Biological Forum – An International Journal 13(4): 659-664(2021)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Influence of Moisture Stress and Dates of Sowing on the Performance of Heat Tolerant Maize Genotypes

***B.N. Shwetha*[1*], *B.M. Chittapur*[2], *P.H. Kuchanur*[3], *B.G. Koppalkar*[4], *A.S. Halepyati*[5], *Mahadevaswamy*[6] and *H. Veeresh*[7]**

[1]*Assistant Professor, Department of Agronomy, College of Agriculture, Raichur, (Karnataka), India.*
[2]*Rtd. Director of Extension, University of Agricultural Sciences, Raichur, (Karnataka), India.*
[3]*Professor and Head, Department of Genetics and Plant Breeding, College of Agriculture, Bheemarayanagudi, University of Agricultural Sciences, Raichur, (Karnataka), India.*
[4]*Professor and Head, Department of Agronomy, College of Agriculture, Raichur, (Karnataka), India.*
[5]*Professor and Head, Institute of Organic Farming, University of Agricultural Sciences, Raichur, (Karnataka), India.*
[6]*Professor and Head, Department of Agricultural Microbiology, College of Agriculture, Raichur, (Karnataka), India.*
[7]*Assistant Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Raichur, (Karnataka), India.*

(Corresponding author: B.N. Shwetha)*
(Received 01 September 2021, Accepted 06 November, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Maize production is strongly affected by changing climate particularly the rainfall which is either delayed and/or comprised of frequent dry spells and heavy showers during kharif season. However, there is no escape from these vagaries of mansoon. And therefore, production practices like adjusting sowing time and use of tolerant cultivars which helpful in addressing these issues are to be employed for sustained production. To derive some of these option specially for kharif season a field experiment was formulated to know the effect of extended sowing (mid June, July and August) and periodic dry spells of 20 days (20-40, 40-60, 60-80 and 80-100 DAS) on heat tolerant maize genotypes (RCRMH 2, RCRMH 3 and RCRMH 4) in TBP irrigation command in the semi arid tropics of India during rainy season. In the present study July sowing is relatively stress free hence crop recorded higher RWC (76.88% and 56.39%), ASI (2.65 days), growth and yield parameters and consequently grain yield (5610 kg ha^{-1}) compared to traditional recommendation of June sowing which in fact was next best and comparable, while August sowing was rather discouraging. Interestingly, stress imposed at various stages failed to induce significant variation in these heat tolerant genotypes, of which RCRMH 3 was superior (5511 kg ha^{-1}) to RCRMH 4, while RCRMH 2 recommended for summer in the region was comparable.

Keywords: Rainy season, Dates of sowing, Moisture stress, Heat tolerant genotypes, Growth and yield.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most versatile crop having wider adaptability under varied agro-climatic conditions in a range of production environments, from the temperate hill zones to the semi-arid desert margins. It accounts for 10 per cent of total food grain production in the country. It is the only food cereal crop grown in diverse seasons (in all three seasons- *kharif*, *rabi* and spring), varied ecologies and for wide range of uses (APEDA, 2019). The phenomenal growth in the maize production and its spread across the regions in recent years is because of its high yield potential, easy cultivation and adoptability to varied climatic conditions which proved maize a golden grain in India. Indian maize summit (2018) reported that maize is important to India as 15 million Indian farmers are engaged in maize cultivation. Being potential in generating good income to farmers besides providing gainful employment, it can be consider as a potential crop for doubling farmer's income. There is also a tremendous potential for maize in value chain in the country. The consumption of maize crop has increased at a CAGR of 11% in last five years. These trends open up vistas of opportunity for India's maize sector. However, there has been a significant fluctuation in yield and production under changing climatic condition as climatic variability affects maize yield and the various crop processes and activities in maize production.

