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MORPHO-PHYSIOLOGICAL TRAITS AND YIELD OF SOME PROMISING MAIZE (*Zea mays* L.) HYBRIDS UNDER WATERLOGGING STRESS

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ABSTRACT
A field experiment was conducted during 2014 to study physiological traits vis-à-vis yield parameters of fifteen promising maize hybrids under waterlogging stress imposed at two critical stages *viz*, seedling stage (2-leaf stage) and knee-high stage that were compared with normal conditions. Experiment was laid out in a split plot design with three replications. The plot size was 3.0 m having two rows of plants spaced at 60 cm. Results revealed that only four cultivars *viz*, PMH 1, Vivek Hybrid 21, Vivek Hybrid 43 and HQPM 4 could survive (14.00-19.67%) through waterlogging stress at seedling stage while 45.52-60.22% plants survived through knee-high stage waterlogging. The agronomic traits of the stressed plants at seedling stage such as plant height, stover and grain yield were significantly lower than plants of normal conditions. Among them, Vivek Hybrid 21 was the best having the highest yield (0.83 kg/plot) and lowest percent reduction (66.8%) under stress. Waterlogging at seedling stage resulted in significant reduction in chlorophyll content (SPAD value) and leaf area index (LAI) while anthesis silking interval (ASI) and leaf senescence were enhanced. Significantly lower reduction in SPAD value (20.6%) and LAI (28.7%) and less increase in ASI (192%) and leaf senescence (66.5%) was observed in cultivar Vivek Hybrid 21. Though a reduction in the value of all the agronomic traits were also observed with plants undergone water logging stress at knee-high stage, all the plants survived well through stress. The reduction in yield was in the range of 14.3 to 69.7%. ASI and leaf senescence of plants were increased while chlorophyll and LAI decreased under waterlogging stress. Thus, the cultivar Vivek hybrid 21 was tolerant at seedling stage while HQPM 1, HQPM 4 and HQPM 5 were tolerant to knee-high stage waterlogging stress.

KEYWORDS: Grain yield, Maize, Physiological attributes Waterlogging stress.

INTRODUCTION

Maize is a versatile crop which can be grown in diverse environmental conditions. In India, maize is the third most important food crop after rice and wheat. The major maize growing states that contributes more than 80 % of the total maize production are Andhra Pradesh (20.9 %), Karnataka (16.5 %), Rajasthan (9.9 %), Maharashtra (9.1 %), Bihar (8.9 %), Uttar Pradesh (6.1 %), Madhya Pradesh (5.7 %) and Himachal Pradesh (4.4%) (Murdia *et al.,* 2016). It is cultivated predominantly during *kharif* (monsoon/rainy) season where it often suffers from unavoidable waterlogging stress at one or other stages of crop growth due to erratic rains. Maize is generally considered to be a flood tolerant species due to its ability to produce early adventitious roots and morphological adaptaters (aerenchyma) during excess soil moisture conditions (Drew *et al.*, 1979; Fausey *et al*., 1985). The tolerance of maize genotypes towards this particular type of stress varies considerably and is highly influenced by the degree of stress and the genotype of the plant (Torbert *et al*., 1993). Under the International Center for Agricultural Research (ICAR-CIMMYT) collaborative program, large number of maize germplasm has been screened for waterlogging tolerance in India (Zaidi *et al.*,2005). Many promising tolerant lines have been identified and further improved for developing waterlogging tolerant cultivars. In India, about 8.5 million ha of arable soil is affected due to waterlogging and during the summer–rainy season is one of the major production constraints for maize. Therefore, cultivars suitable for waterlogging conditions are required; hence we investigated physiological traits vis-à-vis yield parameters of some promising maize hybrids.

