Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2021; 10(1): 2055-2060
Received: 29-10-2020
Accepted: 08-12-2020

BS Ganigara
Assistant Professor, Seed Science & Technology, Agriculture College, Bheemarayanagudi. University of Agricultural Sciences, Raichur, Karnataka, India

Shakuntala NM
Professor and Head, Department of Seed Science and Technology, Agriculture College, Raichur. University of Agricultural Sciences, Raichur, Karnataka, India

Basave Gowda
Special Officer (Seeds), National Seed Project (Crops), Seed Unit, University of Agricultural Sciences, Raichur, Karnataka, India

Vijaykumar Kurnalliker
Assistant Professor, Seed Science & Technology, Agriculture College, Raichur. University of Agricultural Sciences, Raichur, Karnataka, India

Srinivas AG
Professor of Entomology, Agriculture College, Raichur. University of Agricultural Sciences, Raichur, Karnataka, India

PH Kuchanur
Professor of Genetics and Plant Breeding, Agriculture College, Bheemarayanagudi. University of Agricultural Sciences, Raichur, Karnataka, India

Ananda N
Assistant Professor of Agronomy, AICRP (Linseed), University of Agricultural Sciences, Raichur, Karnataka, India

Corresponding Author:
BS Ganigara
Assistant Professor, Seed Science & Technology, Agriculture College, Bheemarayanagudi. University of Agricultural Sciences, Raichur, Karnataka, India

Impact of elevated temperature and carbon dioxide on seed production of heat tolerant maize RCRMH-2

BS Ganigara, Shakuntala NM, Basave Gowda, Vijaykumar Kurnalliker, Srinivas AG, PH Kuchanur and Ananda N

Abstract
In scenario of global climate changes, air temperature may increase between 1.4 - 5.8 °C and atmospheric carbon dioxide (CO_2) concentration is predicted to rise from today's value of current 370–550 ppm by 2050 and could reach between 730 and 1010 ppm by 2100. These changes may increase the frequency of extremes, including drought conditions, which will have significant consequences for crop growth and seed production in the future. An investigation was carried out to study the response of elevated carbon dioxide and temperature regimes on seed production of heat tolerant maize RCRMH-2 under Open Top Chamber (OTC's) at Centre for Agro-climatic studies, University of Agricultural Sciences, Raichur, Karnataka during summer season 2019 and 2020. Morphological parameters and pysiological parameter indicated that, maize can be positively affected by CO_2 enrichment and temperature regime, in part, because of improved water relations. The exposure of the crop elevated CO_2 and temperature regime resulted in all the treatments the temperature was more than the threshold temperature (35 °C mean) during the reproductive stage. This might lead to pollen abortion. Also the silk might have dried at in this temperature and relative humidity leads to non seed setting in all the treatments. The results indicated that in summer season (Jan-May) maize exposed to elevated temperature affects the flowering stage during the months of March and April results in wilting, leaf firing and tassel blast leads to non availability of pollen grains for seed set.

Keywords: Heat tolerant, elevated CO_2 and temperature, pollen abortion, tassel blast

Introduction
Maize (Zea mays L.) is the C4 species which is the most extensively grown in the world. Maize production and productivity varies constantly depending on environmental changes. In scenario of global climate changes, air temperature may increase between 1.4 - 5.8°C (Cubasch *et al*. 2001) [11] and atmospheric carbon dioxide (CO_2) concentration is predicted to rise from today's value of current 370–550 ppm by 2050 and could reach between 730 and 1010 ppm by 2100 (Solomon *et al*. 2007). These changes may increase the frequency of extremes, including drought conditions, which will have significant consequences for crop growth and food supply in the future (Easterling *et al*. 2007) [14].