The occurrence of extreme climate variability such as may be characterized by prolonged dry period or heavy rainfall spell coinciding with the critical stages of crop growth and development may lead to significantly reduced crop yields and extensive crop losses. Maize production has been on steady decline due to erratic rainfall variability and the area planted to maize also been reduced to adapt to the anticipated drought period (Naveenkumar *et al.*, 2018). Drought is one of the main causes of reduced maize production and food insecurity across the globe and particularly in India, where agriculture production is largely rainfed (Rodney *et al.*, 2019). Daryanto, *et al.* (2016) estimated that the occurrence of midseason droughts particularly at the vegetative and productive phases for maize reduces yields by 39.3%, as maize is more sensitive to drought compare to other cereals, especially at flowering because anthers and silks are separated by about 1 m, and pollen and stigma are exposed to the environment. The crop is particularly sensitive to dry spells a week before and two weeks after flowering resulting in an average yield loss of 20 to 50% (Silvestro *et al*., 2018). According to Mirzaei *et al.*, (2011) drought stress at stages of stem elongation, flowering and grain filling stages induced 32 %, 32 % and 35 % reduction in grain yield.

Maize production systems, therefore, should adapt to climatic aberrations to minimize their negative effects. It requires a adaptation or mitigation measures such as choice of maize crop variety, adaptation of cultural management practices (Oseni and Masarirambi, 2011), which include practices such as adjusting the cropping calendar to synchronize crop planting and the growing period with soil moisture availability based on seasonal climate/ rainfall forecast, changing the maize variety to plant.

Planting time is one critical agronomical intervention in crop production which plays an important role in determining growth and yield of seasonal crops including maize as planting time is equally important as selection of suitable cultivar and the crop performance is subject to variation because of the very great differences in weather at planting time between seasons and within the range of climates (Otegui *et al*., 1995). Southworth *et al*. (2000) reported that under future climate change scenarios later planting dates produced higher yields.

Kindie *et al.*, (2018) stated that incorporation of heat and drought tolerance into maize varieties increased yield by 99% under the baseline climate and by 115, 136 and 222% under the hotter climate change scenarios that involved a mean temperature increase of 1, 2 and 4°C, respectively. Similarly, varieties with combined heat and drought tolerance traits increased maize yield by 150, 185 and 329% under the hotter and drier climate change scenarios with a mean temperature increase of 1, 2, and 4 °C, respectively.

Keeping these facts in view, this study was carried out to know the influence of dates of sowing and stress imposed at various stages on heat tolerant genotypes in Tunga Bhadra Project irrigation command falling in semiarid tropics of India.

MATERIALS AND METHODS

The present study was conducted during rainy season (*kharif)* of 2019-20 at Agricultural Research Station, Dhadesugur, University of Agricultural Sciences, Raichur, Karnataka, India, situated between 15°46″N latitude and 76°45″E longitude at an altitude of 358 meters above the mean sea level. The experimental soil was black clayey with pH 7.53 (near neutral in reaction), EC 0.86 (normal in soluble salts), 0.47 % of organic carbon (low), 282 kg ha^{-1} of available nitrogen (medium) and 47 kg ha^{-1} of phosphorus (medium) and 356 kg ha^{-1} of potassium (high). The experiment was laid in split split plot design with three replications, in which main plot consisted of three dates of sowing at monthly interval (*viz.*, D_1- June, D_2-July and D_3-August) , sub plots with four moisture stress treatments at twenty days interval from 20 DAS to 100 DAS *viz.*,S_1-withholding of irrigation at 20-40 DAS, S_2-withholding of irrigation at 40-60 DAS, S_3-withholding of irrigation at 60-80 DAS and S_4-with holding of irrigation at 80-100 DAS, and genotypes *viz*., RCRMH 2, RCRMH 3 and RCRMH 4 in sub-sub plots. Of the moisture stress treatments, only S_2 of June month and S_1 of August month were experienced drought (Table 1). The genotypes used were heat stress tolerant single cross maize hybrids developed and recommended for Zone-2 of Karnataka state by University of Agricultural Sciences, Raichur, Karnataka in collaboration with CIMMYT-Asia, Hyderabad under 'Heat Stress Tolerant Maize for South Asia through public private partnership' (HTMA) project funded by USAID.