MATERIALS & METHODS

Field experiment was conducted in *kharif* 2014 at Tirhut College of Agriculture, Dholi (25°99'56'' N, 85°59'40'' E, 52.12 m asl) research farm located in Muzaffarpur district of Bihar, India. A total of 15 promising hybrids *viz.*, PMH 1, HM 4, HM 11, HM 9, HQPM 5, HQPM 1, Prakash, Vivek QPM 9, Vivek Hybrid 21, Seedtech 2324, Vivek Hybrid 43, PMH 4, HM 10, HQPM 4 and Bio 9681 were screened against waterlogging stress imposed at two critical stages *viz*, seedling stage (2-leaf stage) and knee-high stage that were compared with normal conditions. Experiment was laid out in a split plot design with three replications. Main plots had three environment *viz.* i) Normal, ii) flooding/water logging stress at seedling, and iii) flooding/ water-logging stress at knee high stage, whereas sub-plots had different hybrid cultivars. The plot

size was 3.0 m having two rows of plants spaced at 60cm. Water-logging treatment was imposed in all the treatment plots by keeping continuous submergence with irrigation water, with an average depth of ponding about 7 inch for six days. After 6 days, water was drained out of the plots. Observations were recorded for parameters *viz*., plant survival (%), plant height (cm), chlorophyll content (SPAD value), anthesis-silking interval (days), leaf senescence (no. of senesced leaves/ plant), leaf area index (LAI), test weight (g), stover yield/plot (kg) and grain yield/plot (kg). Plant survival was recorded by count. Leaf senescence was recorded on the basis of visual score of proportion of leaves completely senesced on the each plant. Plant height was measured from the soil level up to the tip of the young shoot. Chlorophyll content was measured by SPAD leaf chlorophyll meter (Ling *et al.*, 2011). Anthesis silking interval (ASI) was calculated as the difference between numbers of days from 50% anthesis to 50% silking. This evaluation was recorded by daily visual observations during the flowering period (Zaidi *et al.*, 2004). For calculating LAI, representative plants were marked to measure leaf length (L) and maximum leaf width (W) for the largest leaf, and then leaf area and leaf area index (LAI) were calculated according to the method of Montgomery as: Leaf area = L x W x 0.75; LAI= (leaf area per plant x plant number per plot)/ plot area (Ren *et al.*, 2016). Statistical analyses of experimental data were carried out by using SPSS software. Analysis of variance was carried out to test the significance of treatment effect. F-test, least significant difference (LSD) and standard error of means (SEm) were calculated by standard method (Ott and Longnecker, 2008).

RESULTS & DISCUSSION

A statistically significant difference between maize cultivars for adverse effect of waterlogging on plant survival was apparent from the result (Table 1). Only four cultivars *viz*, PMH1, Vivek Hybrid 21, Vivek Hybrid 43 and HQPM 4 could survive (14.00-19.67 %) through waterlogging stress at seedling stage while 45.52-60.22 % plants survived through waterlogging stress at knee-high stage. Data indicated that maize hybrids were more susceptible to waterlogging stress at seedling stage than at knee-high stage. Flooding at any time when the growing point is below the water level may kill plants in a few days, especially if temperatures are high. Growing point tissues are depleted of oxygen. It is reported that maize plants can usually survive short periods of flooding of less than 48 hours (Wenkert *et al.*, 1981).

TABLE 1: Effect of waterlogging stress on survival of different hybrid cultivars

Cultivar (Factor A)	Survival (%)			
	B1	B2	B3	Mean (A)
PMH 1	93.33	15.33	72.00	60.22
HM 4	86.67	0.00	65.67	50.78
HM 11	84.33	0.00	70.00	51.44
HM 9	88.67	0.00	62.33	50.33
HQPM 5	87.67	0.00	59.67	49.11
HQPM 1	86.67	0.00	66.67	51.11
Prakash	86.67	0.00	62.33	49.67
Vivek QPM 9	96.67	0.00	60.00	52.22
Vivek Hybrid 21	96.67	19.67	56.67	57.67
Seedtech 2324	93.33	0.00	60.00	51.11
Vivek Hybrid 43	62.57	14.00	60.00	45.52
PMH 4	97.67	0.00	57.67	51.78
HM 10	92.33	0.00	59.00	50.44
HQPM 4	92.33	16.67	66.67	58.56
Bio 9681	83.33	0.00	56.67	46.67
	LSD (p=0.05)		SEm (±)	
Factor (A)	3.71		1.15	
Factor (B) at same level of A	3.19		1.46	
Factor (A) at same level of B	4.07		0.9	

B1= Normal **B2**= Waterlogging at seedling stage **B3**= Waterlogging at knee-high stage
LSD = Least significant difference (p=0.05) **SEm**= Standard error of means

