I.J.S.N., VOL. 2(3) 2011: 529 - 533 ISSN 2229 – 6441

INTERNATIONAL JOURNAL OF SCIENCE AND NATURE

www.scienceandnature.org

HEAT USE EFFICIENCY AND HELIO-THERMAL UNITS FOR MAIZE GENOTYPES AS INFLUENCED BY DATES OF SOWING UNDER SOUTHERN TRANSITIONAL ZONE OF KARNATAKA STATE

[1]Girijesh, G.K., [1]Kumara swamy, A.S., [1]Sridhara, S. [2]Dinesh Kumar, M., [2]Vageesh, T.S & [2]Nataraju, S.P.
[1]Agricultural College, Shimoga
[2]Zonal Agricultural Research Station, Navile, Shimoga

ABSTRACT
A field experiment was carried out during *kharif* seasons of 2005 and 2006 to study the effect of heat and thermal unit use of maize cultivars in red sandy loam soil at Zonal Agricultural Research Station, Shimoga (Karnataka, India). The experiment consisted of three dates of sowing *viz*., first fortnight of June, second fortnight of June and first fortnight of July with six cultivars *viz*., two double cross hybrids (All-rounder and 30 R-77), two single cross hybrids (NAH-2049 and 30 V-92) and two composites (NAC-6004 and NAC-6002) was laid out in split-plot design replicated thrice. Results indicated a high degree of linear relationship between GDD and dry matter accumulation of maize with all the genotype groups across dates of sowing. Higher heat use efficiency was recorded with the crop sown in first fortnight of June and decreased with each delay in sowing. Grain yield of maize was found inversely related to the helio-thermal units. Thus, early sowings escape adverse situation during its life cycle in maize.

KEY WORDS: GDD, Heat use efficiency, helio-thermal units, maize

INTRODUCTION
Three important climatic parameters *viz.*, temperature, rainfall and light are most important for optimum crop growth and development there by exploits the potentiality of a crop. Among these, temperature plays a vital role in almost all biological processes of crop plants. It is one of the most important climatic factors affecting the growth, development and yield of crops. Influence of different time of sowing as well as temperature on growth and yield of wheat has been studied under field conditions through the accumulated heat units by Rajput *et al*. (1987). However, the growing degree day (GDD) concept may mislead as the minimum and maximum temperatures are being considered for calculating GDD which are the events occurring at a particular point of time in a day. As the planting is delayed beyond optimum date/ideal time, the maize yields go down. Early sown maize plants are able to face and tolerate the adverse weather and environment. In rainfed situation, the sowing of maize is generally done with the onset of monsoon rains. Most suitable temperature for germination is 21 ^{0}C and for growth 32 ^{0}C (Jain, 1973). Extremely high temperature, moisture stress and low humidity during flowering damage the flowering and the foliage, desiccation of pollen and interfere with the pollination resulting in poor grain formation. Thus, rate of development of maize from planting to anthesis is a function of temperature rather than photosynthesis (Brower, *et al*., 1970). So a field experiment was conducted to study the effect of Growing Degree Days (GDD) on dry matter production, heat use efficiency and yield response of maize genotypes to Helio-Thermal Units (HTU).

Genotypes	Year					
	2005			2006		
	D_1	D_2	D_3	D_1	D_2	D_3
	Date of Sowing					
	11.06.05	26.06.05	10.07.05	14.06.06	29.06.06	12.07.06
	Date of harvesting					
All-Rounder, NAH-2049, NAC 6004 (Long duration)	09-10-05	29-10-05	15-11-05	22-10-06	06-11-06	16-11-06
30 R V 92 & 30 R-77 (Medium duration)	13-10-05	21-10-05	09-11-05	12-10-06	02-11-06	11-11-06
NAC 6002 (Short duration)	19-09-05	24-09-05	18-10-05	22-09-06	06-10-06	19-10-06

$D_1 = 1^{st}$ fortnight of June $D_2 = 2^{nd}$ fortnight of June, $D_3 = 1^{st}$ fortnight of July

MATERIAL AND METHODS
A field experiment was carried out during *kharif* seasons of 2005 and 2006 on red sandy loam soils (*Alfisols)* of Zonal Agricultural Research Station, Shimoga, Karnataka state (India). Eighteen treatment combinations, three dates of sowing (June first fortnight, June second fortnight of July first fortnight) and six cultivars of maize (two double cross hybrids: All-rounder and 30 R-77, two single cross

hybrids : 30 V-92 and NAH-2049 and two composites : NAC-6004 and NAC-6002) were tried in a split-plot design with three replications. Dates of sowing and harvesting of different genotype groups is given above:

