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GENOTYPIC VARIABILITY IN MAIZE AGAINST EXCESS SOIL MOISTURE STRESS

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SUMMARY

The impact of excess soil moisture stress on maize genotypes was examined by applying waterlogging for a period of seven days at knee high stage. In general, plant growth was suppressed in all the genotypes. Genotypes namely CM 121, CM 122 and CM 132 were least affected due to the stress condition. These lines also showed better recovery for total leaf area which was considered a desirable trait for the tolerance. Better nodal root development ability has played significant role in survival of plants under waterlogging. Tasseling and anthesis were comparatively less sensitive, while silking was highly sensitive to the stress, resulting in long anthesis silking interval (ASI) and thereby barrenness of the cobs. Genotypes having <5 days ASI have performed well under the stress. The study indicated that better nodal root development and lower ASI, in general, may be used as morpho-physiological traits for screening maize germplasm against excess soil moisture stress.

***Key words*: Anthesis silking interval, maize genotypes, tasseling, waterlogging**

INTRODUCTION

Among various abiotic stresses, excess soil moisture, caused by flooding, waterlogging or a high water table, is one of the most important constraints for maize production and productivity in Asian region. In East Asia alone, floods and waterlogging problem affect 15% of the total maize growing area. In India, waterlogging is of serious concern, affecting about 8.5 m ha of arable land. Out of the total 6.2 m ha area under maize, about 2.5 m ha is affected by waterlogging resulting in an average loss of 25-30% of national maize production every year.

There is no proper ventilation system in maize plants for oxygen transport between above ground parts and inundated roots, therefore, crop suffers severely, whenever it experiences prolonged waterlogging situation; either due to heavy rainfall or due to growth on poorly drained soils. However, genotypic variability with regards to waterlogging tolerance in maize has been identified (Tolbert *et al.* 1993, Rathore *et al.* 1998). In past, several studies have been undertaken to examine the impact of waterlogging on maize and to understand the basic mechanism behind the tolerant/susceptible reaction. (Van Toai 1988, ShiolowLong and Tech Ming 1997, Rathore *et al.* 1997, 1998). The promising morpho-physiological traits associated with excess soil moisture/ waterlogging tolerance in maize is yet to be identified. In view of this, the present investigation was undertaken to quantify the impact of waterlogging stress, genotypic variability and to identify the morpho-physiological traits associated with the stress tolerance or susceptibility.

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MATERIALS AND METHODS

The experiment was conducted under pot culture conditions in the net-house of the Department of Crop Physiology, NDUAT, Kumarganj, Faizabad, during Kharif season of 1998. Each pot (iron tray of size 30 x 30 cm) was filled with dry and well-prepared soil (pH 7.5, EC 1.4 dS/m). Each of the ten genotypes (Table 1, inbred lines and varieties) were grown in the trays. Fertilizers at the rate of 80, 40 and 40 kg ha^{-1} of N, P and K, respectively were applied in soil. The treatment was applied 30-35 DAS by placing the trays in a pond, in way that complete tray and basal portion of the plants (4-5 cm) submerged continuously for seven days. After the treatment, trays were taken out of the pond for analyzing the impact of the treatment on plant growth and development, and finally yield and yield attributes.

All the plant growth parameters were analyzed immediately after the stress treatment. Plant height was measured from the soil surface up to the tip of the plant. Leaf area (cm^2/plant) was determined using automatic leaf area meter (LICOR). Stem elongation rate (SER) was calculated by measuring the increase in plant height at each alternate day and the total value was divided by number of days to which the stress was applied. For analyzing the root length, the roots were washed gently under running tap water so as to avoid any damage and to recover complete root set. Dry matter of different plant parts and total dry weight was estimated by sun drying and then in oven at 80º ± 1ºC, till the constant weight was achieved.

Nodal root development was determined by counting the newly emerged roots from the stem nodes above the ground surface. Visual injury symptoms were scored on a scale of 1-9, immediately after the treatment as 1 : very healthy, 3 : less than 50% foliar damage, 5 : 50% foliar damage, 7 : 75% foliar damage, 9 : all foliage dead, no green leaf.

Grain yield/plant and yield attributing characters were analyzed at the time of harvest. ASI (anthesis-silking interval) was estimated by calculating the difference between days to 50% anthesis and silking. All the findings were statistically analyzed using completely randomized factorial design (C.R.D.-factorial) and presented in Tables 1-3.