Table 1: Amount of rainfall (mm) received during different stress stages of Experiment during 2019-20.

Stages of stress	D_1-June	D_2-July	D_3-August
S_1	66.5	37.6	248
S_2	Stress occurred	101.8	64.4
S_3	43.6	198	54.8
S_4	274.2	62.8	Stress occurred

The crop was sown on 18th June, 20th July and 16th August of 2019 and all the specific package of practices recommended for the cultivation of maize in the region was followed. Moisture stress was imposed by withholding irrigation. The Sunscan canopy analyzer probe was used for recording LAI (Saxena and Singh, 1968) and the canopy temperature was measured by using a hand held Infrared thermometer, between 11.30 am and 01:30 pm during clear sunny days. RWC (Relative water content) was estimated as per the method of Barrs and Weatherly (1962). Proline content was measured by methods given by Bates *et al*. (1973). Besides, other observation on growth and yield were recorded by following standard procedures. Data were subjected to statistical analysis as described by Gomez and Gomez (1984). Means were compared using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Many physiological and biochemical processes are influenced by weather particularly moisture deficit condition and temperature stress and, therefore, it is very difficult to understand and assess crop performance as multiple mechanisms are involved in the adoption/response process. In the present study among the stress stages S_2 of June (108.22 µmoles g^{-1}) and S_4 of August crop (107 µmoles g^{-1}) recorded higher amount of proline content in leaves than the rest of the stress stages which were actually experienced stress. Enhanced accumulation of proline during stress helps to mitigate osmotic stress employing various coherent phenomena relating to plant anatomy and physiology with cellular mechanisms (Bray, 1997; Evelin *et a*l., 2009). Proline has been addressed as a unique low molecular weight osmolyte which responds to stresses related to osmosis in wide plant varieties (Delauney and Verma, 1993; Hasegawa *et al*., 2000). Further, it is an important variable amino acid in determining protein and membrane structures and scavenges reactive oxygen species (ROS) under drought stress (Ashraf and Foolad, 2007).

Leaf relative water content (RWC) is another important indicator of water status in plants; which reflects the balance between water supply to the leaf tissue and transpiration rate (Lugojan and Ciulca 2011). Among the stress stages also, though the stress was experienced at S_2 (60 DAS) of June and S_4 stage (100 DAS) of August, relative water content was only numerically decreased compared to non-stressed treatments but not to a significant level, this might be due to use of stress tolerant genotypes which shown accumulation of higher amount of proline during stressed condition. The proline accumulated, thus, helped in minimizing osmotic potential in turn leaf water potential which renders the host plants to sustain the photosynthetic apparatus by retaining elevated organ hydration and turgor pressure maintenance (Ruiz-Lozano *et al*., 1995; Wang *et al.,* 2004; Kandowangko *et al*., 2009). Among the genotypes RCRMH 3 was recorded higher relative water content, while RCRMH 2 was on par.

Canopy temperature was also an indicator of moisture stress. Use of canopy temperatures to detect water stress in plants is based upon the assumption that transpired water evaporates and cools the leaves below the temperature of the surrounding air. As water becomes limiting, transpiration is reduced and the leaf temperature increases (Jackson, 1982). But as a result of maintenance of relative water content in the stressed treatments by the use of stress tolerant genotypes in the present study helped in increase in canopy temperature only to little extent in water stressed treatments (31.02°C and 29.93°C at 60 and 100 DAS of S_2 of June and S_4 of August, respectively) but on par with the non water stressed treatments.

Anthesis-silking interval (ASI) has been reported to be a more valuable diagnostic trait for cultivar performance under drought stress. Kahiu *et al.* (2013) reported that under drought stress environment ASI increased up to 7.7 days from an average of 1.6 days under non stress environment. But in the present study, increase in ASI in drought stress treatments S_2 and S_4 (2.86) was not to the significant level because of the maintenance of leaf relative water status and leaf canopy temperature moderation due to increased proline accumulation in these treatments.