A common cultivation practices have followed for all genotypes as per the recommended package of practices for the Agro-climatic Zone. Geographically, the experimental site is situated at 14°.0' to 14°.1' N latitude and 75°.40' to 75°.42' E longitude at an altitude of 650 meters above mean sea level. The normal rainfall of experimental site was 800 mm (54 rainy days) with maximum temperature being recorded in the month of April (35.8°C) and minimum temperature (14.8°C) during January (Table-1 and Fig.1). Sowing of maize was done in rows 60 cm apart with intra row spacing of 30 cm. A common dose of 50 kg N, 50 Kg P_2O_5 and 25 Kg of K_2O was applied in the form of urea, DAP and muriate of potash as basal at sowing. Another 50 kg N was given as top dress in the form of urea at 30 DAS. Recommended dose of farm yard manure @ 7.5 tones/ha was applied 15 days earlier to sowing to all treatment plots.

Growing degree days at different phenological stages were calculated by summation of daily mean temperature above base temperature for a corresponding period from sowing, as suggested by Monteith (1984).

$$GDD = \sum \frac{(T_{max} + T_{min})}{2} - T_{base}$$

Where, T_{max}, T_{min} and are maximum, minimum temperature.

T_{base} is base temperature was taken as 10^0 C.

Heat use efficiency was calculated as:

$$HUE = \frac{\text{Total dry matter (g m}^2)}{GDD}$$

The index helio thermal unit (HTU) serves to be effective in taking into account and expressing the effect of varying ambient temperature on the duration between the phenological events for comparing the crop response to the ambient temperature between phenological stages. Helio thermal unit was calculated using the formula given by Rajput (1980).

HTU = Σ GDD x Cumulative Sun Shine Hours (from sowing to physiological maturity)

Helio-thermal use efficiency was calculated by using the formula:

$$HTUE\ (kg/HTU) = \frac{\text{Yield (kg)}}{HTU}$$

To relate the yield to helio-thermal units, the selected maize cultivars were grouped into three *viz.*, long duration group (All-rounder, NAH-2049 and NAC-6004) 130-140 days, medium duration group i.e., 120-130 days (30 R-77 and 30 V-92) and short duration composite NAC-6002 (90-100 days).

TABLE 1. Monthly meteorological data for the year 2005 and 2006 against normal at ZARS, Shimoga

Month	Total rainfall (mm)			Mean Max. Temperature (°C)			Mean Min. Temperature (°C)			Mean Relative humidity (%)			Actual cumulative sunshine hrs.	
	N	2005	2006	N	2005	2006	N	2005	2006	N	2005	2006	2005	2006
Jan.	0.3	0	0	31.0	28.0	31.1	14.0	15.8	14.3	75	63.0	81.4	284.2	272.0
Feb.	2.2	0	0	32.5	32.4	32.9	14.6	17.9	14.5	75	68.0	82.8	280.8	274.0
Mar.	9.5	0	9.5	35.1	36.8	34.9	18.3	18.4	18.0	78	78.4	85.8	295.1	273.6
Apr.	43.8	251.6	24.2	35.9	37.0	36.9	18.6	20.9	19.0	79	83.4	90.0	242.4	265.8
May	56.6	40.4	60.0	34.8	35.5	34.9	20.6	20.5	21.2	82	82.5	91.6	248.6	230.1
June	123.4	255.8	139.4	30.2	30.7	29.9	19.2	20.1	19.5	85	87.3	91.2	95.8	94.0
July	151.2	351.6	201.8	28.2	28.2	27.6	19.5	19.6	20.0	87	85.0	90.9	84.7	77.4
Aug.	120.5	148.0	150.0	27.5	28.8	27.1	19.4	19.2	19.8	90	82.0	91.5	103.2	124.5
Sept.	106.4	48.4	99.6	29.6	29.5	29.2	19.5	19.3	20.1	87	87.0	90.7	128.5	124.5
Oct.	133.7	304.6	29.2	29.5	29.6	30.3	19.4	20.5	20.2	86	88.0	88.1	122.8	93.5
Nov.	55.5	8.8	75.6	30.2	27.8	29.6	17.3	17.9	17.5	83	85.0	87.6	200.1	204.5
Dec.	8.8	0	0	30.0	29.7	32.1	14.3	14.5	14.8	81	84.0	85.8	268.0	255.5
Total √	811.9	1409	789.3	31.2	31.2	31.4	17.89	18.72	18.24	82.3	81.1	88.1	2354.2	2289.4

N = Normal (Average of 29 years from 1975-2004)

RESULTS AND DISCUSSION

Growing degree day

The maximum heat units of 1768.8 degree days from sowing to physiological maturity were recorded by sowing in first fortnight of July which is almost equal to June first fortnight sowing (1766.8 degree days) (Table-2). However, at seedling stage (up to 30 DAS) highest heat units were recorded in June first fortnight sowing.