RESULTS AND DISCUSSION

In general, excess soil moisture treatment reduced the plant height, stem elongation rate (SER), leaf area and root length (Table 1) irrespective of the genotypes. However, there was a remarkable genetic variability with regards to all the growth parameters. Maximum reduction in plant height due to waterlogging was found in CM 500 (16.76%) and CM 600(16.4%), whereas the impact was negligible in case of CM 122(1.93%). Data on SER revealed that 7 days of the stress decreased the elongation rate in all the genotypes. Stress condition severely inhibited SER in CM 119(68.87%) and CM 104(64.19%). Inhibition in leaf area was highly significant in all the genotypes under stress condition. Under control condition, maximum leaf area was found in CM 500(1140.33 cm^2/plant), whereas minimum was in Navjot (810.73 cm^2/plant). The stress severely affected leaf area in CM 119(54.99%). The effect was comparatively less pronounced in case of CM 121 (17.59%) and CM 132 (20.93%). The data clearly showed that root length is reduced, more or less, in each genotype, under the stress conditions. The impact was most severe in case of CM 119 (17.64%) and least in CM 121 (3.53%).

Being the exponential growth stage, leaf area development, stem and root elongation rates were comparatively faster under non-flooded condition in all the genotypes (Table 1). Waterlogging causes suppression in all the growth characters resulting in stunted plant growth (Table 1). Reduced plant height due to stress condition seems to be a stress survival/tolerance strategy. Importance of slow growth during submergence was suggested as a way to maintain high carbohydrate supply and hence prolonged energy supply in maize as well as in rice (Setter and Laureles 1996, Singh *et al.* 1997).

Stress treatment significantly affected dry matter production of different plant parts and thereby total dry weight (Table 2). In general, stem was comparatively more affected than root and leaf. However, in some

Table 1. Effect of excess soil moisture at knee high stage on different growth parameters of maize genotypes

Genotypes	Plant height (cm)		Stem elongation rate (cm/day)		Leaf area (cm^2/plant)		Root length (cm)	
	C	W	C	W	C	W	C	W
CM 104	120.33	113.57	1.63	0.60	862.6	454.0	57.30	53.13
CM 116	121.53	108.80	2.70	0.90	1100.7	671.9	38.50	32.20
CM 119	131.83	118.00	2.57	0.80	934.2	420.4	40.43	33.30
CM 121	115.57	106.43	2.63	1.66	946.7	780.6	51.80	49.97
CM 122	122.60	120.23	2.50	1.73	878.8	685.3	36.93	31.60
CM 132	128.23	121.83	3.43	0.43	950.0	751.1	33.70	32.10
CM 500	113.13	94.17	1.07	0.57	1140.0	667.2	27.50	23.50
CM 600	127.30	106.33	1.27	0.93	1084.0	646.1	40.77	37.67
Navjot	126.40	111.63	3.67	1.83	810.7	638.2	46.30	44.83
Jaunpur Local	126.40	107.00	3.53	1.60	1084.9	763.6	36.76	32.87
Mean	124.33	113.88	2.50	1.05	971.29	647.84	41.00	37.11
L.S.D. (P=0.05)	G=4.53, F=2.68, GxF=6.18		G=0.26, F=0.12 GxF=0.37		G=11.88, F=5.31 GxF=16.81		G=1.03, F=0.46 GxF=1.46	

C = Control, W = Waterlogging

Table 2. Effect of excess soil moisture on dry matter partitioning and total biomass of maize genotypes

Genotypes	Leaf dry wt. (g $plant^{-1}$)		Stem dry wt. (g $plant^{-1}$)		Root dry wt. (g $plant^{-1}$)		Total dry wt. (g $plant^{-1}$)	
	C	W	C	W	C	W	C	W
CM 104	1.41	1.22	1.63	1.35	1.15	0.97	4.19	3.54
CM 116	1.52	1.30	1.87	1.44	1.17	0.97	4.55	3.71
CM 119	1.46	1.23	1.78	1.33	1.27	1.06	4.51	3.62
CM 121	1.59	1.42	1.84	1.67	1.53	1.36	4.96	4.45
CM 122	1.63	1.41	1.71	1.59	1.45	1.20	4.79	4.20
CM 132	1.49	1.31	1.61	1.44	1.38	1.15	4.47	3.90
CM 500	1.67	1.33	2.05	1.39	1.46	1.18	5.18	3.90
CM 600	1.50	1.30	1.60	1.40	1.37	1.19	4.48	3.89
Navjot	1.52	1.20	1.76	1.41	1.30	1.12	4.58	3.73
Jaunpur Local	1.63	1.23	1.70	1.37	1.27	1.08	4.60	3.68
Mean	1.54	1.30	1.76	1.44	1.34	1.13	4.63	3.86
L.S.D. (P=0.05)	G=0.057, F=0.025, GxF=0.0259		G=0.058, F=0.026 GxF=0.082		G=0.036, F=0.016 GxF=0.051		G=0.89, F=0.38 GxF=1.32	

