**International Journal of Ecology and Environmental Sciences**
www.ecologyjournal.in
Online ISSN: 2664-7133; Print ISSN: 2664-7125; Impact Factor: RJIF 5.28
Received: 05-08-2020; Accepted: 20-08-2020; ; Published: 06-09-2020
Volume 2; Issue 3; 2020; Page No. 230-233

# Climate resilient heat tolerant maize (*Zea mays* L.) hybrids yield potential under well-watered conditions in subtropics

**MR Umesh[1], Prakash H Kuchnur[2], Vivekananda Reddy[3], N Manjunatha[4]**
[1-4] Department of Agronomy, University of Agricultural Sciences, Raichur, Karnataka, India

**Abstract**
A field experiment was conducted to evaluate newly developed heat tolerant maize hybrids canopy development and yield potential during rainy season relatively lower temperature. Four new hybrids tested in 60 and 45 cm row spacings and recommended and 25% graded fertilizers compared with local hybrids and existing recommendations. Results indicated that row spacing at 60 cm was found optimum to enhance growth and to achieve higher maize grain yield. Increased fertilizer rate at 25% higher than present recommendation was significant impact on grain yield of these hybrids. Among tested hybrids, RCRMH-2 was out yielded (19.4%) over local popular maize hybrid 900 M Gold. Light interception, leaf area index, aboveground biomass and yield attributes of maize hybrids was significantly influenced by row spacing and fertilizers rate.It indicated that heat tolerant maize hybrids are well performed during *Kharif* under well-watered condition.

**Keywords:** climate resilience, climate smart, fertilizers, heat tolerant, maize hybrids

## Introduction

*H*eat stress is a major factor limiting crop yield in many agricultural regions of the world. When plants grown near to optimal temperature less likely to affect grain yield. Maize (*Zea mays* L.) is a major cereal crop worldwide and is also very susceptible to drought and heat. High temperature (heat wave) stress at critical developmental stages of maize plants also causes significant yield loss Every year 15 to 20% of the potential world maize production is lost due to these stresses (Lobell *et al.*, 2011) [8]. Heat use efficiency, fertilizers and date of sowing also influence on productivity of groundnut (Meena and Yadav, 2013). Maize plants become susceptible to high temperatures after reaching eight-leaf stage (Chen *et al.*, 2010) [2]. However, level of damage depends on stage as well as duration in which it prevails (Cicchino *et al.*, 2010) [4]. Excess heat waves during reproductive phase will create vulnerable yield loss (Wahid *et al.*, 2007). The most significant factors associated with maize yield reduction include shortened life cycle, reduced light interception and increased sterility (Chen *et al.*, 2012) [3]. Increasing plant density would require more fertilizer especially nitrogen and water. The nitrogen recommendation for maize in the region is based on hybrids under optimum condition. Most of the farmers use high amount of nitrogen fertilizer haphazardly since there is little information available on nitrogen requirement for hybrid maize production in the region.

The CIMMYT, India has developed several heat tolerant maize hybrids in collaboration with public institutes across Asia (CIMMYT, 2017) [5]. These are tested for tolerance capacity under severe air temperature during summer in subtropical India. This field experiment was carried out with an objective to evaluate the suitability and yield potential and economics of heat tolerant maize hybrids under optimum temperature during rainy season under protected irrigated condition.

