Bangladesh J. Bot. **50**(1): 171-177, 2021 (March) **- Short communication**

RADIATION USE EFFICIENCY, BIOMASS PRODUCTION AND GRAIN YIELD OF HEAT TOLERANT SUMMER MAIZE (*ZEA MAYS* L.) HYBRIDS IN SUBTROPICAL ENVIRONMENT

K Subrahmanyam, MR Umesh*, N Ananda, Prakash H Kuchanur, MY Ajayakumar and BM Chittapur

Department of Agronomy, College of Agriculture, University of Agricultural Sciences, Raichur- 584104, Karnataka, India

Keywords: Irrigation regimes, HUE, Leaf area index, Radiation interception, RUE

Abstract

Radiation use efficiency (RUE), heat use efficiency (HUE), biomass production and grain yield of contrasting heat tolerant summer maize hybrids and irrigation regimes during hot summer in subtropics of India were assessed. Experiment was conducted with RCRMH-1, RCRMH-2 and Arjun hybrids under well-watered based on 1.0 IW/CPE (I_1), mild stress at 0.75 IW/CPE (I_2) and severe stress at 0.5 IW/CPE (I_3). Results indicated that RCRMH-2 outyielded 13.3 and 26.4% over RCRMH1 and Arjun, respectively. In well-watered (I_1) plots all the hybrids performed better than other irrigation regimes I_2 and I_3. Among hybrids RCRMH-2 showed lower grain yield reduction under water stress condition. While RUE of RCRMH-2 under I_1, I_2 and I_3 were 1.93, 1.72 and 1.53 g/MJ, respectively. It also showed higher biomass production, LAI and HUE over rest of the hybrids. Radiation, water and heat use efficiencies, yield attributes and yield were higher in January sown plants.

Drought is an important factor limiting maize production throughout the world (Gholipoor *et al*. 2013). As water resource for crop production becomes a limiting factor, adaptation of so called drought tolerant (DT) hybrids could be a viable approach for maintaining sustainable crop production under drought stress. Several studies reported that DT maize hybrids showed a yield advantage over conventional hybrids under drought stress (Sammons *et al*. 2014, Zhao *et al*. 2015). The severity would be aggravated if grown under high temperature. Crop biomass production is dependent on the ability of the crop canopy to intercept radiation and converts intercepted it into biomass radiation-use efficiency (RUE). It is widely recognized that maize sensitive to water and temperature stresses throughout the growing season (Andrade 1995, Banziger *et al*. 2000). Reduction of whole crop RUE is the most important cause of grain yield loss in maize under drought stress. In subtropical regions hot summer affects plant growth, pollen viability and seed development. Heat tolerant species can withstand heat stress and minimum effect on plant growth. CIMMYT-Asia, Hyderabad under 'Heat Stress Tolerant Maize for South Asia through public private partnership' (HTMA) project funded by USAID has developed heat tolerant maize hybrids. However, little information is available on their suitability to water stress under different planting windows and the morpho-physiological determinations for yield of HYMH in subtropics were not evaluated. Data have shown, evaluation of species tolerant to heat stress was based on genetic and morphological features but not on management strategies to overcome heat stress. Hence it was hypothesized that heat tolerant maize hybrids (HTMH) could perform better under water stress and delayed summer planting due to their morphological adjustments. Keeping these facts in mind an experiment was designed with an objective to estimate yield potential of hybrids and resource use efficiencies under water stress and well-watered condition.

*Author for correspondence: <mrumeshagri@gmail.com>.

Field experiment was conducted in 2015 at Raichur ($16^0$12' N, 77^{o}20' E, 389 m), University of Agriculture Sciences, Raichur Karnataka, India. The soil of the experimental site was had pH 8.1, organic carbon 0.45%. Before planting available soil nitrogen, phosphorus and potassium were 243, 34 and 292 kg/ha, respectively. During the rainy season 2014, cluster bean was sown under normal production practice and kept fallow during winter 2014 - 2015. Meteorological data during the cropping period for the 2015 as well as long-term mean data (1930 - 2014) were collected from observatory located at 100 m away from experimental site.