Whereas, these physiological parameters *viz.*, accumulation of proline, canopy temperature etc. were higher in the June sown crop during 60 DAS (107.83) and in August sown crop during 100 DAS (104.25) at which they experienced stress among the dates of sowing, and in these treatments ASI was increased numerically but not to a significant level. In contrast to this, relative water content was significantly higher in the month of July (56.39 %) because of non exposure of crop to and it was on par with June sowing (53.62 %) at both 60 and 100 DAS

Among the genotypes, all the cultivars being inherently tolerant to heat performed equally well under moisture stress condition indicating their resilience to moisture stress. Nevertheless, among them RCRMH 3 performed better than the RCRMH 4, while RCRMH 2 was on par. Simiarly Grazesiak (1990) observed that response of hybrids to periodic water shortage was in general less differentiated and weaker than drought resistance observed in inbreds. Electrolyte loss from leaf tissue under water or thermal stress and changes of proline in leaves to decrease of photosynthetic rate caused by drought, was greater in inbreds than in hybrids.

Further, differential sowing time and stress created morphological differences *viz*., plant height, number of leaves and total dry matter production at harvest which were significantly lower with August sown crop (167.93 cm, 6.17 and 287.84 g pl^{-1} respectively). While, yield traits viz., number of grain rows per cob, cob weight per plant and 100-kernel weight were higher with July sown crop (13.48, 32.93 g and 31.22 g respectively). Among the stress stages no significant difference was noticed in terms of plant height, number of leaves and total dry matter production, however, the values reduced marginally in the treatments experiencing water stress at S_2 (176.28 cm, 6.63 and 312.97 g pl^{-1} respectively) and S_4 (177.24 cm, 6.66 and 314.60 g pl^{-1} respectively) stages which might be due to planting of stress tolerant genotypes as already mentioned, which withstood the impact of water stress due to their inherent ability. Among the genotypes significantly higher height, number of leaves and total dry matter production was recorded with ¯RCRMH 3 (181.97 cm, 6.90 and 324.12 g pl^{-1} respectively) over RCRMH 4 (178.37 cm, 6.66 and 316.13 g pl^{-1} respectively), while RCRMH 2 (172.45cm, 6.40 and 304.91g pl^{-1} respectively) was comparable.

Similar variations were recorded with respect to yield and yield traits viz., number of grain rows per cob, cob weight per plant and 100-kernel weight were influenced by dates of sowing and genotypes under water stress condition, wherein, grain yield was significantly higher in July sowing (5610 kg ha^{-1}) and it was on par with the June sowing (5352 kg ha^{-1}). This might be due to better production environment particularly moisture (rainfall in this instance) as evidenced from Table 1 which helped crop to perform near to potential. The lower kernel yield in August sowing was mainly due to the fact that it was near to the closure of season besides this part of the season being intimidating for growth which consequently advanced maturity without sufficient source and sink development and the translocation of photosynthates to developing grain. According to Fisher *et al.*, (2015) the onset of the rainy season is crucial to the timing of rainfed crops: if a farmer plants too early, soil moisture will be insufficient; if a farmer plants too late, intense rain might affect the crop, the same result can be seen in the present study. Southworth *et al*., (2000) reported that under future climate change scenarios later planting dates produce higher yields. In their study in almost all cases the highest mean maximum decadal yield occurred at a later planting date under future climate change, this augurs well with present finding.

The S_2 and S_4 stages of stress recorded numerically lower kernel yield (5256 and 5260 kg ha^{-1} respectively) but not to a significant level compared to non-water stressed treatments which might be due to use of heat tolerant genotype which are inherently tolerant to stress also as evidenced in the present investigation in terms of maintenance of relative water content and moderating canopy temperature through accumulation of proline under water stress condition.