Focus on maize because of the importance of this crop to small holders and have a wide range of uses than other cereal such as human food, as a feed grain, fodder crop, and for hundreds of industrial purposes. The reason for this it broad global distribution, its low price relative to other cereals, its diverse grain types and its wide range of biological and industrial properties (Ammani *et al*. 2012) [4]. By 2050 demand for maize will double in the developing world, and maize is predicted to turn out to be the crop with the greatest production globally, and in the developing world by 2025 (Cairns *et al*. 2012) [7].

Maize is C_4 species capable of using solar energy more effectively and can tolerate relatively high temperature up to a critical value. Both high and low temperatures have a negative effect on the growth and development of maize (Nguyan *et al*. 2009; Chen *et al*. 2012; Ur Rahman *et al*. 2013) [25, 10, 31]. High temperatures can induce an array of morphological, anatomical, physiological and biochemical changes within maize (Cairns *et al*. 2012) [7].

A major challenge ahead for those involved in the seed industry, therefore, is to provide cultivars that can maximize future crop production in a changing climate (Ainsworth *et al*. 2008a; Bruins 2009; Ceccarelli *et al*. 2010). Ainsworth *et al*. (2008b) [2, 9, 3] considered that this will be possible within a decade.

There are very few studies about temperature and CO_2, interaction with each other. High temperature and rising CO_2 level caused by global climate change and water stress which may be a consequence of these were investigated.

Many studies have been conducted to examine the effects of elevated CO_2 and elevated temperature on growth and yield during during *kharif* and *Rabi* season. There is a need for more experimentation on seed production of different crops during summer season under global warming situation. In view of this conducted the experiment during summer and results are discussed here.

Materials and Methods

An investigation was carried out to study the response of elevated levels of CO_2 and temperature regimes on growth, yield and seed quality of maize under Open Top Chamber at Centre for Agro-climatic studies, Main Agricultural Research Station during summer (Jan-May) 2019 and 2020 and the laboratory studies at Seed Unit, University of Agricultural Sciences, Raichur.

Maize hybrid RCRMH-2 was utilized in this study. Male parent (CML 451) and female parent (CAL 1514) were sown as per the staggering followed in hybrid seed production in each OTC and in reference plot with spacing of 60 cm × 20 cm. Four male plants (First day sowing for two plants and third day sowing for two plants) and 16 female plants (seed sown on sixth day) were raised in each OTC with four replications. Such plots were watered regularly and soon after emergence, all the agronomic practices for raising the crop were practiced as per the package of practices of the University of Agricultural Sciences, Raichur.

Treatments Details

T_1: Elevated CO_2 @ 550 ± 25ppm with normal temperature
T_2: Elevated CO_2 @ 550 ± 25 ppm + 2 °C rise in temperature
T_3: Reference open top chamber (Ambient CO_2 @410 ± 25 ppm)
T_4: Ambient CO_2 @ 410 ± 25ppm with 2 °C rise in temperature
T_5: Reference plot (Open field)

To maintain the above said conditions, pure CO_2 mixed with ambient air was supplied to the chambers and maintained at set levels using manifold gas regulators, pressure pipelines, solenoid valves, rotameters, sampler, pump and CO_2 analyzer. The opening and closing of these valves were regulated on the basis of actual concentration of CO_2 within the OTC and the set CO_2 level for that particular OTC which is regulated through linked Program Logic Control (PLC) and Supervisory Control and Data Acquisition (SCADA) system.

Crop measurements

Plant height: Plant height was measured from base of the plant to the collar of flag leaf at harvesting stage and mean height was calculated and expressed in centimeters

Chlorophyll content

The chlorophyll content of five randomly selected plants were measured at 30, 60, 90 DAS and at harvest. Chlorophyll content was estimated by Arnon method.

Five hundred mg of fresh leaf material was taken and ground with help of pestle and mortar with 10ml of 80 percent acetone. The homogenate was centrifuged at 3000 rpm for 15 minutes. The supernatant was stored. The residue was re-exctracted with 5 ml of 80 per cent acetone. The extract was utilized for chlorophyll estimation. Absorbance was recorded at 663 and 645nm in Spectophotometer. The amount of chlorophyll was calculated according to Arnon (1949) [5].