Effect of waterlogging stress at seedling stage

The agronomic traits of the stressed plants such as plant height, stover and grain yield were significantly lower than plants of normal conditions (Table 2). Statistically significant differences among the cultivars were observed for various parameters except test weight. Among these, Vivek Hybrid 21 was the best having significantly the highest plant height (108.7 cm), stover yield (0.47 kg/plot) and grain yield (0.83 kg/plot). The percent reduction in plant height, stover yield and grain yield were also the lowest *viz.*, 21.1 %, 6.0 %, and 66.8 %, respectively in Vivek Hybrid 21 compared to other cultivars (highest value being 47.6 %, 96.1 %, and 86.3 %, respectively) under water-logging conditions. Decrease in plant height of maize under waterlogging was also reported by Ren *et al.* (2014) while Rathore *et al.* (1998) reported that under waterlogged conditions, maize yield had positive correlation with the plant height. Howell and Hiler (1974) and Bhan (1977) demonstrated that grain yield of maize decreased by 20-35 % after waterlogging for only 1-2 days

at 3-leaf stage. Li *et al.* (2011) found that waterlogging for one day had little effect on maize production, but waterlogging for more than three days decreased yield by over 40 %. At 6-leaf stage, waterlogging for 5-7 days, as well as 7 days at tasseling stage, resulted in total loss of summer maize. However, in contrast to ours, these studies were conducted in pot experiments and were not consistent.

TABLE 2: Effect of waterlogging stress at seedling stage on agronomic traits of different hybrid cultivars

Cultivar (Factor A)	Plant height (cm)			Stover yield/plot (kg)			Grain yield/plot (kg)			Test weight (g)		
	B1	B2	Mean	B1	B2	Mean	B1	B2	Mean	B1	B2	Mean
PMH 1	165.0	86.5	125.8	1.57	0.13	0.79	3.63	0.50	2.07	228.0	163.4	195.7
Vivek Hybrid 21	137.7	108.7	123.2	0.50	0.47	0.53	2.50	0.83	1.67	217.1	125.0	171.1
Vivek Hybrid 43	82.4	79.2	80.8	2.57	0.10	1.01	3.43	0.47	1.95	201.0	151.7	176.4
HQPM 4	154.3	97.3	125.8	1.60	0.30	0.90	4.37	0.63	2.50	217.0	176.7	196.9
	LSD	SEm (±)		LSD	SEm (±)		LSD	SEm (±)		LSD	SEm (±)	
Factor (A)	11.90	3.04		0.16	0.06		NS	0.19		NS	8.24	
Factor (B) at same level of A	13.11	1.73		0.20	0.11		0.83	0.28		NS	5.79	
Factor (A) at same level of B	9.52	6.73		0.13	0.07		0.30	0.06		NS	6.0	

B1= Normal **B2**= Waterlogging at seedling stage **LSD** = Least significant difference (p=0.05)
SEm= Standard error of means **NS**=Non Significant

Waterlogging at seedling stage resulted in significant reduction in chlorophyll content (SPAD value) and LAI, while anthesis-silking interval (ASI) and leaf senescence were enhanced (Table 3). SPAD values under normal conditions varied from 27.83 to 45.30 while under waterlogged conditions varied from 23.03 to 34.13. Significantly lower reduction in SPAD value (20.6 %) was observed in cultivar Vivek Hybrid 21 under waterlogging at seedling stage. Yield under both normal and waterlogging conditions has been reported to be positively correlated to SPAD values at both genotypic and phenotypic level. Differences in the relative content of chlorophyll were evidenced under flooding and the tolerant cultivars had higher chlorophyll (SPAD value). Zaidi *et al.* (2007a) using a chlorophyll meter observed that more tolerant maize genotypes had lower chlorophyll degradation.

