Botany Research International 2 (3): 211-217, 2009
ISSN 2221-3635

Response of Maize (*Zea mays* L.) To Excess Soil Moisture (ESM) Tolerance at Different Stages of Life Cycle

[1]*Ajaz A. Lone and* [2]*M.Z.K. Warsi*

[1]K.D Research Station,
Sher-e-Kashmir University of Agricultural Sciences and Technology Shalimar, Kashmir, India
[2]Department of Genetics and Plant Breeding,
College of Post Graduate Studies, GBPUA and T, Pantnagar, India

Abstract: Excess Soil Moisture (ESM) in varying forms posses serious threat to overall production and productivity of maize in Asian region particularly in South East Asia and India. Maize responds differently to ESM conditions at different stages of its life cycle. Further a particular genotype shows differential behaviour to varying levels of waterlogging stress. Seedling stage being very susceptible to excess soil water as was observed in cup screening experiment. Out of 15 genotypes (parents and their crosses made in half diallel fashion), sussceptible genotypes performed poorly and did not reach two leaf stage or even germinated. Most of the genotypes were grouped into first three classes out of the total pre assigned five classes on the basis of their response to waterlogging, reflecting the degree of susceptibility at seedling stage in maize. In normal cup screening trial all the genotypes performed normally. At knee height stage, responses to ESM in different genotypes showed fair correspondence with the responses at seedling. Flooding at knee height stage of the crop growth resulted in immediate wilting of plants starting from the base of the plant and subsequent lodging of most of the plants. In leaves, wilting started from the tip and proceeded towards the base of the leaf. In tolerant genotypes there was profuse appearance of adventitious roots on even up to five nodes in some cases. In most of the genotypes Anthesis Silking Interval (ASI) got widened even more than eight days in some cases was recorded, which subsequently resulted in barrenness of plants and reduction of overall yield. Plant height and ear height was severely affected and in almost all genotypes there was reduction in plant height due to flooding treatment. Physiological traits also got affected due to flooding. There was decrease in transpiration rate and Photosynthetically Active Radiation (PAR) got increases in most of the genotypes due to flooding. SPAD values (relative greenness) of the plants got reduced. There was no sinificant change in leaf temperature in most of the cases. Drastic reduction in most of the genotypes was observed but still Pop 3121 and Pop 3118 showed fairly better yields under waterlogged conditions. ASI and PAR showed negative correlation with yield while as nodes bearing adventitious roots showed positive correlation with yield under water logged conditions. In most of the genotypes there was fading of leaf colour immediately after flooding treatment as reflected by their corresponding SPAD values. Tarun 83 showed immediate epinastic effects in the upper leaves on flooding

Key words: Response, Maize, Excess soil moisture

INTRODUCTION

Maize (*Zea mays* L.) assumes its cultivation under much diverse agro climatic zones extending from subtropical to cooler temperate regions. Therefore inevitably the crop remains open to varied types of biotic as well as abiotic stresses. Among the various abiotic stresses, Excess Soil Moisture (ESM) stress caused by temporary water logging, due to heavy rains or high ground water table or heavy soil texture is one of the most important constraint for maize production and productivity in Asian regions. In South East Asia alone,

Corresponding Author: Ajaz A. Lone, K.D Research Station,
Sher-e-Kashmir University of Agricultural Sciences and Technology Shalimar, Kashmir

about 15% of total maize growing area is affected by floods and water logging. The maize crop suffers badly whenever it encounters temporary ESM conditions during the monsoon season or grown in poorly drained converted paddy fields after a rainy season rice crop [1].

Maize is generally considered to be a flood tolerant species due to its ability to produce early adventitious roots and morphological adaptaters (arenchyma) during excess soil moisture conditions Drew *et al.* [3] and Fausey *et al*. [4]. In monsoon sowing it is difficult to avoid water logging at one or other stages of crop growth due to erratic rains. Further low lying area also faces severe water logging problems during winter season sowings. The tolerance of maize genotypes towards this particular type of stress varies considerably and is higly influenced by the degree of stress and the genotype of the plant Torbert *et al*. [5].

