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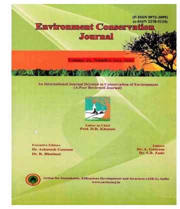

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Performance of heat resilient maize hybrids to different levels of fertilizers in Tungabhadra Project command area

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ABSTRACT

The high temperature and heat stress are the main factors that limit the optimum yield of maize in tropical countries. Improvement in the agronomic practices is need of the hour to overcome heat stress in maize hence the experiment was conducted to study the response of heat resilient maize hybrids to different fertilizer levels on nutrient uptake, dry matter production and yield. It was laid out in split plot design and replicated thrice. Main plot includes genotypes (*viz*., RCRMH-2, RCRMH-3, RCRMH-11 and Cargill 900M Gold) and sub plots with three fertilizer levels (*viz*., 75 % Recommended Dose of Fertilizer (RDF), 100 % RDF and 125 % RDF. The 100 % RDF was 187.5:75:37.5 kg NPK ha^{-1}). Results revealed that significantly higher grain yield was recorded by genotype, RCRMH-3 (5841 kg / ha) and RCRMH-2 (5627 kg / ha) and suitable for summer seasons as compared to RCRMH-11 (5139 kg / ha) and Cargill 900M Gold (4695 kg / ha). Among the fertilizer levels, increase in fertilizer levels from 75 (4922 kg / ha) to 100 % (5365 kg / ha) increased the grain yield significantly and further increase to 125 % RDF (5689 kg / ha), there is no significant differences among the treatments. These treatments also showed similar effects with respect to growth and yield parameters contributing for the higher yield and monetary benefits.

Introduction

Maize is the major crop grown under diverse environment conditions. Due to its greater degree of adaptability and higher productivity maize is grown in commercial scale. It is mainly consumed by humans, serves as fodder to livestock and raw material in many processing industries (Hearn, 2014) and hence it stands as third most important food grain in India after wheat and rice. In India scenario, 28% of maize produced is used for food purpose, 11% for livestock feed, 48% as feed for birds, 12% in wet milling industry (e.g. starch and oil production) and only 1% for seed purpose (Anon., 2017). In tropical areas, where temperature rise has become a major problem, the heat stress conditions is the limiting factor affecting yield and productivity of maize (Sultan and Gaetani, 2016). Reduction in crop production and yield will be due to change in microclimate due to high temperatures which have adverse effect on the plant physiology. The heat stress caused due to rise in temperature above 30 ^{0}C have adverse effect on the physiological processes (Jagadish *et al*., 2011), such as higher respiration rate, shortening of plant life cycle, reduced light interception, hampered photosynthesis and higher pollen sterility (Vani *et al*., 2001). Increase in heat stress two weeks before flowering have adverse effect on yield due to leaf firing by premature damage to the leaf tissue (Jagadish *et al.,* 2011), accelerated leaf senescence rate (Lobell *et al.,* 2012) and early lodging of plants. The heat stress will cause tassel blasting which reduces the production of pollen, reduced

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pollen viability and pollination rate when high temperature occurs at the on-set of flowering (Meseka *et al.,* 2018). Heat stress during grain-filling stage leads to reduced grain-filling period, lower kernel set and reduced grain weight (Pradhan *et al*., 2012), causing reduction in 10% grain yield. For every increase in temperature over 30 ^{0}C, 1 per cent reduction in yield of the crop and by 1.7 per cent grain yield under drought stress conditions (IPCC, 2007). The combination of both drought and heat stress will affect 40 per cent yield reduction (Lobell *et al.,* 2011; Lobell and Schlenker, 2011). The climate change impacts will be more for the less resilient impoverished countries. This change in environmental conditions will reduce 10 to 20 per cent yield reduction in maize until and unless new agronomic practices will come to help in food security (Lobell, 2008; Pye-smith, 2011). The genotypic response to heat stress during reproductive stage reduced the grain yield to an extent of 50% (Saifi *et al*., 2018). This was owing to a stronger inhibitory effect during vegetative development on physiological variables such as crop growth rate, average net assimilation rate, and harvest index of the three cultivars. The sterility will increase with the increase in temperature. Under high temperature conditions, there will be decrease in chlorophyll content and it will have adverse effect on photosynthesis (Abdel-Rasoul *et al.,* 2009; Chaves *et al*., 2013). The agronomic impacts of climate change will depend principally on how well the agriculture crops can adapt to these conditions. Sowing hybrid maize after January or when the tasseling coincides with high temperature during March induce male sterility and yield will be drastically reduced (Muneeb *et al*., 2017).

