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Morphological and Yield Responses of Maize (*Zea mays* L.) Genotypes Subjected to Root Zone Excess Soil Moisture Stress

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ABSTRACT

Waterlogging is one of the major constraints limiting maize (*Zea mays* L.) production, especially on the Indian subcontinent. The present study was carried out to evaluate 10 maize genotypes for morphological and yield responses under root zone excess soil moisture stress. Excess soil moisture stress was imposed by flooding the field for five days at the knee height and taselling stages. As a consequence of stress, a significant reduction in total leaf number including green leaves and dead leaves, leaf area, dry matter accumulation, yield and yield attributes, was observed. Nodal root number increased under stress condition. Days to 50% anthesis and ear emergence was delayed. The duration between anthesis to silking was widened under excess soil moisture stress. Reduction in grain yield increased when plants were exposed to stress at the knee height stage. When waterlogging was impose at the knee height stage, there was a 43% reduction in grain yield, but yield was reduced by 25% when stress was imposed at the taselling stage. The genotypes 'V-32', 'V-33', and 'CML-204' were relatively resistant to excess soil moisture stress while 'CML-56', 'CM-119', and 'CM-211' were susceptible. An increase in nodal root number, and reduced widening in the anthesis-silking interval caused by waterlogging are suggested as being parameters for rapid screening of excess soil moisture stress-resistant maize genotypes.

Keywords: maize, morphological changes, waterlogging, yield, yield attributes
Abbreviations: CD, critical difference; **DAS**, days after sowing; **SEm**, standard error of the mean

INTRODUCTION

Excess soil moisture stress, waterlogging and flooding are the major problems worldwide causing severe damage to crop plants (Perata *et al.* 2011). Maize (*Zea mays* L.) is an important cereal crop, cultivated in temperate to tropical regions of the world. On a global scale, nearly 40% of world maize production is in the USA, followed by China (FAO 2009). Excess soil moisture stress caused by waterlogging, a high water table or heavy soil texture, is the one of the most serious constraints, lowering the production and productivity of maize not only in India, but in the entire Asia. In India, excess soil moisture is the second most serious constraint after drought, which affects about 8.5 million ha of arable land. Out of total 6.55 million ha area grown under maize, about 2.5 million ha are affected by excess soil moisture stress, lowering annual maize production by 25-30% (Directorate of Maize Research 2001).

Morphological, anatomical and physiological adaptations in plants ensure their survival under stress conditions. The extent of damage depends upon the crop, growth stage and environmental conditions at the time of stress. The submergence of maize roots for more than one day may restrict the optimum production of the crop (Joshi and Dastane 1966; Halim *et al.* 1969; Ritter and Beer 1969; Singh and Ghildyal 1980). When maize plants were exposed to waterlogging stress at different growth stages, plant growth and yield were reduced at all the stages. Excess soil moisture stress imposed at the knee height stage reduced plant growth (Paliwal and Lal 1976) and yield (Lone and Warsi 2009) significantly in maize genotypes. Maize is also very susceptible to waterlogging stress at an early vegetative stage (Mukhter *et al.* 1990; Lone and Warsi 2009), but late vegetative and pollination stages are also very sensitive to waterlogging (Pal and Varade 1984; Fausey *et al.* 1985; Kanwar and Sial 1988).

Maize, when waterlogged, shows an increase in the number of nodes bearing adventitious roots, also termed nodal roots (Lone and Warsi 2009). Development of adventitious roots under waterlogged conditions serves as a survival mechanism by supporting the plants and thus avoiding lodging. The tips of adventitious roots and root hairs help plants to obtain oxygen dissolved in water (Grinieva 1991; Mahal *et al.* 2000; Lizaso *et al.* 2001). Adventitious roots also replace the existing roots that were killed or whose function was impaired by anoxia. Under waterlogging, a positive relationship in maize was found between yield and node-bearing adventitious roots (Lone and Warsi 2009), and between flooding tolerance and the amount of adventitious roots (Zaidi *et al.* 2007; Lone and Warsi 2009). Waterlogging induces aerenchyma formation in maize that facilitates gaseous transport between roots and shoots, and confers waterlogging resistance in the crop (Jackson and Armstrong 1999; Mano *et al.* 2006; Yadav 2010).

Flooding causes greater yield losses in maize (Meyer *et al.* 1987; Kanwar *et al.* 1988; Mukhtar *et al.* 1990; Lizaso and Ritchie 1997; Ferreira *et al.* 2007) and wheat (Ghobadi and Ghobadi 2010) when it occurs early in the season. Flooding in a maize crop for 48 h at the seedling, knee height, tasselling and milk ripe stages decreased grain yield by 59, 35, 63, and 41%, respectively (Paliwal and Lal 1976). Waterlogging at the knee height stage was found to be more detrimental than that of the milking stage. Plant mortality and barrenness of plants, when waterlogged at the knee height stage were higher (12.65 and 14.45%, respectively) than when it was imposed at the milking stage (7.00 and 7.85%, respectively). Waterlogging resulted in a significant reduction in maize yield, mainly due to decreased kernel

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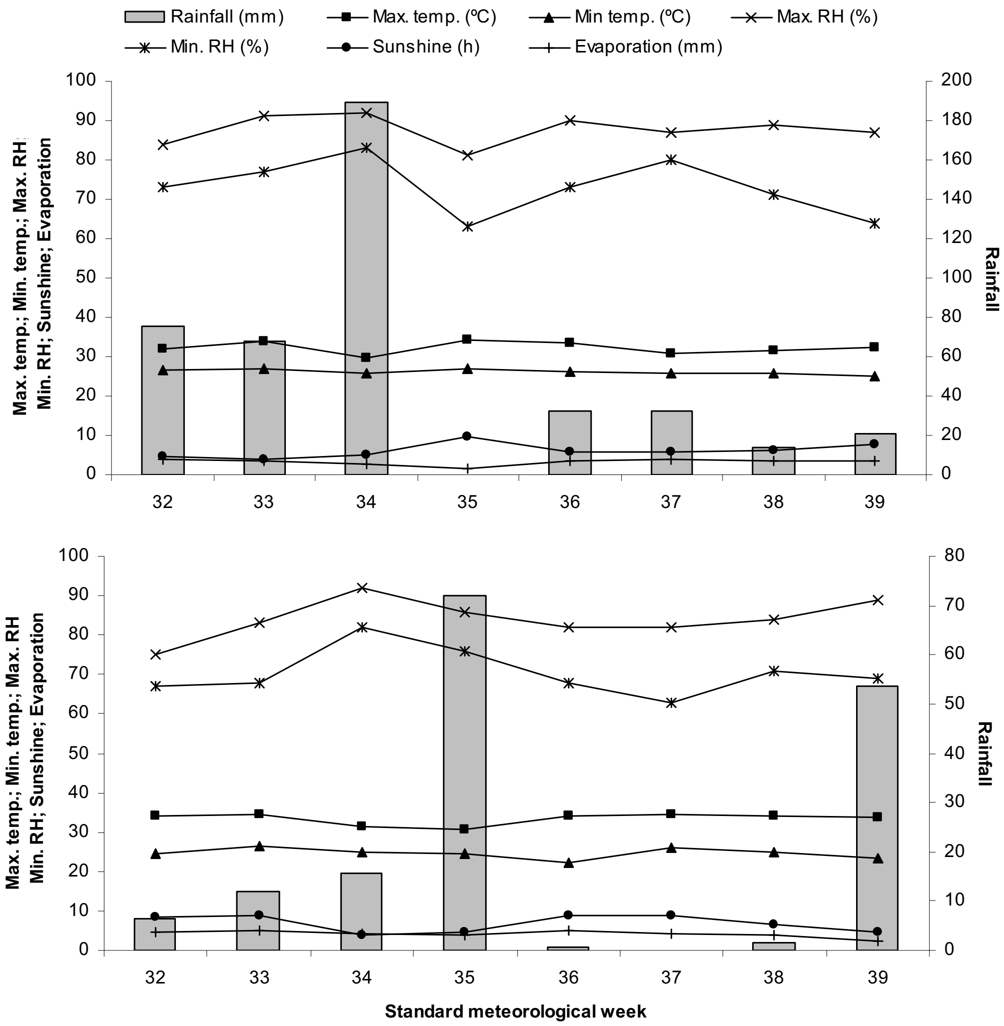

Fig. 1 Metrological data during the 2004-05 (top graph) and 2005-06 (bottom graph) cropping seasons.

rows cob^{-1}, cob length, cob diameter, test weight (1000-grain weight) (Tripathi 2000) and grain number cob^{-1} (Schild *et al.* 1999). However, the magnitude of the effect varied with the stage of crop growth at which waterlogging stress was imposed and the duration of stress (Wu *et al.* 1994). Days to 50% taselling and days to 50% silking were negatively correlated with yield, and these parameters were delayed under waterlogging stress (Baranwal and Singh 2004). Rathore *et al.* (1998) reported that, when water-logged, maize yield is positively correlated with plant height, but negatively correlated with anthesis-silking interval, plant mortality and barrenness. Barrenness and plant mortality accounted for major differences in yield of genotypes tested under the excess soil moisture.

The present investigation aimed to visualize the influence of excess soil moisture stress on critical growth stages, i.e., knee height stage and tasselling stage, on growth, yield and yield attributes of maize genotypes, and to identify morphological parameters associated with excess soil moisture stress in this crop for identifying resistant maize genotypes at the field level.