genotypes leaf dry weight was found to be more sensitive, such as Jaunpur Local, Navjot, CM 500, CM 122 and CM 132. With regards to stem dry weight, CM 500 and CM 119 were noted most susceptible, where as CM 121 and CM 122 were least affected genotypes. The inhibitory effect of soil moisture stress was also noted in case of root weight. Among the genotypes, CM 121 recorded highest root weight (1.53 g/plant), while minimum root weight was found in CM 104 (1.15 g/plant).

The genotypes accumulating higher dry matter before onset of the stress condition had advantage during the stress since they can maintain enough assimilates to sustain normal growth and development after release of the stress (Setter *et al.* 1989, Singh *et al.* 1997). Limitation of photosynthates due to reduced availability of essential nutrients (Rathore *et al.* 1998) may be the major reason for reduced dry weight of different plant parts and total dry weight. Better dry matter yield in case of CM 121 under the stress condition indicate their ability to maintain the tissue ion homeostasis and thereby maintain the normal metabolism, plant growth and development, in spite of the stress conditions. Waterlogging condition increased nodal root development as observed in the present study (Fig. 1). Development of nodal roots, with gas space (aerenchyma) and high porosity, not only provide mechanical support against lodging under wet and loose soil conditions but also the flaccid and swollen root tips above the water surface supplement oxygen demand of the submerged roots (Grineva *et al.* 1988, Anonymus 1997, Rathore *et al.* 1997). Nodal root development on the stem nodes above the ground surface was commonly observed in all the genotypes, both under normal and the stress condition. However, there was significant genetic variability, particularly under waterlogging condition. Nodal root formation in general, was increased with waterlogging condition with exception of few genotypes such as CM 104, CM 116, CM 119 and CM 500.

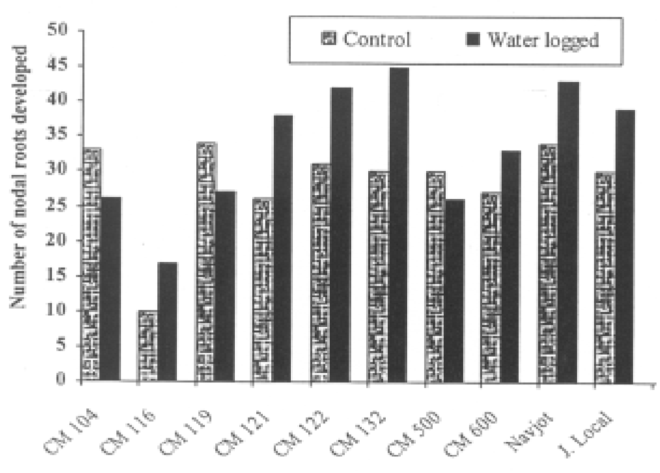

Fig. 1. Effect of excess soil moisture on nodal root development (number) in maize genotypes

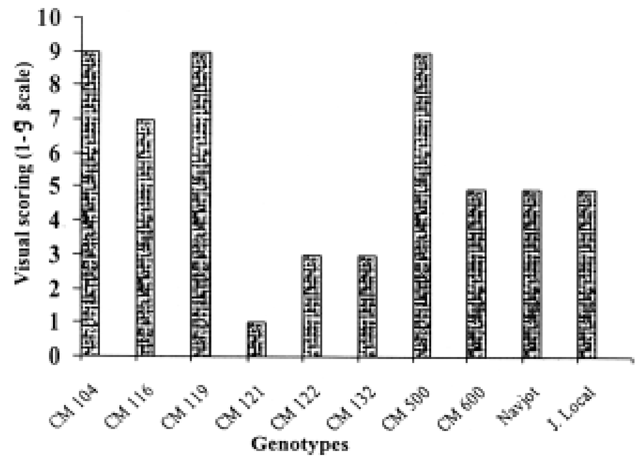

Fig. 2. Visual injury symptom (1-9 scale), 20 days after the stress treatment

The scoring was done on visual observations based on the plant vigour and leaf chlorosis/necrosis. A general impact of the treatment, when compared with control was clearly visible in all the genotypes. The most common symptom was stunted plant growth, yellowing and drying of whole plant and especially the leaves, which started from base and proceeded toward the top of the plant. Three genotypes (CM 104, CM 119 and CM 500) had 9 scores where severe leaf yellowing/mortality of lower leaves with stunted growth were noted. In case of CM 121, there was a nominal injury symptoms and that too in form of yellowing of lower leaves, therefore, it was scored as 1.