## Material and Methods

A field experiment was conducted during *Kharif*2016 at Agricultural College Farm (16°12' N 77°19'3 E, 407m elevation) Raichur, Karnataka, India. The experimental site was clay in texture having alkaline soil pH (8.26) and medium EC (0.18 dS/m). The available nitrogen, phosphorous and potassium before start of experiment was 245.5, 34.4 and 278.6 kg/ha, respectively. The experiment was laid out in split-split plot design with three replications. Treatments consists of row spacing in main plots at 60 cm ($S_1$) and 45 cm ($S_2$) whereas sub factor treatment are fertilizer levels of 100% RDF @150:75:37.5 kg NPK/ha ($F_1$) and 125% RDF ($F_2$) and maize hybrids CAH-1454 ($H_1$), CAH-1437 ($H_2$), RCRMH-2 ($H_3$) and CAH-1526 ($H_4$) and 900 M Gold ($H_5$) were in sub-sub plot. All the hybrids were sown on 16$^{th}$ August and harvested simultaneously at 115 days after sowing. Protective irrigation was given during dry spells. During the cropping period 512.2 mm of rainfall was received in 23 rainy days (Fig.1). Weeds are controlled by pre-emergent application of Pendimethalin @ 1.0 kg a.i./ha followed by intercultivation at 30 DAS. Plant protection measures were followed at regular intervals. Nitrogen was applied in three splits at basal, 30 and 50 DAS whereas P and K were applied at basal.

Transmitted light, incident light and leaf area index (LAI) were measured with SunScan Canopy Analyzer System (Delta T devices, UK). Light interception over inter row space was calculated by data of individual photodiodes embedded in quantum sensor. According to the method of Tsubo *et al.* (2001) [15], the fraction of PAR (fPAR) transmitted was measured during 11:00 to 13:00 on a sunny day. Data during the crop growing season were recorded in 23 and 45 days after sowing. Then the daily incident PAR values were multiplied by corresponding daily fIPAR values to compute daily intercepted PAR (IPAR).

$F = 1 - I_O/It$

Where,
F = Fraction of incident solar radiation intercepted by a canopy layer
$I_o$= Measured incident PAR below a canopy layer
$I_t$ = Radiant flux density on the top of the canopy

Plant samples for dry matter studies were collected at regularly up to harvest. At each sampling, five plants were uprooted at randomly in each treatment and these samples were oven dried at 70ºC in hot air oven for 72h till a constant weight obtained. The dry weight of different plant parts were recorded, the dry matter production per plant was obtained with the summation of dry weight of all plant parts and was expressed per plant basis (g/plant). Yield attributes of all the hybrids were recorded at final harvest from five randomly selected plants. Grain yield of maize were determined by harvesting all the plants in a sampling area of 4.2 m × 3.4 m. The reported grain yields were determined by accounting for a water content of 12% in the sun-dried grains.
The data were statistically analyzed using analysis of variance (ANOVA) as applicable to split plot design (Gomez and Gomez, 1984). The significance of the treatment effects was determined using F-test, and the difference between the means was estimated using least significance difference and Duncan's multiple range tests at 5% probability level. Regression analyses were performed using the data analysis tool pack of SigmaPlot 11 version.

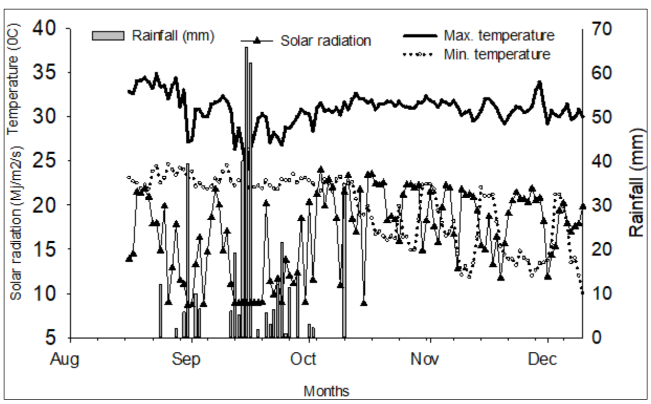
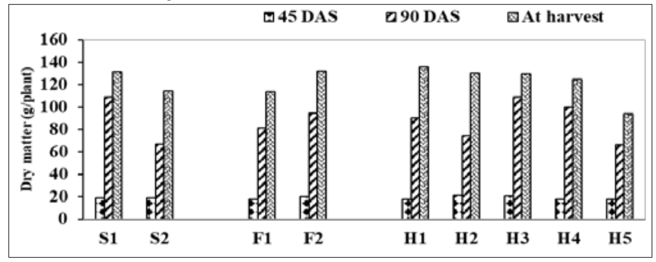



