International Journal of Food, Agriculture and Veterinary Sciences ISSN: 2277-209X (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jfav.htm
2015 Vol. 5 (2) May-August, pp. 92-97/Manzoor and Jayalalitha
Research Article

EFFECT OF WATERLOGGING ON BIOCHEMICAL PARAMETERS AND YIELD IN MAIZE HYBRIDS

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ABSTRACT
A field experiment was conducted at Agricultural College Farm Bapatla, during *kharif* 2014-15 to study the effect of waterlogging on biochemical parameters and kernel yield in maize hybrids. The results of the study revealed that waterlogging for six days decreased the SPAD chlorophyll meter reading (SCMR), total chlorophyll and total sugars by 13.38, 20.19 and 20.33 percent respectively over control at 36 days after sowing (DAS)(*i.e.,* immediately after relieving waterlogging stress) and by 22.98, 14.68 and 21.03 per cent at 46 DAS (*i.e.,*10 days after relieving waterlogging stress). Superoxide dismutase (SOD) activity was increased by 65.71 and 38.61 percent at 36 DAS and 46 DAS respectively over control. Water logging for six days decreased the kernel yield by 48.26 per cent over control. Among the hybrids, Lakshmi-2277 maintained higher SCMR values, total chlorophyll, total sugars and higher SOD activity apart from higher yield under waterlogging condition followed by Bharati-99 where as CN-117 recorded lower values of all the above parameters. Hence, the maize hybrid Lakshmi-2277 followed by Bharati-99 are considered to possess waterlogging tolerance among the eight hybrids studied.

Keywords: *Maize, Biochemical Traits, Total Sugars, Total Chlorophyll, SCMR, SOD Activity, Waterlogging*

INTRODUCTION
Maize [*Zea mays* L.] is the third most important cereal crop after rice and wheat and is known as "queen of cereals" because it has the highest genetic yield potential among the cereals. Maize ranks first in world production (868 Mt from 168 M ha) followed by wheat (691 Mt) and rice (461 Mt). This represents 38% of the total grain production as compared to 30 % for wheat and 20% for rice (Farmers Portal). In South and Southeast Asia alone, over 18% of the total maize growing areas are frequently affected by floods and water-logging problems (Zaidi *et al.*, 2009). Out of the total 6.6 M ha area of maize, about 2.5 M ha is affected by excess soil moisture (ESM) problem that causes on an average 25-30% loss of national maize production almost every year (Rathore *et al.,* 1996). Waterlogging decreased total chlorophyll content, nitrate reductase activity, total leaf soluble sugar and grain yield of all maize genotypes (Prasad *et al.*, 2004). Keles and Oncel (2000) reported that waterlogging stress increased superoxide dismutase (SOD) activity by 50 per cent in all genotypes of wheat and also suggested that increase in SOD activity is vital in the protection of plants against oxidative stress. Keeping these aspects in view, the present study was taken up to study the effect of water logging on biochemical parameters and kernel yield in maize hybrids.

MATERIALS AND METHODS
A field experiment was conducted at Agricultural College Farm, Bapatla during *kharif* 2014-15. The experiment was laid out in sandy clay loam soil in a split plot design with two main treatments and eight maize hybrids as sub plots and replicated thrice. Treatments consisted of waterlogging treatments as main plots, M_1- Control (No waterlogging), M_2 -Waterlogging for 6 days (at knee height stage *i.e.*, 30 DAS) and maize hybrids as subplots (*viz*., 33A96, King-3063, Bharati-99, Sandya-666, Lakshmi-2277, CN-117, JKMH-4545 and SY-280). The plot size was 4mx3m with spacing of 60cmx20cm. Waterlogging stress was imposed at knee height stage *i.e.*, at 30 DAS for six days (from 30 to 35 DAS) and control plants were maintained under normal irrigation. Waterlogging was administered by applying heavy irrigation to the plots and the soil was kept saturated with water above field capacity by continuous flooding, usually

every day twice to create an oxygen deficient environment. The crop was grown following the recommended package of practices and timely plant protection measures were also adopted. The data on yield and yield components were recorded separately plot wise at harvest and analyzed as per the standard statistical procedures described by Gomez and Gomez (1984).The SCMR values were recorded by using SPAD chlorophyll meter at 30 DAS(*i.e.*, before imposition of waterlogging), 36 and 46 DAS. The biochemical parameters like total chlorophyll (Hiscox and Israelstam, 1979), total sugars (Somogyi, 1952) and SOD activity (Dhindsa *et al.*, 1981) were estimated by standard methods at 30, 36 and 46 DAS.