Hence there is a need to screen the collected germplasm with adaptive potential to perform well under temporary water logging conditions and for identifying the morphological and physiological trait conferring resistance to excess soil moisture and incorporating these traits in well adapted genotypes to end up with promising material. The present study was undertaken to quantify the effects of water logging in different maize genotypes in different seasons and to screen the elite maize genotypes for their reaction to temporary water logging conditions and to identify the morphological/ physiological trait conferring tolerance to water logging.

MATERIALS AND METHODS

Maize germplasm comprising of 15 genotypes which included 5 parents and their ten single Crosses made in half diallel fashion were included in the present experiment. Parents Pop3118, Pop3121 and YHPP45 were tolerant to ESM and parents YHPA217 and Tarun 83 were susceptible. Field experiments were conducted during winter and summer seasons of 2006-07 at Crop Research Station, Pantnagar located at 28° 58´-29° 1´ N latitude and 79° 24´-79° 31´ longitudes at an altitude of 244m above the mean sea level. The region lies in the Tarai belt of northern India below the foothills of Himalayan ranges. The soil of the experimental site was Beni silty clay loam upto 0.76m depth followed by silt loam upto 1.50m depth. The soil has been classified as five mixed hyperthermia Aquic Haplerdoll [6]. The soil water depletion data revealed that maize can utilize available H_2O upto 120m profile depth. Plant available water holding capacity upto this depth between-0.03 and -1.5Mpa potential has been ground to be 0.23m.

For Cup screening experiment disposable plastic cups perforated at the base at three points with an orifice of 5 mm diameter were used to grow the maize seedlings. Soil was initially sieved through a mesh with a fine mesh size, then, FYM and chemical fertilizers (NPK) calculated on soil weight basis and thoroughly mixed in the soil. It was ensured by weighing that equal quantity of soil is maintained in each cup in order to maintain a same moisture level in each cup. Filled cups were put in a plastic tray containing upto 5 cm of water. It is necessary to maintain a constant level of water in each tray, so due consideration was given to this aspect. Total soil in the cups got saturated with the water entering from the holes present at the base of cups through capillary action. After 24 hr the cups were ready for sowing. One seed per cup was sown, keeping embryo upside down, at depth of approximately 2.0 cm in fully saturated soil conditions. Trays along with cups and the normally planted cups outside the trays were kept under controlled conditions until seedling establishment (4-5 leaf stage) was there, thereafter, trays were shifted outside for proper seedling growth and development and for observation.

The following observations were recorded after 20 days of sowing for the grouping in to tolerant and susceptible genotypes based on their response as per the methodology devised by [7].

- Seed rotting and no seed germination.
- Coleoptile death immediately after germination.
- Seedling death immediately after emergence.
- Stunted seedling growth and development and severe shoot chlorosis/necrosis.
- Normal seed germination, good seedling growth and development, proper root development floating in water, passing through perforations at the base of the cups.

All the genotypes were sown in randomized block design with plot size of 2m × 5m and spacing of 0.75×30Mts in both winter and summer season and in two sets (Normal and Waterlogged or ESM). Proper fertilization was given to the field based on soil test values. The entire quantity Phosphorus and Potash and one half of the total Nitrogen were applied as a basal doze and the remaining nitrogen was applied in two equal splits at knee height and at flowering stages. Adequate plant protection measures, weeding hoeing operation were carried out when required. In ESM set of experiment, strong bunds were constructed around each plot to impose the water logging treatment at knee height stage of crop growth.