The use of adequate and balanced level of fertilizer will help for the increased and profitable crop production (Dejene Getahun *et al*., 2020). The availability of nutrients at right time during the crop requirement will help for higher yield and crop productivity. The precise release of nutrients to the crop without wastage causing environmental problem is necessary for sustainable development (Wu and Liu, 2008). The environmental factors and plant genetic capacity influence on the nutrient uptake and yield functions (Koocheki and Khajehosseini, 2008). The fertilizer level and uptake influence the grain yield and protein in maize. The fertilizer use has met the nutrient demand of the crops but over long run the use of chemical fertilizer has led to environmental pollution and ecological instability (Iqbal *et al*., 2013; Dibaba *et al*., 2013). The amount of nitrogen, phosphorous ad potassium has positive effect on the protein content of maize (Cai *et al*., 2012). The nitrogen has increased effect on number of grains per cob, weight of grain and yield in different maize hybrids. Muhammad *et al*. (2018) observed that application of potassium had significantly ($P \leq 0.05$) affected on the crop phenology growth (plant height) and yield traits, biological and yield of maize. The physiological traits like leaves number, length of leaf and width, and dry matter production of the plant increases with increased fertilizer levels (Mousavi *et al*., 2019; Barker, 2012; Gao *et al.,* 2020; Pepó and Karancsi, 2017; Hejazi *et al*., 2013). Jadhav (2018) reported that increase in fertilizer dose from 120 kg of nitogen ha^{-1}, 60 kg of phosphorous ha^{-1} and 60 kg of potassium ha^{-1} to 180:90:90 kg / ha of Nitrogen, Phosphorous and potassium had significantly increased the grain yield of maize sown during summer.The systematic effort to develop maize cultivars with heat tolerance was initiated in 2012 under Heat Stress Tolerant Maize for Asia (HTMA) project implemented by International Maize and Wheat Improvement Centre (CIMMYT)-Asia team. In the project, biomarkers and bioassays for heat tolerance as well as genomic regions associated with heat tolerance traits were identified and validated. Using rapid-cycle genomic section (RC-GS) and breeding informatics coupled with DH technology, new heat tolerant germplasms were developed and new generation of heat stress tolerant maize hybrids *viz*., RCRMH-2, RCRMH-3 and RCRMH-11 were developed. Under low input and heat stress conditions the heat resilient maize yield up to 20 to 25 per cent higher than the commercial varieties (Setimela *et al*., 2017). There will be yield advantage of 10 to 25 percent with use of climate-resilient varieties in many maize growing areas of Eastern and Southern Africa (Tesfaye *et al*., 2016; Setimela *et al.,* 2017). The heat tolerant inbreds either resisted or exhibited very little drop in chlorophyll content. Under high temperatures, the chlorophyll content of vulnerable inbreds decreased dramatically. (San *et al.,* 2015).

The tolerance of maize to temperature varies with the genotypes. The mid-day leaf water potential was higher in heat tolerant maize cultivars (3358, FFR-915c and K-8388) than in heat susceptible cultivars (Choko, P-3424 and JX-77). The degree of leaf rolling in heat tolerant cultivars was lower than in heat susceptible cultivars in Japan (Ogata *et al.*, 2016). However, these genotypes need to be evaluated for agronomic managements. The present study was to develop better agronomic management practices for heat resilient maize using different levels of fertilizer dose to increase the yield and profitability.

Material and Methods

During the cropping season, 36.2 mm of rainfall (from January to May) was received. As the crop was grown in irrigated condition, water is not the main constraints but the temperature may be the main factor affected maize genotypes. The maximum temperature was 42 ^{0}C noticed in first forth night of May during which crop was at harvesting stage.

During the 2018 Kharif, field research was carried out at the Main Agricultural Research Station (MARS), University of Agricultural Sciences, Raichur, Karnataka, India, located between 16^o 12 ' North latitude and 77^o 20' East. longitude at an altitude of 389 meters above sea level and falls within Karnataka's North Eastern Dry Zone. The data on weather parameters such as rainfall (mm), mean maximum and minimum temperatures (^{0}C) recorded at the meteorological observatory of the Agricultural Research Station; Siruguppa during the experimental year 2018-19 and the mean of the last 11 years are presented in Table 2. The normal annual rainfall for the past 11 years was 555.9 mm. The highest normal rainfall was received in the month of June (72.2 mm) followed by January (90.1 mm). The total rainfall during 2018-19 was 309.3 mm. The highest monthly rainfall of 76.5 mm was received in September followed by 60.9 mm in June, 56.8 mm in August and 55.4mm in October. The monthly mean maximum temperature ranged from 42 ^{0}C in May to 31^{0}C in December during 2018-19. The months of May, April, March and June were more warmer . The monthly mean minimum temperature ranged from 23^{0}C in November and December to 29^{0}C in May during 2018-19. Experimental site with medium deep black soil and clayey in soil texture. Composite soil sample (0-30 cm) was collected from the experimental site before initiation of the experiment. The soil was air-dried, powdered and allowed to pass through 2 mm sieve and was analyzed for physical and chemical properties. Initial properties of the soil are presented in Table 1.

The heat resilient maize hybrids used are RCRMH-2, RCRMH-3 and RCRMH-11, which are developed in collaboration with CIMMYT-Asia, Hyderabad under HTMA project funded by United States Agency for International Development (USAID). Cargill 900M Gold is medium duration variety released by Syngenta and Monsanto. The experiment was conducted in split plot design having main plot for 4 Genotypes and 1 Check (G_1: RCRMH-2, G_2: RCRMH-3, G_3: RCRMH-11, G_4: CHECK (Cargill 900M Gold)) and subplot containing 3 fertilizer levels F_1: 75% RDF, F_2: 100% RDF, F_3: 125% RDF (RDF: 187.5:75:37.5 NPK kg / ha). Total 12 treatment combinations and 3 replications were followed (table 3).