Where
ΔA = Absorbance at respective wavelength
V = Volume of extract (ml)
W = fresh weight of the sample (g)

Number of leaves

Total number of leaves produced was counted from five plants and their average was taken as number of green leaves per plant.

Days to 50 per cent tasseling (Male)

The number of days taken for 50 per cent tasseling in male parent from the date of sowing in each plot was recorded and expressed in number.

5 Days to 50 per cent silking (Female)

The number of days taken to 50 per cent silking in female parent from the date of sowing in each plot was recorded and expressed in number

Seed yield (q/ha)

The F_1 seed yield per plot was recorded in each treatment from three replications. The total yield per hectare was computed from net plot and expressed in quintal per hectre.

Stover yield (q/ha)

The weight of the stocks from net plot area was recorded after complete drying and expressed in quintal per hectre.

The data collected were analysed statistically by the procedure prescribed by Sundarajan *et al.* (1972) [29]. Critical differences were calculated at 1 per cent level, wherever 'F' test was significant.

Results and Discussion

Growth and yield parameters: The plant height and number of leaves of female parent of maize hybrid RCRMH-2 was significantly influenced by variation in CO_2 and temperature at 100 DAS and data is presented in Table 1 and Fig.1.

The highest plant height and maximum number of leaves was observed in elevated CO_2 at 550 ppm followed by elevated CO_2 + elevated temperature (2 °C rise). Significantly lowest plant height was recorded in control plot with ambient CO_2 and temperature. The reason for better growth performance viz., plant height and number of leaves under elevated CO_2 regime as maize is C4 crop which is CO_2 responsive wherein, increased photosynthetic rate and reduced photorespiration was noticed. In contrast, under elevated temperature regime affected photosynthetic apparatus particularly chloroplast and also morphological character of plants such as plant height and number of leaves per plant compared to reference plot. Growth rates of maize can be positively affected by CO_2 enrichment, in part, because of improved water relations. Similar results are noticed by Leipner *et al*. (1999), Adishesha *et al.* (2017) [25, 1] in maize genotypes, and Ira Khan *et al*. (2018) in maize.

The data presented in Table 1 and depicted in Figure 2 showed that significant differences for the days to 50 per cent tasseling in male parental line (CML 451) and 50 per cent silking in female parent(CAL 1514) due to variation in CO_2 and temperature.

Among the different treatments, less number of days to 50 per cent tasseling (63.75, 64.00, 63.88 in 2019, 2020 and pooled mean data, respectively) and 50 per cent silking (60.25, 60.50 and 60.38 in 2019, 2020 and pooled mean data, respectively) observed in elevated CO_2 followed by elevated CO_2 + elevated temperature (2 °C rise). Maximum number of days to 50 per cent tasseling znd 50 per cent silking required in ambient CO_2 + elevated temperature (2 °C rise).

Table 1: Effect of elevated CO_2 and temperature on plant growth and yield parameters of female parent of maize hybrid RCRMH-2

Treatments	Plant height (cm) at harvesting stage			Number of leaves			Days to 50 per cent of tasseling (CAL 451)			Days to 50 per cent of silking		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1 : Elevated CO_2 @ 550 ± 25ppm with normal temperature	131.63	132.02	131.82	14.00	13.98	13.99	63.75	64.00	63.88	60.25	60.50	60.38
T_2 : Elevated CO_2 @ 550 ± 25ppm with 2 ^{O}C rise in temperature	115.60	117.93	116.76	13.45	13.48	13.47	64.75	65.00	64.88	61.25	61.75	61.50
T_3 : Reference open top chamber (410 ppm CO_2)	95.58	98.80	97.19	13.36	13.42	13.39	66.00	66.50	66.25	62.25	62.75	62.50
T_4 : Ambient CO_2 @410 ± 25ppm with 2 ^{O}C rise in temperature	85.45	83.89	84.67	13.05	12.94	12.99	66.50	67.00	66.75	64.50	64.25	64.38
T_5 : Reference plot (Open field)	72.63	74.73	73.68	13.42	13.50	13.46	65.25	65.25	65.25	62.75	63.00	62.88
Mean	100.18	101.47	100.82	13.46	13.47	13.46	65.25	65.55	65.40	62.20	62.45	62.33
S.Em.±	0.76	1.20	0.76	0.08	0.15	0.10	0.39	0.25	0.23	0.45	0.30	0.29
CD @ 1%	3.19	5.00	3.18	0.33	0.61	0.41	1.64	1.04	0.95	1.86	1.23	1.21