MATERIALS AND METHODS

An experiment was conducted during *kharif* (rainy season) in 2004-05 and 2005-06 at the Agricultural Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. Seeds of 10 maize genotypes viz., 'V-32', 'V-33', 'HUZM-185', 'HUZM-227', 'HUZM-536', 'CML-49', 'CML-56', 'CML-204', 'CM-119' and 'CM-211', procured from the Department of Genetics and Plant Breeding of the Institute, were sown in a field. The experiment was laid out in a split-plot design with three replications under normal fertilization. Each plot was 3 m × 5 m in size, with 5 rows within each plot. During both years, sowing was done on July 2 (ideal sowing period for *kharif* (wet season) maize in this part of the country). Excess soil moisture stress was imposed by flooding the plots and maintaining the water level 10 cm above the soil surface for 5 days. The stress was imposed either at the knee height stage (30 days after sowing) or at the tasselling stage (42 days after sowing). Thereafter, excess water was drained out, and later on plots were maintained at a normal level of soil moisture. Meteorological data for both years of the cropping season are given in **Fig. 1**. Various parameters were recorded in normal and excess moisture-stressed plants at the end of the period of stress. Plants maintained with an optimal supply of soil moisture served as the control and were termed as 'normal'. At harvest, yield and yield attributes were analyzed.

The total number of leaves (green and dead) was counted just after the release of stress, and the average number of leaves per plant was determined. Leaf area of total green leaves per plant (cm^2 $plant^{-1}$) was determined by a leaf area meter (Leaf Area Meter 211, Systronics, India). Nodal roots were counted manually in the standing plants. Days to 50% anthesis was recorded in terms of number of days taken from the date of planting to the date when anthesis occurred in 50% of the plants. Similarly, days to ear emergence and 50% silking were also recorded. Plants were considered to have attained physiological maturity when leaves became completely yellow. The dry weight of shoots was recorded at the end of the stress period and after harvesting by drying plants at 104°C for 1 h then at 65°C until weight became constant. At harvest, yield and yield attributes were analyzed. All observations were made on five randomly selected plants from rows leaving those present in border rows. Data were expressed on a per plant basis.

Data were subjected to statistical analysis by calculating the CD (critical difference) at 5% by the method of Gómez and Gómez (1984).

RESULTS

Leaf number

Excess soil moisture stress imposed either at the knee height stage or the tasselling stage reduced the number of green leaves, dead leaves and, thus, the total number of leaves plant^{-1} (**Tables 1-3**). The differences with respect to genotype, treatment, stage and their interactions were significant ($P < 0.05$). During 2004-05 and 2005-06, on average, the number of green leaves plant^{-1} decreased more when excess soil moisture stress was imposed at the knee height stage than when it was imposed at the taselling stage.

During 2004-05, under excess soil moisture, on average, 'V-32' had the highest number of green leaves plant^{-1}, while 'CML-56' had the minimum (**Table 1**). When excess soil moisture stress was imposed at the knee height stage or at the tasselling stage, fewer green leaves plant^{-1} formed in stressed plants than in normal plants, and the decrease in green leaves plant^{-1} was minimum in 'V-33' (22.0%) and most in 'CML-56' (45.3%).

The number of dead leaves increased under the influence of excess soil moisture stress (**Table 2**). On average, the number of dead leaves plant^{-1} was marginally higher

Table 1 Number of green leaves plant^{-1} at the end of excess soil moisture stress in 10 genotypes of maize under normal and excess soil moisture conditions imposed at knee height or taselling stage during 2004-05 and 2005-06. Values in parentheses indicate the percentage reduction under excess soil moisture stress.

Genotype	Stage of imposing excess soil moisture stress											
	Knee height stage						Tasselling stage					
	2004-05			2005-06			2004-05			2005-06		
	C	ESM		C	ESM		C	ESM		C	ESM	
V-32	12.6	9.6	(23.8)	13.0	9.3	(28.5)	13.0	9.3	(28.5)	15.0	10.3	(31.3)
V-33	12.3	9.6	(22.0)	12.3	10.3	(16.3)	13.3	9.3	(30.1)	14.7	10.0	(32.0)
HUZM-185	10.0	7.3	(27.0)	11.6	6.3	(45.7)	13.3	6.3	(52.6)	13.3	7.7	(42.1)
HUZM-227	12.3	9.3	(24.4)	11.0	7.3	(33.6)	12.6	8.0	(36.5)	14.3	9.3	(35.0)
HUZM-536	12.3	9.3	(24.4)	12.3	9.3	(24.4)	13.0	7.3	(43.8)	13.3	9.7	(27.1)
CML-49	12.0	7.6	(36.7)	12.0	8.3	(30.8)	12.6	7.0	(44.4)	14.3	9.3	(34.9)
CML-56	10.3	5.6	(45.3)	11.0	5.6	(49.1)	12.3	5.3	(56.9)	13.7	6.7	(51.1)
CML-204	12.6	9.3	(26.2)	12.3	9.3	(24.4)	13.3	9.0	(32.3)	15.3	9.3	(39.2)
CM-119	11.0	6.3	(42.7)	11.6	5.6	(51.7)	12.6	5.7	(54.8)	13.7	7.3	(46.7)
CM-211	9.6	6.3	(34.4)	10.6	6.6	(37.7)	12.3	7.0	(43.1)	13.7	8.7	(36.5)
Mean	11.2	8.0		11.5	7.9		12.8	7.1		14.1	8.8	

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD (5%)	SEm±	CD (5%)
Stage	0.24	1.05	0.22	0.97
Treatment	0.16	0.44	0.21	0.59
Stage × Treatment	0.22	0.63	0.30	0.84
Genotype	0.32	0.65	0.32	0.65
Stage × Genotype	0.46	0.92	0.46	0.91
Treatment × Genotype	0.46	0.92	0.46	0.91
Stage × Treatment × Genotype	0.50	1.05	0.51	1.08

C, control, normal, unstressed condition; ESM, excess soil moisture.

Table 2 Number of dead leaves plant^{-1} at the end of excess soil moisture stress in 10 genotypes of maize under normal and excess soil moisture conditions at two stages of growth during 2004-05 and 2005-06. Values in parentheses indicate the percentage increase over the control.

Genotype	Knee height stage						Tasselling stage					
	2004-05			2005-06			2004-05			2005-06		
	C	ESM		C	ESM		C	ESM		C	ESM	
V-32	1.2	2.3	(91.6)	1.3	2.3	(76.9)	2.2	3.6	(63.6)	2.7	3.6	(33.3)
V-33	1.0	2.7	(170.0)	1.3	3.0	(130.8)	2.0	3.7	(85.0)	2.8	3.8	(35.7)
HUZM-185	1.2	4.6	(283.3)	1.4	5.6	(300.0)	2.2	5.6	(154.5)	2.4	6.6	(175.0)
HUZM-227	1.1	5.3	(381.8)	1.2	4.3	(258.3)	2.1	4.3	(104.8)	2.6	4.3	(65.4)
HUZM-536	1.4	3.6	(157.1)	1.4	2.6	(85.7)	2.4	4.6	(91.7)	2.7	4.6	(70.4)
CML-49	1.3	4.3	(230.8)	1.3	3.3	(153.8)	2.3	5.6	(143.5)	2.4	4.6	(91.7)
CML-56	2.2	4.6	(109.1)	2.4	5.6	(133.3)	2.4	6.6	(175.0)	2.9	6.6	(127.6)
CML-204	1.4	2.3	(64.3)	1.4	3.1	(121.4)	2.3	4.0	(73.9)	2.8	4.0	(42.9)
CM-119	1.3	4.3	(230.8)	1.5	5.3	(253.3)	2.3	6.6	(187.0)	2.5	6.6	(164.0)
CM-211	1.5	4.3	(186.6)	1.4	5.3	(278.6)	2.5	5.6	(124.0)	2.4	5.6	(133.3)
Mean	1.4	3.8		1.5	4.0		2.3	5.0		2.6	5.0	

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD (5%)	SEm±	CD (5%)
Stage	0.05	0.24	0.04	0.20
Treatment	0.08	0.24	0.07	0.20
Stage × Treatment	0.12	0.34	0.10	0.28
Genotype	0.19	0.39	0.19	0.39
Stage × Genotype	0.28	0.56	0.28	0.56
Treatment × Genotype	0.28	0.56	0.28	0.56
Stage × Treatment × Genotype	0.28	0.57	0.27	0.56

C, control, normal, unstressed condition; ESM, excess soil moisture.

when excess soil moisture stress was imposed at the taselling stage than when it was imposed at the knee height stage. During 2004-05 under excess soil moisture, 'CML-56' recorded the highest number of dead leaves plant^{-1} while 'V-32' had the minimum. During 2004-05, at the knee height stage, in comparison to unstressed plants, there was an increase in the number of dead leaves plant^{-1} following excess soil moisture stress, maximum in 'HUZM-185' (283.3%) and minimum in 'CML-204' (64.3%) (**Table 2**). Under similar conditions during 2005-06, the minimum increment in the number of dead leaves plant^{-1} was observed in 'V-32' (76.9%) and the maximum in 'HUZM-185' (300.0%) (**Table 2**). During 2004-05, excess soil moisture stress at the tasselling stage caused the minimum increment in the number of dead leaves plant^{-1} in 'V-32' (63.6%) and maximum in 'CML-56' (175.0%). During 2005-06 the trend was the same as for 'V-32', but the maximum increment was observed in 'HUZM-185' (175.0%).

During 2004-05, when excess soil moisture stress was imposed at the knee height stage, the maximum total number of leaves (green + dead) plant^{-1} was recorded in 'V-33' followed by 'V-32' and 'CML-204', but in these genotypes values did not differ significantly (**Table 3**). The minimum total number of leaves plant^{-1} was recorded in 'CML-56'

Table 3 Total number of leaves (green + dead) plant^{-1} at the end of excess soil moisture stress in 10 genotypes of maize under normal and excess soil moisture conditions imposed at knee height or taselling stage during 2004-05 and 2005-06. Values in parentheses indicate the percentage reduction under excess soil moisture stress.