The recommended doses of fertilizers are applied through application of urea, di-ammonium phosphate and muriate of potash. Complete dose of phosphorus, potassium and half of recommended nitrogen was applied at the time of sowing in seed lines. Remaining half of nitrogen was split in two doses *viz*., 25% applied at 30 DAS and another 25% applied at tasseling stage, respectively.

Observations on the various growth parameters were recorded at 30, 60, 90 DAS and at harvest. The average leaf area was expressed in cm^2 /plant (Stickler *et al*., 1961). Leaf area index (LAI) was calculated by using below mentioned formula given by Watson (1952).

$$\textbf{Leaf area index (LAI)} = \frac{\textbf{Leaf area (cm}^2\textbf{)}}{\textbf{Ground area (cm}^2\textbf{)}}$$

Total N, P and K uptake was calculated for each treatment separately using the following formula and uptake of N, P and K were expressed in kg / ha.

$$\textbf{Nutrient uptake} = \frac{\textbf{Per cent of nutrient concentration}}{\textbf{100}} \textbf{ x Biomass (kg/ha)}$$

Statistical analysis of data

The experimental data collected on various growth and yield components of plant were subjected to Fisher's method of "Analysis of variance"

(ANOVA). Data collected for one season; effect of treatment were statistically analyzed. Whenever F-test was significant for comparison amongst the treatments means an appropriate value of critical differences (CD) was worked out. Otherwise against CD values abbreviation NS (Non-Significant) was indicated.

Results and Discussion

The main objective of the experiment is to develop and evaluate the efficiency of heat resilient maize under varied fertilizer rate. Heat resilient varieties have low yield potential due to heat stress than other regional varieties. The growth parameters were significantly higher in heat resilient maize varieties. RCRMH-3 is heat stress tolerant and drought tolerant medium maturing, single cross maize hybrid which is a multiple disease resistant medium maturing single cross maize hybrid**.**

Table 1: Physico-chemical properties of soil from the experimental site before experiment

SN	Particulars	Value
	Particle size distribution	
1	Sand (%)	21.62
	Silt (%)	23.51
	Clay (%)	54.44
2	Textural class	Clay soil
3	Soil pH (1:2.5)	8.01
4	EC (dSm^{-1})	0.39
5	Organic carbon (%)	0.43
	Available nutrients (kg / ha)	
1	Available nitrogen (N kg / ha)	231.0
2	Available phosphorous (P_2O_5 kg / ha)	24.0
3	Available potassium (K_2O kg / ha)	364.1

Growth components

Leaf area

Leaf area is very important aspect with respect to photosynthesis. Among the genotypes, RCRMH-3 found to significantly higher leaf area (84.22 dm^2/plant) (Table 4) and was significantly superior over Cargill 900M Gold (67.67 dm^2/plant). Among the fertilizer levels, the highest leaf area was recorded in 125 % RDF (82.00 dm2/plant) and was significantly superior over 75 % RDF (71.00 dm^2/plant) (Table 4). Non-significant interaction was observed in leaf area plant^{-1} due to the effect of genotypes and fertilizer levels at all the stages of crop growth.

The increased leaf area may be due to high photosynthetic rate leading to improved plant growth. The heat tolerance in hybrids is due to increased chlorophyll content in leaves with lower MDA content and electrolyte leakage (Kumar *et al*., 2012). Increase in antioxidative capacity in maize will help for the heat tolerance and improved growth (Almeselmani *et al*., 2006; Babu and Devaraj, 2008). Lower production of Reactive Oxygen Species due to enhanced synthesis of ascorbate (asa) and glutathione (GSH) will help the plant for higher adaptation and growth under heat stress (Xu *et al*., 2006).Higher leaf area per plant at higher fertilizer level may be due to increased in cell division, assimilation rate and metabolic activities in plant (Jat, 2006; Kumar and Thakur, 2004; Massey and Gaur, 2006). The leaves number and leave length and breadth will be increased due to application of NPK fertilizers (Arpad *et al*., 2020). The different plant growth stages have different tolerance to heat stress due to number of genes regulating the effect leading to complex mechanisms (Maestri *et al.,* 2002).

Leaf area index (LAI)

The LAI increased progressively with the increase in age and maximum at 90 DAS and declined thereafter upto harvest. The variations in LAI due to genotypes and fertilizer levels were significant at all the growth stages. Among the genotypes RCRMH-3 recorded significantly higher LAI (7.11) (Table 4) and was closely followed by RCRMH-2 (6.78) and these two treatments were on par with each other but significantly superior over Cargill 900M Gold (5.67) (Table 4). RCRMH-11 was on par with RCRMH-3.The highest LAI was recorded in 125 % RDF (6.92) (Table 4) and was significantly superior over 75 % RDF (6.00) but on par when compared to 100% RDF (6.42) (Table 4). The interaction were non-significant.Due to higher leaf area, LAI was higher in hybrids. The genotypes, RCRMH-2 and RCRMH-3 showed higher LAI, indicating the efficiency of these hybrids in covering the land area in short time as compared to Cargill 900M Gold. LAI was higher due to higher rate of nitrogen (Bindhani *et al*., 2007; Meena *et al*., 2007; Oscar and Tollenaar, 2006; Sharar *et al*., 2003). This in turn increases the efficiency of the hybrids in tapping the solar radiation. The higher values of LAI might be associated with increased nutrition, which played an important role in increased cell division and elongation in meristematic tissues. This might be due to increase in leaf number and size of leaves due to higher nitrogen dosage (Zothanmawi *et al.*, 2018).