Table 2: Physiological response of maize genotypes to dates of sowing and moisture stress during rainy season.

Dates of sowing	Proline @ 60 DAS (µmoles g^{-1})	Proline @ 100 DAS (µmoles g^{-1})	RWC @ 60 DAS (%)	RWC @ 100 DAS (%)	Canopy temp @ 60 DAS °C	Canopy temp @ 100 DAS °C	ASI (days)
Dates of sowing (D)							
D_1	107.83 ^{a}	101.92 ^{a}	73.02 ^{a}	53.62 ^{a}	31.50 ^{a}	29.88 ^{a}	2.82 ^{a}
D_2	101.58 ^{b}	98.42 ^{b}	76.88 ^{a}	56.39 ^{a}	30.30 ^{a}	29.62 ^{a}	2.65 ^{a}
D_3	101.50 ^{b}	104.25 ^{a}	71.09 ^{b}	51.77 ^{b}	30.51 ^{a}	29.58 ^{a}	3.05 ^{b}
S.Em±	1.46	1.40	0.94	0.76	1.69	1.59	0.06
Stages of stress (S)							
S_1	102.33 ^{b}	99.56 ^{b}	74.14 ^{a}	54.54 ^{a}	30.68 ^{a}	29.68 ^{a}	2.83 ^{a}
S_2	108.22 ^{a}	99.11 ^{b}	72.95 ^{a}	54.15 ^{a}	31.02 ^{a}	29.73 ^{a}	2.86 ^{a}
S_3	101.89 ^{b}	100.44 ^{b}	74.26 ^{a}	53.99 ^{a}	30.71 ^{a}	29.43 ^{a}	2.82 ^{a}
S_4	102.11 ^{b}	107.00 ^{a}	73.30 ^{a}	53.03 ^{a}	30.68 ^{a}	29.93 ^{a}	2.86 ^{a}
S.Em±	1.59	1.61	0.97	0.83	0.49	0.52	0.06
Genotypes (G)							
G_1	103.83 ^{a}	101.25 ^{ab}	73.54 ^{ab}	53.94 ^{ab}	30.77 ^{a}	29.70 ^{a}	2.84 ^{ab}
G_2	107.50 ^{a}	105.00 ^{a}	75.26 ^{a}	55.25 ^{a}	30.66 ^{a}	29.56 ^{a}	2.77 ^{a}
G_3	99.58 ^{b}	98.33 ^{b}	72.18 ^{b}	52.58 ^{b}	30.88 ^{a}	29.81 ^{a}	2.91 ^{b}
S.Em±	1.39	1.39	0.86	0.72	0.42	0.44	0.06
Interactions							
D x S	NS	NS	NS	NS	NS	NS	NS
D x G	NS	NS	NS	NS	NS	NS	NS
S x G	NS	NS	NS	NS	NS	NS	NS
D x G x S	NS	NS	NS	NS	NS	NS	NS

D_1: June
D_2: July
D_3: Aug

S_1: Water stress at 20-40DAS
S_2: Water stress at 40-60DAS
S_3: Water stress at 60-80DAS
S_4: Water stress at 80-100DAS

G_1: RCRMH 2
G_2: RCRMH 3
G_3: RCRMH 4
Check : RCRMH 2

Note: The values between the same set of classes for each treatment followed by the same letter are not significantly different

Table 3: Response of maize genotypes to dates of sowing and moisture stress during rainy Season.