Genotype	Knee height stage						Taselling stage					
	2004-05			2005-06			2004-05			2005-06		
	C	ESM		C	ESM		C	ESM		C	ESM	
V-32	13.8	11.9	(13.8)	14.3	11.6	(18.9)	15.2	12.9	(15.1)	17.7	13.9	(21.5)
V-33	13.3	12.3	(7.5)	13.6	13.3	(2.2)	15.3	13.0	(15.0)	17.5	13.8	(21.1)
HUZM-185	11.2	11.9	(5.9)*	13.0	11.9	(8.5)	15.5	11.9	(23.2)	16.0	14.3	(10.6)
HUZM-227	13.4	14.3	(6.3)*	12.2	11.6	(4.9)	14.7	12.3	(16.3)	16.9	13.6	(19.5)
HUZM-536	13.4	12.9	(3.7)	13.7	11.9	(13.1)	15.4	11.3	(26.6)	16.0	14.3	(10.6)
CML-49	13.3	11.9	(10.5)	13.3	11.6	(12.8)	14.9	12.6	(15.4)	16.7	13.9	(16.8)
CML-56	12.5	10.2	(18.4)	13.4	11.2	(16.4)	14.7	11.9	(19.0)	16.6	13.3	(19.9)
CML-204	14.0	11.6	(17.1)	13.7	12.4	(9.5)	15.6	13.0	(16.7)	18.1	13.3	(26.5)
CM-119	12.3	10.6	(13.8)	13.1	10.9	(16.8)	14.9	12.1	(18.8)	16.2	14.3	(11.7)
CM-211	11.1	10.6	(13.8)	12.0	11.9	(0.8)	14.8	12.6	(14.9)	16.1	14.3	(11.2)
Mean	12.8	11.8		13.2	11.8		15.1	12.4		16.8	13.9	

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD 5 (%)	SEm±	CD 5 (%)
Stage	0.07	0.32	0.07	0.28
Treatment	0.06	0.17	0.11	0.31
Stage × Treatment	0.09	0.24	0.16	0.44
Genotype	0.25	0.50	0.27	0.54
Stage × Genotype	0.35	0.70	0.38	0.76
Treatment × Genotype	0.35	0.70	0.38	0.76
Stage × Treatment × Genotype	0.35	0.69	0.38	0.77

C, control, normal, unstressed condition; ESM, excess soil moisture. * Per cent increase over normal.

Table 4 Area of green leaves (cm^2 plant^{-1}) at the end of excess soil moisture stress in 10 genotypes of maize under normal and excess soil moisture conditions imposed at knee height or taselling stage during 2004-05 and 2005-06. Values in parentheses indicate the percentage reduction under excess soil moisture stress.

Genotype	Knee height stage						Taselling stage					
	2004-05			2005-06			2004-05			2005-06		
	C	ESM		C	ESM		C	ESM		C	ESM	
V-32	4178.7	3992.0	(4.5)	4303.8	4190.6	(2.6)	5323.3	4557.0	(14.4)	5498.2	4997.2	(9.1)
V-33	3166.6	2600.5	(17.9)	3201.8	2634.3	(17.7)	4919.6	4146.4	(15.7)	4949.0	4404.9	(11.0)
HUZM-185	3133.1	2073.2	(33.8)	3310.1	2017.6	(39.0)	5073.9	4105.3	(19.1)	4866.7	4166.4	(14.4)
HUZM-227	2964.6	2009.3	(32.2)	3005.0	2068.6	(31.2)	4969.9	4036.2	(18.8)	5101.0	4291.3	(15.9)
HUZM-536	3382.8	2971.4	(12.2)	3447.4	3037.9	(11.9)	5143.2	4196.8	(18.4)	5482.6	4694.0	(14.4)
CML-49	3532.1	2764.4	(21.7)	3840.8	2929.5	(23.7)	5015.3	4040.6	(19.4)	5105.1	4112.1	(19.5)
CML-56	2452.6	1718.6	(29.9)	2347.8	1814.4	(22.7)	4559.9	3442.0	(24.5)	4387.2	3510.8	(20.0)
CML-204	4131.9	3650.7	(11.6)	4176.5	3793.5	(9.2)	5296.4	4394.9	(17.0)	5475.1	4802.1	(12.3)
CM-119	3086.3	2374.1	(23.1)	2919.4	2174.3	(25.5)	4944.3	3869.3	(21.7)	4828.0	4072.6	(15.6)
CM-211	2956.9	2090.6	(29.3)	3080.4	2134.8	(30.7)	4826.1	3790.8	(21.5)	4816.2	3705.8	(23.1)
Mean	3298.5	2624.5		3363.4	2679.6		5007.2	4097.0		5050.9	4275.7	

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD 5 (%)	SEm±	CD 5 (%)
Stage	49.22	211.80	32.18	138.47
Treatment	22.17	61.55	14.12	39.20
Stage × Treatment	31.35	86.86	19.97	55.32
Genotype	79.34	158.05	32.60	64.94
Stage × Genotype	112.21	223.30	46.10	91.75
Treatment × Genotype	112.21	223.30	46.10	91.75
Stage × Treatment × Genotype	114.17	236.52	51.28	112.08

C, control, normal, unstressed condition; ESM, excess soil moisture.

Table 5 Plant dry weight (g $plant^{-1}$) at the end of excess soil moisture stress in 10 genotypes of maize under normal and excess soil moisture conditions imposed at knee height or tasselling stage during 2004-05 and 2005-06. Values in parentheses indicate the percentage reduction under excess soil moisture stress.

Genotype	Knee height stage						Taselling stage					
	2004-05			2005-06			2004-05			2005-06		
	C	ESM		C	ESM		C	ESM		C	ESM	
V-32	42.1	36.2	(14.0)	41.8	39.7	(5.0)	88.4	78.4	(11.3)	83.7	77.5	(7.4)
V-33	30.1	24.6	(18.3)	32.6	26.0	(20.2)	81.5	66.6	(18.3)	83.8	71.6	(14.6)
HUZM-185	30.3	21.2	(30.0)	30.2	22.1	(26.8)	77.1	51.0	(33.9)	75.9	56.9	(25.0)
HUZM-227	32.5	24.4	(24.9)	33.2	24.6	(25.9)	72.1	55.6	(22.9)	77.6	58.5	(24.6)
HUZM-536	34.1	27.5	(19.4)	36.3	27.7	(23.7)	73.9	65.2	(11.8)	79.4	67.3	(15.2)
CML-49	32.9	25.2	(23.4)	33.8	25.6	(24.3)	73.2	54.9	(25.0)	77.5	62.8	(19.0)
CML-56	22.9	15.4	(32.7)	21.7	15.5	(28.5)	48.6	29.8	(38.7)	51.1	32.2	(37.0)
CML-204	35.8	28.1	(21.5)	38.6	29.2	(24.4)	80.3	68.4	(14.8)	84.0	71.4	(15.0)
CM-119	28.9	22.1	(23.5)	28.5	21.1	(25.9)	69.9	42.9	(38.6)	66.4	42.3	(36.3)
CM-211	28.5	22.9	(19.6)	28.9	22.0	(23.8)	78.3	53.7	(31.4)	78.8	54.6	(30.7)
Mean	31.9	22.0		32.6	23.1		74.3	56.2		75.8	59.7	

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD 5 (%)	SEm±	CD 5 (%)
Stage	0.33	1.46	0.76	3.30
Treatment	1.39	3.86	0.24	0.67
Stage × Treatment	1.96	5.45	0.34	4.95
Genotype	1.74	3.47	1.03	2.05
Stage × Genotype	2.46	4.90	1.45	2.90
Treatment × Genotype	2.46	4.90	1.45	2.90
Stage × Treatment × Genotype	2.73	5.56	1.50	3.16

C, control, normal, unstressed condition; ESM, excess soil moisture.

and ‘HUZM-185’. The reduction in the percentage of total number of leaves $plant^{-1}$, on account of excess soil moisture stress at the knee height stage, was also maximum in ‘CML-56’ (18.4%) followed by ‘CML-204’ (17.1%). The genotypic performance was almost the same when excess soil moisture stress was imposed at the taselling stage.

Green leaf area

Excess soil moisture stress reduced green leaf area (**Table 4**). Differences with respect to genotype, treatment, stage and their interactions were significant ($P < 0.05$). The reduction in green leaf area under excess soil moisture stress was more pronounced when it was imposed at the knee height stage (nearly 20%) than at the taselling stage (15-19%).

Under excess soil moisture stress, during 2004-05, the maximum green leaf area $plant^{-1}$ was recorded in ‘V-32’ (4274.9 cm^2 $plant^{-1}$) followed by ‘CML-204’ (4118.3 cm^2 $plant^{-1}$), while the minimum was in ‘CML-56’ (2580.3 cm^2 $plant^{-1}$). A similar pattern was observed during 2005-06.

During 2004-05, under excess soil moisture stress at the knee height stage, ‘V-32’ registered the maximum leaf area $plant^{-1}$ and the reduction, as compared to the control, was also least in this genotype (3992.7 cm^2 $plant^{-1}$ and 4.5%, respectively), while the minimum leaf area $plant^{-1}$ was recorded in ‘CML-56’ (1718.6 cm^2 $plant^{-1}$) and the reduction was higher in this genotype (29.9%). The maximum reduction in leaf area on account of excess soil moisture stress at the knee height stage was recorded in ‘HUZM-185’ (33.8%).

During 2005-06, under excess soil moisture stress at the knee height stage, ‘V-32’ maintained the highest leaf area $plant^{-1}$ (4190.6 cm^2 $plant^{-1}$) (**Table 4**) with minimum reduction (2.6%), and ‘HUZM-185’ exhibited maximum reduction (39.0%). The reduction pattern in leaf area in different genotypes, under the influence of excess soil moisture stress at the knee height stage during 2004-05 and 2005-06, followed an almost similar trend.

Excess soil moisture stress at the taselling stage also reduced the leaf area $plant^{-1}$ significantly, and the response of different genotypes was almost the same with that observed at the knee height stage.