Dry matter accumulation

RCRMH-3 and RCRMH-2 were on par with each other but recorded significantly higher dry matter accumulation in leaves over RCRMH-11 and Cargill 900M Gold (Table 4). Dry matter accumulation in leaves increased with the advancement in age till 90 DAS and declined thereafter and the data was significant due to different treatments. Among the fertilizer levels, 125 % RDF was recorded highest dry matter accumulation in leaves plant^{-1} and significantly superior over 75 % RDF but on par when compared to 100% RDF (Table 4). The dry matter

Table 2: Monthly meteorological data for the year 2018-19 and the average of 11 years (2007-2018) at Agricultural Research Station, Dhadesugur

Months	Temperature (°C)		Rainfall (mm) 2018-19	Relative humidity (%)	Average rainfall (mm) 2007-2018
	Maximum	Minimum			
June-2018	38	26	60.9	76.10	72.2
July-2018	34	25	22.1	72.26	41.6
August-2018	34	26	56.8	84.52	53.0
September-2018	34	24	76.5	85.97	48.8
October-2018	34	25	55.4	81.16	48.4
November-2018	33	23	1.4	76.80	54.5
December-2018	31	23	0.0	76.55	67.8
January-2019	33	24	0.0	75.10	90.1
February-2019	36	25	0.0	71.21	27.0
March-2019	38	25	0.0	54.74	5.9
April-2019	41	28	19.0	45.73	16.6
May-2019	42	29	17.2	44.26	30.0
Total			309.3		555.9

accumulation in stem followed similar trend with that of leaves. RCRMH-3 (61.87) and RCRMH-2 (59.58) were on par with each other, but recorded significantly higher dry matter accumulation in leaves over RCRMH-11 (54.39) and Cargill 900M Gold (49.73) (Table 4). The difference between RCRMH-11 and Cargill 900M Gold was non-significant. Among the fertilizer levels, highest dry matter accumulation in stem plant^{-1} was recorded in 125 % RDF (60.23) and was significantly superior over 75 % RDF (52.13) but on par with 100% RDF (56.81) (Table 4). The interaction effect between genotypes and fertilizer levels was non-significant at all the crop growth stages. Among the genotypes, RCRMH-3 recorded significantly higher dry matter accumulation in tassel plant^{-1} (4.59) and was closely followed by RCRMH-2 (4.42 and) and these two treatments were on par with each other,but significantly superior over RCRMH-11 (4.03) and Cargill 900M Gold (3.69) (Table 4). Application of 125% RDF recorded significantly higher dry matter accumulation in tassel plant^{-1} (4.47) over 75 % RDF (3.87) but on par with 100% RDF (4.21) (Table 4). Among the genotypes, RCRMH-3 recorded significantly higher dry matter accumulation in cob plant^{-1} (224.83 g) and was closely followed by RCRMH-2 (216.54 g) and these two treatments were on par with each other, but significantly superior over Cargill 900M Gold (180.71 g) (Table 4). The significantly highest dry matter accumulation in cob plant^{-1} was recorded in 125 % RDF (218.90 g) over 75 % RDF (189.46 g) but on par with 100% RDF (206.45 g) (Table 4).

Among the genotypes, RCRMH-3 recorded significantly higher total dry matter production plant^{-1} (325.44 g) and was closely followed by RCRMH-2 (313.42 g) and these two treatments

Table 3: Treatment combinations

Treatments	Genotype	Fertilizer level
T_1: G_1 F_1	RCRMH-2	75% RDF
T_2: G_1 F_2	RCRMH-2	100% RDF
T_3: G_1 F_3	RCRMH-2	125% RDF
T_4: G_2 F_1	RCRMH-3	75% RDF
T_5: G_2 F_2	RCRMH-3	100% RDF
T_6: G_2 F_3	RCRMH-3	125% RDF
T_7: G_3 F_1	RCRMH-11	75% RDF
T_8: G_3 F_2	RCRMH-11	100% RDF
T_9: G_3 F_3	RCRMH-11	125% RDF
T_{10}: G_4 F_1	Cargill 900M Gold	75% RDF
T_{11}: G_4 F_2	Cargill 900M Gold	100% RDF
T_{12}: G_4 F_3	Cargill 900M Gold	125% RDF