Treatments were arranged in split-split plot design with date of planting being the main plot, water regimes as sub plot and the maize hybrids in the sub-sub plot with three replications. The water regimes consisted of 1.0, 0.75 and 0.5 IW/CPE. Irrigation scheduled based on pre-fixed IW/CPE of 5 cm irrigation depth. The hybrids (RCRMH-1 and RCRMH-2) were heat stress resilient maize hybrids that have developed in collaboration with CIMMYT-Asia, Hyderabad under 'Heat Stress Tolerant Maize for South Asia through public private partnership' (HTMA) project funded by USAID. Arjun is a medium duration hybrid released by UAS, Dharwad recommended for the region. The maize was sown on 20 January, 2015 and 20 February, 2015. At each spot, two seeds were hand dibbled in 60 cm row spacing and 20 cm between plants within rows. The blanket fertilizer rate 150 : 75 : 37.5 kg N, P_2O_5 and K_2O/ha were applied in the form of urea, diammonium phosphate, muriate of potash, respectively.

Observations on growth parameters were recorded at regular intervals up to harvest. Plants from one-meter row length were used to record the dry matter production at various stages of growth. These samples were oven dried at 72^{o}C until constant dry weight. Leaf area index, incident and transmitted photosynthetically active radiation (PAR) was measured at every 10 days interval using SunScan canopy analyzer (Delta-T Device, Cambridge. UK). In each plot two spots in the two central rows were chosen and marked for PAR measurements. At each spot incident and transmitted light was recorded simultaneously. All the measurements were recorded on clear sunny days between 11:00 - 14:00 IST. The fraction of intercepted PAR was then calculated as per Manoj *et al*. (2019) difference between the incident and transmitted ratio to incident radiation. Radiation use efficiency (RUE) (g/MJ) was calculated following Tsubo *et al.* (2001).

$$\text{RUE} = \frac{Y_{biomass}}{I_0 \times F}$$

Where, $Y_{biomass}$ was above ground biomass (g/m^2), I_O was the flux density of the incident PAR above the crop canopy (MJ/m^2) and F is fraction of PAR intercepted. Growing degree days (GDD) was calculated by $(T_{max} + T_{min})/2\text{-}T_b)$ where, T_{max} = Maximum temperature, T_{min} = Minimum temperature, T_b = Base temperature (10^{o}C). In the end of the growing season at physiological maturity, cobs from each of the net plot were harvested to determine grain yield (kg/ha).

HUE (kg/ ^{o}C) = Grain yield (kg/ha) × growing degree days (GDD)

WUE (kg/ha-cm) was worked out by the ratio of maize grain yield per total consumptive use of water (mm) of water used was calculated.

The evaporation losses were obtained by using USWB class-A pan evaporimeter located at meteorological observatory of the research station. During the investigation no runoff events occurred, and deep percolation was considered as nil. At physiological maturity plants from 15.36 m^2 were harvested from the centre rows of each plot to determine grain and stover yield and estimated grain moisture percentage. The experimental data were subjected to statistical analysis adopting Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984). The level of significance used in "F" test was given at 5 per cent. Critical difference (CD) values are given in the tables at 5% level of significance, wherever the F test was significant at 5% level.

Results and Discussion

During the crop growth period 13.32% lower rainfall was received as against the normal rainfall (286.7 mm) of the region. The mean monthly minimum temperature was recorded during January (15.4°C) and maximum in May (36.3°C). Mean monthly evaporation increased from beginning of cropping season (January) up to harvest of crop (June). The lowest mean monthly pan evaporation was recorded in January (4.65 mm) and the highest in May (8.61 mm).

