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Growing Degree Days and Heat Use Efficiency of Fingermillet Varieties at Different Sowing Dates

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ABSTRACT

A field experiment was conducted at Agricultural College Farm, Bapatla on sandy loam soil during *kharif* 2015 to study the crop heat unit requirement on growth and yield of fingermillet (*Eleusine coracana* L.) varieties sown at different dates. The highest drymatter (3665kg ha^{-1}) at harvest and grain yield (2305 kg ha^{-1}) was recorded with (D_2) 2nd fortnight of July sowing. Higher values of Growing Degree Days (GDD) and Heat Use Efficiency (HUE) were also observed with (D_2) 2nd fortnight of July and significant linear relationships were observed for drymatter and grain yield for all the three varieties of fingermillet with GDD and HUE.

Key words: Fingermillet, Growing Degree Days, Heat Use Efficiency.

Finger millet (*Eleusine coracana* L.) is an important food crop next to rice, wheat and maize, valued as a staple food. In India it has the pride place of having highest productivity among millets. One of the striking features of finger millet is its resilience and ability to adjust to diverse agro-ecological conditions which is reflected in having highest productivity among millets (Seetharam, 1997). Knowledge of accumulated GDD can provide an estimate of harvest date as well as crop development stage (Ketring and Wheles, 1989). Growing Degree Days provides a scientific basis for determining the effect of temperature, radiation or photoperiod on phenological behavior of the crop. The prediction of crop growth stage is necessary for management decision such as timing of fertilizer application, scheduling of irrigation and harvesting etc and also required for crop modeling and management.

MATERIAL AND METHODS

The experimental soil was sandy loam having pH 6.86 and organic carbon 0.10 per cent. The available nitrogen, phosphorus and potassium contents were 56.4, 25.6, and 250.0 kg ha^{-1}, respectively. The experiment was laid out in Randomized Block Design with factorial concept in three replications and consisted of nine treatments, viz., three varieties (Chaitanya, Bharathi and Hima) and three dates of sowings (1st fortnight of July, 2nd fortnight of July and 1st fortnight of August). A uniform dose of 60:30:30 kg NPK per hectare was applied to the experimental plots. Entire quantity of phosphorus and potash and 1/3 of nitrogen was applied as basal. The remaining nitrogen was applied in two equal splits at 30 DAS and 60 DAS.

Growing degree days were calculated from date of sowing to harvesting of the crop to give accumulated growing degree days. This was expressed as ^{0}C day. The GDD were calculated by the following equation (Iwata, 1984). Base temperature of 10^{o}c was taken for fingermillet (Nagaraju, 2008).

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

Where, T_{max} = Maximum temperature , T_{min} = Minimum temperature , T_b = Base temperature

Heat use efficiency or Thermal time efficiency is expressed as kg ha^{-1} ^{0}C^{-1} day^{-1}. This was calculated using the following formula (Haider *et al.,* 2003)

$$HUE = \frac{\text{Total drymatter / Seed yield (kg ha}^{-1})}{\text{Accumulated heat units } (^0\text{C day})}$$

Regression analysis was carried out for development of models for prediction of growth and yield of fingermillet (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Drymatter production (kg ha^{-1}) at harvest was significantly influenced by dates of sowing and varieties. At harvest, (D_2) 2nd fortnight of July sowing accumulated significantly higher drymatter (3665kg ha^{-1}). The highest drymatter (3375 kg ha^{-1}) was recorded with variety Chaitanya (V_2) which was on par with 3085 kg ha^{-1} of Bharathi (V_3) and both these varieties were significantly superior to Hima (V_3) with 2745 kg ha^{-1} (Table 1).

Grain yield was significantly influenced by dates of sowing and varieties. The highest grain yield of 2305 kg ha^{-1} was recorded when the crop was sown on (D_2) 2nd fortnight of July followed by 1995 kg ha^{-1} with (D_3) 1st fortnight of August sowing and 1807 kg ha^{-1} with (D_1) 1st fortnight of July sowing (Table 1).