Overall impact of the stress on plant growth and development was finally visible on yield attributes and grain yield (Table 3), as both are summation of all metabolic processes and growth events during complete life cycle of a crop plant. In the present study, ASI has been found to play a lead role for yield attributes and grain yield. In case of <5 days of ASI, there was no significant correlation, but above that it dictated the yield potential of genotypes. In some genotypes, there was no silking at all which resulted infinite ASI value and thereby barrenness and zero yield. Similar observations have been recorded by Rathore *et al.* (1996) in different inbred lines, varieties and hybrids of maize. The present study revealed that male flower formation (tasselling and anthesis) and its function was least susceptible to the stress condition. On the other

Table 3. Effect of excess soil moisture on yield and yield attributes of maize genotypes

Genotypes	A.S.I.		Cob length (cm)		Number of grains/cob		Grain yield (g/plant)	
	C	W	C	W	C	W	C	W
CM 104	3.7	0.0	11.1	4.5	104.0	0.0	46.2	0.0
CM 116	4.7	0.0	13.2	3.8	156.7	0.0	70.0	0.0
CM 119	5.0	0.0	10.6	3.5	99.7	0.0	35.3	0.0
CM 121	3.0	5.0	12.7	10.6	225.7	164.3	64.4	44.9
CM 122	3.3	3.7	14.6	7.4	205.0	101.7	68.3	30.2
CM 132	3.3	4.3	13.2	5.4	192.7	86.3	68.4	24.8
CM 500	4.3	0.0	13.5	2.2	198.7	0.0	69.9	0.0
CM 600	3.3	5.0	13.0	6.0	168.3	63.0	66.8	18.2
Navjot	3.0	0.0	13.6	2.3	214.3	0.0	45.8	0.0
Jaunpur Local	3.0	0.0	13.4	2.8	167.3	0.0	64.8	0.0
Mean	3.66	1.8	12.9	4.9	173.2	29.4	59.9	11.8
L.S.D. (P=0.05)	G=0.90, F=1.21, GxF=2.11		G=1.12, F=0.91 GxF=2.02		G=9.2, F=7.8 GxF=14.2		G=2.31, F=1.89 GxF=3.34	

hand, silk formation (female flower) was highly susceptible. Silk initiation and silking largely depends on the availability of photosynthates from sources, viz. green leaves and temporary storage sink (through remobilization) as observed in maize under drought condition (Balonos and Edmeades 1996). The soil moisture stress may have resulted in insufficient amount of assimilates for silk initiation which resulted infinitives ASI and plant barrenness (no grain formation). Findings of the present study revealed that out of 10 genotypes three (CM 121, CM 122 and CM 132) were least affected due to the soil moisture stress. In these genotypes normal growth and development was maintained significantly, in spite of the stress condition. The study revealed that these three tolerant maize genotypes have moderate elongation ability, high nodal root development and effective (<5.0 days) ASI. Therefore, both ASI and nodal root development ability can be used as morpho-physiological traits for the screening of maize germplasm against excess moisture/ waterlogging stress.

The stress condition, in general, reduced cob length in all genotypes. In some genotypes there was smaller cob formation, but no silking resulting in barren cobs as happened in CM 104, CM 116, CM 119, CM 500, Navjot and Jaunpur local. Minimum inhibition with regards to cob length, grain number/cob and finally the grain yield/ plant was observed in case of CM 121. Anthesis-silking interval (ASI) was found to be a good indicator of tolerance/susceptibility against the stress. In most of the genotypes (CM 104, CM 116, CM 119, CM 500, Navjot and Jaunpur local) ASI was infinitive due to no silking at all. (Table 3). There was fairly good negative relationship between ASI and the grain yield under the stress condition (Table 3). Under normal condition, where ASI was 5 or <5 days, there was no direct relation with the grain yield. On the other hand, under the stress, where ASI was more than 5 days, it was directly correlated with the grain yield through the grain number/plant.

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