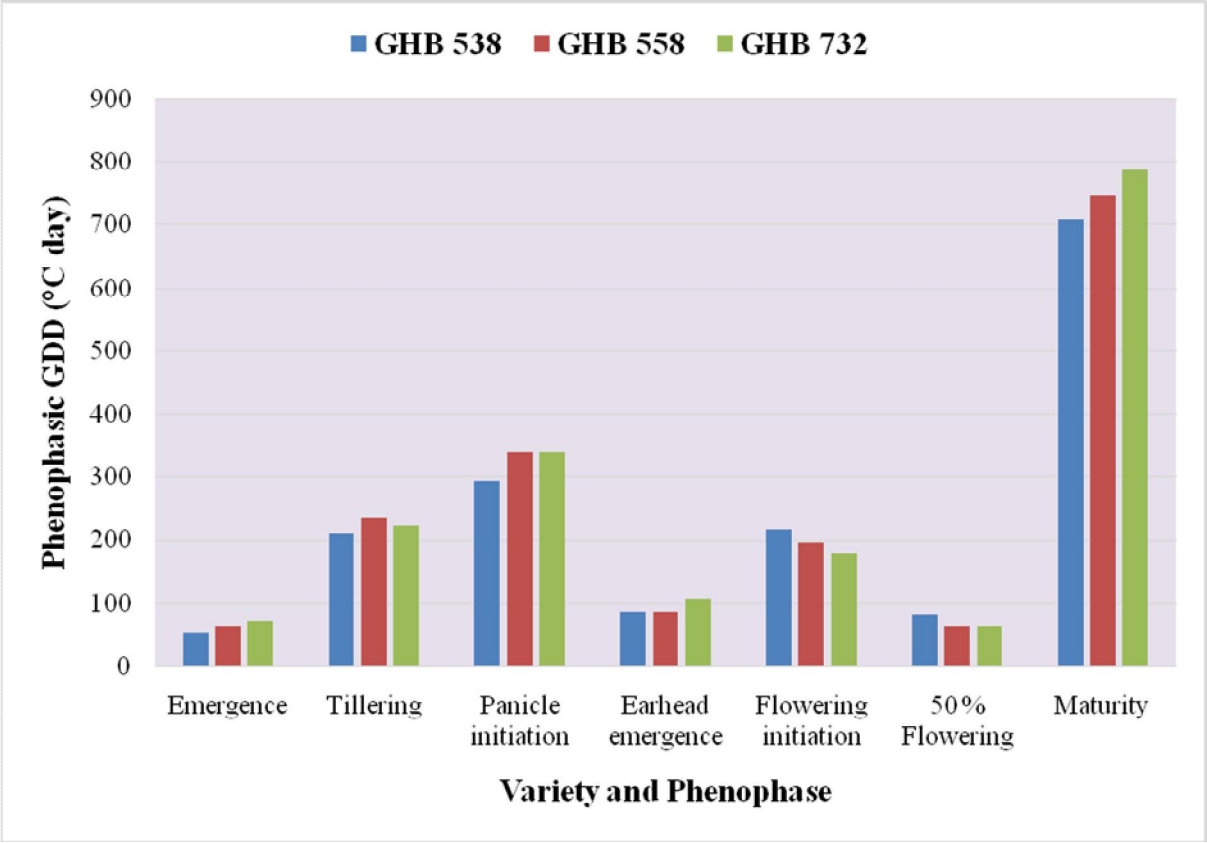

Fig. 5 Phenophasic growing degree days as influenced by variety

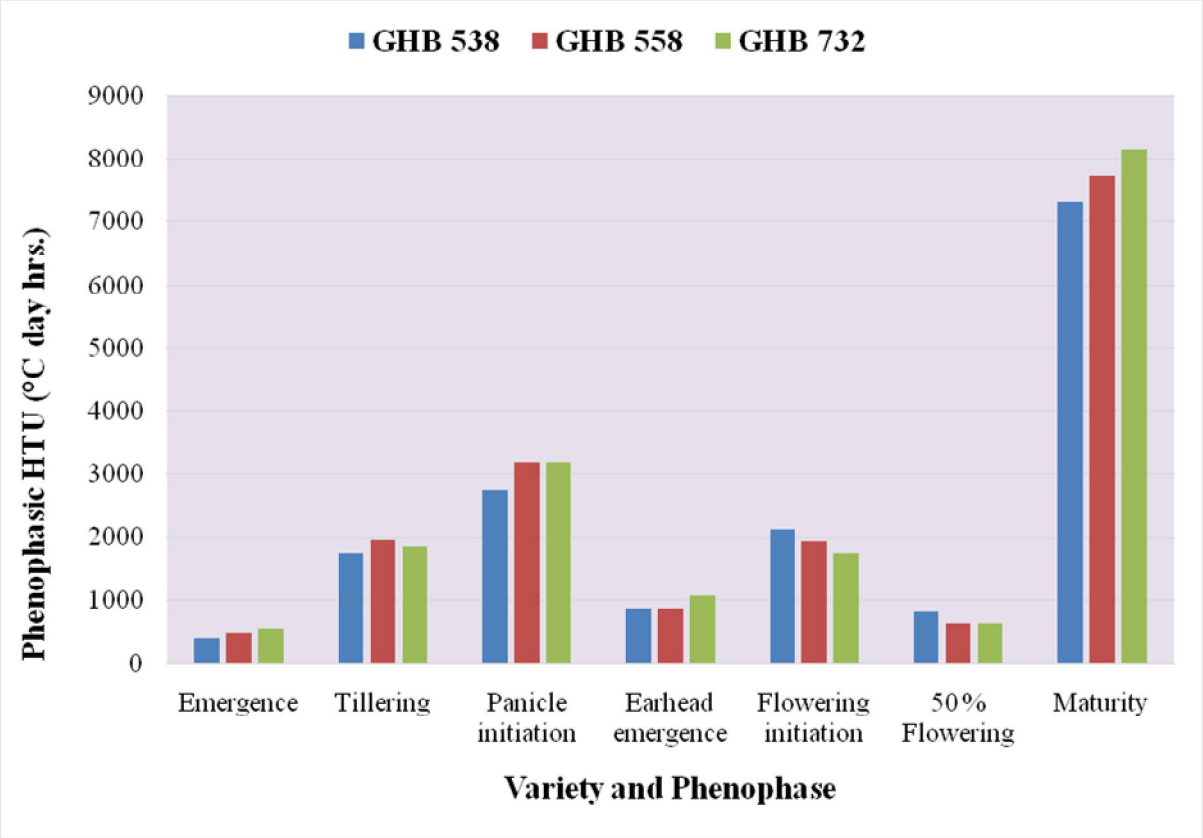

Fig. 6 Phenophasic heliothermal units as influenced by variety

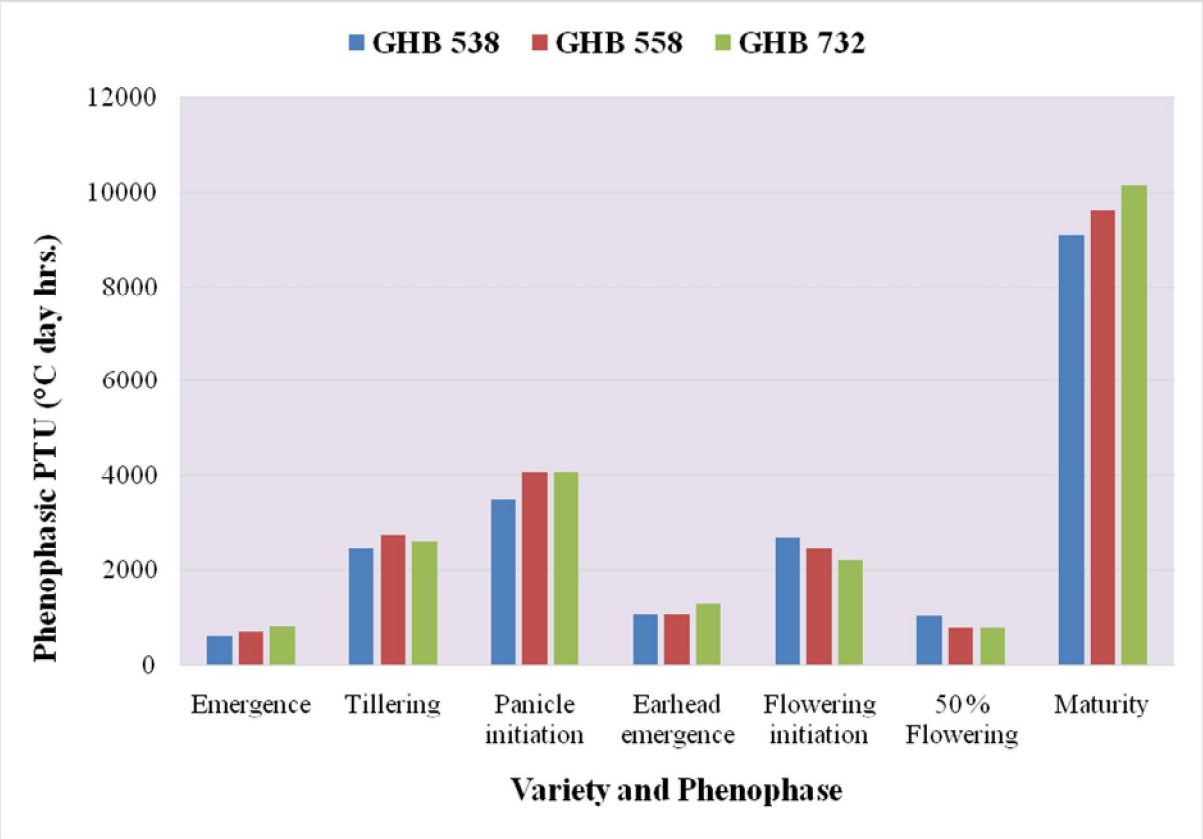

Fig. 7 Phenophasic photothermal units as influenced by variety

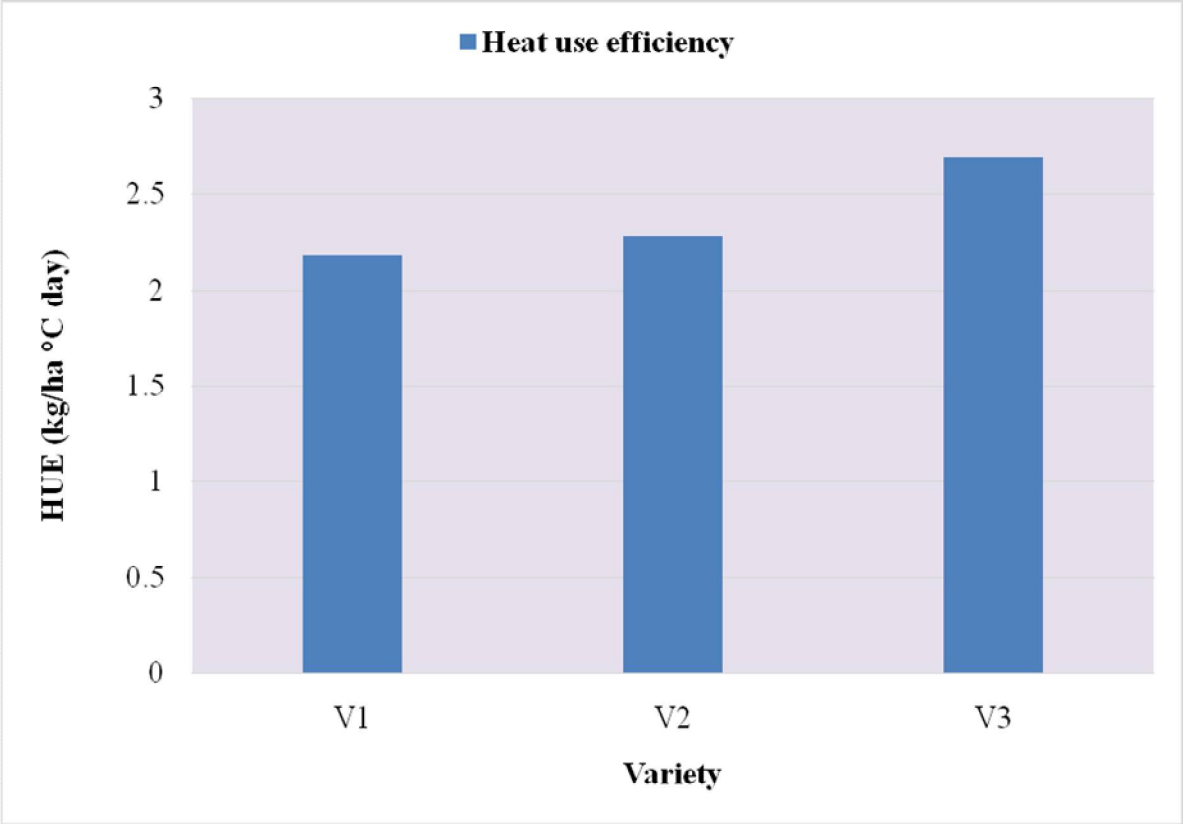

Fig. 8 Heat use efficiency as influenced by variety

Effect of varieties:

Thermal indices during different phenophases

Pearl millet variety significantly showed the result of date of sowing. All the thermal indices like GDD, HTU and PTU highest in GHB 732 variety and lowest was observed in GHB 538 variety (Table 1 and Fig. 5,6 and 7). In all variety (GHB 538, GHB 558 and GHB 732), maturity stage has a