Table 2: Influence of elevated CO_2 and temperature on total chlorophyll content and stover yield in female parent of hybrid maize RCRMH-20

Treatments	Total chlorophyll content (mg/g of fresh weight)									Stover yield (q/ha)		
	25 DAS			50 DAS			90 DAS					
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1: Elevated CO_2 @ 550 ± 25ppm with normal temperature	2.13	2.15	2.14	3.24	3.29	3.26	0.90	0.88	0.89	17.86	19.48	18.67
T_2: Elevated CO_2 @ 550 ± 25ppm with 2 ^{O}C rise in temperature	1.95	1.98	1.96	2.88	2.93	2.90	0.76	0.74	0.75	15.94	16.35	16.15
T_3: Reference open top chamber (410 ppm CO_2)	1.75	1.77	1.76	2.49	2.54	2.51	0.55	0.71	0.63	14.17	14.79	14.48
T_4: Ambient CO_2 @410 ± 25ppm with 2 ^{O}C rise in temperature	1.10	1.12	1.11	1.82	1.79	1.80	0.24	0.26	0.25	9.74	11.46	10.60
T_5: Reference plot (Open field)	1.54	1.58	1.56	2.08	2.15	2.11	0.48	0.53	0.50	11.09	12.29	11.69
Mean	1.69	1.72	1.71	2.50	2.54	2.52	0.58	0.62	0.60	13.76	14.87	14.32
S.Em.±	0.02	0.02	0.01	0.02	0.03	0.02	0.01	0.04	0.02	0.20	0.36	0.21
CD @ 1%	0.07	0.09	0.05	0.07	0.12	0.09	0.04	0.18	0.10	0.82	1.08	0. 64

(a) Tassel start drying from tip (b) Tassel blast (c) Dried silk

Plate 2: Effect of elevated CO_2 and temperature in maize hybrid RCRMH-2

T_1: Elevated CO_2 @ 550 ± 25ppm with normal temperature

T_2: Elevated CO_2 @ 550 ± 25 ppm + 2ºC rise in temperature

T_3: Reference open top chamber (Ambient CO_2 @410 ± 25 ppm)

T_4: Ambient CO_2 @ 410 ± 25ppm with 2^oC rise in temperature

T5: Reference plot (Open field)

Plate 2: Effect of Elevated CO_2 and temperature on Cobs in hybrid maize RCRMH-2

Physiological parameters

The data on the chlorophyll content of the maize as influenced by variation in CO_2 and temperature at different growth stages (30, 60, 100 DAS) are presented in Table 2 and Figure.3.