Dates of sowing	Plant height (cm) @ Harvest	No. of leaves @ harvest	TDM @ Harvest (g)	No of grain rows per cob	No of grains per row	100 Kernel weight (g)	Grain yield (kg ha^{-1})
Dates of sowing (D)							
D_1	178.10 ^{a}	6.69 ^{a}	319.56 ^{a}	13.31 ^{a}	27.71 ^{a}	29.59 ^{a}	5352 ^{a}
D_2	186.73 ^{a}	7.10 ^{a}	337.76 ^{a}	13.48 ^{a}	32.93 ^{a}	31.22 ^{a}	5610 ^{a}
D_3	167.93 ^{b}	6.17 ^{b}	287.84 ^{b}	12.38 ^{b}	22.19 ^{b}	22.93 ^{b}	4968 ^{b}
S.Em$\pm$	2.59	0.11	5.07	0.20	1.60	1.64	87
Stages of stress (S)							
S_1	178.70 ^{a}	6.66 ^{a}	316.85 ^{a}	13.14 ^{a}	28.42 ^{a}	28.61 ^{a}	5353 ^{a}
S_2	176.28 ^{a}	6.63 ^{a}	312.97 ^{a}	13.07 ^{a}	26.85 ^{a}	28.24 ^{a}	5256 ^{a}
S_3	178.13 ^{a}	6.66 ^{a}	315.79 ^{a}	13.02 ^{a}	28.11 ^{a}	27.31 ^{a}	5372 ^{a}
S_4	177.24 ^{a}	6.66 ^{a}	314.60 ^{a}	13.00 ^{a}	27.04 ^{a}	27.48 ^{a}	5260 ^{a}
S.Em$\pm$	2.99	0.12	5.64	0.23	0.62	0.51	100
Genotypes (G)							
G_1	178.34 ^{ab}	6.66 ^{ab}	316.13 ^{ab}	13.19 ^{ab}	27.44 ^{ab}	27.96 ^{ab}	5300 ^{ab}
G_2	181.97 ^{a}	6.90 ^{a}	324.12 ^{a}	13.34 ^{a}	29.02 ^{a}	29.25 ^{a}	5511 ^{a}
G_3	172.45 ^{b}	6.40 ^{b}	304.91 ^{b}	12.65 ^{b}	26.36 ^{b}	26.53 ^{b}	5119 ^{b}
S.Em$\pm$	2.58	0.10	4.95	0.20	0.56	0.46	86
Interactions							
D x S	NS	NS	NS	NS	NS	NS	NS
D x G	NS	NS	NS	NS	NS	NS	NS
S x G	NS	NS	NS	NS	NS	NS	NS
D x G x S	NS	NS	NS	NS	NS	NS	NS

D_1: June	S_1: Water stress at 20-40DAS	G_1: RCRMH 2
D_2: July	S_2: Water stress at 40-60DAS	G_2: RCRMH 3
D_3: Aug	S_3: Water stress at 60-80DAS	G_3: RCRMH 4
	S_4: Water stress at 80-100DAS	Check : RCRMH 2

Note: The values between the same set of classes for each treatment followed by the same letter are not significantly different

Li *et al*. (2002) reported that during soil drought, the drought-sensitve variety showed less capabilities in osmoregulation and cell elasticity regulation, slower decrease in stomatal conduces, more rapid decline in photosynthetic rate and PS II photochemical efficiency compared with drought-tolerant variety which regained its pre stress stomata conductance, photosynthetic rate and PS II photochemical efficiency faster than drought-sensitive variety. Among the genotypes, RCRMH 3 recorded significantly higher kernel yield (5511 kg ha^{-1}) followed by RCRMH 2 (5300 kg ha^{-1}), while lower kernel yield was recorded with RCRMH 4. The results corroborate with Shivalingappa (2018) who observed superiority of RCRMH 3 over other cultivars during summer at the same location. And the similar results also found with Eric *et al.* (2016) who documented that the yield advantage of DT hybrids in high-and medium-ET environments supports the concept that DT hybrids enhance productivity in water-limited environments relative to non-DT hybrids. They noticed an average three-fold greater yield benefit (6.5%) for DT maize hybrids in water-limited situations when compared with favorable environments (1.9%).

CONCLUSIONS

From the present study it can be concluded that in view of increased climatic variability especially in terms of precipitation variability resulting in increased frequency and intensity of dry spells during rainy season mitigation strategies *viz.*, changing sowing dates from too early to mid and use of heat (stress) tolerant genotypes are better options for sustained production of maize in Tunga Bhadra Project irrigation command in semi arid tropics.