TABLE 3: Effect of waterlogging stress at seedling stage on physiological traits of different hybrid cultivars

Cultivar (Factor A)	Chlorophyll content* (SPAD value)			Leaf area index*			Anthesis silking interval (days)			Leaf senescence* (no. of senesced leaves/ plant)		
	B1	B2	Mean	B1	B2	Mean	B1	B2	Mean	B1	B2	Mean
PMH 1	44.03	25.10	34.57	6.21	2.87	4.54	2.67	8.67	5.67	1.33	4.33	2.83
Vivek Hybrid 21	35.60	28.27	31.93	3.59	2.56	3.08	4.13	6.92	5.53	2.00	3.33	2.67
Vivek Hybrid 43	27.83	23.03	25.43	4.71	2.43	3.57	3.90	9.57	6.74	2.57	5.10	3.83
HQPM 4	45.30	34.13	39.72	6.48	3.17	4.83	2.33	6.00	4.17	1.33	3.00	2.17
	LSD	SEm (±)		LSD	SEm (±)		LSD	SEm (±)		LSD	SEm (±)	
Factor (A)	3.56	1.16		0.06	0.02		1.04	0.29		1.11	0.32	
Factor (B) at same level of A	4.14	2.90		0.12	0.02		1.22	0.42		0.36	0.19	
Factor (A) at same level of B	3.23	0.98		0.10	0.03		1.33	0.39		NS	0.47	

B1= Normal **B2**= Waterlogging at seedling stage **LSD** = Least significant difference (p=0.05)
SEm= Standard error of means **NS**=Non Significant *Observation taken at flowering

There was significant reduction in leaf area of maize hybrids under waterlogging stress however, among the hybrids that survived, the lowest reduction in LAI (28.7 %) was observed in cultivar Vivek Hybrid 21 and the highest in PMH-1 (53.8%). Zaidi *et al.* (2003) also observed a severe reduction in leaf area in Indian maize genotypes under flooding and tolerant maize genotypes had a lower reduction in leaf area than susceptible genotypes (Zaidi *et al.*, 2004). ASI and leaf senescence increased under waterlogging stress. The ASI ranged between 2.33 to 4.13 days under normal condition while it was 6.00 to 9.57 days in waterlogged conditions. Among all the surviving maize hybrids, significantly less increase in ASI (67.6 %) was observed in cultivar Vivek Hybrid 21 compared to the highest in PMH-1 (224.7 %). The flooded condition led to negative impacts on reproductive performance because of a delay in silking which resulted in long intervals between male and female flowering. A greater index for ASI indicates a lower tolerance. Other authors also concluded that maize genotypes more susceptible to flooding tend to have longer ASI while most tolerant genotypes had shorter ASI (Zaidi *et al.*, 2003, 2004; deSouza *et al.*, 2011). Rathore *et al.* (1998) reported that under waterlogged conditions, maize yield was

negatively correlated with anthesis-silking interval (ASI). Leaf senescence in different maize hybrids was significantly enhanced (up to 225.6%) from normal to waterlogged conditions, and the lowest increase (66.5 %) was recorded in the cultivar Vivek Hybrid 21. In normal conditions, average number of leaves senesced per plant was 1.33 to 2.57 while under waterlogged condition it was 3.00 to 5.10. The differences among cultivars within same condition (normal or waterlogged) were however non-significant. Zubairi *et al.* (2012) also reported that waterlogging influenced the growth of maize plants. The leaves which were present on the lower portion of the plant showed leaf senescence and became bronze in colour. In waterlogged conditions, oxygen does not transport efficiently and loss of essential ions takes place.

Effect of waterlogging stress at knee-high stage

Similar trend of results were apparent under water logging stress imposed at knee-high stage but all the cultivars survived through stress. Analysis of variance in normal and waterlogged conditions showed significant difference for most of the parameters. The agronomic traits of the waterlogging stressed plants such as plant height, stover and grain yield were significantly lower than plants of normal conditions (Table 4).

TABLE 4: Effect of waterlogging stress at knee-high stage on agronomic traits of different hybrid cultivars

