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Evaluation of Maize (*Zea mays* L.) Genotypes for Morphological and Root Characters under Excessive Moisture Stress Condition

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A B S T R A C T

Maize is highly productive crop if it is grown under optimal environmental and management conditions. Waterlogging, caused by contingent flooding, continuous rainfall and inadequate drainage or a high water table, is one of the most important constraints for maize production in Asia and many other parts of the world. In the present experiment 6 maize genotypes was studied under waterlogged condition for seven days inundation at three different growth stages viz, at the seedling stage (10 days after sowing), the knee high stage (30 days after sowing) and tasseling stage (50 days after sowing). Days to 50% anthesis (DT), Days to 50% silking (DS), number of dried leaves and number of brace roots increased but plant height ,ear height, root fresh weight, root dry weight and root length were decreased under waterlogged condition.BAU-15-102 performed better than all other genotypes under waterlogged condition.

Introduction

Maize is the third most important crop in India after rice and wheat (Al-Swailem *et al.*, 2005; Yadav *et al.*, 2014). It is under cultivation across the globe, including tropical, subtropical and temperate regions, from sea level to 3000 m above sea level. The Composition per 100 g of edible portion of maize (dry) is Protein 11.1g, Fat 3.6 g, Fibre 2.7 g, Calories 342, Amino acids 1.78 mg, Carbohydrates 66.2 g, Calcium 10 mg, Iron

2.3 mg, Carotene 90 ug, Vitamin C 0.12 mg etc. (Gopalan *et al.*, 2007). There are many theories depicting the specific origin of maize in Mesoamerica. Being a C_4 plant, it is most productive in terms of food nutrients produced per unit land area, per unit of water transpired and per unit of time.

Among the various abiotic stresses, waterlogging, caused by contingent flooding, continuous rainfall and inadequate drainage or a high water table, is one of the most important constraints for maize production in Asia and many other parts of the world. In South Asia alone, more than 15% of the total maize growing area is affected by floods and water-logging problems (Rathore *et al.*, 1997; Chen *et al.*, 2014), resulting into production losses by 25- 30% yearly.

Responses of plant to anoxia lead to changes at the molecular, biochemical, physiological, anatomical and morphological levels. The aerenchyma formation (Mano *et al.*, 2006) in root cortex, stem hypertrophy and adventitious root aids for adaptation under to flooding stress. Excess moisture stress at knee-high stage, suppressed plant growth and development (stunted growth), considerable reduction in dry matter accumulation, transpiration, leaf area development, affected anthesis and silking, anthesis-silking interval (ASI) and eventually resulted poor grain formation and poor yield (Rathore *et al.*, 1997). Waterlogging at early growth stages causes severe reductions in plant height, dry matter accumulation, and yield (Liu *et al.*, 2010; Mukhtar *et al.*, 1990; Rao and Li 2003). Maize is also very susceptible to waterlogging stress at an early vegetative stage (Mukhtar *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). When the plants undergone excessive moisture stress at different growth stage resulted into reduced plant growth and yield. Maize, when waterlogged, shows an increase in the number of nodes bearing adventitious roots, also termed nodal roots (Lone and Warsi 2009). Under waterlogged conditions, development of adventitious roots acts as a survival mechanism by anchoring the plants and thus avoiding lodging. The tips of adventitious roots and root hairs help plants to obtain oxygen dissolved in water (Grinieva *et al.*, 1991; Mahal *et al.*, 2000; Lizaso *et al.*, 2001).

The present investigation aimed to study the effect of excess soil moisture stress on critical growth stages, i.e., seedling stage, knee height stage and taselling stage, affecting morphological and root attributes of maize genotypes to identifying resistant maize genotypes at the field level.