RESULTS AND DISCUSSION

No significant differences were observed between main treatments, maize hybrids and their interactions also at 30 DAS, while at 36 DAS, significant differences were observed between main treatments, maize hybrids and their interactions pertaining to biochemical parameters. At 46 DAS, significant differences were observed between main treatments and maize hybrids but the interaction was non-significant (Table 1). Waterlogging treatment significantly reduced the total chlorophyll content (0.83 and 0.93 mg/g) at 36 and 46 DAS respectively, over control plants (1.04 and 1.09).

Waterlogging treatment reduced the total chlorophyll content by 20.19 and 14.68 per cent at 36 and 46 DAS respectively, over control plants. The reduction in chlorophyll content values might be due to the increased chlorophyll degradation and decreased chlorophyll synthesis under excess moisture conditions (Kumutha *et al.*, 2008). Similar results were also reported in maize by Asha and Pandey (2007) and Ajaz and Warsi (2009) and winter rape (Zhou *et al.*, 1997). Among the hybrids tested, Lakshmi-2277 recorded higher total chlorophyll content (0.97 and 1.06 mg/g) at 36 and 46 DAS, respectively and it was on a par with all other hybrids except CN-117.

The lower total chlorophyll content was recorded by CN-117 (0.85 and 0.97 mg/g) at 36 and 46 DAS respectively. Among the interactions, under waterlogging condition, the maize hybrids Lakshmi-2277 and SY-280 recorded higher total chlorophyll content where as CN-117 recorded lower total chlorophyll content. Under non-waterlogging condition, CN-117 and 33A96 recorded higher total chlorophyll content, where as Lakshmi-2277 recorded lower total chlorophyll content.

At 36 and 46 DAS waterlogging treatment showed reduction in SCMR values (42.33 and 45.07) respectively over control plants (48.87 and 58.52). Waterlogging treatment reduced the SCMR values at 36 and 46 DAS by 13.38 and 22.98 per cent respectively over control plants (Table 2). The reduction in SCMR values was attributed to the reduction in chlorophyll content under excess moisture conditions due to increased chlorophyll degradation and decreased chlorophyll synthesis (Kumutha *et al.*, 2008). Similar results were also reported in brassica (Asharaf and Mehmood, 1990) and maize (Asha and Pandey, 2007; Ajaz and Warsi, 2009).

Among the hybrids tested, Lakshmi-2277 recorded higher SCMR values (47.84 and 54.30) at 36 and 46 DAS respectively and it was on a par with Bharati-99, JKMH-4545, Sandya-666 and SY-280. The lower SCMR values were recorded by CN-117 (42.19 and 49.15) at 36 and 46 DAS, respectively. Among the interactions, under waterlogging condition, Lakshmi-2277, Bharati-99 and SY-280 maintained higher SPAD chlorophyll meter readings, where as CN-117 maintained lower SPAD chlorophyll meter readings. Under non-waterlogging condition, Lakshmi-2277 and Sandya-666 maintained higher SPAD chlorophyll meter readings, where as CN-117 maintained lower SPAD chlorophyll meter readings.

The SOD activity gradually increased after waterlogging treatment. The maximum SOD activity was found at 36 DAS (*i.e.*, immediately after relieving water logging stress) in waterlogged plants (Table 3). At 36 and 46 DAS waterlogging treatment showed significant increase in SOD activity (1.74 and 1.40 mg^{-1} protein h^{-1}) respectively over control plants (1.05 and 1.01 mg^{-1} protein h^{-1}). Waterlogging treatment increased the SOD activity at 36 and 46 DAS by 65.7 and 38.6 per cent respectively over control plants. SOD activity is vital in the protection of plants against oxidative stress caused by waterlogging. The increase in antioxidant enzyme activities like SOD during waterlogging is primarily to take care of post hypoxia oxidative stress.