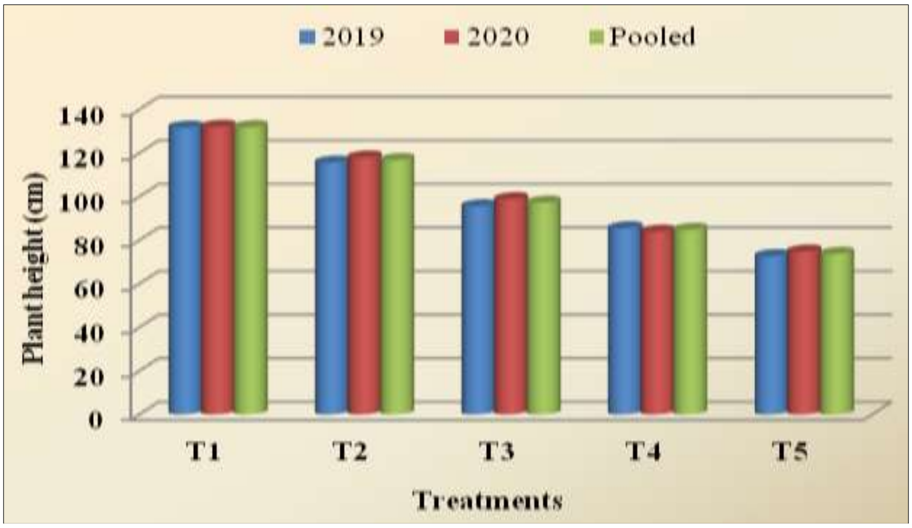


Fig 3: Influence of elevated CO_2 and temperature on plant height (cm) of female parent of maize hybrid RCRMH-2

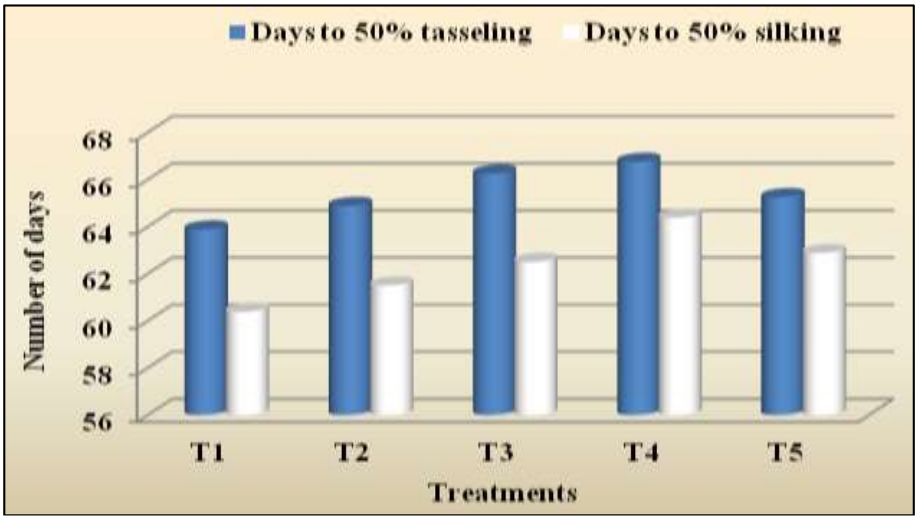
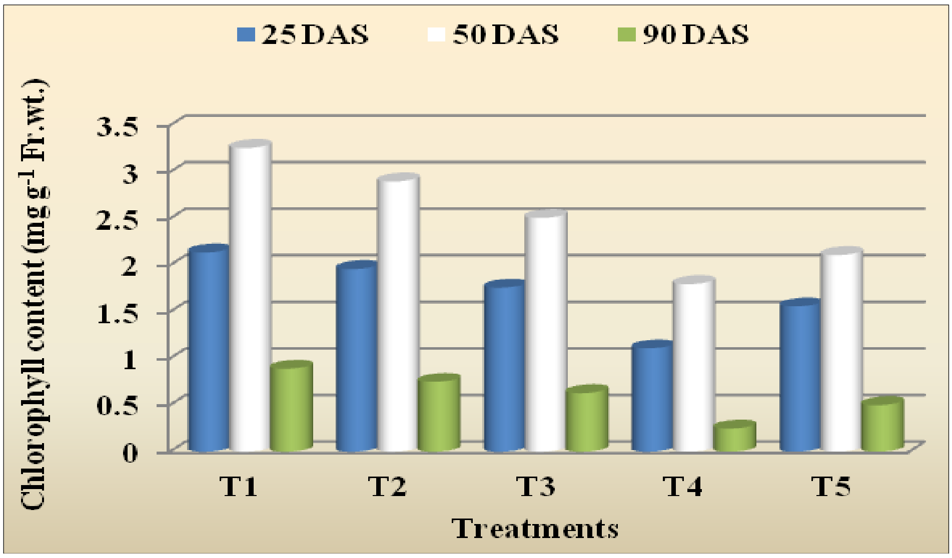