**Fig 1:** Rainfall distribution, daily solar radiation, minimum and maximum temperature during cropping period at experimental site

## Results and Discussion

### Growth Attributes

Above ground dry matter production of maize hybrids was significantly influenced by row spacing and population density (Fig.2) was higher in optimum plant population (83,333 plants/ha) at row spacing 60 cm and higher fertilizer rate @ 187:93:47 NPK kg/ha. Hybrids differed significantly in the development pattern throughout the growing period. Hybrid RCRMH-2 has produced higher dry matter (139.8 g/plant) over rest of the hybrids. Further, it was enhanced by application of graded fertilizers (134.7 g/plant) and wider row spacing (134.5 g/plant). Plant height, number of green leaves was significantly higher in wider row spacing at 60 cm and also by graded fertilizers application. Sarlangue *et al.* (2007) [12] reported that above ground biomass per plant at maturity and plant density had significant relationship between yields at 10.3 to 13.7 plants $m^{-2}$.Among hybrids, RCMH-2 has accumulated more biomass over rest of the hybrids.




$S_1$- 60cm; $S_2$- 45 cm $F_1$-150:75:37.5 kg NPK/ha; $F_2$-187:93:47 kg NPK/ha; $H_1$- CAH-1454; $H_2$- CAH-1437; $H_3$- RCRMH-2; $H_4$- CAH-1526; $H_5$- 900 M Gold

**Fig 2:** Leaf area index (a), Light interception (b) and dry matter production per plant (c) as influenced by plant population, fertilizer rate and maize hybrids Leaf area index and light interception (%)

Light interception was higher in closer spaced dense population at 45 cm with more fertilizer application (Fig. 2). Among hybrids RCMH- 2 has intercepted light and greater LAI than rest of the hybrids followed by CAH- 1526 and CAH 1454. Leaf area index (LAI) was higher in closer row spacing at 45 cm along with fertilizer rate 25% higher than RDF. It indicated that maize hybrids canopy development was influenced by spacing and fertilizer rate. At same experimental site Subrahmanyam (2017) reported that heat tolerant maize hybrids put forth more leaf area per plant as indicated by leaf area index and intercepted more light during summer period.

### Yield and yield attributes

Grain yield of maize was not significantly influenced by plant populations and fertilizer levels (Table 1). The lower spacing and recommended dose of fertilizers are sufficient for better yield. Among tested hybrids significantly higher grain yield was produced by RCRMH-2 (7958 kg/ha) and lowest in CAH-1454 (5903 kg/ha). The genetic potential coupled with optimum row spacing and fertilizer application enhances yield. Biomass at final harvest was significantly influenced by row spacing and fertilizer application rate) and was maximum in high density planting, application of fertilizers 25% higher than recommended dose (Table 1). Among hybrids biomass yield was higher in CAH 1454 (11042 kg/ha) followed by CAH 1526. Ashrafi and Seiedi (2011) [1] indicated that plant density had significant effects on plant height, number of kernels per ear, the number of grain rows and number of grains per ear row. Increments in maize grain yield with increasing *density* were more associated with increases in biomass production than with increments in HI (Sarlangue *et al.*, 2007) [12]. Subrahmanayam (2017) also evaluated heat tolerant maize hybrids for their potentiality during summer hot season results showed that heat tolerant hybrids were out yielded over conventional hybrids. Further these hybrids superiority in minimum percentage of leaf firing, tassel blast percentage, anthesis-silking interval, pollen shedding duration.