Table 1: Effect of waterlogging on total chlorophyll (mg/g fresh weight) in maize

Name of the Hybrid	30 DAS			36DAS			46DAS		
	Control	Waterlogging	Mean	Control	Waterlogging	Mean	Control	Waterlogging	Mean
33A96	0.83	0.80	**0.82**	1.06	0.80	**0.93**	1.07	0.90	**0.98**
King-3063	0.85	0.85	**0.85**	1.02	0.85	**0.93**	1.10	0.92	**1.01**
Bharati-99	0.82	0.84	**0.83**	1.04	0.88	**0.96**	1.08	0.96	**1.02**
Sandya-666	0.87	0.86	**0.87**	1.03	0.81	**0.92**	1.07	0.90	**0.98**
Lakshmi-2277	0.88	0.86	**0.87**	1.01	0.93	**0.97**	1.12	1.00	**1.06**
CN-117	0.86	0.84	**0.85**	1.09	0.61	**0.85**	1.09	0.86	**0.97**
JKMH-4545	0.89	0.83	**0.86**	1.04	0.86	**0.95**	1.13	0.92	**1.02**
SY-280	0.81	0.83	**0.82**	1.02	0.89	**0.96**	1.11	0.98	**1.04**
Mean	**0.85**	**0.84**		**1.04**	**0.83**		**1.09**	**0.93**	
	Main	**Hybrids**	**Interaction**	**Main**	**Hybrids**	**Interaction**	**Main**	**Hybrids**	**Interaction**
SEm	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.01
CD (5%)	NS	NS	NS	0.02	0.05	0.02	0.03	0.05	NS
CV	3.87	4.20		3.37	4.93		3.78	4.03	

Table 2: Effect of waterlogging on SPAD chlorophyll meter reading (SCMR) in maize

Name of the Hybrid	30 DAS			46 DAS			90 DAS		
	Control	Waterlogging	Mean	Control	Waterlogging	Mean	Control	Waterlogging	Mean
33A96	8.80	10.07	**9.43**	12.87	11.33	**12.10**	11.67	9.80	**10.73**
King-3063	9.33	9.33	**9.33**	13.53	10.93	**12.23**	11.93	9.53	**10.73**
Bharati-99	9.27	9.47	**9.37**	12.87	11.33	**12.10**	11.40	9.80	**10.60**
Sandya-666	9.27	9.40	**9.33**	12.80	11.20	**12.00**	11.47	9.47	**10.47**
Lakshmi-2277	9.67	9.00	**9.33**	13.33	11.20	**12.27**	12.07	9.60	**10.83**
CN-117	8.27	7.87	**8.07**	12.00	9.27	**10.63**	10.93	7.80	**9.37**
JKMH-4545	8.87	9.67	**9.27**	13.20	11.20	**12.20**	11.60	9.93	**10.77**
SY-280	8.67	9.80	**9.23**	12.93	11.47	**12.20**	11.47	9.47	**10.47**
Mean	**9.02**	**9.33**		**12.94**	**10.99**		**11.57**	**9.43**	
	Main	**Hybrids**	**Interaction**	**Main**	**Hybrids**	**Interaction**	**Main**	**Hybrids**	**Interaction**
SEm	0.22	0.37	0.16	0.27	0.31	0.17	0.18	0.26	0.12
CD (5%)	NS	NS	NS	0.92	0.90	NS	0.63	0.77	NS
CV	11.96	9.90		10.86	6.32		8.47	6.15	

Table 3: Effect of waterlogging on SOD activity (units mg^{-1} protein h^{-1}) in maize