Among the varieties, the highest grain yield of 2173 kg ha^{-1} was recorded with Chaitanya which was significantly superior to Bharathi and Hima with grain yield of 1970 kg ha^{-1} and 1934 kg ha^{-1} respectively. However, grain yield obtained with Bharathi and Hima were on par with each other. The interaction between dates of sowing and varieties was non-significant for drymatter production and grain yield. (Table 1)

The higher drymatter production and grain yield recorded with (D_2) 2nd fortnight of July could be attributed to the cumulative effect of increased plant height, more tiller production and crop had an opportunity of longer growth period with sufficient light, temperature, relative humidity bright sunshine hours coupled with optimum day length which might have increased photosynthesis, in turn, drymatter production and yield. On the other hand delay in sowing during 1st fortnight of August resulted in vegetative phase coinciding with short day periods resulting in lower biomass accumulation and in turn low yield. Under late sown conditions, lack of soil moisture due to cessation of rains also affects grain yield potential. Similar findings were observed by Ravi kumar *et al.*(1992), Murthy (1999) and Nagaraju and Mohan kumar (2006).

Days to maturity

Days to maturity was significantly influence by dates of sowing and varieties. However, the interaction between dates of sowing and varieties was non-significant. Delay in maturity was noticed with D_2 sowing compared to other two

Table 1. Drymatter production, grain yield, and days to maturity of fingermillet varieties as influenced by dates of sowing.

Treatments	Drymatter production (kg ha^{-1})	Grain yield (kg ha^{-1})	Days to maturity
Varieties(V)			
(V_1)Chaitanya	3375	2173	109.7
(V_2)Bharathi	3085	1970	104.2
(V_3)Hima	2634	1934	101.0
SEm±	99.0	55.31	1.28
CD (0.05)	296	165	3.8
Dates of sowing(D)			
(D_1)1 st fortnight of July	2426	1807	99.0
(D_2)2nd fortnight of July	3665	2305	109.6
(D_3)1 st fortnight of August	3003	1995	105.7
SEm±	99.0	55.31	1.2
CD (0.05)	296	165	3.8
Interactions(V x D)			
SEm±	171.5	95.7	2.22
CD (0.05)	NS	NS	NS
CV (%)	9.8	8.1	3.67

Table 2. Accumulated Growing Degree Days (GDD) during different phenophases of fingermillet varieties at different dates of sowing (Data statistically not analyzed)

Growth stages	Dates of sowing			Mean
	(D_1)1 st Fortnight of July	(D_2) 2 nd Fortnight of July	(D_3) 1 st Fortnight of August	
(V_1) Chaitanya				
Maximum Tillering	423	478	436	446
Anthesis	654	763	753	724
Maturity	2016	2155	2060	2077
(V_2) Bharathi				
Maximum Tillering	402	441	394	412
Anthesis	675	700	716	697
Maturity	1960	2056	1997	2004
(V_3)Hima				
Maximum Tillering	362	382	372	372
Anthesis	675	738	695	703
Maturity	1867	2009	1884	1920

Table 3. Growing Degree Days, total drymatter, grain yield and Heat Use Efficiency (HUE) of fingermillet varieties at different dates of sowing (Data statistically not analyzed).