Materials and Methods

An experiment was conducted during kharif 2018 at the agricultural research farm, Birsa Agricultural University, Kanke, Ranchi. Seeds of 6 maize genotypes viz., BAU-15-145, BAU-15-102, BAU-15-180, BAU-15-78 -1, BAU-15-122 and BAU-15-87, taken from the maize research project, were sown in maize research plot. The experiment was laid out in a randomized block design with two replications under normal fertilization. After sowing Atrazine @ 4 g/ L was sprayed to arrest the weed growth. Four manual weedings were carried out during crop period. Each plot was 1m in length, row to row spacing 0.5m and plant to plant spacing was 0.2m.Plastic sheets of 6feet depth was laid out by the side of control plots to avoid the water seepage from the flooding treatment plots. Excess soil moisture stress was imposed by flooding the plots and maintaining the water level 10 cm above the soil surface for 7 days. The stress was imposed either at the seedling stage (10 days after sowing), the knee high stage (30 days after sowing) and tasseling stage (50 days after sowing) The excess water was drained out after 7days of flooding and later on plots were maintained at a normal level of soil moisture. Various parameters were recorded in normal and excess moisture-stressed plants at the maturity of plants. Plants maintained under normal irrigation served as the control and others at three flooding time viz., the seedling stage (10 days after sowing TRT 1), the knee high stage (30 days after sowing, TRT 2) and tasseling stage (50 days after sowing TRT3) were treatment plots. Days to 50% anthesis (DT) 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 as 50% silking (DS) were also recorded. The height of the plants was measured from the ground level to the apex of plant and the average was expressed as plant height in cm. The ear height was measured from the ground level to the node where ear emerged on the stalk and the average was expressed as ear height in cm. Total count of leaf emerged on the plants as leaf per plant (LPP) and number of dried leaf as number of dry leaf per plant(NDL). Representative whole plant along with roots and leaves were sun dried completely and weighed to get plant dry weight (PDW). Number of brace roots developed were counted and denoted as (NBR). Roots were taken out and washed thoroughly and weighed to take root fresh weight (RFW), and then dried and weighed to take readings of dry root weight (RDW). Length of roots were measured in cm and designated as (RL).

Results and Discussion

Days to 50% tasseling (DT)

Days to 50% tasseling were higher at knee high stage for all the genotypes in comparison to both of other stages. Maximum % increase was observed in BAU-15-87(15.9%) and minimum in BAU-15-102(8.3%) in TRT2. In TRT1, maximum was for BAU-15-145 and BAU-15-78 -1 (6.7%), minimum for BAU-15-180& BAU-15-122 (4.4). In TRT3, highest was in BAU-15-87 (5.6%) and lowest in BAU-15-102 & BAU-15-122 (1.8%). Data is presented in table 1.

Days to 50% silking (DS)

In TRT1, maximum % increase in days to 50% silking(DS) was found in BAU-15-87 (10.5%) and minimum in BAU-15-102(5%). In TRT2 maximum %increase was observed in BAU-15-87 (21.1%) and minimum in BAU-15-102(10%). But in TRT3 maximum was observed in BAU-15-87 (24.6%) and minimum in BAU-15-102(13.3%).Similarly Shah *et al*.,(2012) and Ren *et al.*, (2014) has also observed that delay in days to 50% silking was highest at knee high stage. Data presented in table 2.

Ear height (EH)

Maximum % decrease of ear height was observed in BAU-15-145(20.3%) and minimum in BAU-15-102 (8.7%) when waterlogging was exposed at 30days after sowing (TRT2). In TRT1 highest % decrease was found in BAU-15-145 (31.2%) and lowest in BAU-15-102 (7%). In TRT3 highest %reduction was on served in BAU-15-180 (4.8%) and lowest in BAU-15-102(1.95). Zhang *et al.*, (2013) has also observed similar results in their experiments. Data are presented in table 3.

Plant height (PH)

In TRT1maximum reduction in plant height was observed in BAU-15-78-1 (25%) and minimum in BAU-15-102 (22%). In TRT2 maximum height reduction was observed in BAU-15-122 & BAU-15-87 (10.9%) and minimum in BAU-15-102(8.9%). In TRT3 not much difference was observed among the %reduction for this trait (Table 4).