Plant dry weight at the end of the stress period

Excess soil moisture stress reduced dry matter accumulation by plants (**Table 5**). Significant differences were observed with respect to genotype, treatment, stage and their interactions. The reduction in dry matter production was more when stress was imposed at the knee height stage (29.0 – 31.0%) than that when it was imposed at the tasselling stage (21.0 – 25.0%). Under excess soil moisture stress, during 2004-05, ‘V-32’ registered maximum dry matter production (54.6 g $plant^{-1}$), minimum for ‘CML-56’ (20.7 g $plant^{-1}$). An almost similar trend was observed during 2005-06.

When stress was imposed at the knee height stage during 2004-05, ‘V-32’ (36.2 g $plant^{-1}$) maintained the highest dry matter production $plant^{-1}$ and the reduction under excess soil moisture stress was also minimum (14.0%) in this genotype. The minimum dry matter production $plant^{-1}$ was recorded in ‘CML-56’ (15.4 g $plant^{-1}$) with the highest reduction (32.7%). The trend was almost the same during 2005-06 when excess soil moisture stress was imposed at the knee height stage.

Due to excess soil moisture stress at the tasselling stage during 2004-05, maximum dry matter production was recorded in ‘V-32’ (78.4 g $plant^{-1}$); this genotype also showed the minimum reduction (11.3%) compared to control plants. The maximum reduction in dry matter under excess soil moisture stress was in ‘CML-56’ (38.7%). An almost similar trend was observed during 2005-06.

Plant dry weight at harvest

The reduction in plant dry weight due to excess soil moisture stress imposed at the knee height or tasselling stage persisted until maturity, even after the release of stress (**Table 6**). Significant differences were observed with respect to genotype, treatment, stage and their interactions.

Dry matter production was lower when stress was imposed at the knee height stage than when it was imposed at the tasselling stage. Under excess soil moisture stress, during 2004-05, ‘V-32’ maintained the highest dry matter $plant^{-1}$ (185.0 g $plant^{-1}$) and the minimum was in ‘CML-56’ (120.0 g $plant^{-1}$) at harvest. An almost a similar trend was observed during 2005-06.

During 2004-05, a comparison of different genotypes indicated that when excess soil moisture stress was imposed at knee height stage, the dry weight of plant at harvest was maximum in 'V-32' (179.5 g plant^{-1}), and, compared to other genotypes the reduction was also minimum (15.2%) in this genotype. The minimum dry matter production plant^{-1} was recorded in 'CML-56' (115.3 g plant^{-1}), but the reduction was maximum in 'HUZM-185' (33.4%). An almost similar trend was found during 2005-06.

When excess soil moisture stress was imposed at the tasselling stage during 2004-05, maximum dry matter production was attained by 'V-32' (190.5 g plant^{-1}) and the minimum by 'CML-56' (125.8 g plant^{-1}) at harvest. The trend was almost the same during 2005-06. During 2004-05, the maximum reduction in total dry matter production in stressed plants, compared to the control, was recorded in 'CM-119' (20.2%) and the minimum in 'HUZM-536' (6.9%). A similar trend was observed during 2005-06 with the exception of 'V-32', which registered the minimum reduction (6.1%) in total dry matter production during this year.

Number of nodal roots

In maize, nodal roots are formed under normal as well as excess soil moisture stress conditions (**Table 7**). Nodal roots formed in all genotypes under excess soil moisture stress. Differences with respect to genotype, treatment,

Table 6 Plant dry weight (g plant^{-1}) at harvest in 10 genotypes of maize under normal and excess soil moisture conditions imposed at knee height or tasselling stage during 2004-05 and 2005-06. Values in parentheses indicate the percentage reduction under excess soil moisture stress.

Genotype	Knee height stage						Tasselling stage					
	2004-05			2005-06			2004-05			2005-06		
	C	ESM		C	ESM		C	ESM		C	ESM	
V-32	211.6	179.5	(15.2)	212.1	187.8	(11.5)	210.6	190.5	(9.5)	210.7	197.8	(6.1)
V-33	198.5	159.0	(19.9)	192.3	167.5	(12.8)	197.7	174.4	(11.8)	201.3	184.5	(8.3)
HUZM-185	190.0	126.5	(33.4)	189.8	146.8	(22.7)	191.5	168.0	(12.3)	194.6	164.6	(15.4)
HUZM-227	204.7	138.7	(32.2)	196.9	159.3	(19.1)	204.8	173.8	(15.1)	209.2	174.9	(16.3)
HUZM-536	199.9	149.4	(25.3)	201.5	157.7	(21.7)	199.8	186.0	(6.9)	198.6	182.4	(8.2)
CML-49	193.5	134.0	(30.7)	198.5	160.9	(18.9)	194.1	169.6	(12.6)	198.9	179.7	(9.7)
CML-56	151.6	115.3	(23.9)	153.7	123.1	(19.9)	152.8	125.8	(17.7)	158.2	134.2	(15.2)
CML-204	206.0	174.3	(15.4)	204.0	175.3	(14.1)	206.9	184.0	(11.1)	204.0	190.8	(6.5)
CM-119	193.6	133.1	(31.3)	193.8	152.3	(21.4)	195.2	155.8	(20.2)	200.5	167.0	(16.4)
CM-211	190.4	141.2	(25.8)	185.5	155.0	(16.4)	191.5	164.1	(14.3)	191.6	167.8	(12.4)
Mean	194.0	145.1		192.8	158.6		194.5	170.2		196.8	174.4	

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD 5 (%)	SEm±	CD 5 (%)
Stage	0.74	3.19	0.35	1.53
Treatment	1.35	3.76	0.67	1.88
Stage × Treatment	1.91	5.31	0.96	2.65
Genotype	2.56	5.11	1.67	3.32
Stage × Genotype	3.63	7.22	2.36	4.70
Treatment × Genotype	3.63	7.22	2.36	4.70
Stage × Treatment × Genotype	3.73	7.56	2.35	4.73

C, control, normal, unstressed condition; ESM, excess soil moisture.

Table 7 Number of nodal roots plant^{-1} at the end of excess soil moisture stress in 10 genotypes of maize under normal and excess soil moisture conditions imposed at knee height or tasselling stage during 2004-05 and 2005-06. Values in parentheses indicate the percentage increase under excess soil moisture stress.

Genotype	Knee height stage						Tasselling stage					
	2004-05			2005-06			2004-05			2005-06		
	C	ESM		C	ESM		C	ESM		C	ESM	
V-32	29.0	40.7	(28.7)	29.0	40.3	(28.0)	34.0	47.0	(27.7)	33.7	44.7	(24.6)
V-33	28.0	37.7	(25.7)	27.3	37.3	(26.8)	33.7	46.0	(26.7)	32.5	43.0	(24.4)
HUZM-185	25.7	31.3	(17.9)	26.7	33.0	(19.1)	31.3	40.0	(21.8)	30.7	38.7	(20.7)
HUZM-227	27.3	34.3	(20.4)	26.6	34.7	(23.3)	32.3	41.3	(21.8)	31.3	39.3	(20.4)
HUZM-536	27.0	35.3	(23.5)	27.0	36.0	(25.0)	32.7	42.0	(22.1)	31.7	41.0	(22.7)
CML-49	26.0	32.7	(20.5)	23.0	30.0	(23.3)	32.0	39.7	(19.4)	30.3	35.7	(15.1)
CML-56	24.0	28.0	(14.3)	20.3	25.0	(18.8)	28.7	34.7	(17.3)	30.7	32.7	(6.1)
CML-204	28.7	36.3	(20.9)	23.0	31.7	(27.4)	33.7	44.0	(23.4)	34.0	43.0	(20.9)
CM-119	25.3	30.3	(16.5)	23.3	30.0	(22.3)	31.3	37.0	(15.4)	31.0	38.4	(19.1)
CM-211	26.0	29.3	(11.3)	24.3	31.3	(22.4)	31.3	36.7	(14.7)	31.0	38.3	(19.0)
Mean	26.7	33.6		25.1	32.9		32.1	40.8		31.7	39.5	

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD 5 (%)	SEm±	CD 5 (%)
Stage	0.21	0.91	0.25	1.10
Treatment	0.55	1.53	0.27	0.74
Stage × Treatment	0.78	2.16	0.38	1.05
Genotype	0.81	1.61	0.52	1.04
Stage × Genotype	1.15	2.28	0.74	1.47
Treatment × Genotype	1.15	2.28	0.74	1.47
Stage × Treatment × Genotype	1.23	2.49	0.77	1.59

C, control, normal, unstressed condition; ESM, excess soil moisture

Table 8 Days to 50% anthesis (days) at the end of excess soil moisture stress in 10 genotypes of maize under normal and excess soil moisture conditions imposed at knee height or tasselling stage during 2004-05 and 2005-06. Values in parentheses indicate the percentage increase under excess soil moisture stress.