Dates of Sowing	Total GDD (^{0}C day)	Total Drymatter (kg ha^{-1})	Grain Yield (kg ha^{-1})	HUE of TDM(kg ha^{-1} ^{0}C^{-1} d^{-1})	HUE of Grain Yield(kg ha^{-1} ^{0}C^{-1} d^{-1})
(V_1) Chaitanya					
(D1) 1 st Fortnight of July	2016	2758	2064	1.37	1.02
(D_2) 2 nd Fortnight of July	2155	3944	2313	1.83	1.07
(D_3) 1 st Fortnight of August	2060	3425	2141	1.66	1.04
(V_2)Bharathi					
(D1) 1 st Fortnight of July	1960	2392	1672	1.22	0.85
(D_2) 2 nd Fortnight of July	2056	3672	2378	1.79	1.16
(D_3) 1 st Fortnight of August	1997	3192	1934	1.60	0.97
(V_3)Hima					
(D1) 1 st Fortnight of July	1867	2130	1684	1.14	0.90
(D_2) 2 nd Fortnight of July	2009	3380	2367	1.68	1.18
(D_3) 1 st Fortnight of August	1884	2392	1819	1.27	0.97

dates of sowing D_1 and D_3. Among the dates of sowing (D_2) 2nd fortnight of July required significantly maximum days (109.6) to mature than (D_1) 1st fortnight of July (101.6 days) and it was on par with (D_3) 1st fortnight of August *i.e.*, 105.7 days. Among the varieties, Chaitanya (V_1) took 109.7 days to mature and was significantly superior to Bharathi (V_2) and Hima (V_3) with 104.2 and 101.0 days to maturity, respectively.(Table 1)

Growing Degree Days (GDD)

The accumulated GDD during different phenophases of the three fingermillet varieties under different dates of sowing are presented in Table 2. For different dates of sowing and varieties, the accumulated GDD from sowing to maturity during different phenophases ranged from 362 with (D_1) 1st fortnight of July for variety Hima to 2155 with 2nd fortnight of July for Chaitanya. Among the sowing dates, 2nd fortnight of July recorded the highest GDD followed by sowing during 1st fortnight of August.

Table 4. Regression relationship between TDM / GY and GDD for fingermillet varieties.

Varieties	Regression equation	Coefficient of determination (R^2)
	TDM and GDD	
Chaitanya	TDM = -13294+8.206 GDD	0.96*
Bharathi	TDM = -22655+12.84 GDD	0.94*
Hima	TDM= -13573+8.44 GDD	0.92*
	GY and GDD	
Chaitanya	GY = -1543+1.789 GDD	0.98*
Bharathi	GY = -11130+6.535GDD	0.96*
Hima	GY= -1022+1.536 GDD	0.94*

*Significant

Table 5. Regression relationship between TDM/ GY and HUE for fingermillet varieties.

Varieties	Regression equation	Coefficient of determination (R^2)
	TDM and GDD	
Chaitanya	TDM= -729.5+2533 HUE	0.90*
Bharathi	TDM = -355.8+2242 HUE	0.89*
Hima	TDM = -558.8+2341HUE	0.79*
	GY and HUE	
Chaitanya	GY = -3113+5054 HUE	0.98*
Bharathi	GY = -83.12+ 2068 HUE	0.86*
Hima	GY = -696.5+2624 HUE	0.82*

*Significant

The highest GDD accumulated with (D_2) 2nd fortnight of July sowing compared to (D_1) 1st fortnight of July sowing might be due to longer crop duration and optimum temperature range (Murthy 1999). Among varieties, Chaitanya accumulated the highest GDD which might be due to its higher crop growth days (115 days) compared to Bharathi and Hima. The results are in accordance with those of Amgain (2011), Gaile (2012) and Ghanekhar *et al.*(2012).

Heat Use Efficiency (HUE)

Among the varieties, Chaitanya performed better than Bharathi and Hima in terms of HUE for both drymatter production and grain yield.The highest HUE for drymatter was recorded with (D_2) 2nd fortnight of July sowing for Chaitanya followed by Bharathi and Hima (Table 3). Higher drymatter and grain yield with (D_2) 2nd fortnight of July might be attributed to higher HUE at this sowing date compared to other sowings. The lowest HUE for drymatter with 1st fortnight of July sowing might be due to the lowest drymatter whereas, lowest grain yield with 1st fortnight of July sowing might have decreased the HUE of grain yield at this date.