Fig 2: Influence of elevated CO_2 and temperature on days to 50% tasseling and silking of hybrid maize RCRMH-2



T_1: Elevated CO_2 @ 550 ± 25ppm
T_2: Elevated CO_2 @ 550 ± 25ppm temperature in temperature
T_3: Reference open top chamber with normal temperature (410 ppm CO_2)
T_4: Ambient CO_2 @ 410 ± 25ppm with 2°C rise with 2°C rise in
T_5: Reference plot (Open field)

Fig 3: Influence of elevated CO_2 and temperature on total chlorophyll of seed parent of maize hybrid RCRMH-2

Among different treatments, significantly highest chlorophyll content (2.14, 3.26 and 0.89 mg g^{-1} fresh weight in pooled mean data of two years respectively) was recorded at 30, 60 and 100 DAS in T_1 (elevated CO_2). Which was followed by elevated CO_2 with 2 °C rise in temperature (T_2) and lowest chlorophyll content was recorded in ambient CO_2 + elevated temperature(2 °C) (T_4) at all the stages. The increase in chlorophyll content may be due to the maximum utilization of carbon in the tissues which in turn increased the chlorophyll content. This was supported by several authors (Hamid *et al*., 2009, Srivastav *et al*, 2012) [16, 28], Adishesha *et al.* (2017[a]) [1] reported similar results in maize genotypes. Mishra and Agrawal (2014) [24] reported in mung bean.

Further, the pollen viability and silk receptivity was calculated based on number of potential kernels per ear. But due to non availability of pollen grains, there is no seed setting in all the treatments (Plate 2). Seed quality parameters are not discussed here. Probable reasons for non seed setting are disused here.

Tassel blast and silk receptivity

Tassel blast is a typical symptom of heat stress in maize plants. Tassel blast refers to drying of the complete tassel without pollen extrusion (Plate1a and 1 b). It is quite stable, and once symptoms appear, they remain for a long period. Tassel blast and silk receptivity is estimated based on number of fertilized kernels per ear.

The most critical variable in phenological development is temperature and each plant has a specific range of temperature for growth as defined as the upper and lower limit (threshold) and an optimum (Hatfield *et al*., 2011) [17]. For maize during the vegetative stage this has been identified as 8 to 38 °C with an optimum of 34 °C (Badu-Apraku *et al*., 1983 and Kiniry *et al.*, 1991) [6, 22] while the range for the reproductive stage is 8–30 °C. For survival of pollens which are sensitive to temperature, temperature exceeding 35 °C have been proven detrimental to pollen viability (Dupuis and Dumas, 1990 and Herrero and Johnson, 1980) [13, 19]. Productivity of corn is affected by temperatures exceeding 35°C during pollination due to dehydration of the pollen (Hatfield *et al*., 2011) [17].

In the present study period, the maximum temperature recorded was 38.1 °C to 40.8 °C with RH 50.00 to 50.40 per cent in 2019 and 36.4 °C to 39.3 °C with RH 58 to 54 per cent in 2020 during the reproductive stage. The temperature exceeding 35 °C would cause the pollen viability and lead to tassel blast in high temperature and low humidity. In all the treatments the temperature was more than the threshhold temperature during the reproductive stage. This might lead to pollen abortion. Also the silk might have dried at in this temperature and relative humidity leads to non seed setting in all the treatments (Plate 1 C).