Cultivar (Factor A)	Plant height (cm)			Stover yield/plot (kg)			Grain yield/plot (kg)			Test weight (g)		
	B1	B3	Mean	B1	B3	Mean	B1	B3	Mean	B1	B3	Mean
PMH 1	165.0	132.7	148.8	1.54	0.64	1.09	3.63	1.70	2.67	228.0	198.3	213.1
HM 4	146.3	121.7	134.0	0.57	0.46	0.51	2.10	1.80	1.95	214.9	187.5	201.2
HM 11	142.3	131.0	136.7	0.62	0.41	0.51	2.07	1.43	1.75	199.0	193.9	196.4
HM 9	145.0	134.7	139.8	0.95	0.45	0.70	2.53	1.33	1.93	240.4	215.4	227.9
HQPM 5	152.3	128.0	140.2	1.16	0.83	1.00	4.53	1.83	3.18	205.9	202.8	204.3
HQPM 1	144.3	126.7	135.5	0.82	0.52	0.67	4.40	1.90	3.15	208.6	206.1	207.4
Prakash	139.3	119.7	129.5	1.05	0.48	0.77	3.30	1.00	2.15	210.2	179.5	194.9
Vivek QPM 9	136.7	125.0	130.8	1.28	1.04	1.16	3.47	1.60	2.53	193.5	156.4	175.0
Vivek Hybrid 21	137.7	124.0	130.8	0.90	0.62	0.76	2.50	1.10	1.80	217.1	136.2	176.6
Seedtech 2324	146.0	108.7	127.3	1.24	0.77	1.01	3.23	1.50	2.37	226.0	165.2	195.6
Vivek Hybrid 43	139.2	101.7	120.5	2.54	0.35	1.45	3.43	1.23	2.33	151.7	136.5	144.1
PMH 4	137.7	122.0	129.8	0.60	0.43	0.52	2.30	1.30	1.80	200.0	175.7	187.8
HM 10	151.7	117.7	134.7	1.33	0.41	0.87	3.60	1.60	2.60	228.1	215.3	221.7
HQPM 4	154.3	127.3	140.8	1.61	0.80	1.21	4.37	1.80	3.08	217.0	200.6	208.8
Bio 9681	143.3	118.0	130.7	0.72	0.89	0.81	2.50	1.27	1.88	237.9	218.3	228.1
	LSD	SEm (±)		LSD	SEm (±)		LSD	SEm (±)		LSD	SEm (±)	
Factor (A)	5.9	1.7		0.40	0.14		0.31	0.11		30.6	10.5	
Factor (B) at same level of A	6.8	1.5		0.55	0.20		0.25	0.15		42.8	14.9	
Factor (A) at same level of B	4.4	2.5		0.56	0.19		0.11	0.06		43.0	14.8	

B1= Normal **B3**= Waterlogging at knee-high stage LSD = Least significant difference (p=0.05) **SEm**= Standard error of means

Statistically significant differences among the cultivars were observed for all these parameters. The cultivar HQPM 1, HQPM 4 and HQPM 5 were found tolerant to waterlogged condition with better agronomic performance particularly grain yield which was between 1.8. to 1.90 kg/plot compared to the lowest value of 1.00 kg/plot. The reduction in grain yield in these cultivars under waterlogging stress ranged from 56.8 % to 59.6 % compared to the highest reduction of 69.7 %. Ren *et al.* (2014) reported that summer maize was most susceptible to waterlogging damage at the three-leaf stage. They also reported that the maximum grain-filling rate was decreased under waterlogging which corroborates our studies.

Waterlogging at knee-high stage also resulted in significant reduction in chlorophyll content (3.0 to 29.6 %) and LAI (15.0-60.4 %), while anthesis-silking interval (99.7-262.2 %) and leaf senescence (120.6-300.7 %) were enhanced (Table 5). In most of the cultivars, a higher increase in ASI and leaf senescence was observed at knee-high stage than at seedling stage. SPAD values under normal conditions varied from 27.83 to 47.30 while under waterlogged conditions varied from 27.0 to 41.50. Significantly lower reduction in SPAD value (27.0 %) was observed in cultivar Vivek Hybrid 43. The cultivars, HQPM 4 and HQPM 5 maintained chlorophyll under waterlogging stress at knee-high stage. There was significant reduction in LAI of maize hybrids under waterlogging stress however, among them the lowest reduction in LAI (15.00 %) was observed in cultivar HM-4 and the highest in Prakash (60.38 %). Reduction in LAI of maize was also reported by Ren *et al.* (2014). ASI and leaf senescence was found to increase under waterlogging stress. The ASI ranged between 2.00 to 4.33 days under normal condition while it was 5.67 to 11.00 days in waterlogged conditions. Among all the maize hybrids, significantly less increase in ASI (99.73 %) was observed in cultivar HM 9 compared to the highest in PMH 1 (262.17 %). The ASI in HQPM 4 (5.67 days) and HQPM 5 (6.67 days) under waterlogged condition was in moderate range. Leaf senescence in different maize hybrids was significantly enhanced (up to 300.75 %) from