The treatments included in the experiment were a) No flooding or control and b) Seven days continuous Soil submergence at knee height stage of crop growth. Soil submergence depth was kept around 0.05m and was maintained through continuous application of water. After seven days, pounding water was drained out from the plots through surface drainage. For recording observations, plants were randomly selected each plot and in both sets. Regular methods of recording data were used in taking all the morphological observations. Leaf canopy temperature (LT), Photosynthetically Active Radiations (PAR) and Transpiration Rate (TR) were measured with the help of Steady state porometer between 1200 hours and 1400 hours under cloud free conditions in both normal and water logging sets in both seasons. SPAD values were measured with the help of SPAD meter. Appropriate statistical procedures were applied to the recorded data to end up with the interpretations. The analysis of variance (ANOVA) was used to testify effect of water logging [8].

RESULT AND DISCUSSION

The flooding treatment to the water logged set revealed prominent influence of water logging on the overall performance of plants under both winter and summer conditions. Effect of water logging on maize crop is being categorized in following broad categories.

Cup Screening for Esm Tolerance at Seedling Stage of Maize: Cup screening trial was laid in the month of May 2005. The average maximum temperature during that time was 37.0°C and minimum of 20.8°C. The trial was laid down in two set (normal and ESM) following the method originally developed by Porto [9] with certain modifications. After 20 days, observations on six seedling parameters were recorded and accordingly conclusions were drawn. The genotypes are presented in different groups, according to their response in the cup screening trial under ESM conditions.

Group I: Seed rotting and no seed germination

YHPA 217, YHPA 217 × YHPP 45

Group II: Coleoptile death immediately after germination

Tarun 83, Pop 3118 × YHPA 217, Pop 3121 × YHPA 217, YHPA 217 × Tarun 83

Group III: Seedling death immediately after emergence

YHPP 45, Pop 3118 × Pop 3121, Pop 3118 × YHPP 45

Group IV: Stunted seedling growth and development and severe shoot chlorosis/necrosis

Pop 3118, Pop 3118 × Tarun 83, Pop 3121 × Tarun 83

Group V: Normal seed germination, good seedling growth and development, proper root development floating in water, passing through perforation at the base of cups.

Pop 3121, Pop 3121 × YHPP 5, YHPP 45 × Tarun 83

Table1: Analysis of variance for different traits under normal and ESM conditions in winter and summer sown Maize *Under Normal conditions*

Source of variation	d.f	Season	ASI	Plant height	Nodes bearing adventitious roots	Yield	PAR	Leaf temperature	Transpiration rate	SPAD valu e
Replication	2	Winter	3.74	440.272	0.014	34689.42	329.6	2.193	0.234	1030.427
		Summer	2.452	2396.672	0.102	717052.4	2895.645	0.45	0.49	0.65
Genotype	14	Winter	2.029**	608.087**	0.429**	212735.3**	44576.24**	0.083	2.915**	3956.918**
		Summer	1.255**	2438.928**	0.252**	459122.9**	44584.73	1.727	14.185**	65.925**
Error	28	Winter	1.095	345.751	0.039	26265.15	270.207	0.074	0.269	1026.28
		Summer	0.391	1319.606	0.031	52628.44	222.917	0.035	0.307	0.852

Under ESM conditions

Source of variation	d.f	Season	ASI	Plant height	Nodes bearing adventitious roots	Yield	PAR	Leaf temperature	Transpiration rate	SPAD valu e
Replication	2	Winter	5.696	265.131	0.161	217640.2	176.778	0.158	2.247	0.042
		Summer	0.763	509.308	0.093	123254	2380.8	0.306	0.417	1.777
Genotype	14	Winter	2.393**	699.176**	0.304**	4578789.0**	72805.57**	0.168	1.165**	25.480**
		Summer	3.902**	520.850**	0.369**	337334.3**	57499.64**	1.016	12.986**	43.654**
Error	28	Winter	3.045	37.429	0.026	47529.02	1679.354	0.153	0.131	1.652
		Summer	0.445	11.895	0.034	36326.54	177.891	0.028	0.391	0.843