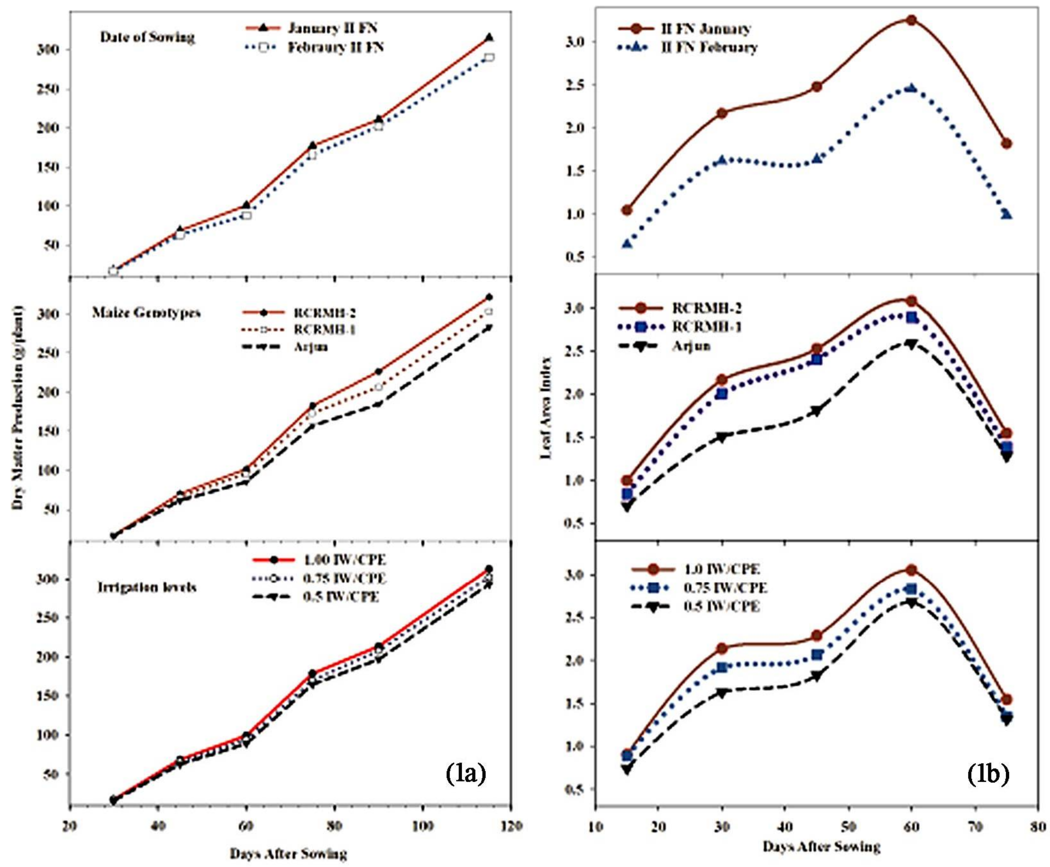

Fig. 1. Dry matter production (1a) and leaf area index (1b) of summer maize hybrids in different growing period as influenced by date of planting and irrigation regimes.

Above ground biomass production was significantly ($p = 0.05$) influenced by date of planting, hybrids and irrigation regimes (Fig. 1). At maturity, January sown crop has produced greater dry matter accumulation (314.8 g/plant) over February (290.5 g/plant). Whereas it was greater in irrigation water scheduled at 1.0 IW/CPE (321.5 g/plant) over severe and mild stress. At each water regime, hybrids biomass did not differ significantly. Hybrid RCRMH-2 has accumulated higher dry matter over RCRMH-1 and Arjun hybrids. Further, it was higher at irrigation 1.0 IW/CPE during the critical periods. Crop life cycle thus eventually resulted in greater grain yield due to the availability of soil moisture at root zone with frequent irrigation. In general, HT maize hybrids show greater partitioning of biomass to the grain (Banziger *et al.* 2000). In this study under well-watered condition, it was found that all the hybrids are equally potential whereas

HTMH were over yielded except Arjun under lower irrigation regimes. The maximum LAI values were achieved at grand growth stage coincided with silking (Fig. 1). It was significantly (p = 0.05) influenced by planting date, hybrids and irrigation regimes. At 60 DAS, maximum LAI in January sown crop (3.25) over February crop water regime had a significant effect, on maximum LAI it was higher in 1.0 IW/CPE (3.08). Maize hybrid RCRMH-2 showed improved LAI over other hybrids. Significant increase in leaf area could be due to increased number of green leaves per plant. This was mainly due to less inter plant competition for space, light, nutrients and moisture in turn led to better utilization of available resources (Pandey *et al.* 2000).

