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Thermal time requirement and energy use efficiency for single cross hybrid maize in south Telangana agro climatic zone of Andhra Pradesh

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ABSTRACT

Field experiment was conducted during *kharif* seasons of 2009 and 2010 at Agricultural Research Institute, A.N.G.R. Agricultural University, Rajendranagar, Hyderabad to study heat and radiation use efficiency of maize crop. The experiment was in four dates of sowing (7 July, 21 July, 6 August and 22 August in 2009 and 18 June, 02 July, 17 July and 02 August in 2010) with recommended dose of fertilizer (200kg ha^{-1}). Results revealed that the mean AGDD, AHTU and APTU were 1740±29, 9025±1477 and 21155±812, respectively from emergence to physiological maturity. Crop took 110±4 calender days from emergence to physiological maturity. Progressive delay in sowing caused a decrease in AGDD *i.e.*, 1754 to 1717 in 2009 and 1788 to 1746 in 2010. Higher heat use efficiency of 8.44 and 8.42kg °C day^{-1} for biomass and 4.93 and 4.68 kg °C day^{-1} for grain and radiation use efficiency of 7.99 and 8.19 kg MJ^{-1} for biomass and for grain 4.55 and 4.57 kg MJ^{-1}were obtained in crop sown on 21 July in 2009 and 18 June in 2010 respectively.

Keywords: Hybrid maize, GDD, Phenology, HUE, RUE

The critical agrometeorological variables associated with agricultural production are precipitation, air temperature and solar radiation (Hoogenboom, 2000). By relating and comparing the agro-climatological requirements of the crop with the existing agro-climatic conditions in an area, one can find the extent to which the requirements are satisfied during the different phases of the crop growth and development (Todorov, 1981). The growth rate and development of crops from planting to maturity is dependent mainly upon temperature. The effect of temperature on crop is accounted through the concept of heat unit, which is based on the fact that crops need certain amount of temperature requirement for the completion of each stage of its ontogeny. The seasonal variation of crops and varieties can be effectively answered through its heat unit requirements. According to Schulze *et al*. (1997), 1500 to 1700 growing degree days (GDD) are required for growing maize for grain, but can vary according to cultivar. As per Dahiya and Narwal (1989), the GDD requirement of maize cultivars showed variation with sowing dates depending upon temperature during each growth phase and also the cultivar.

In maize variation in sowing date modifies the radiative and thermal conditions during its growth. In the maize crop grown under well-supplied water and nutrient conditions, the temperature and solar radiation are reported to have greater effect on growth and development of crop. Shift in sowing dates directly influence both thermo and photoperiod, and consequently a great bearing on the phasic development and partitioning of drymatter. Quantification of these effects may help in the choice of sowing time and match phenology of crop in specific environment to achieve higher heat and radiation use efficiency.

Heat and radiation use efficiencies in terms of drymatter or yield are important aspects, which have great practical application. The total heat and radiant energy available to any crop is never completely converted to drymatter under even the most favourable agroclimatic conditions. Efficiency of conversion of heat and radiant energy in to drymatter and grain yield depends upon genetic factors, sowing time and crop type (Rao *et al.*, 1999). Maximum heat use efficiency and of 49.76 g°C^{-1} day^{-1} was obtained when the corn crop was sown on 15 June and the crop was fertilized with 120 kg N ha^{-1} during *Kharif* season on alluvium soils during *Kharif* season in the Tarai region, (Kushwaha *et al.,* 2010).

By keeping above facts a field investigation was carried out to generate information on phenophase wise thermal requirement and, heat and radiation use efficiency in *Kharif* maize of South Telangana agro climatic zone of Andhra Pradesh.