FUTURE SCOPE

The variability in climate being on the rise, such studies still need to be continued using diverse pool of crop varieties; not just heat stress tolerant genotypes made use in the study. Stay green character, leaf blast and leaf rolling besides other physiological and biochemical variations also need to be considered in such studies.

Acknowledgment. The authors are highly thankful to the University of Agricultural Sciences, Raichur and Farm superintendent of Agricultural Research Station, Dhadesugur for providing facilities to conduct this research.

Conflict of Interest. The authors declare no conflict of interest.

REFERANCES

APEDA (2019), *https://apeda.gov.in*

Ashraf, M., & Foolad, M. R. (2007). Roles of glycine betaine and proline in improving plant abiotic stress resistance. *Environment and Experimental Botony*, *59*: 206–216.

Barrs, H. D., & Weatherly, P. E. (1962). A re-examination of relative turgidity for estimating water deficit in leaves. *Australian Journal of Biological Sciences*, *15*: 413-428.

Bates, L. S., Waldren, R. P., & Teare, I. D. (1973). Rapid determination of free proline for water-stress studies. *Plant and Soil*, *39*: 205–207.

Bray, E.A. (1997). Plant responses to water deficit. *Trends Plant Science*, *2*: 48–54.

Delauney, A. J., and Verma, D. P. S. (1993). Proline biosynthesis and osmoregulation in plants. *Plant Journal*, *4*, 215–223.

Daryanto, S., Wang, L. and Jacinthe, P. A. (2016). Global Synthesis of Drought Effects on Maize and Wheat Production. PLoS ONE 11(5): e0156362. doi:10.1371/journal.pone.0156362

Eric, A., Kraig, R., Guillermo, R. B., Alan, S. and Ignacio A. C. (2016). Drought-tolerant corn hybrids yield more in drought-stressed environments with no penalty in non-stressed environments. *Front. Plant Sci*., *7*: 1534.

Evelin, H., Kapoor, R., & Giri, B. (2009). Arbuscular mycorrhizal fungi in alleviation of salt stress: *A review. Annals of Botany*, *104*: 1263–1280.

Fisher, M., Tsedeke, A., Lunduka, R.W., Asnake, W., Alemayehu, Y. and Madulu, R. B. (2015). Drought tolerant maize for farmer adaptation to drought in sub-Saharan Africa: Determinants of adoption in eastern and southern Africa. *Climatic Change*., *133*: 283–299.

Gomez, K. A., & Gomez, A. A. (1984). Statistical Procedures for Agriculture Research. 2nd *Edition. John Wiley and Sons*, New York.

Grazesiak, S. (1990). Reaction to drought of inbreds and hybrids of maize (*Zea mays* L.) as evaluated by field and green house experiments. *Maydica*, *35*(3): 303-311.

Hasegawa, P. M., Bressan, R. A., Zhu, J. K., & Bohnert, H. J. (2000). Plant cellular and molecular responses to high salinity. *Annual Review of Plant Physiology and Plant Molecular Biology*, *51*: 463–499.

Indian maize summit. (2018). Maize vision 2022 - A knowledge Report. https://ficci.in/spdocument/22966/India-Maize-Summit.pdf .

Li, Y., Pan, H. C., & Li, D. Q. (2002). Physiological differences between desiccation tolerant and desiccation sensitive varieties of maize (*Zea mays* L.) during heat stress and rehydration. Journal of Zhejiang University: *Agriculture and Life Science*, *28*(3): 249-254.

Jackson, R. D. (1982). Canopy temperature and crop water stress. *Advances in Irrigation*, *1*: 43-85.

Kahiu, N., Juma, O. C. and Sicily, M. (2013). Combining, earliness, short anthesis to silking interval and yield based selection indices under intermittent water stress to select for drought tolerant maize. *Australian Journal of Crop Science*, *7*(13): 2014-2020.