Similar findings were noticed in maize, at temperatures above 38 °C and poor seed set in maize was been attributed to both a direct effect of high temperature (Johnson and Herrero, 1981, Carberry *et. al.*, 1989) [20, 8] and pollen desiccation (Schoper *et al*. 1986; Lonnquist and Jugenheimer 1943) [27, 23]. Diurnal max/min day/night temperature of 40/30 °C (35 °C mean) cause zero yield in maize (Hatfield and Prueger, 2015) [18]. Subjecting plants to a more intense heat stress (generally greater than 4 °C above optimum) resulted in severe yield loss extending to complete crop failure. (Ghosh *et al*., 2000: Sato *et al*., 2000: Kadir *et al*., 2006 and Tesfaendrias *et al*., 2010) [15, 26, 21, 30].

Conclusion

The effect of increased temperature exhibit a larger impact on seed set than on vegetative growth. During Summer season (Jan-May) maize exposed to elevated temperature affects the flowering stage during the months of March and April results in wilting, leaf firing and tassel blast leads to non availability of pollen grains for seed set. According to future scenarios, this situation showed that elevated CO_2 and temperature brought about the increase in maize biomass.

References

1. Adishesha, Janagoudar BS, Amaregouda A. Biochemical response of maize (*Zea mays* L.) genotypes to elevated carbon dioxide and temperature regimes. Journal of Pharmaognosy and Phytochemistry 2017b;6(5):511-518.