Table 2: Yield reduction in genotypes under ESM conditions in all environments

S. No.	Genotypes	Per cent yield reduction E_1	E_2
Parents (Inbreds)			
1.	Pop 3118	30.41	35.13
2.	Pop 3121	21.15	9.48
3.	YHPA 217	52.33	35.97
4.	YHPP 45	18.79	1.91
5.	Tarun 83	35.46	66.27
$F_{1's}$			
6.	Pop 3118 × Pop 3121	29.27	32.07
7.	Pop 3118 × YHPA 217	31.25	43.53
8.	Pop 3118 × YHPP 45	29.56	22.27
9.	Pop 3118 × Tarun 83	42.50	37.43
10.	Pop 3121 × YHPA 217	27.05	25.60
11.	Pop 3121 × YHPP 45	53.34	27.88
12.	Pop 3121 × Tarun 83	42.02	29.38
13.	YHPA 217 × YHPP 45	35.82	36.58
14.	YHPA 217 × Tarun 83	46.16	30.01
15.	YHPP 45 × Tarun 83	48.90	31.46

It was evident that saturated soil conditions severely affected seed germination and seedling growth. Susceptible parents YHPA 217 and Tarun 83 were not able to grow beyond coleoptile stage. Resistant parents viz., Pop 3118 and Pop 3121 showed sound seedling growth. Among the crosses performance varied among different cross combinations. Out of total 15 genotypes, about 60 per cent genotypes were not able to establish themselves even in the very juvenile stages of seedling growth and got vanished very early.

Effect of Water Logging on Plant Growth and Visually Observable Traits: Analysis of variance in normal and waterlogged conditions showed significant difference in most of the characters except leaf temperature in winter crop as shown in Table 1. In general Anthesis Silking Interval (ASI) got widened due to water logging treatment the range for ASI under normal conditions was 3.0 to 5.6 day in winter season and 3.0 to 5.0 in summer season. When in case of water logging set the range was from 5.0 to 12.6 in winter crop, while in summer crop it was 3.0-7.0. in case of tolerant genotypes like Pop3118, Pop3121, YHPP45 and in crosses like Pop3118 × YHPP45, Pop3121 × Tarun83 and Pop3118 × YHPA217 the values for ASI were lower. Widening of ASI resulted in poor pollination which in term affected the overall grain production; similar results were obtained by Rathore *et al.* [10] and Savita *et al.* [11]. Nodes bearing adventitious roots increased after flooding treatment in both the seasons. Even upto five nodes bearing adventitious roots were observed in Pop3121 one week after flooding treatment. Under normal conditions the numbers of nodes bearing adventitious roots were almost similar in all the genotypes. This increase in number of nodes proves to be an effective mechanism for providing mechanical anchorage under wet conditions in latter stages of growth. Grinieva *et al.* [12] and Savita [13] observed that besides mechanical support to the plant adventitious roots helps plants in sucking oxygen dissolved in water. In general all the genotypes showed reduction in height and stunted growth after flooding treatment. Average height under ESM conditions over both the seasons was found to be 141.20cms while average height under normal conditions was found to be 192.40cms.

Grain yield showed drastic reduction under ESM conditions in both the seasons Table.2. In winter trial, overall yield was higher in all the genotypes in both sets of experiments but still per cent yield loss was higher. The per cent yield reduction varies from 18.79 per cent in YHPP45 (tolerant genotype) to 53.34 percent in Pop 3121 × YHPP45, While in case of summer trial, overall yields were lower but highest reduction in yield was found in Tarun83 (susceptible genotype) 66.27 per cent and lowest reduction of 1.91 per cent in case of YHPP45. Palwadi and Lal [14] studied that there was significant reduction in total number of ears per hectare number of rows per ear, number of grain per row and 1000-grain weight of maize due to 48 hrs of waterlogging. Also, flowering of maize crop for 48 hrs at seedling, knee height, tasselling and milk-ripe stages decreased grain yield by 59, 35, 63 and 41 per cent, respectively