normal to waterlogged conditions, and the lowest increase (120.62 %) was recorded in the cultivar Vivek Hybrid 43. In normal conditions, average number of leaves senesced per plant was 1.00 to 2.57 while under waterlogged condition it was 3.33 to 5.67. The differences among cultivars within same condition (normal or waterlogged) were non-significant. Lizaso and Ritchie (1997) also reported that root zone saturation resulted in increased leaf senescence and reduced photosynthesis.

TABLE 5: Effect of waterlogging stress at knee-high stage on physiological traits of different hybrid cultivars

Cultivar (Factor A)	Chlorophyll content* (SPAD value)			Leaf area index*			Anthesis silking interval (days)			Leaf senescence* (no. of senesced leaves/ plant)		
	B1	B3	Mean	B1	B3	Mean	B1	B3	Mean	B1	B3	Mean
PMH 1	44.03	31.50	37.77	6.21	3.48	4.85	2.67	9.67	6.17	1.33	5.00	3.17
HM 4	36.13	31.93	34.03	3.60	3.06	3.33	4.00	9.00	6.50	1.67	5.00	3.33
HM 11	36.50	34.37	35.43	3.83	2.90	3.37	4.00	8.33	6.17	1.67	4.00	2.83
HM 9	38.60	28.40	33.50	4.39	2.77	3.58	3.67	7.33	5.50	1.33	5.33	3.33
HQPM 5	47.30	40.10	43.70	6.81	3.85	5.33	2.00	6.67	4.33	1.00	3.67	2.33
HQPM 1	46.73	37.27	42.00	6.60	3.99	5.30	2.33	7.67	5.00	1.33	4.33	2.83
Prakash	41.53	34.90	38.22	5.30	2.10	3.70	3.33	9.33	6.33	1.33	4.67	3.00
Vivek QPM 9	42.03	39.40	40.72	5.59	3.19	4.39	2.67	7.67	5.17	1.67	4.00	2.83
Vivek Hybrid 21	35.60	33.20	34.40	3.59	2.12	2.85	4.33	9.67	7.00	2.00	5.00	3.50
Seedtech 2324	41.00	38.10	39.55	5.04	3.05	4.04	3.33	7.33	5.33	1.67	4.00	2.83
Vivek Hybrid 43	27.83	27.00	27.42	4.71	2.25	3.48	3.90	11.00	7.45	2.57	5.67	4.12
PMH 4	35.30	34.90	35.10	3.32	2.51	2.92	4.00	9.00	6.50	1.67	4.33	3.00
HM 10	43.87	30.90	37.38	5.93	3.32	4.63	2.67	9.33	6.00	1.33	5.33	3.33
HQPM 4	45.30	41.50	43.40	6.48	3.70	5.09	2.33	5.67	4.00	1.33	3.33	2.33
Bio 9681	37.27	29.27	33.27	4.14	2.40	3.27	3.67	7.67	5.67	1.67	5.67	3.67
	LSD	SEm (±)		LSD	SEm (±)		LSD	SEm (±)		LSD	SEm (±)	
Factor (A)	4.36	1.50		0.06	0.02		0.70	0.24		0.76	0.26	
Factor (B) at same level of A	6.14	2.12		0.08	0.03		0.87	0.34		0.47	0.12	
Factor (A) at same level of B	6.15	2.11		0.08	0.03		0.93	0.32		NS	0.38	

B1= Normal B3= Waterlogging at knee-high stage **LSD** = Least significant difference (p=0.05)
SEm= Standard error of means NS=Non Significant *Observation taken at flowering

It is clear from the study that maize cultivars were more adversely affected by waterlogging stress at seedling stage than at knee-high stage. The cultivar Vivek Hybrid 21 was tolerant at seedling stage while HQPM 1, HQPM 4 and HQPM 5 were tolerant to knee-high stage waterlogging stress with better agronomic performance, particularly grain yield, vis-à-vis physiological traits like leaf chlorophyll, leaf area index, anthesis-silking interval and leaf senescence of plants under stress.

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