2. Ainsworth EA, Rogers A, Leakey ADB. Targets for crop biotechnology in a future high-CO_2 and high-O3 world. Plant Physiology 2008a;147:13-19.
3. Ainsworth EA, Beier C, Calfapietra C, Ceulemans R, Durand-Tardif M, Farquhar GD *et al*. Next generation of elevated CO_2 experiments with crops: a critical investment for feeding the future world. Plant, Cell and Environment 2008b;31:1317-1324.
4. Ammani AA, Ja'afaru AK, Aliyu JA, Arab AI. Climate Change and Maize Production: Empirical Evidence from Kaduna State, Nigeria. Journal of Agricultural Extension 2012;16(1):1-8.
5. Aron D. Copper enzymes isolated chloroplasts, polyphenoloxidase in Beta vulgaris. Plant Physiology 1949;24:1-15.
6. Badu-Apraku B, Hunter RB, Tollenaar M. Effect of temperature during grain filling on whole plant and grain yield in maize (*Zea mays* L.). Canadian J Plant Sci 1983;63:357-363
7. Cairns JE, Sonder K, Zaidi PH, Verhulst PN, Mahuku G, Babu R *et al*. Maize production in a changing climate: Impacts, adaptation, and mitigation strategies. Advances in Agronomy 2012;114:1-65.
8. Carberry PS, Muchow RC, McCown. Testing the CERES-Maize simulation model in semi-arid tropical environment. Field Crops Res 1989;20:297-315.
9. Ceccarelli S, Grando S, Maatougui M, Michael M, Slash M, Haghparast R *et al*. Plant breeding and climate changes. Journal of Agricultural Science, Cambridge 2010;148:627–637.
10. Chen J, Xu W, Velten J, Xin Z, Stout J. Characterization of maize inbred lines for drought and heat tolerance. Journal of Soil and Water Conservation 2012;67(5):354-364.
11. Cubasch U, Meehl GA, Boer GJ, Stouffer RJ, Dix M, Noda A *et al*. Projections of future climate change, in Climate Change, The Scientific Basis: Contribution of WGI to the Third Assessment Report of the IPCC, edited by J.T. 2001.
12. Houghton *et al*. Cambridge Univ. Press, New York 2001,525-582.
13. Dupuis L, Dumas C. Influence of temperature stress on in vitro fertilization and heat Shock protein synthesis in maize (*Zea mays* L.) reproductive systems. Plant Physiology 1990;94:665-670.
14. Easterling WE, Aggarwal PK, Batima P, Brander KM, Erda L, Howden SM *et al*. Food, fibre and forest products. Climate Change, Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, Eds., Cambridge University Press, Cambridge, UK 2007,273-313.
15. Ghosh SCA, Koh, Ichiro, Kusutani, Akihito, Toyota, *et al*. Effects of temperature at different growth stages on nonstructural carbohydrate, nitrate reductase activity and yield of potato. Environ. Control Biol 2000;38:197–206.
16. Hamid N, Jawaid F, Amin D. Effect of short- term exposure to two different carbondioxide concentrations on growth and some biochemical parameters of edible beans.(*Vigna radiata* and *Vigna unguiculata*) Pak. J. Bot 2009;41(4):18311836.
17. Hatfield JL, Boote KJ, Kimball BA, Ziska LH, Izaurralde RC, Ort D *et al*. Climate impacts on agriculture: Implications for crop production. Agronomy J 2011;103:51-370.
18. Hatfield JL, Prueger JH. Temperature extremes: Effect on plant growth and development. Elsevier. Weather and climate extremes 2015,1-7.
19. Herrero MP, Johnson RR. High temperature stress and pollen viability in maize. Crop 1980;20:796-800.
20. Johnson R, Herrera MP. Corn pollination under moisture and high temperature stress. Proceedings of the corn and sorghum Industry research conference, Chicago, (American seed Trade Association, Washington, DC 1981,66-77.
21. Kadir S, Sidhu G, Al-Khatib ~ K. Strawberry (*Fragariaananassa* duch.) growth and productivity as affected by temperature. Hort Science 2006;41:1423-1430.
22. Kiniry JR, Bonhomme R. Predicting maize phenology. In: Hodges T, editor. Predicting Crop Phenology. Boca Raton, FL: CRC Press, 1991,115-131p.
23. Lonnquist JH, Jugenheimer RW. Factors affecting the success of pollination in corn. Journal of Am. Soc. Agron 1943;35:923-933.
24. Mishra AK, Agrawal SB. Cultivar specific response of CO_2 fertilization on two tropical mung bean (*Vigna radiata* L.) cultivars: ROS generation, antioxidant status, physiology, growth, yield and seed quality. J. Agro. Crop Sci 2014, ISSN 0931-2250.
25. Nguyan HT, Leipner J, Stamp P, Guerra-Peraza O. Low temperature stress in maize (*Zea mays* L.) induces genes involved in photosynthesis and signal transduction as studied by suppression subtractive hybridization. Plant Physiology and Biochemistry 2009;47(2):116-122.
26. Sato S. The effects of moderately elevated temperature stress due to globalwarming on the yield and the male reproductive development of tomato (*Ly-copersicon esculentum mill.).* Hort Research 2003;60:85-89.
27. Schoper JB, Lambert RJ, Vasilas BL. Maize pollen viability and ear receptivity under water and high temperature stress. Crop Science 1986;26:1029-1033.
28. Srivastav N, Dheer Singh, Alok Shukla SK, Guru Munna Singh, Rana DS. Effect of high temperature stress at post anthesis stage on photo system II, senescence, yield and yield attributes of wheat genotypes. Indian J. Plant Physiol 2012;17(2):158-165.
29. Sundarajan N, Nagaraju S, Venkataraman S, Jaganath MH. Design and analysis of field exp., Univ. Agric. Sci., Bangalore. Karnataka, India, 1972.
30. Tesfaendrias MT, McDonald MR, Warland J. Consistency of long-termmarketable yield of carrot and onion cultivars in muck (organic) soil in relationto seasonal weather. Can. J. Plant Sci 2010;90:755-765.
31. Ur Rahman S, Arif M, Hussain K, Hussain S, Mukhtar T, Razaq A *et al*. Evaluation of Maize Hybrids for Tolerance to High Temperature Stress in Central Punjab. Columbia International Publishing American Journal of Bioengineering and Biotechnology 2013;1(1):30-36.