Yield attributes of maize hybrids *viz.*, grains per cob, 100-seed weight, lower shrivelled grains per cob and grain yield per plant were significantly influenced by planting dates and irrigation levels (Table 1). Significantly 31.2% higher grain yield was recorded in January sown crop over February. Similarly, irrigation regime at 1.0 IW/CPE had 11.0 and 29.9% higher yield over 0.75 and 0.5 IW/CPE, respectively. Yield improvement in early planting was accomplished by greater yield attributes as well as accumulated GDD and congenial environment. Application of higher levels of irrigation water at 1.0 IW/CPE has also resulted in yield improvement. High temperature has adverse effect on the growth and development of plants and the yield may be reduced when

Table 1. Yield attributes, grain and stover yield of summer maize hybrids influenced by date of planting and irrigation regimes.

	Grains/ cob	100 seed weight (g)	Shrivelled grains/cob	Grain yield/ plant (g)	Grain yield (kg/ha)	Stover yield (kg/ha)
Planting time						
January 2nd Fortnight	451.1	30.6	7.80	115.7	6088	12104
February 2nd Fortnight	382.3	24.5	9.20	86.1	4188	11367
LSD (p = 0.05)	67.7	5.3	1.10	18.0	344	713
Irrigation regimes						
1.00 IW/CPE	437.8	31.5	7.33	108.9	5950	12653
0.75 IW/CPE	417.5	27.5	7.81	100.8	5296	11897
0.50 IW/CPE	394.8	23.7	10.36	93.0	4169	10656
LSD (p = 0.05)	32.3	3.9	1.41	8.0	366	592
Maize hybrids						
RCRMH-2	451.8	30.8	7.36	109.9	5922	12496
RCRMH-1	429.0	26.1	8.34	104.5	5134	11800
Arjun	369.3	25.7	9.79	88.3	4359	10910
LSD (p = 0.05)	33.2	3.5	1.65	9.6	320	358
Interaction LSD (p = 0.05)						
D × H × I	NS	NS	NS	NS	783	876

the temperature reaches beyond 35^0C during pollination and grain filling stage (Smith 1996). The higher grain and stover yield in 1.0 IW/CPE which provided frequent irrigations might have helped to maintain adequate soil moisture in the root zone throughout the crop period. It may have beneficial effect on yield attributes of all hybrids. Maize hybrid RCRMH-2 had 13.3 and 26.4% greater yield over RCRMH-1 and Arjun, respectively. However, extent of reduction varied with planting dates and irrigation levels. Effect of high temperature was observed by decreased grain yield in February sown up to an extent of 45.37% over early planting. Mohsen and Peyman (2008) showed that skipping single irrigation at any of the growth stage has significant influence on grain yield. Khan *et al.* (2003) also reported that irrigation levels varied significantly on grain weight, indicated that more frequent irrigation resulted in higher seed weight and grain yield.

Better performance of hybrids was associated with greater resource use efficiency particularly water, solar radiation indicated by greater RUE, HUE and WUE in January sown crop over February sown. Whereas, early sown hybrid has added advantage over late sown crop which was affected by high temperature (Table 2). Late maturity increases the risk of high temperature, pollen abortion, shorter silking and tasselling interval, leaf firing *etc*. Abbas *et al.* (2015) found WUE of maize was higher under limited irrigation, but sufficient irrigation for maize was more profitable than limited irrigation. The present study also indicated grain yield was higher in frequent irrigation schedule at 1.0 IW/CPE even though it failed to observe highest WUE.

Table 2. Water, radiation and heat use efficiencies of summer maize hybrids under date of planting and irrigation regimes.