**Table 1:** Yield attributes of maize hybrids grown under different row spacings and fertilizer levels

| Treatment | Cobs/ plant | Rows/ cob | Cob barrenness (%) | Seeds/ row | 100- seed weight (g) | Grain yield (kg/ha) | Stover yield (kg/ha) |
|---|---|---|---|---|---|---|---|
| *Row Spacing* | | | | | | | |
| $S_1$- 60 cm | 1.22 | 14.33 | 9.10 | 29.4 | 28.39 | 7299 | 8556 |
| $S_2$- 45 cm | 1.36 | 13.64 | 8.66 | 27.16 | 27.44 | 6850 | 10593 |
| C.D. (p=0.05) | NS | NS | NS | 2.4 | NS | NS | 854 |
| *Fertilizer levels* | | | | | | | |
| $F_1$-150:75:37.5 kg NPK/ha | 1.26 | 13.87 | 8.41 | 27.34 | 27.25 | 7023 | 8721 |
| $F_2$-187:93:47 kg NPK/ha | 1.31 | 14.11 | 9.35 | 29.25 | 28.57 | 7127 | 10228 |
| C.D. (p=0.05) | NS | NS | NS | 1.83 | 1.26 | NS | 896 |
| *Hybrids* | | | | | | | |
| $H_1$-CAH-1454 | 1.24 | 14.22 | 7.98 | 25.91 | 28.32 | 5903 | 11042 |
| $H_2$-CAH-1437 | 1.23 | 14.06 | 8.66 | 28.75 | 29.20 | 7552 | 9236 |
| $H_3$-RCRMH-2 | 1.41 | 13.17 | 8.84 | 27.63 | 29.96 | 7958 | 9478 |
| $H_4$-CAH-1526 | 1.23 | 14.10 | 10.46 | 30.74 | 25.21 | 7297 | 10095 |
| H5-900 M Gold | 1.32 | 14.39 | 8.46 | 25.44 | 26.88 | 6662 | 8022 |
| C.D. (p=0.05) | NS | NS | NS | 2.84 | 2.13 | 1187 | 1351 |

**Economic returns**

Increased level of fertilizers application @ 187-93-47 NPK kg/ha has higher cost of cultivation (Rs. 39.5 x $10^3$/ha) as compared to recommended levels (Table 2). This might be due to additional cost towards higher nutrient dose. Higher net returns at 60 cm row spacing (Rs. 75 x $10^3$/ha) was mainly ascribed to higher grain yield. Higher net returns and benefit cost ratio was with the application of higher levels of nutrients owing to more grain yield as compared to increase in cost of cultivation. Among hybrids, RCRMH-2 production has given greater net returns (Rs.88.6 x $10^3$/ha) and benefit: cost ratio (3.39) as compared to local popular hybrid 900 M Gold and others. It may be ascribed to differences in maize grain yield potential among hybrids inspite of similar cost of production (Rs. 37.0 x $10^3$/ha).

The present study thus indicates that high yielding heat tolerant hybrids perform better in optimum temperature condition during rainy season. Maize hybrid RCRMH-2 has higher grain yield potential, harvest index which enhanced economic returns over existing hybrids in the region. To achieve higher yield row spacing of 60 cm was found better than narrow row spacing at 45 cm. Further, application of 15% higher than existing recommendation was found to be effective in achieving higher yield potential and economic returns.