Heat use efficiency (HUE)

Total dry matter per plant was found to be significant at all crop growth stages. Significantly higher dry matter per plant was noticed recorded with June first fortnight sown crop at all the stages. The progressive decrease in total dry matter per plant was observed with each delay in sowing in all the genotypes (Table 3). There was a overall reduction of 16.5 and 39 per cent reduction in total dry matter per plant, respectively, with June second fortnight and July first fortnight sowings when compared to June first fortnight sowing. Reason could be exploitation of climatic and soil moisture at important growth stages by the crop sown early and higher leaf area index which might have provided more photosynthetic area (LAI) and contributed more dry matter. The interaction effect of date of sowing and genotype significantly influenced the leaf area index (LAI). There was a progressive decline in LAI for every delay in sowing in all the genotypes at different crop growth stages (Table 4). Also attributed to higher growing degree days available for and heat use efficiency by early sown crop. High degree of linear relationship exists between total dry matter production and growing degree days for early sown crop (Fig. 2). The slope of the linear regression indicated the HUE. Means higher the slope of the curve higher the efficiency *i.e.* higher dry matter production per unit of heat was higher at all growth stages with June first fortnight than later sown crop (Table 2).

TABLE 2: Heat use efficiency (g/GDD) as influenced by date of sowing in maize

Crop Growth Stage	1st fortnight of June			2nd fortnight of June			1st fortnight of July		
	Growing degree days	Total dry matter (g/plant)	Heat use efficiency	Growing decree days	Total dry matter (g/plant)	Heat use efficiency	Growing decree days	Total dry matter (g/plant)	Heat use efficiency
30 DAS (knee ht. stage)	433.1	20.2	0.047	421.1	16.1	0.038	427.2	9.99	0.023
60 DAS (Silking stage)	861.4	138.1	0.160	860	117.8	0.137	879.2	95.5	0.109
90 DAS (grain development stage)	1313.2	215.3	0.164	1306.6	168.2	0.129	1331.8	129.2	0.097
At physiological manurity	1766.8	251.8	0.143	1761.1	194.6	0.110	1768.8	146.3	0.083

TABLE 3: Extent of reduction in total dry matter accumulation of maize due to delay in sowing dates

Genotypes	Reduction in total dry matter accumulation /plant (%)	
	2nd fortnight of June	Dry matter accumulation first fortnight of June
AR	16	41
30-R-77	12	35
30-V92	17	42
NAH-2049	14	41
NAC-6002	15	27
NAC-6004	25	47
Overall	16.5	39

TABLE 5. Grain yield of maize as influenced by date of sowing and genotypes

Cultivar group	1st fortnight of June	2nd fortnight of June	1st fortnight of July	Mean
		Long duration		
NAH-2049	8253	6035	4289	6195
All-rounder	7286	5585	4017	5630
NAC-6004	6399	4900	3764	5021
Mean	7313	5507	4023	5615
		Relative lesser duration		
30 R-77	6295	5794	3518	5203
30 V-92	6764	4514	3499	4926
Mean	6530	5154	3508	5064
		Short duration		
NAC-6002	5000	4562	4528	4697
Grand mean	6668	5232	3936	5278

TABLE 6. Extent of reduction in yield of maize due to delay in sowing dates

Genotypes	Reduction in grain yield (%)	
AR	Yield 2nd fortnight of June	First fortnight of July
30-R-77	23	45
30-V92	08	44
NAH-2049	33	48
NAC	27	48
6002	8.8	9.4
NAC-6004	23	42
Overall	22	41

TABLE 7. Yield response of Maize to helio thermal units and helio-thermal use efficiency across dates of sowing and genotype groups

Cultivar group	1^{st} fortnight of June	2^{nd} fortnight of June	1^{st} fortnight of July
Long duration			
Yield (kg/ha)	7313	5507	4023
HTU	7142	7231	8371
HTUE (kg/HTUE)	1.02	0.76	0.48
Relative lesser duration			
Yield (kg/ha)	6530	5154	3508
HTU	6449	6918	7650
HTUE (kg/HTUE)	1.01	0.75	0.46
Short duration			
Yield (kg/ha)	5000	4562	4528
HTU	4588	4724	5910
HTUE (kg/HTUE)	1.09	0.96	0.77

Higher heat use efficiency of 0.047, 0.16, 0.164 and 0.143 g/GDD was recorded with the crop sown in first fortnight of June at 30, 60, 90 DAS and at physiological maturity, respectively but decreased correspondingly with each delay in sowing (Table 4)

Yield

The pooled data on grain yield revealed that both main and sub plots varied significantly with each other with the highest grain yield of 6668 kg per ha being obtained by sowing in first fortnight of June and second and third date of sowing were next in the order (Table 5). The yield reduction of maize due to delayed sowing was to an extent of 22 and 41 per cent in crop sowing during second fortnight of June and first fortnight of July, respectively, compared to first date of sowing (Table 6). Extent of yield reduction was more with long duration varieties.