	Water use efficiency (kg/ha-mm)	Grain yield based RUE (g/MJ)	Heat use efficiency (HUE) (kg/^{0}C)
Planting time			
January 2nd fortnight	10.87	1.81	3.19
February 2nd fortnight	7.38	1.65	1.86
CD (p = 0.05)	0.24	0.10	0.16
Irrigation regimes			
1.0 IW/CPE	7.14	1.87	2.93
0.75 IW/CPE	9.59	1.73	2.60
0.5 IW/CPE	10.64	1.58	2.04
CD (p = 0.05)	0.76	0.16	0.17
Maize hybrids			
RCRMH-2	9.86	1.93	2.92
RCRMH-1	9.11	1.72	2.53
Arjun	8.41	1.53	2.13
CD (p = 0.05)	0.48	0.14	0.15
Interaction CD (p = 0.05)			
D × H × I	NS	NS	0.37

Irrigation scheduled at 1.0 IW/CPE had higher WUE, HUE and RUE values over mild and severe stress. Hybrid differences in resource use efficiencies were observed at well water condition but not at mild and severe water stress. RCRMH-2 showed significantly maximum RUE, HUE and WUE compared to RCRMH-1 and Arjun hybrids. Further, RUE recorded at different intervals also showed significant differences between planting dates, irrigation levels and hybrids (Fig. 2). All the tested hybrids showed lower RUE when sown late. Whereas, Irrigation provided at 0.75 and 0.5 IW/CPE have lower RUE throughout the growing season. Similar to results of the present study, previous studies have compared the RUE values of new and old maize hybrids and found the higher RUE in new hybrids. It was mainly attributed to an improved photosynthetic capacity which resulted in greater biomass accumulation in turn grain yield (Tollenaar and Anguilera 1992, Luque *et al.* 2006, Zhao *et al.* 2015).

Results of RUE, WUE and HUE of the maize hybrids were significantly reduced by water stress (Table 2). Water stress by irrigation at 0.5 IW/CPE had 14.7, 20.7 and 27% lower WUE, RUE and HUE over irrigation at 1.0 IW/CPE, respectively. Earl and Davis (2003) reported that maize RUE was reduced under mild (13%) and severe (24%) water stress. Further, daily solar radiation was also crucial to achieve higher dry matter production (Van Roekel and Purcell 2014). Leaf area influences the interception and utilization of solar radiation of crop canopies and consequently dry matter accumulation and ultimately the grain yield (Abbas *et al*. 2005, Linsquist *et al*. 2005). RUE was positively correlated with TDM, LAI, LI at 60 DAS, HUE, grain and stover yields suggested that it was dependent on growth and yield attributes of maize.

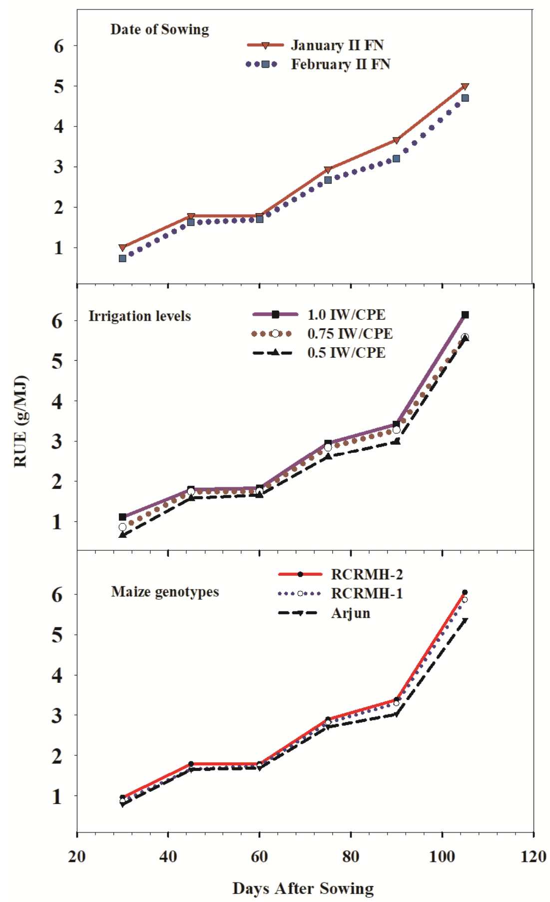

Fig. 2. Radiation use efficiency (RUE) (g/MJ) of summer maize hybrids based on dry matter as influenced by date of planting and irrigation regimes.