Name of the Hybrid	30 DAS Control	Waterlogging	Mean	36DAS Control	Waterlogging	Mean	46DAS Control	Waterlogging	Mean
33A96	1.06	1.04	**1.05**	1.01	1.78	**1.39**	0.92	1.38	**1.15**
King-3063	1.05	0.97	**1.01**	1.08	1.61	**1.35**	0.99	1.34	**1.17**
Bharati-99	1.01	1.02	**1.01**	1.06	1.87	**1.46**	1.03	1.48	**1.25**
Sandya-666	1.03	1.08	**1.05**	1.06	1.69	**1.37**	1.03	1.40	**1.21**
Lakshmi-2277	1.05	1.03	**1.04**	1.04	1.89	**1.46**	1.04	1.45	**1.24**
CN-117	1.01	1.03	**1.02**	1.02	1.60	**1.31**	0.99	1.33	**1.16**
JKMH-4545	1.06	1.03	**1.04**	1.07	1.67	**1.37**	1.02	1.35	**1.18**
SY-280	1.06	1.00	**1.03**	1.08	1.80	**1.44**	1.05	1.49	**1.27**
Mean	**1.04**	**1.02**		**1.05**	**1.74**		**1.01**	**1.40**	
	Main	**Hybrids**	**Interaction**	**Main**	**Hybrids**	**Interaction**	**Main**	**Hybrids**	**Interaction**
SEm	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.01
CD (5%)	NS	NS	NS	0.02	0.07	0.02	0.03	0.06	NS
CV	3.65	3.91		2.52	3.98		3.04	3.89	

Table 4: Effect of waterlogging on total sugars (mg g^{-1} dry weight) and kernel yield (Kg ha^{-1}) in maize

Name of the Hybrid	30 DAS Control	Waterlogging	Mean	36DAS Control	Waterlogging	Mean	46DAS Control	Waterlogging	Mean	Kernel yield Control	Waterlogging	Mean
33A96	18.29	17.85	**18.07**	19.43	15.61	**17.52**	20.94	16.52	**18.73**	4640.28	2011.94	**3326.11**
King-3063	17.74	18.43	**18.08**	19.62	15.44	**17.53**	21.34	16.51	**18.92**	4873.61	1841.11	**3357.36**
Bharati-99	18.81	18.16	**18.49**	20.16	16.29	**18.23**	21.59	17.27	**19.43**	4848.61	2875.56	**3862.08**
Sandya-666	18.09	18.20	**18.15**	19.71	15.61	**17.66**	20.85	16.91	**18.88**	4192.78	1727.78	**2960.28**
Lakshmi-2277	18.00	18.73	**18.37**	20.02	16.79	**18.41**	21.69	17.38	**19.54**	4741.39	3018.89	**3880.14**
CN-117	17.57	18.63	**18.10**	19.55	14.68	**17.12**	21.18	15.61	**18.39**	4076.11	1795.83	**2935.97**
JKMH-4545	18.83	19.00	**18.91**	19.68	15.79	**17.74**	21.29	17.01	**19.15**	4566.67	2548.33	**3557.50**
SY-280	18.50	17.83	**18.17**	20.42	16.13	**18.27**	21.49	17.32	**19.41**	4560.83	3065.00	**3812.92**
Mean	**18.23**	**18.35**		**19.82**	**15.79**		**21.30**	**16.82**		**4562.53**	**2360.56**	
	Main	**Hybrids**	**Interaction**	**Main**	**Hybrids**	**Interaction**	**Main**	**Hybrids**	**Interaction**	**Main**	**Hybrids**	**Interaction**
SEm	0.10	0.29	0.09	0.13	0.23	0.09	0.16	0.36	0.13	68.66	165.50	58.07
CD (5%)	NS	NS	NS	0.44	0.68	NS	0.55	NS	NS	237.61	483.09	NS
CV	2.73	3.82		3.48	3.22		4.08	4.58		9.72	11.71	