Genotype	Knee height stage						Tasselling stage					
	2004-05			2005-06			2004-05			2005-06		
	C	ESM		C	ESM		C	ESM		C	ESM	
V-32	46.7	47.3	(1.3)	46.7	48.7	(4.1)	46.3	46.7	(0.9)	47.6	47.7	(0.2)
V-33	46.7	47.7	(2.1)	46.0	47.3	(2.7)	45.7	46.7	(2.1)	46.0	46.4	(0.9)
HUZM-185	47.0	49.3	(4.7)	47.7	49.3	(3.2)	45.3	45.7	(0.9)	47.2	47.0	(0.4)
HUZM-227	46.7	49.7	(6.0)	46.7	49.3	(5.3)	46.0	46.3	(0.6)	47.6	47.7	(0.2)
HUZM-536	47.7	48.7	(2.1)	46.7	47.3	(1.3)	46.3	46.3	(0.0)	46.6	46.7	(0.2)
CML-49	46.3	48.3	(4.1)	46.3	49.0	(5.5)	46.7	47.0	(0.6)	46.4	46.3	(0.2)
CML-56	45.7	48.7	(6.2)	46.7	48.7	(4.1)	47.7	47.0	(1.5*)	46.9	46.7	(0.4)
CML-204	46.7	47.3	(1.3)	45.0	46.7	(3.6)	45.0	45.7	(1.5)	45.7	45.7	(0.0)
CM-119	45.3	47.7	(5.0)	46.3	49.7	(6.8)	47.3	47.3	(0.0)	47.4	47.7	(0.6)
CM-211	47.3	49.7	(4.8)	47.7	49.0	(2.7)	46.0	47.0	(2.1)	47.9	48.0	(0.2)
Mean	46.6	48.4		46.8	47.0		46.2	46.6		46.9	47.0	

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD 5 (%)	SEm±	CD 5 (%)
Stage	0.10	0.44	0.24	1.03
Treatment	0.07	0.19	0.27	0.76
Stage × Treatment	0.10	0.27	0.39	1.07
Genotype	0.26	0.53	0.28	0.57
Stage × Genotype	0.37	0.74	0.40	0.80
Treatment × Genotype	0.37	0.74	0.40	0.80
Stage × Treatment × Genotype	0.37	0.75	0.50	1.08

C, control, normal, unstressed condition; ESM, excess soil moisture. *Per cent reduction over normal.

stage and their interactions were significant ($P < 0.05$) during both years of the experiment, except for the treatment × genotype interaction. During 2004-05, under excess soil moisture stress, 'V-32' recorded the maximum number of nodal roots (42.6 plant^{-1}) and 'CML-56' the minimum (30.3 plant^{-1}). An almost similar trend was observed under stress conditions during 2005-06. Induction in nodal root formation was marginally higher when excess soil moisture stress was imposed at the knee height stage (20.3-27.0%) than when it was imposed at the tasselling stage (19-21.0%) (**Table 7**).

Under excess soil moisture stress at the knee height stage, 'V-32' registered the highest number of nodal roots plant^{-1} (40.7) and the increment over the control was also maximum in this genotype (28.7%). Under similar conditions, total number of nodal roots plant^{-1} was minimum in 'CML-56' (28.0) and the increment under excess soil moisture stress compared to the control was also of lower magnitude (14.3%) in this genotype. Excess soil moisture stress at the knee height stage during 2005-06 showed an almost similar trend as observed during 2004-05.

At the tasselling stage, total nodal roots plant^{-1} in control as well as in plants under excess soil moisture stress were more than that observed at the knee height stage under respective conditions, although the percentage increase on account of excess soil moisture stress was marginally lower. Those genotypes which registered the highest number of nodal roots plant^{-1} and the highest per cent increase in nodal roots under excess soil moisture stress at the knee height stage, again maintained the same trend under excess soil moisture stress at the tasselling stage.

Days to 50% anthesis

Significant differences were recorded with respect to days to 50% anthesis in plants under normal and excess soil moisture stress conditions during both years of investigation. Data are presented in **Table 8**.

On average, excess soil moisture stress extended the days required to 50% anthesis. The delaying effect was pronounced when excess soil moisture stress was imposed at the knee height stage than at the tasselling stage. Although differences were evident during both years, it was significant during 2004-05. During both years, under the influence of excess soil moisture stress, days required to 50% anthesis was maximum in 'CM-211' and minimum in 'CML-204'.

The per cent increase in days to 50% anthesis, on account of excess soil moisture at the knee height stage, was minimum in 'V-32' and 'CML-204', and maximum in 'CML-56'. During 2005-06, the maximum per cent increase in days to 50% anthesis due to excess soil moisture stress at the knee height stage was recorded in 'CM-119' (6.8%).

Days to ear emergence

Excess soil moisture stress, irrespective of stage, delayed the emergence of the ear. Significant variations were observed with respect to genotype, treatment, stage and their interactions. Data are shown in **Table 9**. Excess soil moisture stress at the knee height stage delayed the emergence of the ear more than that at the tasselling stage. During 2004-05, under excess soil moisture stress at the knee height stage, the maximum number of days required for the ear emergence was observed in 'HUZM-185' (49.5 DAS), and the minimum in 'CML-204' (47.3 DAS). Excess soil moisture stress at the knee height stage increased the number of days required for the emergence of the ear, being maximum in 'CML-56' (7.4%) and minimum in 'V-33' (2.1%). During 2005-06, the percentage increase in the number of days for the emergence of ear due to excess soil moisture stress at the knee height stage was least in 'HUZM-536' and most in 'CM-119'. During both years, the decreased in this value was least in 'V-33'.

When excess soil moisture stress was imposed at the tasselling stage during 2004-05, the percentage increase in days to emergence of the ear was minimum in 'CM-119' (1.2%). During 2005-06, excess soil moisture stress at the tasselling stage caused the least reduction in days to ear emergence in 'V-33' (2.9%) and the most in 'CML-49' and 'CM-211' (7.0%).

Days to 50% silking

Excess soil moisture stress manifested a significant effect on days to 50% silking during both years of investigation (**Table 10**). Significant differences ($P < 0.05$) were recorded with respect to genotype, treatment, stage and their interactions.

On average, excess soil moisture stress increased the duration required for 50% silking. This delaying effect was more pronounced when stress was imposed at the tasselling stage. During 2004-05, under excess soil moisture stress condition; 'HUZM-227' took the longest time (53.7 DAS) for 50% silking. During 2005-06, under stress condition, 'CML-56' took the most time for 50% silking (56.5 DAS). During 2004-05, excess soil moisture stress at the knee height stage increased days to 50% silking by 8.6% in 'CML-56' (maximum) and by 3.4% in 'CML-204' (minimum) (**Table 10**). The trend was almost the same during 2005-06. During 2004-05, excess soil moisture stress at the tasselling stage caused maximum percentage enhancement in days to 50% silking in 'CM-119' (8.5%) and minimum in 'CML-204' (3.8%). During 2005-06, when excess soil moisture stress was imposed at the tasselling stage, a variable trend was recorded with respect to days to 50% silking. The maximum percentage increase was observed in 'CML-49' (12.8%) and the minimum in 'HUZM-536' (5.0%).

Anthesis-silking interval

Since excess soil moisture stress affected days to 50% anthesis and days to 50% silking, the interval between anthesis and silking also changed. The differences were significant for genotype, treatment, stage and their interactions (**Table 11**). Excess soil moisture stress widened the duration between anthesis and silking. The effect was more pronounced when stress was imposed at the tasselling stage than when it was imposed at the knee height stage. The trend

Table 9 Days to ear emergence (days) in 10 genotypes of maize under normal and excess soil moisture conditions imposed at knee height or tasselling stage during 2004-05 and 2005-06. Values in parentheses indicate the percentage increase under excess soil moisture stress.

Genotype	Knee height stage						Taselling stage					
	2004-05			2005-06			2004-05			2005-06		
	C	ESM		C	ESM		C	ESM		C	ESM	
V-32	47.0	48.3	(2.7)	47.2	49.0	(3.7)	47.4	48.3	(1.9)	47.3	49.3	(4.1)
V-33	47.5	48.5	(2.1)	47.3	48.7	(2.9)	46.7	48.5	(3.7)	47.3	48.7	(2.9)
HUZM-185	48.0	50.5	(5.0)	48.0	50.3	(4.6)	46.7	50.5	(7.5)	47.3	50.7	(6.7)
HUZM-227	47.5	50.6	(6.1)	47.5	50.2	(5.4)	46.8	50.6	(7.5)	48.7	50.7	(3.9)
HUZM-536	47.0	49.9	(5.8)	47.2	48.4	(2.5)	47.4	49.9	(5.0)	47.3	48.7	(2.9)
CML-49	47.5	49.7	(4.4)	47.5	50.3	(5.6)	47.6	49.7	(4.2)	47.7	51.3	(7.0)
CML-56	46.0	49.7	(7.4)	47.5	49.4	(3.8)	48.3	49.7	(2.8)	48.3	50.3	(4.0)
CML-204	47.5	48.6	(2.3)	46.3	47.8	(3.1)	46.3	48.6	(4.7)	46.3	47.7	(2.9)
CM-119	46.5	48.6	(4.3)	47.3	50.6	(6.5)	48.0	48.6	(1.2)	48.7	51.7	(5.8)
CM-211	48.3	50.3	(4.0)	48.4	50.6	(4.3)	47.7	50.3	(5.2)	47.7	51.3	(7.0)
Mean	47.3	49.5		47.4	49.5		47.3	48.0		47.7	50.0	

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD 5 (%)	SEm±	CD 5 (%)
Stage	0.06	0.27	0.20	0.85
Treatment	0.11	0.31	0.39	1.10
Stage × Treatment	0.16	0.43	0.56	1.55
Genotype	0.28	0.55	0.43	0.86
Stage × Genotype	0.39	0.78	0.61	1.21
Treatment × Genotype	0.39	0.78	0.61	1.21
Stage × Treatment × Genotype	0.39	0.78	0.71	1.48

C, control, normal, unstressed condition; ESM, excess soil moisture.

Table 10 Days to 50% silking (days) in 10 genotypes of maize under normal and excess soil moisture conditions imposed at knee height or tasselling stage during 2004-05 and 2005-06. Values in parentheses indicate the percentage increase under excess soil moisture stress.