Leaves per plant (LPP)

Per cent reduction in number of leaves per plant was observed maximum in BAU-15-78 -1 (45.6%) and minimum in BAU-15-102(18.6%) in TRT1. This reduction was highest in BAU-15-180 (22.6%) and least in BAU-15-102(6.2%) in TRT2. In TRT3 highest reduction percentage was observed in BAU-15-145 (10.58%) and lowest in BAU-15-180 (7.58%).Similar results are also observed by Shah *et al.,* (2012).Data are presented in table 5.

Number of dry leaves (NDL)

Waterlogging increased the number of dry leaves in all the three treatments for 7 days flooding in comparison to control plants. In TRT1 maximum % increase was observed in BAU-15-122 (106.9% 0 and minimum in BAU-15-102 (20%). In TRT2 maximum increase percentage was observed in BAU-15-122 (153%) and minimum in BAU-15-102 (51.6%). In TRT3 maximum increase % was observed in BAU-15-122 (184.6%) and minimum in BAU-15-102(73.1%). These findings are in congruence with the observation of Lizaso and Ritchie (1997) (Table 6).

Plant dry weight (PDW)

In TRT1 maximum reduction was observed in BAU-15-180 (30.6%) and mimimum in BAU-15-102(12.5%). In TRT2, maximum was observed in BAU-15-180 (34%) and mimimum in BAU-15-102914.6%). But in TRT3 maximum was observed in BAU-15-180 (32.1%)and mimimum in BAU-15-102(13.8%). This observation was also supported by the findings of Shah *et al.*, (2011). Data are presented in table 7.

Fresh root weight (FRW)

In TRT1 maximum reduction was in BAU-15-180 (12%) and minimum in BAU-15-102(4%). In TRT2 maximum reduction found in BAU-15-78 -1 (22%) band minimum in BAU-15-102(8.9%). In TRT3, maximum reduction was recorded for BAU-15-78 -1 (16.7%) and minimum in BAU-15-102 (2.9%). These findings are in congruence with the findings of Li *et al.,* (2018) who reported that waterlogging inhibited maize root and lateral root growth. Data are presented in table 8.

Dry root weight (DRW)

In TRT1 maximum reduction was observed in BAU-15-78 -1 (26.9%) and minimum in BAU-15-102(13.9%). In TRT2 maximum reduction was found in BAU-15-78 -1(36.7%) and minimum in BAU-15-102(23.9%). In TRT3 maximum reduction was found in BAU-15-78 -1(52.2%) and minimum in BAU-15-102(39.9%). Osman *et al.,* (2013) has also found results similar to these findings. Data are presented in table 9.

Number of brace roots (NBR)

In TRT1maximum increase was observed in BAU-15-102(104.3%) and minimum in BAU-15-180 (23.5%).

In TRT2 maximum increase was observed in BAU-15-102(180.7%) and minimum in BAU-15-180 (47.2%). TRT3maximum increase was observed in BAU-15-102(227.1%) and minimum in BAU-15-87 (62.7%). Zaidi *et al.,* (2007) and Khaldun *et al.,* (2017) has reported increase in brace root development is under waterlogged condition as a adaptation mechanism for anchorage and avoiding lodging. Data are presented in table 10.

Table.1 Effect of waterlogging treatment on days to 50% tasseling(DT) in days at different stages of maize genotypes. Values in parentheses indicate the percentage increase over the control

Genotypes	Control	TRT1	TRT2	TRT3
BAU-15-145	52.5	56(6.7)	59(12.4)	54.5(3.8)
BAU-15-102	54.5	57(4.6)	59(8.3)	55.5(1.8)
BAU-15-180	56.5	59(4.4)	65(15)	58(2.7)
BAU-15-78 -1	52.5	56(6.7)	59(12.4)	55(4.8)
BAU-15-122	56.5	59(4.4)	63(11.5)	57.5(1.8)
BAU-15-87	53.5	57(6.5)	62(15.9)	56.5(5.6)