The increased SOD activity not only helps in scavenging the post hypoxic reactive oxygen species (ROS) build up which causes lipid peroxidation and denaturation of proteins and nucleic acids, but also to detoxify cellular system of ROS produced during hypoxia itself. Similar results were also reported in rape plants (Balakhnina *et al.,* 2012), in pigeonpea (Kumutha *et al.,* 2009) and wheat (Keles and Oncel, 2000). Among the hybrids tested, Lakshmi-2277 recorded higher SOD activity (1.46 mg^{-1} protein h^{-1}) at 36 DAS and it was on a par with Bharati-99, SY-280 and 33A96. The lower SOD activity was recorded by CN-117 (1.31 mg^{-1} protein h^{-1}) at 36 DAS. At 46 DAS (*i.e*., 10 days after relieving water logging stress) SY-280 recorded higher SOD activity (1.27 mg^{-1} protein h^{-1}) and it was on a par with Lakshmi-2277 and Bharati-99. The lower SOD activity was recorded by 33A96 (1.15 mg^{-1} protein h^{-1}). Among the interactions, under waterlogging condition, Lakshmi-2277 and Bharati-99 maintained higher SOD activity, whereas CN-117 maintained lower SOD activity. Under non-waterlogged condition King-3063 and SY-280 maintained higher SOD activity whereas 33A96 maintained lower SOD activity.

Waterlogging treatment showed reduction in total sugars (15.79 and 16.82 mg/g) at 36 and 46 DAS, respectively over control plants (19.82 and 21.30 mg/g).Tthe total sugars got reduced by 20.33 and 21.03 per cent at 36 and 46 DAS respectively over control plants (Table 4). Reduction in total sugars in waterlogging treatment was due to oxygen deficiency and anaerobic conditions and less root activity which impaired water absorbing ability of the plants and also inhibited the synthesis and transport of photosynthetic assimilates (Wample and Thorton, 1984). Similar reduction in sugar content due to waterlogging was also reported in maize (Rai *et al*., 2004; Prasad *et al.,* 2004) and pigeonpea (Kumutha *et al.,* 2009). Maize hybrids were also significantly differed for total sugars at 36 DAS. Among the hybrids tested, Lakshmi-2277 recorded higher total sugar content (18.41 mg/g) at 36 DAS and it was on a par with Bharati-99 and SY- 280. The lower total sugar content was recorded by CN-117 (17.12 mg/g) at 36 DAS. At 46 DAS, no significant difference was found among maize hybrids pertaining to total sugars.

Significant differences were observed between waterlogging treatments and maize hybrids with regards to kernel yield but the interaction was non-significant (Table 4). The kernel yield was reduced by 48.3 per cent due to waterlogging over control. Similar results were also reported in maize (Ajaz and Warsi, 2009; Zaidi *et al*., 2003). The maize hybrid Lakshmi-2277 recorded higher kernel yield (3880.1 Kg ha^{-1}) followed by Bharati-99 and SY-280. The lower kernel yield (2936.0 Kg ha^{-1}) was recorded by the maize hybrid CN-117. Reduction in yield in waterlogging treatment was due to oxygen deficiency, anaerobic conditions and less root activity which can impair the water absorbing ability of the plants as indicated by the reduction in leaf turgidity as well as translocation of dry matter possibly due to damage caused to the root system. Such inhibition may also be due to adverse effects of waterlogging on water and mineral uptake (Hocking *et al.,* 1987). Waterlogging stress induced low oxygen concentration in soil (hypoxia) or complete absence of oxygen (anoxia) which affected the nutrient uptake, synthesis and translocation of growth regulators, photosynthesis, respiration and carbohydrate partitioning and decreased the yield of crops (Ferreira *et al.*, 2008*).*

Conclusion

From the above results, it can be concluded that waterlogging stress significantly affected biochemical parameters and kernel yield in maize. Kernel yield decreased by 48.3 per cent under waterlogging condition. Among the maize hybrids, Lakshmi-2277 recorded higher value of biochemical parameters and kernel yield followed by Bharati-99 and SY-280, where as CN-117 recorded lower value of biochemical parameters and kernel yield under waterlogging condition. Lakshmi-2277 is a superior hybrid in maintaining higher SOD activity, SCMR, total chlorophyll and total sugars apart from higher kernel yield under waterlogged condition due to its quick recovery after waterlogging stress, followed by Bharati-99 and SY-280. Hence, the maize hybrid Lakshmi-2277 is recommended to Agro-Climatic Zone -III (Guntur and Prakasam) of Andhra Pradesh because of its inbuilt tolerance to waterlogging stress.

REFERENCES

Ajaz AL and Warsi MZK (2009). Response of maize (*Zea mays* L.) to excess soil moisture (ESM) tolerance at different stages of life cycle. *Botany Research International* **2**(3) 211-217.