Genotype	Knee height stage						Tasselling stage					
	2004-05			2005-06			2004-05			2005-06		
	C	ESM		C	ESM		C	ESM		C	ESM	
V-32	48.0	50.3	(4.6)	48.3	50.7	(4.7)	48.3	50.4	(4.2)	49.7	53.0	(6.2)
V-33	48.3	50.3	(4.0)	48.7	50.7	(3.9)	48.4	50.4	(4.0)	48.8	52.7	(7.4)
HUZM-185	50.3	53.7	(6.3)	50.3	53.7	(6.3)	50.4	53.3	(5.4)	50.8	57.3	(11.3)
HUZM-227	49.3	53.7	(8.2)	49.7	53.7	(7.4)	49.4	53.7	(8.0)	49.8	56.7	(12.2)
HUZM-536	49.3	51.0	(3.3)	49.3	51.3	(3.9)	49.4	51.7	(4.4)	49.4	52.0	(5.0)
CML-49	49.0	52.0	(5.8)	49.3	52.3	(5.7)	49.7	52.7	(5.7)	49.7	57.0	(12.8)
CML-56	48.7	53.3	(8.6)	49.0	53.7	(8.8)	49.9	53.8	(7.2)	50.2	55.3	(9.2)
CML-204	48.3	50.0	(3.4)	48.7	50.3	(3.2)	48.1	50.0	(3.8)	48.4	51.3	(5.7)
CM-119	48.0	52.3	(8.2)	48.3	52.7	(8.3)	48.3	52.8	(8.5)	48.7	54.0	(9.8)
CM-211	50.0	53.3	(6.2)	50.3	53.7	(6.3)	50.3	53.4	(5.8)	50.7	54.3	(6.6)
Mean	48.9	52.0		49.2	52.3		48.6	52.2		49.5	56.4	

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD 5 (%)	SEm±	CD 5 (%)
Stage	0.18	0.76	0.15	0.64
Treatment	0.21	0.59	0.24	0.67
Stage × Treatment	0.30	0.84	0.34	0.95
Genotype	0.32	0.63	0.29	0.59
Stage × Genotype	0.45	0.89	0.42	0.83
Treatment × Genotype	0.45	0.89	0.42	0.83
Stage × Treatment × Genotype	0.49	1.02	0.48	0.99

C, control, normal, unstressed condition; ESM, excess soil moisture.

Table 11 Anthesis-silking interval (days) in 10 genotypes of maize under normal and excess soil moisture conditions imposed at knee height or taselling stage during 2004-05 and 2005-06.

Genotype	Knee height stage				Taselling stage			
	2004-05		2005-06		2004-05		2005-06	
	C	ESM	C	ESM	C	ESM	C	ESM
V-32	3.3	4.0	3.3	3.3	3.0	5.0	3.0	6.0
V-33	3.0	4.0	3.0	3.3	4.0	5.0	3.3	6.0
HUZM-185	4.3	5.0	4.3	5.0	6.0	8.3	4.0	9.0
HUZM-227	4.0	5.0	4.0	5.0	4.3	8.3	3.0	9.0
HUZM-536	3.3	4.3	4.0	5.0	4.0	6.0	4.0	6.0
CML-49	4.3	5.0	4.3	4.3	4.3	6.0	4.3	9.0
CML-56	4.0	6.3	4.0	5.3	3.0	7.0	5.0	8.0
CML-204	3.0	4.0	4.0	5.0	4.0	6.0	4.0	6.0
CM-119	4.0	6.0	3.7	4.0	2.3	6.0	2.3	6.0
CM-211	4.3	5.0	4.3	5.0	4.7	6.3	4.3	6.3
Mean	3.8	4.9	3.9	4.5	4.0	6.4	3.7	7.9

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD 5 (%)	SEm±	CD 5 (%)
Stage	0.10	0.44	0.06	0.26
Treatment	0.13	0.35	0.16	0.46
Stage × Treatment	0.18	0.50	0.23	0.64
Genotype	0.16	0.31	0.16	0.32
Stage × Genotype	0.22	0.44	0.22	0.45
Treatment × Genotype	0.22	0.44	0.22	0.45
Stage × Treatment × Genotype	0.26	0.54	0.27	0.57

C, control, normal, unstressed condition; ESM, excess soil moisture.

Table 12 Days to physiological maturity (days) in 10 genotypes of maize under normal and excess soil moisture conditions imposed at knee height or taselling stage during 2004-05 and 2005-06. Values in parentheses indicate the percentage reduction under excess soil moisture stress.

Genotype	Knee height stage						Taselling stage					
	2004-05			2005-06			2004-05			2005-06		
	C	ESM		C	ESM		C	ESM		C	ESM	
V-32	80.6	78.3	(2.9)	79.6	78.6	(1.3)	80.0	73.3	(8.4)	80.0	72.6	(9.3)
V-33	79.3	78.6	(0.9)	78.6	79.3	(0.9)*	80.0	72.6	(9.3)	79.3	73.3	(7.6)
HUZM-185	78.0	72.0	(7.7)	78.6	72.0	(8.4)	78.3	68.6	(12.4)	79.3	68.0	(14.2)
HUZM-227	79.3	73.0	(7.9)	79.6	73.0	(8.3)	78.6	68.0	(13.5)	79.6	68.6	(13.8)
HUZM-536	79.6	75.3	(5.4)	80.0	75.3	(5.9)	79.6	71.0	(10.8)	80.0	71.0	(11.3)
CML-49	79.3	72.6	(8.4)	78.6	72.6	(7.6)	80.0	69.3	(13.4)	79.3	69.3	(12.6)
CML-56	76.6	68.3	(10.8)	77.3	65.0	(15.9)	77.0	62.3	(19.1)	77.6	62.6	(19.3)
CML-204	80.6	76.6	(5.0)	80.6	77.0	(4.5)	80.6	73.6	(8.7)	80.6	74.0	(8.2)
CM-119	77.6	70.3	(9.4)	77.6	70.0	(9.8)	77.6	67.6	(12.9)	78.0	67.6	(13.3)
CM-211	78.3	70.3	(10.3)	78.3	70.	(9.8)	78.3	67.6	(13.7)	78.6	68.3	(13.1)
Mean	78.9	73.5		78.9	73.3		79.0	69.4		79.2	69.5	

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD 5 (%)	SEm±	CD 5 (%)
Stage	0.10	0.47	0.25	1.11
Treatment	0.28	0.79	0.33	0.94
Stage × Treatment	0.40	1.11	0.48	1.33
Genotype	0.39	0.77	0.51	1.03
Stage × Genotype	0.55	1.10	0.73	1.46
Treatment × Genotype	0.55	1.10	0.73	1.46
Stage × Treatment × Genotype	0.60	1.22	0.79	1.64

C, control, normal, unstressed condition; ESM, excess soil moisture. *Per cent increase under ESM

was almost similar during both years.

During 2004-05, under excess soil moisture condition, the average duration between anthesis and silking was minimum in 'V-32' and 'V-33' (4.5 days) and the maximum in 'HUZM-185', 'HUZM-536' and 'CML-56' (6.7 days). During 2005-06, 'V-32' registered the minimum duration (4.5 days) for this parameter under excess soil moisture stress, while the maximum was recorded in 'HUZM-185' (7.5 days).

Days to physiological maturity

Excess soil moisture stress at the knee height and taselling stages, in general, significantly reduced the duration between sowing and maturity. Data pertaining to this parameter are presented in **Table 12**.

Excess soil moisture stress induced physiological maturity of the crop. During 2004-05, under normal conditions, the crop matured in 78.9 days, but under excess soil moisture the maturation period decreased to 71.5 days. Physiological maturity was attained in 69.4 days when excess soil moisture was imposed at the taselling stage, but when it was imposed at the knee height stage, the crop matured in 73.5 days. A similar pattern was observed during 2005-06.

During 2004-05, under excess soil moisture condition, 'CML-56' took the least number of days to attain physiological maturity (65.3 days) and 'V-32' the maximum (75.8 days). During 2005-06 almost same trend was observed.

During 2004-05, under excess soil moisture condition at the knee height stage, the percentage reduction in days to

Table 13 Number of cobs row^{-1} (each row had 15 plants initially) in 10 genotypes of maize under normal and excess soil moisture conditions imposed at knee height or taselling stage during 2004-05 and 2005-06. Values in parentheses indicate the percentage reduction under excess soil moisture stress.

Genotype	Knee height stage						Taselling stage					
	2004-05			2005-06			2004-05			2005-06		
	C	ESM		C	ESM		C	ESM		C	ESM	
V-32	11.7	10.7	(8.5)	11.3	10.0	(11.5)	12.0	11.0	(8.3)	11.0	10.7	(2.7)
V-33	11.3	10.7	(5.3)	11.3	10.0	(11.5)	12.0	11.0	(8.3)	11.3	10.3	(8.8)
HUZM-185	10.7	9.7	(9.3)	10.3	8.7	(15.5)	11.7	10.7	(8.5)	10.7	10.0	(6.5)
HUZM-227	11.7	9.0	(23.1)	11.0	8.3	(24.5)	11.7	10.0	(14.5)	11.0	9.3	(15.5)
HUZM-536	11.3	10.0	(11.5)	10.7	9.0	(15.9)	12.0	10.0	(16.7)	11.3	10.7	(5.3)
CML-49	10.0	8.7	(13.0)	10.0	7.7	(23.0)	11.3	9.7	(14.2)	9.3	9.7	(4.1)
CML-56	11.7	5.7	(51.3)	11.0	5.3	(51.8)	11.7	9.3	(20.5)	9.0	6.7	(25.5)
CML-204	11.0	10.3	(6.4)	11.0	9.3	(15.5)	11.7	11.0	(6.0)	10.3	10.3	(0.0)
CM-119	11.7	8.3	(29.1)	10.7	8.3	(22.4)	11.7	11.0	(6.0)	9.3	9.3	(0.0)
CM-211	10.7	8.7	(18.7)	10.7	8.3	(22.4)	11.3	10.3	(8.8)	10.0	9.3	(7.0)
Mean	11.2	9.2		10.8	8.5		11.7	10.4		10.3	9.7	

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD 5 (%)	SEm±	CD 5 (%)
Stage	0.07	0.29	0.22	0.96
Treatment	0.17	0.47	0.18	0.51
Stage × Treatment	0.24	0.66	0.26	0.72
Genotype	0.28	0.55	0.25	0.50
Stage × Genotype	0.39	0.78	0.36	0.71
Treatment × Genotype	0.39	0.78	0.36	0.71
Stage × Treatment × Genotype	0.41	0.83	0.42	0.90

C, control, normal, unstressed condition; ESM, excess soil moisture.