**Table 2:** Economic returns of maize hybrids under modified spacing and fertilizer application

| Treatment | Cost of production (‘000 Rs. /ha) | Gross return (‘000 Rs. /ha) | Net Return (‘000 Rs. /ha) | BC Ratio |
|---|---|---|---|---|
| *Row spacing* | | | | |
| $S_1$- 60 cm | 40.3 | 115.3 | 75.0 | 2.73 |
| $S_2$- 45 cm | 42.2 | 111.8 | 69.6 | 2.65 |
| *Fertilizer levels* | | | | |
| $F_1$-150:75:37.5 kg NPK/ha | 37.3 | 108.8 | 71.5 | 2.73 |
| $F_2$-187:93:47 kg NPK/ha | 39.5 | 112.6 | 73.1 | 2.80 |
| *Hybrids* | | | | |
| $H_1$-CAH-1454 | 37.0 | 99.2 | 62.2 | 2.68 |
| $H_2$-CAH-1437 | 37.0 | 120.3 | 83.3 | 3.25 |
| $H_3$-RCRMH-2 | 37.0 | 125.6 | 88.6 | 3.39 |
| $H_4$-CAH-1526 | 37.0 | 117.3 | 80.3 | 3.17 |
| $H_5$-900 M Gold | 37.7 | 105.3 | 67.6 | 2.79 |

**Acknowledgment**

The authors are thankful to CIMMYT, India for providing new hybrids for agronomic evaluation, University of Agricultural Sciences, Raichur for financial.

**References**

1. Ashrafi V, Seiedi MN. Influence of different plant densities and plant growth promoting Rhizobacteria (PGPR) on yield and yield attributes of corn (Zea mays L.) Rec. Res. Sci. Tech. 2011; 3(1):63-66
2. Chen J, Xu WJ, Xin Z. Role of Phosphatidic acid in high temperature tolerance in maize. Crop Science, 2010; 50:2506-2515
3. Chen J, Xu W, Velten J, Xin Z, Stout J. Characterization of maize inbred lines for drought and heat tolerance. J Soil Water Conserv. 2012; 67(5):354-364
4. Cicchino M, Rittalino Edreira JI, Uribelarrea M, Otegui ME. Heat stress in field grown maize: Response of physiological determinants of grain yield. Crop Sci, 2010; 50:1438-1448
5. CIMMYT. Heat stress tolerance maize for Asia, 2017. https://htma.cimmyt.org/
6. Gomez KA, Gomez AA. Statistical procedures for agricultural research (2 ed.). John wiley and sons, New York, 1984, 680p.
7. Hodges T, Evans DW. Light interception model for estimating the effects of row spacing on plant competition in maize. J Prod. Agri. 1990; 3(2):190-195.

8. Lobell DB, Banziger M, Magorokosho C, Vivek B. Nonlinear heat effects on African maize at evidenced by historical yield trials. Nature Climate Change, 2011; 1:42-45.
9. Maddonni GA, Otegui ME. Leaf area, light interception, and crop development in maize. Field Crops Res. 1996; 48(1):81-87
10. Meena RS, Yadav RS. Groundnut yields as influenced by heat unit efficiency, levels of fertility and varieties under different growing environment in hyper arid zone of Rajasthan. Indian J Eco. 2013: 40(1):110-114.
11. Modarres AM, Hamilton RI, Dijak MW, Dwyer LM, Stewart DW, Mather DE, *et al*. Plant population density effects on maize inbred lines grown in short-season environments. Crop Sci. 1998; 38(1):104-108.
12. Sarlangue T, Andrade FH, Calviño PA, Purcell LC. Why do maize hybrids respond differently to variations in plant density? Agron. J. 2007; 99(4):984-991.
13. Schoper JB, Lambert RJ, Vasilas BL, Westgate ME. Plant factors controlling seed set in maize: the influence of silk, pollen, and ear-leaf water status and tassel heat treatment at pollination. Plant Phy. 1987; 83(1):121-125.
14. Subrahmanyam K. Effect of sowing dates and irrigation regimes on productivity and resource use efficient of maize hybrids during summer. MSc thesis submitted to University of Agricultural Sciences, Raichur Karnataka India, 2017, pp:1-124.
15. Tsubo M, Walker S, Mukhala E. Comparisons of radiation use efficiency of mono-/inter-cropping systems with different row orientations. Field Crops Res. 2001; 71(1):17-29
16. Whaid A, Gelani S, Shraf M, Foolad MR. Heat tolerance in plants: An overview. Env. Exptl. Bot, 2007; 61:199-223.