Effect of Waterlogging on Physiological Traits: There was also heavy impact on some of the physiological traits in all the genotypes due to flooding treatment except leaf temperature which remained mostly constant under both normal and waterlogged conditions and in both winter and summer crop. Transpiration rate got reduced due to flooding treatment. In winter season Pop 3118' showed minimum (7.96) transpiration rate in waterlogged set while as Pop3118 × YHPP45 showed maximum transpiration rate (10.16) in summer season, also Pop3118 showed minimum transpiration rate (8.29) and Pop3121 × Tarun 83 showed maximum transpiration rate (14.86). Relative greenness of leaves was also affected due to flooding treatment as there was fading of leaf colour in most of the case as reflected by their corresponding SPAD values.

WINTER SUMMER

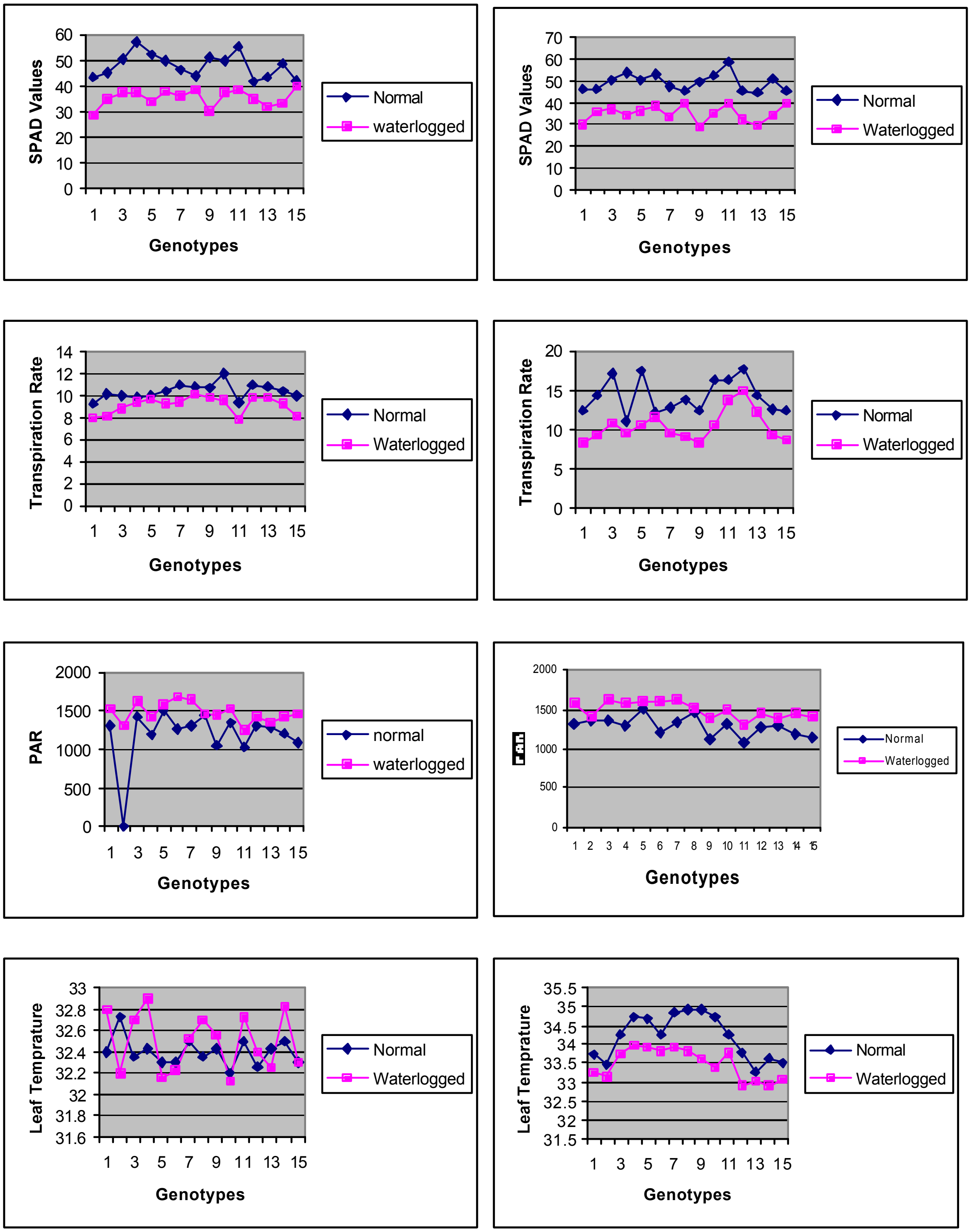

Fig: 1: Comparison of different physiological traits of maize under normal and ESM conditions in winter and summer season plantings

Table3: Intercharacter corrlelations among different morphological and physiological traits of maize under normal and ESM conditions in winter and summer season palntings

		Plant Height		Nodes bearing adventitious roots		Yield		PAR		Transpiration rate		SPAD values		LeafTemperature	
Character	Season	Normal	ESM	Normal	ESM	Normal	ESM	Normal	ESM	Normal	ESM	Normal	ESM	Normal	ESM
ASI	WS	0.081	0.152	-0.193	0.250	0.099	0.116	0.046	0.041	-0.067	0.236	-0.096	-0.044	-0.076	-0.142
		-0.136	-0.164	-0.116	-0.290	-0.025	-0.014	-0.006	-0.069	0.080	0.259	-0.071	0.332*	-0.003	-0.067
Plant Height	WS		0.047	-0.010	0.274	0.272	-0.098	0.003	-0.096	-0.069	0.066	-0.058	0.198	-0.165	
				0.071	0.272	-0.023	0.153	0.007	0.063	0.012	0.045	-0.040	0.074	0.149	0.136
Nodes bearing adventitious roots	WS					-0.146	-0.130	-0.192	-0.081	-0.321**	-0.286	0.191	-0.153	0.069	-0.209
						-0.275	-0.098	-0.335	-0.077	-0.125	-0.012	0.091	-0.035	0.057	0.135
Yield	WS							0.018	-0.059	-0.006	-0.158	0.236	0.117	0.185	-0.149