were on par with each other, but significantly superior over Cargill 900M Gold (261.57 g) (Table 4). The difference between RCRMH-11 (286.10 g) and Cargill 900M Gold was non-significant. Among the fertilizer levels, the highest total dry matter production plant^{-1} was recorded in 125 % RDF (316.84 g) and was significantly superior over 75 % RDF (274.23 g) but on par when compared to 100% RDF (298.83 g) (Table 4).The number of green leaves plant^{-1} and leaf area were directly proportional to the dry matter accumulation in leaves. The highest dry matter accumulation in leaves of RCRMH-3 and RCRMH-2 was mainly due to their genetic makeup. Further, increase in fertilizer level from 75 % to 125 % RDF increases the dry matter accumulation in leaves due to increase in cell division, assimilation rate and metabolic activities in plant (Mohamed *et al*., 2010). The genotypes, RCRMH-3 and RCRMH-2 were recorded higher dry matter accumulation in stem due to their genetic ability to grow taller and produce thicker stem. Increase in fertilizer level from 75 % to 125 % RDF also recorded higher dry matter accumulation in stem due to increased net assimilation and photosynthetic rate in plants with higher levels of NPK. Variation in dry matter production in different parts of plant and total dry matter accumulation in genotypes may be attributed to better growth and development of genotypes *viz.*, RCRMH-3 and RCRMH-2. In the present investigation, these genotypes attained higher plant height and produced more number of leaves compared to other genotypes. With respect to fertilizer levels, maximum dry matter accumulation was obtained under higher fertilizer level (125% RDF) which may be due to more availability of nutrients from inorganic fertilizers. The 125 % RDF may have supplied better nutrient (NPK) throughout the growing period of the crop. This helped in production of growth promoters like auxin, an important growth promoter that enhanced cell division and elongation that in turn produced the higher dry matter of maize crop (Kumar, 2008; Kurne *et al.,* 2017; Siam *et al.,* 2008). Raju *et al.* (1997) reported that higher doses of nitrogen applied to maize increased its availability and uptake, resulting in production of more photosynthates in terms of dry matter. Likewise, Tomar *et al*. (2017) also observed 100% NPK along with 5 t FYM+ Azotobacter + PSB application recorded significantly higher growth attributes *viz*., plant height (203.6 and 198.9 cm) and dry matter accumulation (265.1 and 269.4 g) during 2010 and 2011 respectively.

Yield components

Significantly higher cob length was recorded in RCRMH-3 (15.19 cm) followed by RCRMH-2 (14.63 cm), RCRMH-11 (13.35 cm) and Cargill 900M Gold (12.21 cm) and they were significant with each other. Application of 125 % RDF recoded significantly higher cob length (14.79 cm) over 75 % RDF (13.94 cm) and was on par with 100% RDF (12.80 cm). The genotype, RCRMH-3 recorded significantly higher number of grains cob^{-1} (451.1) over Cargill 900M Gold (362.5) and RCRMH-11 (396.6), but on par with RCRMH-2 (434.4). 125 % RDF application recorded significantly higher number of grains cob^{-1} (439.2) over 75 % RDF (380.1) and was on par with 100 % RDF (414.2).Among the genotypes, RCRMH-3 recorded significantly higher test weight (30.1 g) and was closely followed by RCRMH-2 (29.0 g) and these treatments were found on par with each other but significantly superior over Cargill 900M Gold (24.2 g). The differences between RCRMH-11 (26.4 g) and Cargill 900M Gold was non-significant. Among the fertilizer levels, application of 125 % RDF recorded significantly higher test weight (29.3 g) and superior over 75 % RDF (25.3 g). However, there is no significance difference between 100% (27.6 g) and 125 % RDF.

Table 4: Growth indices of heat resilient maize hybrids at different growth stages as influenced by fertilizer levels

Treatments	Leaf area (dm^2 /plant)	Leaf area index	DMA in leaves (g /plant)	DMA in stem (g /plant)	DMA in tassel (g /plant)	DMA in cob (g /plant)	TDMA of plant (g /plant)
Genotype (V)							
V_1: RCRMH-2	81.11	6.78	38.89	59.58	4.42	216.54	313.42
V_2: RCRMH-3	84.22	7.11	40.38	61.87	4.59	224.83	325.44
V_3: RCRMH-11	74.22	6.22	35.50	54.39	4.03	197.66	286.10
V_4: Cargill 900M Gold	67.67	5.67	32.46	49.73	3.69	180.71	261.57
Mean	76.80	6.44	36.80	56.39	4.18	204.93	296.63
S.Em. ± C.D. at 5 %	2.42 8.37	0.19 0.66	1.15 3.96	1.16 3.27	0.13 0.45	6.38 22.07	9.23 31.97
Fertilizer levels (F)							
F_1: 75 % RDF	71.00	6.00	34.03	52.13	3.87	189.46	274.23
F_2: 100 % RDF	77.42	6.42	37.08	56.81	4.21	206.45	298.83
F_3: 125 % RDF	82.00	6.92	39.31	60.23	4.47	218.90	316.84
Mean	76.80	6.44	36.80	56.39	4.18	204.93	296.63
S.Em. ± C.D. at 5 %	1.62 4.86	0.18 0.53	0.78 2.34	1.19 2.38	0.09 0.26	4.34 13.0	6.28 18.8
Interaction (V X F)							
a) V x F (V at same level of F) S.Em. ± C.D. at 5 %	3.23 NS	0.45 NS	1.62 NS	2.45 NS	0.25 NS	8.72 NS	12.64 NS
b) V x F (overall) S.Em. ± C.D. at 5 %	3.58 NS	0.35 NS	1.71 NS	2.62 NS	0.19 NS	9.53 NS	13.80 NS