Helio-thermal units

Helio thermal units available for the crop from it's sowing to physiological maturity were higher for the crop sown during 1^{st} fortnight of July. This is true for all genotype groups (Table 6). This is because of the growth of the later sown crops extended up to November second week where in monsoon ceases and grain filling stages of delayed sown crops subjected to bright sunny days coupled with long dry spells. However, the short duration composite was found relatively stable with respect to yield as the reduction in yield due to delayed sowing was only to an extent of 9.4 per cent as against over 40 per cent in remaining genotypes. Even the availability of helio thermal units for short duration variety did not vary much across dates of sowing due to its low maturity period.

Helio-thermal use efficiency (HTUE)

Helio-thermal use efficiency recorded by the crop sown during first fortnight of June was higher than in later dates (Table 7). This is true with respect to all genotype groups. However, short duration genotype NAC-6002 has exhibited high HTUE than long duration groups. This could be attributed to exposure of long duration genotypes to bright sunny days coupled with long dry spells at their later growth period (grain filling stage). While, inverse relationship between HTU and grain yield of maize under delayed sowing was noticed with all the genotype groups (Table 7). Negative relationship of HTU with the yield also reported by Rajaput *et al.*(1987) and Thavaprakash *et al.* (2007) in baby corn.

In all, early sown maize has taken the advantage of optimum temperature and sunlight during the early stages of plant development and there by avoided adverse situations during its life cycle. Results obtained clearly indicate the negative correlation between helio-thermal units (HTU) and yields of maize. Surprisingly, HTU under delayed sowing was higher. This is because delayed sown crops exposed more to the cloud free situation coupled with dry weather during later part of their growth period where monsoon season ceases. Thus, the role of HTU should be understood in various crops for all Agro-climatic Zones of the country.

REFERENCES

Brouwer, R., Jenneskens, P.J. & Borggreve (1970) *Growth responses of shoots and roots to interruptions of irrigation supply*. Jaarb. IBS:29-36.

Jain (1973) New Agronomy boosts in maize yield *Indian Fmg.* **23** (1): 17-20.

Monteith, J.C. (1984) Consistency and Convenience in the choice of units for agricultural sciences, *Expl. agric*., **20**: 115-117.

Rajput, R. P. (1980) Response of soybean crop to climatic and soil environments. *Ph.D. Thesis*, IARI, New Delhi, India.

Rajput, R. P., Deshmukh, M.R. & Paradkar, V.K. (1987) Accumulated heat units and phenology relationship in wheat as influenced by planting dates under late sown conditions. *J. Agron. Crop Sci*., **159**:345-348

Thavaprakash N. & Jagannathan, R. Velayudham & Gurusamy, L. (2007) Seasonal influence on phenology and accumulated heat units in relation to yield of baby corn. *International Journal of Agricultural Research,* **2**(9):826-831.

TABLE 4. Interaction effect on (DxG) leaf area index (LAI) of maize

DOS/ Genotype	30 DAS							90 DAS							At harvest						
	V_1	V_2	V_3	V_4	V_5	V_6	Mean	V_1	V_2	V_3	V_4	V_5	V_6	Mean	V_1	V_2	V_3	V_4	V_5	V_6	Mean
D_1	2.07	1.53	1.72	2.31	1.65	1.64	1.82	4.72	4.41	4.28	5.03	3.65	4.46	4.42	1.36	1.19	1.24	1.61	0.67	1.02	1.18
D_2	1.27	1.18	1.15	1.43	1.21	1.21	1.24	4.19	3.83	3.94	5.06	3.47	3.78	4.05	1.04	1.07	1.11	1.23	0.64	0.81	0.98
D_3	1.07	.97	1.00	1.08	1.15	0.92	1.03	2.74	2.82	2.21	2.86	2.64	2.45	2.62	0.81	0.66	0.77	0.69	0.50	0.58	0.70
Mean	1.47	1.27	1.29	1.61	1.34	1.26	1.36	3.88	3.68	4.48	4.31	3.26	3.56	3.70	1.07	0.97	1.04	1.18	0.60	0.80	0.94
S. Em ± 0.10 CD (P=0.05) 0.28 Interaction at fixed level of main plot CD (P=0.05) 0.58								S. Em ± 0.15 CD (P=0.05) 0.42 Interaction at fixed level of main plot CD (P=0.05) 0.68							S. Em ± 0.067 CD 0. 05 0.186 Interaction at fixed level of main plot CD (P=0.05) 0.26						

D_1 = 1st fortnight of June V_1 = All-rounder V_4 = NAH-2049
D_2 = 2nd fortnight of June V_2 = 30 R-77 V_5 = NAC-6002
D_3 = 1st Fortnight of July V_3 = 30V-92 V_6 = NAC-6004