Table 14 Grain number cob^{-1} in 10 genotypes of maize under normal and excess soil moisture conditions imposed at knee height or taselling stage during 2004-05 and 2005-06. Values in parentheses indicate the percentage reduction under excess soil moisture stress.

Genotype	Knee height stage						Taselling stage					
	2004-05			2005-06			2004-05			2005-06		
	C	ESM		C	ESM		C	ESM		C	ESM	
V-32	337.3	329.3	(2.4)	327.0	322.0	(1.5)	335.0	333.3	(0.5)	335.3	330.3	(1.5)
V-33	333.3	326.3	(2.1)	316.3	313.3	(0.9)	334.6	324.3	(3.1)	326.3	311.3	(4.6)
HUZM-185	322.0	300.6	(6.6)	288.3	268.6	(6.8)	322.6	269.3	(16.5)	324.0	281.6	(13.1)
HUZM-227	326.3	314.6	(3.6)	307.3	295.0	(4.0)	332.6	281.0	(15.5)	330.0	311.0	(5.8)
HUZM-536	335.6	320.0	(4.6)	306.0	296.0	(3.30	335.6	315.6	(6.0)	339.0	313.3	(7.6)
CML-49	295.3	256.6	(13.1)	304.0	290.6	(4.6)	308.6	301.0	(2.5)	308.3	298.3	(3.2)
CML-56	275.6	234.0	(15.1)	81.3	48.3	(40.6)	283.0	54.6	(80.7)	279.0	158.6	(43.2)
CML-204	341.6	333.6	(2.3)	318.6	304.3	(4.5)	342.6	319.0	(6.9)	346.3	328.6	(5.1)
CM-119	316.6	295.6	(6.6)	282.6	260.3	(7.9)	298.3	238.0	(20.2)	299.0	282.6	(5.5)
CM-211	310.0	295.0	(4.8)	276.6	252.6	(8.7)	309.0	266.0	(13.9)	311.6	288.6	(7.4)
Mean	319.4	300.6		280.8	265.1		320.2	270.2		319.9	290.4	

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD 5 (%)	SEm±	CD 5 (%)
Stage	10.05	43.26	3.83	16.50
Treatment	5.90	16.38	5.05	14.03
Stage × Treatment	8.34	23.11	7.14	19.80
Genotype	13.43	26.75	7.68	15.30
Stage × Genotype	18.99	37.80	10.86	21.61
Treatment × Genotype	18.99	37.80	10.86	21.61
Stage × Treatment × Genotype	20.25	42.74	11.79	24.34

C, control, normal, unstressed condition; ESM, excess soil moisture.

attain physiological maturity under excess soil moisture – compared to the control – was minimum in 'V-33' (0.9%) and maximum in 'CML-56' (10.8%). During 2005-06, an almost similar trend was obtained.

Excess soil moisture stress at the taselling stage during 2004-05 resulted in minimum percentage decrease in crop duration in 'V-32' (8.4%) and maximum in 'CML-56' (19.1%). The trend was almost the same for the next year with the only variation being that the minimum change was recorded in 'V-33' (7.6%), although, once again, it was maximum in 'CML-56' (19.3%).

Cob number per row

The effect of excess soil moisture of different stages on cob number row^{-1} in different genotypes during 2004-05 and 2005-06 are presented in **Table 13**. The differences with respect to genotype, treatment, stage and their interactions were significant. Excess soil moisture, on average, reduced the cob number row^{-1}. Reduction was higher in plants stressed at the knee height stage. The pattern was almost the same for both experimental years.

During 2004-05 and 2005-06, excess soil moisture stress at the knee height stage caused the least reduction in this parameter in 'V-33' (5.3 and 11.5%, respectively), and the maximum in 'CML-56' (51.3 and 51.8%, respectively). When excess soil moisture stress was imposed at the taselling stage the minimum reduction during 2004-05 and 2005-06 was recorded in 'CML-204 and 'CM-119' (6.0 and 0.0%, respectively). Nevertheless, the reduction in cob number row^{-1} was also to a lesser magnitudes in 'V-32' (8.3 and 2.7%, respectively) and 'V-33' (8.3 and 10.3%, respec-

Table 15 Test weight (g 1000^{-1} seeds) in 10 genotypes of maize under normal and excess soil moisture conditions imposed at knee height or tasselling stage during 2004-05 and 2005-06. Values in parentheses indicate the percentage reduction under excess soil moisture stress.

Genotype	Knee height stage						Tasselling stage					
	2004-05			2005-06			2004-05			2005-06		
	C	ESM		C	ESM		C	ESM		C	ESM	
V-32	241.2	205.7	(14.7)	242.3	202.9	(16.3)	238.3	219.2	(8.0)	236.1	215.5	(8.7)
V-33	226.8	194.0	(14.5)	222.5	193.7	(12.9)	225.2	205.1	(8.9)	222.4	202.5	(8.9)
HUZM-185	198.8	137.1	(31.0)	196.2	133.9	(31.8)	199.0	148.5	(25.4)	195.7	145.4	(25.7)
HUZM-227	215.8	160.4	(25.7)	214.8	157.1	(26.9)	213.5	174.7	(18.2)	210.1	171.8	(18.2)
HUZM-536	247.4	160.8	(35.0)	243.4	158.2	(35.0)	248.9	181.2	(27.2)	245.4	179.8	(26.7)
CML-49	154.2	130.4	(15.4)	152.3	133.3	(12.5)	174.4	154.5	(11.4)	173.2	149.8	(13.5)
CML-56	105.2	54.2	(48.4)	105.1	51.6	(50.9)	103.1	61.3	(40.5)	100.0	60.7	(39.3)
CML-204	251.4	187.5	(25.4)	249.0	186.9	(24.9)	248.8	205.2	(17.5)	245.0	203.7	(16.9)
CM-119	208.0	136.3	(34.5)	206.9	136.0	(34.3)	205.8	174.9	(15.0)	202.1	173.2	(14.3)
CM-211	189.5	143.3	(24.4)	186.3	141.9	(23.8)	191.9	170.5	(11.2)	188.4	165.3	(12.3)
Mean	203.9	152.4		201.9	149.6		203.0	171.6		199.6	169.9	

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD 5 (%)	SEm±	CD 5 (%)
Stage	1.08	4.65	0.56	2.42
Treatment	1.45	4.04	1.62	4.50
Stage × Treatment	2.06	5.71	2.29	6.35
Genotype	2.48	4.95	1.91	3.81
Stage × Genotype	3.51	7.00	2.71	5.39
Treatment × Genotype	3.51	7.00	2.71	5.36
Stage × Treatment × Genotype	3.72	7.62	3.06	6.28

C, control, normal, unstressed condition; ESM, excess soil moisture.

tively), and maximum in 'CML-56' (20.5 and 25.5%, respectively).

Grain number per cob

Grain number cob^{-1} was determined under normal and excess soil moisture stress imposed at the knee height and tasselling stages. Data are presented in **Table 14**. Significant differences were observed with respect to genotype, treatment and stage; except for the treatment × genotype interaction, other interactions did not differ significantly.

Compared to the control, excess soil moisture stress reduced grain number cob^{-1}. The reduction was marginally higher when stress was imposed at the tasselling stage than at the knee height stage. Under excess soil moisture stress, during 2004-05, 'V-32' maintained the highest number of grains cob^{-1} (328.6 grains cob^{-1}), minimum in 'CML-56' (51.5 grains cob^{-1}). An almost similar trend was observed during 2005-06.

During 2004-05, excess soil moisture stress at the knee height stage caused the least percentage reduction in grain number cob^{-1} in 'V-33' (2.1%) and the maximum in 'CML-56' (15.1%). During 2005-06, an almost similar pattern existed during 2004-05.

When excess soil moisture stress was imposed at the tasselling stage, the minimum percentage reduction in grain number cob^{-1} was recorded in 'V-32' (0.5%) and the maximum in 'CML-56' (80.7%) (**Table 14**). During 2005-06, an almost a similar pattern was observed.

Test weight of 1000 seeds

Test weight (1000-seed weight) of different genotypes under normal and excess soil moisture stress at the knee height and tasselling stages are presented in **Table 15**. Differences were significant with respect to genotype, treatment, stage and their interactions.

In general, excess soil moisture stress reduced test weight. The reduction was pronounced when stress was imposed at the knee height stage. Under excess soil moisture stress during 2004-05, 'V-32' maintained the highest test weight (212.5 g), while 'CML-56' the lowest (57.8 g). An almost a similar trend was observed during 2005-06.

When the percentage reduction in test weight compared to the control was computed, it was evident that when excess soil moisture stress was imposed at the knee height stage during 2004-05, the minimum percentage reduction was in 'V-33' (14.5%) and maximum in 'CML-56' (48.4%). Also, during 2005-06, an almost similar pattern was observed.

During 2004-05 as well as 2005-06, when plants were subjected to excess soil moisture stress at the tasselling stage, the percentage reduction in test weight in different genotypes followed a similar trend as observed under stress imposed at the knee height stage.

Grain yield

Grain yield of different genotypes was recorded under normal and excess soil moisture stress at the knee height and tasselling stages (**Table 16**). The differences were significant with respect to genotype, treatment, stage and their interactions.

Excess soil moisture stress reduced seed yield $plant^{-1}$ and the reduction was more pronounced when stress was imposed at the knee height stage. Under excess soil moisture stress, during 2004-05, 'V-32' registered the maximum grain yield $plant^{-1}$ (154.9 g), minimum in 'CML-56' (15.0 g). Genotypic performance was almost similar during 2005-06.

During 2004-05, excess soil moisture stress at the knee height stage caused the minimum percentage reduction in grain yield in 'V-33' (18.7%), maximum in 'CML-56' (79.8%). Different genotypes followed almost a similar trend during 2005-06.