RDF - 187.5:75:37.5 kg NPK ha^{-1} **DAS -** Days after sowing **DMA**-Dry matter accumulation

Among the genotypes, RCRMH-3 (5841 kg / ha) recorded significantly higher grain yield (5841 kg / ha) and was closely followed by RCRMH-2 (5627 kg / ha) and these treatments were on par with each other, but found significantly superior over Cargill 900M Gold (5695 kg / ha) (Table 5). There is no significant difference between RCRMH-11 (5139 kg / ha) and Cargill 900M Gold (5695 kg / ha). With respect to fertilizer levels, significantly higher grain yield (5689 kg / ha) was observed with application of 125 % RDF over 75 % RDF (4922 kg / ha), but on par with 100 % RDF (5365 kg / ha) (Table 5).Significantly higher stover yield was recorded with RCRMH-3 (7497 kg / ha) and RCRMH-2 (7220 kg / ha). These two treatments were on par with each other, but significantly superior over Cargill 900M Gold (6026 kg / ha) (Table 5). The stover yield between RCRMH-11 (6591 kg / ha) and Cargill 900M Gold was on par. Increase in fertilizer dose from 75 % RDF (6317 kg / ha) to 125 % RDF (7299 kg / ha) recorded significantly higher stover yield (Table 5). The difference between to 100 % RDF (6884 kg / ha) and 125 % was on par with each other. Among the interaction effect, there is due to genotypes and fertilizer levels with respect to stover yield was not significant.The improved plant architecture, plant could able to intercept more solar radiation and thus, plant could synthesize more photosynthates and accumulate them in different plant parts (leaves, stem, tassel and cob). This ultimately as a result increase in stover and grain yield. Similar to cob length, the cob girth was also influenced by genotypes and enhanced by nutrients. Hence, the maize hybrids *viz.,* RCRMH-3 and RCRMH-2 showed higher girth at high level of RDF (Saruhan and Sireli, 2005). Genetic character of maize hybrids (RCRMH-3 and RCRMH-2) was the main factor attributed for increase in cob length. Further, application of 125 % or 100 % NPK increased cob length indicated that these hybrids respond for high level of nutrients. Results are in line with the findings of Majid *et al.* (2017) and Patil *et al*. (2018). Application of different nitrogen doses had significant influence the girth of cob in BARI hybrid maize-7 and BARI hybrid maize-9. The cob girth increased with increasing nitrogen levels. BARI hybrid maize-9 produced the highest cob girth (16.67 cm) with application of 345 kg N ha^{-1}, which hasn't significant difference with 230 kg N ha^{-1} (Majid *et al.,* 2017).Patil *et al.* (2018) observed that, application of 200 kg N ha^{-1} recorded significantly higher number of cobs $plant^{-1}$, cob length and cob girth without husk as compared to rest of nitrogen levels (100 and 150 kg N ha^{-1}). Likewise, application of 50 kg P_2O_5 and K_2O recorded significantly higher number of cobs $plant^{-1}$, cob length and cob girth without husk as compared to other treatment. The main factor attributed for increased grains cob^{-1} was the genotypic characters and it further enhanced with the increase in fertilizer levels. During this study, increase in fertilizer dose from 75 % to 125 % increases the uptake of nutrients and its assimilation in plant. This increased the cob length and girth, in turn accommodated more number of grains cob^{-1}. Among the genotypes tried, RCRMH-3 was found to be more efficient genotype followed by RCRMH-2 and RCRMH-11. Similar results were reported by Karasu (2012). The test weight is mainly influenced by the genetic character. Among the genotypes tried RCRMH-3 and RCRMH-2 showed the highest test weight indicating their genetic superiority. Further, they responded to high dose of fertilizers and produced higher cob length and girth. This in turn produced bold and good filled seeds. Thus there was increase in test weight. Similar results were reported by Majid *et al.* (2017).Higher yield of maize hybrids *viz*., RCRMH-3 and RCRMH-2 was due to significantly superior growth and yield parameters *viz*., plant height, number of green leaves per plant, leaf area per plant, leaf area index, leaf area duration, total dry matter accumulation, cob length, cob girth, no. Of grains cob^{-1} and test weight. Application of 100 and 125% RDF has produced higher yield. This might be due to optimum supply of nutrients that enhanced the growth (plant height, number of green leaves per plant, leaf area per plant, leaf area index, leaf area duration, total dry matter accumulation, cob length, cob girth) and yield parameters (number of grains cob^{-1} and 100 seed weight) of maize.The stover yield was closely related to growth attributes such as plant height, number of leaves, leaf area, leaf area index, leaf area duration and total dry matter production. In the present investigation, RCRMH-3 and RCRMH-2 showed higher growth attributes (plant height, number of

Table 5: Grain yield (kg / ha), stover yield (kg / ha) and harvest index (%) of heat resilient maize hybrids as influenced by fertilizer levels