Table.2 Effect of waterlogging treatment on days to 50% silking(DS) in days at different stages of maize genotypes. Values in parentheses indicate the percentage increase over the control

Genotypes	Control	TRT1	TRT2	TRT3
BAU-15-145	58	64(10.3)	67(15.5)	71(22.4)
BAU-15-102	60	63(5)	66(10)	68(13.3)
BAU-15-180	60	65(8.3)	72(20)	75(25)
BAU-15-78 -1	58	63(8.6)	68(17.2)	71(22.4)
BAU-15-122	61	66(8.2)	70(14.8)	74(21.3)
BAU-15-87	57	63(10.5)	69(21.1)	71(24.6)

Table.3 Effect of waterlogging treatment on ear height(EH) in cm at different stages of maize genotypes. Values in parentheses indicate the percentage decrease over the control

Genotypes	Control	TRT1	TRT2	TRT3
BAU-15-145	111.4	76.6(31.2)	88.8(20.3)	108.3(2.8)
BAU-15-102	108.7	101(7))	99.2(8.7)	106.6(1.9)
BAU-15-180	102.9	78.5(23.7)	90.6(11.9)	98(4.8)
BAU-15-78 -1	103.7	78.3(24.5)	90.4(12.8)	101.6(2.1)
BAU-15-122	118.6	88.3(25.6)	100.4(15.3)	116.1(2.1)
BAU-15-87	92.2	73.4(20.4)	79.8(13.4)	88.5(4.0)

Table.4 Effect of waterlogging treatment on plant height (PH) in cm at different stages of maize genotypes. Values in parentheses indicate the percentage decrease over the control

Genotypes	Control	TRT1	TRT2	TRT3
BAU-15-145	210.8	162.3(23)	191.1(9.3)	209.2(0.8)
BAU-15-102	213.4	166.4(22)	194.4(8.9)	211.7(0.8)
BAU-15-180	246.7	187.4(24)	220.5(10.6)	245.0(0.7)
BAU-15-78 -1	225.2	168.9(25)	200.8(10.8)	223.55(0.7)
BAU-15-122	244.2	188(23)	217.5(10.9)	242.5(0.7)
BAU-15-87	196.5	149.3(24)	175.2(10.9)	194.8(0.8)

Table.5 Effect of waterlogging treatment on leaves per plant, LPP(no.) at different stages of maize genotypes. Values in parentheses indicate the percentage decrease over the control

Genotypes	Control	TRT1	TRT2	TRT3
BAU-15-145	13.8	9.3(32.5)	11.8(14.5)	12.3(10.8)
BAU-15-102	16.1	13.1(18.6)	15.1(6.2)	14.8(8.4)
BAU-15-180	13.5	8.1(39.6)	10.5(22.6)	12.5(7.8)
BAU-15-78 -1	13.5	7.3(45.6)	9.3(30.8)	12.3(8.50)
BAU-15-122	14.5	10.3(28.7)	12.3(14.8)	13.3(7.9)
BAU-15-87	14.5	9.5(34.4)	11.1(23.1)	13.2(9.3)

Table.6 Effect of waterlogging treatment on number of dry leaves (NDL) at different stages of maize genotypes. Values in parentheses indicate the percentage increase over the control

Genotypes	Control	TRT1	TRT2	TRT3
BAU-15-145	2.9	5.2(81.3)	6.2(116.4)	6.5(127.4)
BAU-15-102	3.2	4.5(20)	4.8(51.6)	5.5(73.1)
BAU-15-180	4.2	5.3(28.1)	6.5(55.8)	6.8(64.65)
BAU-15-78 -1	2.5	4.8(93.3)	5.7(108.1)	6.5(161.0)
BAU-15-122	2.2	4.5(106.9)	5.5(153.0)	6.2(184.6)
BAU-15-87	2.5	4.5(80.5)	5.5(120.8)	5.5(120.8)