Table 1 : Agrometeorological indices during different growth stages of maize under different sowing environments

Sowing dates	Emergence to six leaf stage (P_1)				Six leaf to tasseling (P_2)			
	Days taken	GDD	HTU	PTU	Days taken	GDD	HTU	PTU
7-Jul-09	18	319	1450	4130	48	840	3972	10728
21-Jul-09	17	315	1822	4031	48	817	4055	10295
6-Aug-09	18	293	1005	3698	48	797	4038	9863
22-Aug-09	19	307	1676	3787	54	887	5121	10696
18-Jun-10	18	309	1196	4022	52	851	3157	10988
2-Jul-10	18	289	995	3743	50	811	3195	10376
17-Jul-10	19	292	798	3741	52	825	2847	10410
2-Aug-10	18	306	1735	3872	50	810	3493	10048
Mean	18	304	1335	3878	50	830	3735	10426
SD	1	11	389	163	2	29	722	370
CV%	4	4	29	4	4	3	19	4

Sowing dates	Emergence to six leaf stage (P_1)				Six leaf to tasseling (P_2)			
	Days taken	GDD	HTU	PTU	Days taken	GDD	HTU	PTU
7-Jul-09	52	903	4368	11510	104	1754	9488	21712
21-Jul-09	52	888	4504	11167	107	1739	10031	21180
6-Aug-09	52	861	4185	10616	108	1688	9953	20134
22-Aug-09	58	943	5661	11348	118	1717	11469	20038
18-Jun-10	56	919	3438	11846	110	1788	7473	22472
2-Jul-10	54	875	3249	11179	109	1742	7397	21585
17-Jul-10	56	892	3181	11235	112	1744	7576	21258
2-Aug-10	54	877	3971	10851	113	1746	8811	20864
Mean	54	895	4070	11219	110	1740	9025	21155
SD	2	26	819	378	4	29	1477	812
CV%	4	3	20	3	4	2	16	4

MATERIALS AND METHODS

A field experiment was conducted during *Kharif* seasons of 2009 and 2010 at Agricultural Research Institute farm, ANGRAU, Rajendranagar, Hyderabad having 17^0 19’ N latitude, 78^0 23’ E longitude and 542.3 m above mean sea level. The soil of the experimental site was sandy loam in texture, neutral in reaction, low in available nitrogen, phosphorus and high in available potassium. The experiment was sown in four dates of sowing -7 July, 21 July, 06 August and 22 August in 2009 and 18 June, 02 July, 17 July and 02 August in 2010. The cultivar used for the study was Dekalb Super 900M. Crop was fertilized with uniform dose of 200 kg N, 60 kg P_2O_5, 40 K_2O and 50 kg $ZnSO_4$ kg ha^{-1}. One third of the total N and full P, K and $ZnSO_4$ were applied at the time of sowing as basal. Remaining N was applied in two equal splits 30 days after sowing (DAS) and at tasseling stage. Other cultural operations and plant protection measures were followed as per the recommendations contained in package of practices.

Maize crop growth period was divided into four phenophases *viz*. P_1 = Emergence to six leaf stage; P_2 = Emergence to tasseling stage; P_3 = Emergence to silking stage; P_4 = Emergence to physiological maturity (Hanway, 1962).

Table 2: Energy use efficiency in maize at physiological maturity under different sowing environments

Sowing dates	Biomass (kg ha^{-1})	Grain yield (kg ha^{-1})	Heat use efficiency (kg °C day^{-1})		Radiation use efficiency (kg MJ^{-1})	
			Biomass	Grain	Biomass	Grain
2009						
7-Jul	14810	8256	8.07	4.5	7.99	4.45
21-Jul	15183	8574	8.31	4.7	7.87	4.45
6-Aug	13657	7648	7.67	4.3	7.2	4.03
22-Aug	12530	6636	6.98	3.69	6.09	3.22
2010						
18-Jun	14987	8367	7.99	4.46	8.19	4.57
2-Jul	14660	7897	7.98	4.3	8.08	4.35
17-Jul	13999	7633	7.67	4.18	7.74	4.22
2-Aug	12203	6687	6.64	3.64	6.59	3.61

Growing degree days (GDD), heliothermal units (HTU), photothermal units (PTU), heat use efficiency (HUE) and radiation use efficiency (RUE) were computed. The base temperature of 10°C was used for computation of GDD on daily basis (Leong and Ong, 1983). The agrometeorological indices computed at optimum dose of nitrogen (200 kg N ha^{-1}) were presented in this paper.

The agrometeorological indices were computed during different growth phases of maize by adopting the procedure laid out by Rajput (1980).

Growing degree days (GDD) = {(Tmax + Tmin)/2 }-T_b

Accumulated HTU (°C day hr) = GDD × Duration of sunshine hour.