								0.257	0.206	0.014	0.063	0.160	0.106	-0.269	-0.296*
PAR	WS									0.013	-0.083	-0.018	-0.095	0.085	-0.250
										0.231	-0.020	0.033	-0.022	-0.301*	-0.073
Transpiration rate	WS											-0.128	0.024	-0.109	0.062
												0.090	0.262	-0.101	-0.049
SPAD values	WS													0.099	-0.030
														0.033	0.004

In winter trial SPAD values under normal conditions varied from 41.30 in Pop3121 × Tarun 83 to 56.76 in YHPP45 while as under waterlogged condition it was minimum for Pop3118 (28.46) and maximum of 39.60 per cent for YHPP45 × Tarun 83. In summer trial minimum SPAD value of 28.46 was recorded in Pop3118 × Tarun 83 and maximum of 40.16 in Pop3118 × YHPP45. In both winter and summer season there was enormous effect on PAR due to flooding. In general PAR values got increased due to flooding. The difference in PAR values in winter season was of 253 μmols^{-1} m^{-2}between normal and waterlogged maize crop and it was 370 μmols^{-1} m^{-2}. for summer maize. The comparison of SPAD values, PAR values, Transpiration rate and Leaf temperature between normal and waterlogged trial in both seasons is shown in Fig. 1.

Intercharacter Correlations: The Intercharacter Correlations calculated for different morphological and physiological traits in both seasons is shown in Table 3. In summer season crop, ASI showed negative correlation with yield (r_p=-0.143) yield was positively correlated with plant height under waterlogged conditions in both seasons yield was positively correlated with SPAD values under both conditions and in both seasons. Yield was negatively correlated with nodes bearing adventitious roots under all conditions. Under waterlogged conditions yield showed negative correlation with transpiration rate in winter crop (r_p=-0.158) and summer crop (r_p=-0.063) and positive correlation with SPAD values in both seasons and under both normal and waterlogged conditions.Similar results under waterlogged conditions were also obtained by [11.]