Kandowangko, N. Y., Suryatmana, G., Nurlaeny, N., & Simanungkalit, R. D. M. (2009). Proline and abscisic acid content in droughted corn plant inoculated with *Azospirillum* sp. and *Arbuscular mycorrhizae* fungi. Hayati *Journal of Biosciences*, *16*: 15-20.

Kindie, T., Gideon, K., Cairns, J. E., Zaman-Allah, M., Dagne, W., Zaidi, P. H., Kenneth, J. B., Rahut, D., & Erenstein, O. (2018). Potential benefits of drought and heat tolerance for adapting maize to climate change in tropical environments. *Climate Risk Managt.*, *19*: 106–119.

Lugojan, C., & Ciulca, S. (2011) Evaluation of relative water content in winter wheat. *Journal of Horticulture, Forestry and Biotechnology*, *15*: 173-177.

Mirzaei, A., Naseri, R., & Soleimani, R. (2011). Response of different growth stages of wheat to moisture tension in a semiarid land. *World Applied Sciences Journal*, *12*(1): 83-89.

Naveen Kumar, K. L., Sen, D., & Khanna, V. K. (2018). Effect of maize production in a changing climate: Its impacts, adaptation and mitigation strategies through breeding. *Open Access Journal of Oncology, Open Access Journal of Oncology and Medicine*, *2*(4).

Oseni, T. O., & Masarirambi, M.T. (2011). Effect of climate change on maize (*Zea mays*) production and food security in Swaziland. *American-Eurasian Journal of Agricultural & Environmental Sciences*, *11*(3): 385-391.

Otegui, M. E., Andrade, F. H., & Suero, E. E. (1995). Growth, water use and kernel response of maize to water stress. *Pakistan Journal of Botany*, *29*(1): 103-111.

Saxena, M.C. and Singh, V. (1968). A note on area estimation intact maize leaves. *Indian Journal of Agronomy*.10: 437-439.

Southworth, J., Randolph, J. C., Habeck, M., Doering, O. C., Pfeifer, R.A., Rao, D. G., & Johnston, J. J. (2000). Consequences of future climate change and changing climate variability on maize yields in the mid western United States. *Agriculture Ecosystems & Environment*, 82 (1–3): 139-158.

Ruiz-Lozano, J.M., Azcón, R., & Gomez, M. (1995). Effects of arbuscular mycorrhizal Glomus species on drought tolerance: physiological and nutritional plant responses. *Applied and Environmental Microbiology*, *61*: 456–460.

Silvestro, M., Menkir, A., Bunmi, B., & Wende, M. (2018). Performance assessment of drought tolerant maize hybrids under combined drought and heat stress. *Agronomy*, *8*: 274.

Rodney, W. L., Kumbirai, I. M., Cosmos, M., & Pepukai, M. (2019). Impact of adoption of drought-tolerant maize varieties on total maize production in South Eastern Zimbabwe. *climate and development*, *11*(1): 35–46.

Shivalingappa Bhavikatti. (2019). Performance of maize (*Zea mays* L.) genotypes under different dates of sowing during summer in Tunga Bhadra Project irrigation command. *M. Sc (Agri) Thesis, Univ. Agril. Sci., Raichur*.

Wang, F. Y., Liu, R. J., Lin, X. G., & Zhou, J. M. (2004). Arbuscular mycorrhizal status of wild plants in saline-alkaline soils of the Yellow River Delta. *Mycorrhiza*, *14*: 133–137.

How to cite this article: Shwetha, B.N.; Chittapur, B.M.; Kuchanur, P.H.; Koppalkar, B.G.; Halepyati, A.S.; Mahadevaswamy and Veeresh, H. (2021). Influence of Moisture Stress and Dates of Sowing on the Performance of Heat Tolerant Maize Genotypes. *Biological Forum – An International Journal*, *13*(4): 659-664.