Under severe air temperature early planting in January has yield advantage over February planting. Yield benefits and enhanced resource use efficiencies were observed in early sown crop in January under well-watered condition. Severe water stress has profound impact on growth and yield potential of maize hybrids as indicated in heat tolerant hybrid RCRMH-2 which can improve productivity. Thus, adoption of heat tolerant maize hybrids sown in January may be an important management strategy for producers to face severe air temperature in summer. Besides, RCRMH-2 was found to be better over other hybrids.

References

Abbas G, Hussain A, Ahmad A and Wajid SA 2015. Water use efficiency of maize as affected by irrigation schedules and nitrogen rates. J. Agri. Soc. Sci. **1**(4): 339-34.

Andrade FH 1995. Analysis of growth and yield of maize, sunflower and soybean grown at Balcarce, Argentina. Field Crops Res. **41**: 1-12.

Banziger M, Edmeades GO Beck D and Bellon M. 2000. Breeding for Drought and Nitrogen Stress Tolerance in Maize: From Theory to Practice. CIMMYT, Mexico, DF.

Earl HJ and Davis RF 2003. Effect of drought stress on leaf and whole canopy radiation use efficiency and yield of maize. Agron. J. **95**: 688-696.

Gholipoor M, Choudhary S, Sinclair T, Messina C and Cooper M 2013. Transpiration response of maize hybrids to atmospheric vapour pressure deficit. J. Agron. Crop Sci. **199**: 155-160.

Gomez KA and Gomez AA 1984. Statistical Procedures for Agriculture Research 2nd Ed. John Wiley & Sons, New York.

Khan MB, Asif M and Aman M 2003. Response of some maize (*Zea mays* L.) genotypes to different irrigation levels. Int. J. Agril. Biol. **5**(1): 17-18.

Lindquist JL, Arkebauer TJ, Walters DT, Cassman KG and Dobermann A 2005. Maize radiation use efficiency under optimal growth conditions. Agron. J. **97**: 72-78.

Luque SF, Cirilo AG and Otegui ME 2006. Genetic gains in grain yield and related physiological attributes in Argentine maize hybrids. Field Crops Res. **95**: 383-397.

Manoj KN, Umesh MR Ramesh YM, Anand, SR and Sangu Angadi 2019. Dry matter production and radiation use efficiency of pulses grown under different light conditions. Bangladesh J. Bot. **48**(1): 9-15.

Mohsen SFG and Peyman J 2008. Effect of water stress on yield and some agronomic traits of maize. American-Eurasian J. Agri. Environ. Sci. **4**(3): 302-305.

Pandey RK, Maranville JW and Chetima MM 2000. Deficit irrigation and nitrogen effects on maize in a Sahelian environment: II. Shoot growth, nitrogen uptake and water extraction. Agri. Water Manag. **46**(1): 15-27.

Sammons B, Whitsel J, Stork LG, Reeves W and Horak M 2014. Characterization of drought-tolerant maize MON 87460 for use in environmental risk assessment. Crop Sci. **54**: 719-729.

Smith KL 1996. Ohio agronomy guide. Corn production Ohio state Univ. USA, bulletin. 472.

Tollenaar M and Anguilera A 1992. Radiation use efficiency of an old and new maize hybrid. Agron. J. **84**: 536-541.

Tsubo M, Walker S and Mukhala E 2001. Comparison of radiation use efficiency of mono/intercropping system with different row orientation. Field Crops Res. **71**: 17-29.

Van Roekel RJ and Purcell LC 2014. Soybean biomass and nitrogen accumulation rates and radiation use efficiency in a maximum yield environment. Crop Sci. **54**: 1189-1196.

Zhao J, Yang X, Lin X, Sassenrath GF, Dai S, Lv S, Chen X, Chen F and Mi G 2015. Radiation interception and use efficiency contributes to higher yields of newer maize hybrids in Northern China. Agron. J. **107**: 1473-1480.

(Manuscript received on 18 August, 2019; revised on 3 August, 2020)