Treatments	Cob length (cm)	Number of grains cob^{-1}	Test weight (g)	Grain yield (kg / ha)	Stover yield (kg / ha)	Harvest index (%)
Genotype (V)						
V_1: RCRMH-2	14.63	434.4	29.0	5627	7220	43.8
V_2: RCRMH-3	15.19	451.1	30.1	5841	7497	43.7
V_3: RCRMH-11	13.35	396.6	26.4	5139	6591	43.8
V_4: Cargill 900M Gold	12.21	362.5	24.2	4695	6026	43.7
Mean	13.84	411.1	27.4	5325	6833	43.8
S.Em. ± C.D. at 5 %	0.43 1.49	12.8 44.2	0.8 2.9	166 574	213 736	0.0 NS
Fertilizer levels (F)						
F_1: 75 % RDF	12.80	380.1	25.3	4922	6317	43.7
F_2: 100 % RDF	13.94	414.2	27.6	5365	6884	43.8
F_3: 125 % RDF	14.79	439.2	29.3	5689	7299	43.8
Mean	13.84	411.1	27.4	5325	6833	43.8
S.Em. ± C.D. at 5 %	0.29 0.88	8.7 26.0	0.5 1.7	113 338	145 434	0.0 NS
Interaction						
a) V x F (V at same level of F) S.Em. ± C.D. at 5 %	0.61 NS	17.4 NS	1.2 NS	225 NS	289 NS	0.5 NS
b) V x F (overall) S.Em. ± C.D. at 5 %	0.61 NS	19.1 NS	1.3 NS	248 NS	318 NS	0.8 NS

RDF - 187.5:75:37.5 kg NPK ha^{-1} **DAS -** Days after sowing

green leaves per plant, leaf area per plant, leaf area index and total dry matter accumulation) at all the stages and finally it was exhibited in the stover yield. On the other hand Cargill 900M Gold recorded the lowest growth attributes, thus recoded lower stover yield.

Harvest index

Among the different genotypes with fertilizer levels. There is no significant difference between harvest index but the values ranged from 0.42 to 0.43 (Table 5).

$$\textbf{Harvest Index} = \frac{\textbf{Grain yield (kg/ ha)}}{\textbf{Biological yield (kg/ ha)}}$$

Nutrient uptake and retention

Significant variations were observed with respect to nitrogen uptake by maize due to different genotypes and fertilizer levels.Among the genotypes, RCRMH-3 (213.70 kg / ha) and RCRMH-2 (205.80 kg / ha) were on par with each other but significantly superior over Cargill 900M Gold (171.76 kg / ha) (Table 6). There is no significant difference in nitrogen uptake among the RCRMH-11 (187.86 kg / ha) and Cargill 900M Gold. Among the fertilizer levels, 125 % RDF recorded significantly higher nitrogen uptake (208 kg / ha) over 75 % RDF (180 kg / ha) and was on par with 100% RDF (196.08 kg / ha) (Table 6). The interaction effect due to genotypes and fertilizer levels on nitrogen uptake was non-significant.

The data on phosphorus uptake by maize due to different genotypes and fertilizer levels was significant. Among the genotypes, RCRMH-3 (34.20 kg / ha) and RCRMH-2 (32.9 kg / ha) were on par with each other but significantly superior over Cargill 900M Gold (27.5 kg / ha) (Table 6).

Table 6: Nutrient uptake (kg / ha) of heat resilient maize hybrids as influenced by fertilizer levels

Treatments	N uptake (kg / ha)	P uptake (kg / ha)	K uptake (kg / ha)	Available nutrients after harvest (kg / ha)		
				N	P_2O_5	K_2O
Genotype (V)						
V_1: RCRMH-2	205.80	32.90	155.02	213.02	19.11	330.01
V_2: RCRMH-3	213.70	34.20	161.05	207.00	18.49	321.03
V_3: RCRMH-11	187.86	30.11	142.01	216.12	19.63	341.02
V_4: Cargill 900M Gold	171.76	27.50	130.01	220.25	20.60	358.11
Mean	194.78	31.21	147.11	213.67	19.43	337.47
S.Em. ±	6.06	0.97	4.58	6.42	0.58	10.10
C.D. at 5 %	20.97	3.36	15.84	NS	NS	NS
Fertilizer levels (F)						
F_1: 75 % RDF	180.02	28.82	136.03	205.00	18.10	323.71
F_2: 100 % RDF	196.08	31.42	148.03	213.02	19.52	336.60
F_3: 125 % RDF	208.02	33.31	157.05	223.01	20.71	352.21
Mean	194.78	31.21	147.11	213.67	19.43	337.47
S.Em. ±	4.12	0.66	3.11	4.47	0.41	7.05
C.D. at 5 %	12.36	1.98	9.33	13.41	1.22	21.14
Interaction						
a) V x F (V at same level of F)						
S.Em. ±	8.24	1.34	6.25	8.91	0.82	14.10
C.D. at 5 %	NS	NS	NS	NS	NS	NS
b) V x F (overall)						
S.Em. ±	9.12	1.50	6.88	9.72	0.88	15.32
C.D. at 5 %	NS	NS	NS	NS	NS	NS