Relationship between total drymatter / grain yield with GDD and HUE

Linear regression equations were obtained between total drymatter (TDM) / grain yield (GY) as dependent variable and GDD and HUE as independent variables, based on data of experiment on three sowing dates and three varieties.

The regression analysis conducted for three varieties to test the dependence of TDM and GY on GDD are presented in Table 4. Linear

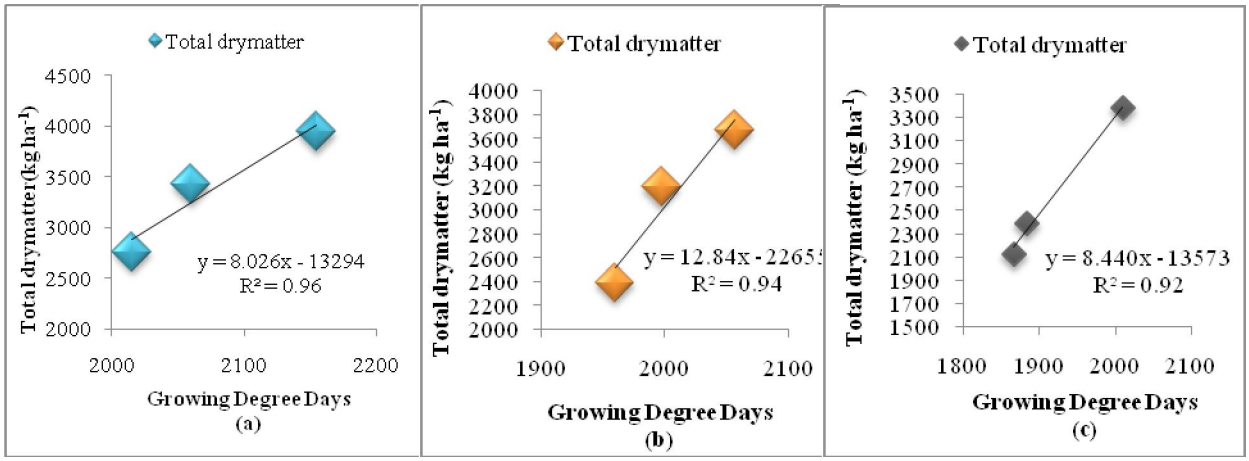

Fig 1. Regression relationship between total drymatter and Growing Degree Days in (a) Chaitanya, (b) Bharathi and (c) Hima varieties.