highest thermal indices compare to the other phenophases because maturity stage have more growth days compare to other phenophases.

GHB 732 variety had days to taken for maturity was 98 days. Less days (90 days) to taken for maturity was observed in GHB 538 variety. GHB 732 variety had highest growing degree days and highest grain yield, so that heat use efficiency was observed highest (2.69 kg/ha °C day). Lowest heat use efficiency (2.18 kg/ha °C day) was observed in GHB 538 variety. (Table 2 and Fig. 8).

Table2: Heat use efficiency (kg/ha °C day) at maturity in terms of grain yield of pearl millet cultivars under different sowing dates.

Sowing date / Variety	Days taken	Grain yield (kg/ha)	∑ AGDD (°C day)	HUE (kg/ha °C day)
D_1	112	3494	1781	**1.96**
D_2	104	3950	1748	**2.26**
D_3	95	4613	1672	**2.76**
D_4	89	4282	1634	**2.62**
V_1	90	3587	1642	**2.18**
V_2	96	3925	1725	**2.28**
V_3	98	4741	1763	**2.69**

CONCLUSION

From the results of one-year field study during summer 2019,it was highlighted thatpearl millet crop sown between 25th January to 15th February recorded significantly more growing degree days, helio-thermal units, photothermal units and heat use efficiency to attain maturity of pearl millet crop as compared to late sown after 25th February. Among different dates of sowing and varieties, D_3 (15th

February) and GHB 732 variety were found to be the most suitable for higher productivity of pearl millet under agro-climatic condition of Junagadh (Gujarat).

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