CONCLUSIONS

The results demonstrated that ESM in general reduced over all plant growth delays flowering and reduced maize grain yield to a considerable extent however there is a inbuilt tolerance ability in some genotypes where the symptoms of waterlogging are not much pronounced. Although Maize crop is susceptible to watrelogging at any stage of its life cycle, but it is significantly yield limiting at Knee height stage stress. Some of the morphological indicators like ASI, Nodes bearing adventitious roots and yield in particular can be used as a criterion to screen the genotypes tolerant to ESM stress. At the same time physiological traits like transpiration rate which got reduced under flooding due to stomatal closure highly affected yield of maize and SPAD values can be used for the same purpose.

ACKNOWLEDGEMENTS

We are thankful to Director of Maize Research (DMR) India, Directorate of Experiment Station, Joint Director, Crop Research Centre, GBPUA and T, Pantnagar India for providing all the necessary facilities needed in carrying out the present investigation.

REFRENCES

1. Shimizu, N.M., 1992. Corn cultivation in converted paddy fields in Japan. Extension Bulletin ASPA-Food and Water Centre. pp: 319-315.
2. Zaidi, P.H. and N.N. Singh, 2001. Effect of waterlogging on growth, biochemical composition of reproduction in maize. J. Plant Biol., 28: 61-69.
3. Drew, M.C., M.B. Jackson and S. Giffard, 1979. Ethylene promoted adventitious rooting and development of cortical air spaces (arenchyma) in roots may be adaptive response to flooding in Zea mays L. Planta, 174: 83-88.
4. Fausey, N.R., T.T. Vantoai and M.B. MnDonald, 1985. Response of ten corn cultivars to flooding: Trans ASAE., 28: 1794-1797.
5. Torbert, H.A., R.G. hoeft, R.M. Vanden-Heuvel, R.L. Mulvancy and S.E. Hollonger, 1993. Short term excess water impact on corn yield and nitrogen recovery. J. Prod Agril., 6: 337-344.
6. Deshpandey, S.B., J.B. Fehren Bacher and A.H. Beavers, 1971. mollisols of tarai region of Uttar Pradesh, Northern India. Morphology and Mineralogy, Geoderma, 6: 179-193.
7. Zaidi, P.H., S. Rafique and N.N. Singh, 2003. Response of maize (*Zea mays* L.) genotypes to excess soil moisture stress morpho-physilogical effects and basis of tolerance. European J. Agron., 19(3): 383-389.
8. Snedecor, G.W. and W.G. Cochran, 1967. Statistical Methods, Sixth edn (Calcutta, Oxford and IBH)
10. Rathore, T.R., M.Z.K. Warsi, N.N. Singh and S.K. Vasal, 1998. Production of maize under excess soil moisture (water logging) conditions. Paper presented in the 4th Asian Regional Maize Conference held during 23 to 28 Feb., 1998 at Manila, Philippines.
11. Savita, U.S., T.K. Rathore and H.S. Mishra, 2004. Response of some maize genotypes to temporary waterlogging. J. Plant Biol., 31(1): 29-36.
12. Grinieva, G.N., B.L. McMichael and H. Person, 1991. Physiological and morphological changes in maize plants under various flooding conditions, plant and their environment. Proc. ISSR Symp. 21-26 Aug., 1988, Uppsala, Sweden.
13. Savita, U.S., 2000. Response of some maize genotypes to temporary water logging. Thesis (Ag.), G.B. Pant University of Agric. Technol. Pantnagar.
14. Palwadi, H.K. and B. Lal, 1976. Note of susceptibility of maize to water logging at different growth stages. Pantnagar J. Res., 1: 141-142.