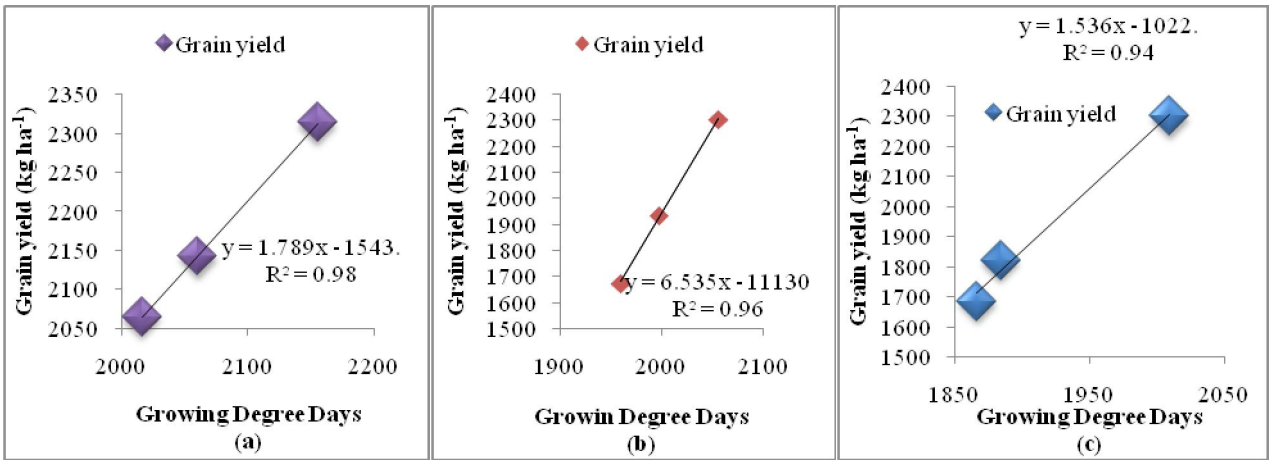

Fig 2. Regression relationship between grain yield and Growing Degree Days in (a) Chaitanya, (b)Bharathi and (c) Hima varieties

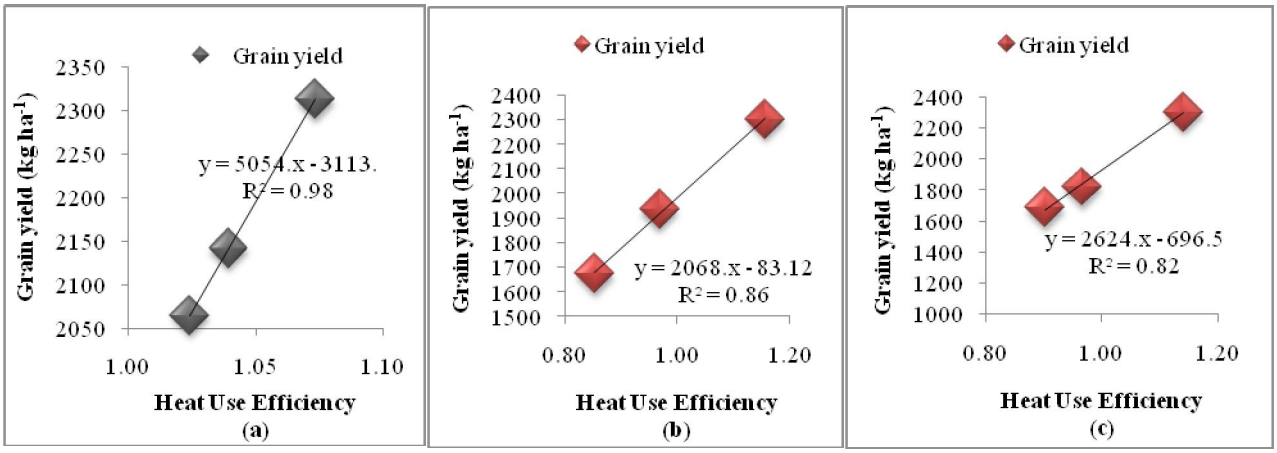

Fig 3 Regression relationship between grain yield and Heat Use Efficiency in (a) Chaitanya, (b) Bharathi and (c) Hima varieties

relationship was obtained between TDM / GY and GDD. The values of coefficient of determination (R^2) obtained for all three varieties indicated their variation (%) of TDM and GY for GDD. Among the three varieties, grain yield and drymatter of Chaitanya variety could be predicted with 96%, 98% accuracy with accumulated GDD at maturity(Fig 1 &2).

For TDM the variation in dependence on accumulated Heat Use efficiency for all three varieties Chaitanya, Bharathi and Hima varied from R^2=90, R^2=89 and R^2=79, respectively and total drymatter of all three varieties could be predicted with more accuracy with Heat Use efficiency during maturity(Table 5). With regard to grain yield of Chaitanya, Bharathi and Hima varieties it could be predicted with 98%, 86% and 82% accuracy respectively with HUE during maturity phase (Fig.3).

It can be concluded that (D_2) 2nd fortnight of July sown crop recorded higher values of GDD, HUE due to longer duration resulting in vigorous growth, thereby higher drymatter and grain yield. Significant linear relationships were observed for drymatter and grain yield of all the three varieties of fingermillet with GDD and HUE. Among the varieties, Chaitanya produced higher drymatter and grain yield.

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