Accumulated PTU (°C day hr) = GDD X Day length (hrs.)

Heat use efficiency (kg ^{0}C day^{-1}) = Biomass or yield (kg ha^{-1}) / GDD

Radiation use efficiency (kg MJ^{-1}) = Biomass (kg ha^{-1}) or yield (kg ha^{-1}) / Radiation

RESULTS AND DISCUSSION

Agrometeorological indices

The agrometeorological indices during different phenophases of maize are presented in Table 1. The accumulated growing degree days (AGDD) ranged from 289 to 319 across the sowing dates with mean of 304±11 from emergence to six leaf stage. Whereas accumulated heliothermal units (AHTU) and accumulated photothermal units (APTU) ranged from 798 to 1822 and 3698 to 4130, respectively from emergence to six leaf stage with a mean of 1335±389 and 3878±163. The coefficient of variation was very low with AGDD (4%) and APTU (4%) whereas the CV was more with AHTU (29%). The crop attained six leaf stage from emergence in 18 calender days ±1 with a CV of 4%. From emergence to tasseling crop took 50±2 days with accumulated growing degree days of 830±29. The AHTU and APTU ranged from 3735±722 and 10426±370, respectively from emergence to tasseling stage. The lower variation with AGDD and APTU and higher variation with AHTU were observed from six leaf to tasseling stage. Crop took 54 calender days from emergence to silking stage. The AGDD, AHTU and APTU were 895±26, 4070±819 and 11219±378, respectively from emergence to silking stage. The coefficient of variation was high (20%) with AHTU compared to AGDD (4%) and APTU (3%). Similarly, the lower variation in AGDD (2%) and APTU (2%) compared to AHTU (16%) were observed from emergence to physiological maturity. The mean AGDD, AHTU and APTU were 1740±29, 9025±1477 and 21155±812, respectively from emergence to physiological maturity. Crop took 110±4 calender days from emergence to physiological maturity.

The shifting of sowing dates corresponds to fluctuations in temperature causing either lengthening or shortening of the growth periods. Further, it was also found that a progressive delay in sowing caused a decrease in AGDD *i.e.,* 1754 to 1717 in 2009 and 1788 to 1746 in 2010. There was no wide variation in duration of vegetative phase (from emergence to six leaf stage) across all the sowing dates during both the years. But, growing degree days varied between 293 to 319 in 2009 and 292 to 309 in 2010 during vegetative stage. Wide variations in duration and growing degree days were observed between sowing dates from emergence to physiological maturity in 2009. During both the years of study, delay in sowing showed a gradual increase in AHTU.

Heat and radiation use efficiency

Crop sown on 21 July in 2009 and 18 June in 2010 showed higher heat use efficiency of 8.44 and 8.32 kg ^{o}C day^{-1} and radiation use efficiency of 7.99 and 8.19 kg MJ^{-1} on 7 July and 18 June in 2010 for biomass were obtained respectively compared to delayed sowing (Table 2). In a similar way sown crop of 21 July and 18 June obtained higher heat use efficiency of 4.93 and 4.68 kg ^{o}C day^{-1} and radiation use efficiency of 4.45 and 4.57 kg MJ^{-1} for grain were obtained during 2009 and 2010, respectively than delayed sowings (Table 2). The heat and radiation use efficiency were decreased with delay in sowing during both the years. Higher HUE (4.93 to 4.45 kg ^{o}C day^{-1}) in early planting could be attributed to the highest grain yield. As the temperature was optimum throughout the growing period crop utilized heat more efficiently and increased biological activity that confirms higher yield. Similar relationship was also expressed by Rajput *et al.* (1987), Paul and Sarkar (2000) in different dates of sowing. Thavaprakash *et al.* (2007) also confirms the same results in Haley corn in Tamil Nadu.

CONCLUSION

It can be concluded that across the sowing dates, mean accumulated growing degree days of 895$\pm$26 and 1740$\pm$29 are required from emergence to silking and from emergence to physiological maturity in hybrid maize. The higher heat and radiation use efficiency can be obtained by sowing the hybrid maize from 18 June to 21 July in South Telangana agro climatic zone of Andhra Pradesh.

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