Asha K and Pandey OP (2007). Effect of waterlogging on metabolic constituents in maize. *Indian Journal of Plant Physiology* **12**(4) 366-372.
Ashraf M and Mehmood S (1990). Effects of waterlogging on growth and some physiological parameters of four *Brassica* species. *Plant and Soil* **121** 203- 209.
Balakhnina T, Bennicelli R, Stêpniewska Z, Stêpniewski W, Borkowska A and Fomina I (2012). Stress responses of spring rape plants to soil flooding. *International Agrophysics* **26** 347-353.
Dhindsa RA, Plumb-Dhindsa P and Thorpe TA (1981). Leaf senescence correlated with increased permeability and lipid peroxidation and decreased levels of superoxide dismutase and catalase. *Journal of Experimental Botany* **126** 93-101, Available: www.farmersportal.gov.in.
Ferreira JL, Coelho CHM, Magalhaes PC, Santana GC and Borem A (2008). Evaluation of mineral content in maize under flooding. *Crop Breeding and Applied Biotechnology* **8** 134-140.
Gomez KA and Gomez AA (1984). *Statistical Procedures in Agricultural Research,* 2nd edition (New York Chichester Wiley) 680.
Hiscox JD and Israelstam GF (1979). A method for extraction of chlorophyll from leaf tissue without maceration. *Canadian Journal of Botany* **57** 1332-1334.
Hocking PJ, Reicosky DC and Meyer WS (1987). Effects of intermittent waterlogging on the mineralnutrition of cotton. *Plant and Soil* **101** 211-221.
Keles Y and Oncel L (2000). Changes of superoxide dismutase activity in wheat seedlings exposed to natural environmental stresses. Communications Faculty of Science, University of Ankara **18** 1-8.
Kumutha D, Sairam RK and Meena RC (2008). Role of root carbohydrate reserves and their mobilization in imparting waterlogging tolerance in greengrem (*vigna radiata* (L.) Wilczek) genotypes. *Indian Journal of Plant Physiology* **33** 735-744.
Kumutha D, Sairam RK, Ezhilmathi K, Srivastava GC, Deshmukh PS and Meena RC (2009). Waterlogging induced oxidative stress and antioxidant activity in pigeonpea genotypes. *Biologia Plantarum* **53**(1) 75-84.
Prasad S, Ram PC and Singh U (2004). Effect of Waterlogging duration on chlorophyll content, nitrate reductase activity, soluble sugar and grain yield of Maize. *Annals of Plant Physiology* **18**(1) 1-5.
Rai RK, Srivastava JP and Shahi (2004). Effect of waterlogging on some biochemical parameters during early growth stages of maize. *Indian Journal of Plant Physiology* **9**(1) 65-68.
Rathore TR, Warsi MZK, Lothrop JE and Singh NN (1996). Production of maize under excess soil moisture (water-logging) conditions. *In: 1st Asian Regional Maize Workshop, P.A.U., Ludhiana* 56-63.
Somogyi M (1952). Note on sugar determination. *Journal of Biological Chemistry* **200** 145-154.
Wample RL and Thorton RK (1984). Differences in the response of sunflower subjected to flooding and drought stress. *Physiology Plantarum* **61** 611-616.
Zaidi PH, Mehrajuddin ML, Jat KP, Singh RP and Dass S (2009). Resilient maize for improved and stable productivity of rain-fed environment of South and South-East Asia, Maize for Asia - Emerging Trends and Technologies, *Proceedings of the 10th Asian Regional Maize Workshop*, 20-23 October, 2008, *Makassar, Indonesia* (in press).
Zaidi PH, Rafique S and Singh NN (2003). Response of maize (*Zea mays* L.) genotypes to excess moisture stress: morpho - physiological effects and basis of tolerance. *European Journal of Agronomy* **19** 383-399.
Zhou W, Zhao D and Lin X (1997). Effects of waterlogging on nitrogen accumulation and alleviation of waterlogging damage by application of nitrogen fertilizer and mixtalol in winter rape (*Brassica napus* L.). *Journal of Plant Growth Regulation* **16** 47-53.