When excess soil moisture stress was imposed at the tasselling stage, the minimum percentage reduction in grain yield $plant^{-1}$ compared to the control during 2004-05 was recorded in 'V-32' (12.3%) and the maximum in 'CML-56' (43.6%). An almost similar trend was observed when excess soil moisture stress was imposed at the tasselling stage.

DISCUSSION

Reduction in leaf area, plant dry matter, yield and yield attributes as a result of excess soil moisture stress were of relatively lesser magnitude in 'V-33', V-32' and 'CML-211, but of relatively higher magnitude in 'CML-56', CM-119'

Table 16 Grain yield (seed weight plant^{-1}) in 10 genotypes of maize under normal and excess soil moisture conditions imposed at knee height or tasselling stage during 2004-05 and 2005-06. Values in parentheses indicate the percentage reduction under excess soil moisture stress.

Genotype	Knee height stage						Tasselling stage					
	2004-05			2005-06			2004-05			2005-06		
	C	ESM		C	ESM		C	ESM		C	ESM	
V-32	186.5	148.2	(20.5)	186.6	151.3	(18.9)	184.1	161.5	(12.3)	185.5	160.4	(13.5)
V-33	167.9	136.5	(18.7)	170.9	137.0	(19.8)	166.6	141.1	(15.3)	169.2	137.7	(18.6)
HUZM-185	141.0	68.7	(51.3)	143.9	70.5	(51.0)	141.4	101.1	(28.5)	140.7	102.1	(27.4)
HUZM-227	166.0	74.7	(55.0)	166.2	77.2	(53.5)	164.5	113.2	(31.2)	164.7	111.1	(32.5)
HUZM-536	163.9	109.3	(33.3)	163.4	111.0	(32.1)	166.5	130.8	(21.4)	165.1	131.7	(20.2)
CML-49	172.3	98.23	(43.0)	173.3	100.6	(42.0)	171.7	124.1	(27.7)	169.9	124.2	(26.9)
CML-56	36.6	7.4	(79.8)	40.7	9.6	(76.4)	40.1	22.6	(43.6)	41.3	25.1	(39.2)
CML-204	174.6	138.2	(20.8)	175.7	135.5	(22.9)	176.7	131.6	(25.5)	176.2	129.5	(26.5)
CM-119	154.4	34.8	(77.5)	156.0	37.6	(75.9)	151.8	102.1	(32.7)	153.3	101.6	(33.7)
CM-211	147.5	35.5	(75.9)	148.0	38.8	(73.8)	144.9	102.7	(29.1)	146.2	102.8	(29.7)
Mean	151.1	85.1		152.3	86.9		150.8	113.1		151.2	112.7	

ANOVA Table

Particulars	2004-05		2005-06	
	SEm±	CD 5 (%)	SEm±	CD 5 (%)
Stage	0.39	1.71	0.39	1.68
Treatment	0.59	1.65	1.00	2.78
Stage × Treatment	0.84	2.33	1.41	3.92
Genotype	2.96	5.89	2.80	5.58
Stage × Genotype	4.18	8.33	3.96	7.89
Treatment × Genotype	4.18	8.33	3.96	7.89
Stage × Treatment × Genotype	4.02	8.03	3.90	7.81

C, control, normal, unstressed condition; ESM, excess soil moisture.

and 'CM-211'. Therefore, these genotypes were classified as being relatively resistant and susceptible to excess soil moisture stress, respectively. The results of both years were also comparable.

Reduction in leaf area under waterlogging is reported in maize (Prasad *et al.* 2007; Srivastava *et al.* 2007) and better recovery in total leaf area after stress is released is observed to be associated with waterlogging-resistance in this crop. In the present study, the percentage reduction in leaf area under waterlogging was lower (20.4 and 17.1%, respectively, at the knee height and tasselling stages) (**Table 4**) than the percentage reduction in number of green leaves plant^{-1} (29.4 and 40.7%, respectively, at the knee height and tasselling stages) (**Table 1**). These indicated that, irrespective of the developmental stage, excess soil moisture stress reduced leaf number plant^{-1} more than leaf area plant^{-1} , and decreased leaf area plant^{-1} was primarily due to reduced green leaves plant^{-1} as a result of induced senescence of older leaves.

Observations clearly indicated that excess soil moisture stress was more injurious to dry matter accumulation in maize plants more when imposed at the knee height stage than at the tasselling stage (**Tables 5, 6**). Excess soil moisture stress at the knee height stage causes more damage to maize plants than at the tasselling stage (Lauer 2001; Zaidi *et al*. 2007). However, Lone and Warsi (2009) reported that waterlogging of maize at knee height stage caused immediate wilting and lodging of the crop. Excess soil moisture stress at the knee height and tasselling stages caused a 43.0 and 25.3% reduction in grain yield plant^{-1}, respectively. Since shoot dry matter, leaf number, leaf area and grain yield were all reduced under excess soil moisture stress, it can be inferred that in maize, excess soil moisture stress at the knee height stage is more detrimental to growth and yield than that at the tasselling stage.

Profuse appearance of nodal roots, even up to five nodes, was observed in waterlogged maize plants (Lone and Warsi 2009). Genotypic differences in nodal roots development have been reported (Shahi *et al.* 2006; Zaidi *et al.* 2007). The amount of nodal roots formed in maize under excess soil moisture stress has been reported to be higher in waterlogging-resistant genotypes (Rathore *et al.* 1997; Baranwal and Singh 2002; Zaidi and Singh 2002; Zaidi *et al*. 2003). The present observations confirmed the significance of nodal roots in conferring waterlogging resistance in maize, probably by providing mechanical support and facilitating oxygen availability to submerged roots, as suggested by Grinieva (1991).

Under excess soil moisture stress anthesis to silking interval (days) is prolonged (Zaidi and Singh 2002; Zaidi *et al*. 2003; Shahi *et al.* 2006). The anthesis to silking interval has also been suggested as a parameter to identify excess soil moisture stress-resistant maize genotypes (Shahi *et al.* 2006; Lone and Warsi 2009). In waterlogging-resistant maize genotypes, although this interval is increased, but to a lesser magnitude as compared to that in waterlogging sensitive genotypes (Shahi *et al.* 2006). In waterlogging-resistant genotypes this interval is reported to be <5 days (Baranwal and Singh 2004; Zaidi *et al.* 2004). In the present investigation, the anthesis to silking duration widened due to waterlogging (**Table 11**). The anthesis to silking interval widened more when stress was imposed at tasselling stage. In some of the genotypes it widened to an extent of 9 days. It is also noted that widening in the duration was of lesser magnitude in excess soil moisture stress resistant genotypes. Widening of the anthesis-silking interval results in poor pollination, which in turn affects overall grain production (Savita *et al.* 2004); probably this was the major factor causing the severe reduction in grain number cob^{-1}, particularly when waterlogging was imposed at the tasselling stage of the crop (**Table 14**). Excess soil moisture stress affects yield and yield components in maize, but the magnitude varies with the stage, duration and the intensity of the stress (Lauer 2001). Mukhtar *et al.* (1990) reported that in maize susceptibility to flooding is maximum at an early vegetative stage followed by late vegetative stage; susceptibility declines with further developmental stages. In the present study the excess soil moisture stress, when applied at the knee height stage, reduces grain yield more than when applied at the tasselling stage (**Table 16**). Zaidi *et al.* (2004) also reported that excess soil moisture stress of knee height stage is more detrimental to yield than that of tasselling stage in maize. The effect of waterlogging at the knee height stage decreased the number of cobs row^{-1} more than when it was imposed at the tasselling stage (**Table 13**). In fact, at the knee height stage, cob primordia are present in the axils of leaves, and when stress is imposed at this stage, their development is hampered. In contrast, at the tasselling stage they have already developed. Therefore, waterlogging at the tasselling stage did not affect the number of cobs row^{-1}. When stress was imposed at the knee height stage, grain number cob^{-1} was on average reduced by only 5%, but when it was imposed at the tasselling stage, the reduction was 12.4% (**Table 14**). This further proved that excess soil moisture stress at the tasselling stage adversely affected anthesis and grain setting. It is reported that waterlogging in maize results in reduction in test weight (1000 seeds weight) and seed yield (Ferreira *et al*. 2007). In the present investigation, excess soil moisture stress at the knee height stage reduced test weight more than excess soil moisture stress at the taselling stage (**Table 15**). Consequently, when excess soil moisture stress was imposed at the knee height stage, the number of grains cob^{-1} in stressed plants was higher than when stress was imposed at the tasselling stage. As a result, at the knee height stage, competition for assimilates between grains of the same cob was higher, resulting in reduced test weight of such plants. Higher grain yield plant^{-1} in waterlogging-resistant genotypes under stress is possible since such genotypes maintain relatively more cobs row^{-1}, higher seed number cob^{-1} (Ferreira *et al.* 2007) and higher test weight under excess soil moisture than susceptible genotypes. Present study further confirmed that excess soil moisture stress reduced yield and yield attributes in maize and genotypic differences existed, as also observed by Ferreira *et al.* (2007). Such variations may be exploited for developing excess soil moisture stress resistant maize genotypes. Development of waterlogging-resistant maize genotypes on the basis of morpho-physiological parameters, yield and yield attributes has been advocated by Shahi *et al.* (2006), Zaidi *et al.* (2007) and Ferreira *et al.* (2007). The present study also indicated that knee height stage is an ideal stage for screening waterlogging-resistant maize genotypes under field condition.

CONCLUSION

Knee height stage was found to be very sensitive to excess soil moisture stress in maize. Therefore, efforts should be made to protect crop from waterlogging stress at this stage. It was also concluded that morphological parameters, viz., more nodal roots, and lesser widening in anthesis-silking interval under excess soil moisture stress condition may be taken as parameters for screening of maize genotypes for excess soil moisture stress resistance in field. It is suggested that further studies are required to investigate the metabolic, hormonal and phenological aspects in relation to waterlogging resistance in maize.

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