RDF - 187.5:75:37.5 kg NPK ha^{-1} **DAS -** Days after sowing

The differences between RCRMH-2 (32.9 kg / ha) and Cargill 900M Gold (27.5 kg / ha) was non-significant. With respect to fertilizer levels, increase in the fertilizer dose from 75 % RDF (28.8 kg / ha) to 100 % RDF (31.4 kg / ha) recorded significantly higher P uptake and further increase to 125 % RDF (33.3 kg / ha) was non-significant (Table 6). The interaction effect due to genotypes and fertilizer levels on phosphorus uptake was non-significant. Potassium uptake by maize differs significantly by maize genotypes and fertilizer levels. Similar to N and P uptake, the genotypes, RCRMH-3 (161 kg / ha) and RCRMH-2 (155 kg / ha) recorded significantly higher K uptake over Cargill 900M Gold (130 kg / ha) (Table 6). The differences in K uptake between RCRMH-11(142.01 kg / ha) and Cargill 900M Gold was non-significant. Among the fertilizer levels, 125 % RDF (157 kg / ha) recorded on par P uptake with 100 % RDF (148 kg / ha) but significantly higher over 75 % RDF (136 kg / ha) Table 6).The interaction between genotypes and fertilizer levels was found non-significant. The data concerned to available soil nitrogen as influenced by genotypes is non-significant and it varied significantly with fertilizer levels. With respect to fertilizer levels, application of 125 % RDF recorded significantly higher available N in soil (223 kg / ha) over 75 % RDF (205 kg / ha) (Table 6). The difference between available N in soil at 100 % RDF and 125 % RDF was non-significant. Interaction effects between genotypes and fertilizer levels with respect to available N in soil not significant. Significant differences in available soil phosphorus were recorded among fertilizer levels but it was non-significant with genotypes. Application of 125 % RDF (20.7 kg / ha) recorded on par P_2O_5 in soil with 100 % RDF (19.52 kg / ha) but significantly higher over 75 % RDF (18.1 kg / ha) (Table 6). Non-significant interaction was observed with respect to available soil phosphorus due to genotypes and fertilizer levels. Significant differences in available soil potassium were recorded among fertilizer levels but it was non-significant with genotypes. Among fertilizer levels, 125 % RDF recorded significantly higher available K in soil after harvest (352.2 kg / ha) over 75 % RDF (323.71 kg / ha) but on par with 100 % RDF (336.60 kg / ha) (Table 6). Non-significant interaction was observed with respect to the available soil potassium due to genotypes and fertilizer levels. The present investigation revealed that the uptake of nutrients was directly proportional to the fertilizer levels applied to the soil. The amount of nutrients taken up by the crops was affected by the mass of vegetative and reproductive organs and their NPK content. Increase in the uptake of nitrogen, phosphorus and potassium by maize genotypes indicates the efficiency of the genotypes in absorption. Further, increase in growth, yield attributes and yield, indicates its ability to utilize these absorbed nutrients. Application of 250 N kg / ha recorded higher nutrient uptake. Increased N uptake at higher doses resulted in an early development of strong growth and a greater photosynthetic rate, resulting in improved nutrient uptake throughout the crop growth cycle. P uptake was significantly influenced by fertilizer levels. The P uptake was high under 250:125:125 NPK kg / ha. This could be attributed to increased growth and dry matter production, as well as enhanced N uptake, as a result of the application of N. The uptake of K was improved with a higher dose of NPK. This could be owing to the synergistic action of N and K, as well as improved root foraging ability as a result of greater NP application, resulting in higher dry matter production (Srikanth *et al.,* 2009). Significantly higher removal of NPK in 100% NPK + 5 t FYM+ Azotobactor + PSB which was superior to rest of its treatments. Application of 75% NPK along with other parts showed lowest removal of NPK as against 100% NPK with either FYM or biofertilizer. Higher uptake of N, P, and K could be owing to the beneficial effect of combining organic and inorganic nutrients (Tomar *et al.,* 2017). Post-harvest soil available N, P and K were favorably influenced by NPK levels. Increased NPK levels recorded higher soil available N, P and K. Patil *et al.* (2018) opined that the higher nitrogen, phosphorous and potassium levels increased nutrients availability to plants, which resulted into higher values of yield attributes and yield under higher levels of NPK. Nagy (2010) revealed that the NPK fertilizer effects indicate that the fertilizers are different on yield of genotype. Altogether, the findings of this study revealed that different maize cultivars produce differently in response to nitrogen fertiliser treatments (Szeles *et al.,* 2019).

Conclusion

RCRMH-3 and RCRMH-2 maize hybrids are resistant to high temperatures and produce more grain, stover, and economic returns. Thus, they are suitable for summer sowing. The fertilizer dose of 100 % RDF (187.5:75:37.5 kg NPK ha^{-1}) found optimum for both the genotypes. Due to higher dry matter accumulation during the crop's growth stages, resistant genotypes had higher nutrient uptake. For climate change scenarios, heat resistant genotypes are the best option.

Conflict of interest

The authors declare that they have no conflict of interest.

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