Table.7 Effect of waterlogging treatment on plant dry weight, PDW (gm) at different stages of maize genotypes. Values in parentheses indicate the percentage decrease over the control

Genotypes	Control	TRT1	TRT2	TRT3
BAU-15-145	362.8	309.0(14.8)	300.0(17.3)	299.5(17.4)
BAU-15-102	285.0	249.2(12.5)	243.2(14.6)	245.4(13.8)
BAU-15-180	361.7	250.7(30.6)	244.1(34)	245.7(32.1)
BAU-15-78 -1	355.8	278.8(21.6)	274.1(25.2)	277.3(22.0)
BAU-15-122	244.8	204.1(16.6)	199.9(18.3)	203(17)
BAU-15-87	354.1	288.1(18.6)	278.7(21.2)	284.3(19.7)

Table.8 Effect of waterlogging treatment on fresh root weight, FRW (gm) at different stages of maize genotypes. Values in parentheses indicate the percentage decrease over the control

Genotypes	Control	TRT1	TRT2	TRT3
BAU-15-145	49.6	44.05(11.2)	38.9(21.6)	42(15.3)
BAU-15-102	45.4	43.6(4)	41.4(8.9)	44.1(2.9)
BAU-15-180	49.2	43.3(12.0)	38.5(21.8)	41.1(16.5)
BAU-15-78 -1	49.0	44.0(10.2)	38.2(22)	40.8(16.7)
BAU-15-122	48.55	45.7(5.9)	39.9(17.8)	42.5(12.5)
BAU-15-87	51.625	49.1(4.8)	44.1(14.5)	46.7(9.5)

Table.9 Effect of waterlogging treatment on dry root weight, DRW (gm) at different stages of maize genotypes. Values in parentheses indicate the percentage decrease over the control

Genotypes	Control	TRT1	TRT2	TRT3
BAU-15-145	15.6	11.8(24.1)	10.4(33.4)	8.0(48.2)
BAU-15-102	14.4	12.4(13.9)	10.8(23.9)	8.7(39.9)
BAU-15-180	15.3	11.3(25.6)	9.9(35.1)	7.6(50.2)
BAU-15-78 -1	14.9	10.9(26.9)	9.4(36.7)	7.1(52.2)
BAU-15-122	14.4	12.4(14.2)	10.9(24.3)	8.6(40.2)
BAU-15-87	15.6	12.2(21.8)	10.7(31.1)	8.4(45.9)

Table.10 Effect of waterlogging treatment on number of brace roots (NBR) at different stages of maize genotypes. Values in parentheses indicate the percentage increase over the control

Genotypes	Control	TRT1	TRT2	TRT3
BAU-15-145	14.9	25.45(70.8)	33.5(124.8)	37.5(151.7)
BAU-15-102	14.0	28.6(104.3)	39.3(180.7)	45.8(227.1)
BAU-15-180	18.1	22.35(23.5)	28(54.7)	31.5(74)
BAU-15-78 -1	13.4	17.2(28.4)	21.9(63.4)	27.4(104.5)
BAU-15-122	15.2	20.85(37.2)	28.7(88.8)	34.2(125)
BAU-15-87	19.3	24.1(24.9)	28.4(47.2)	31.4(62.7)

Table.11 Effect of waterlogging treatment on root length(RL),in cm at different stages of maize genotypes. Values in parentheses indicate the percentage decrease over the control

Genotypes	Control	TRT1	TRT2	TRT3
BAU-15-145	30.1	27.8(7.5)	27.3(9.2)	25.4(15.7)
BAU-15-102	26.7	25.6(3.6)	25.3(5.1)	24.5(8.2)
BAU-15-180	29.7	26.9(9.6)	25.9(12.9)	23.5(20.9)
BAU-15-78 -1	25.7	23.3(9.3)	21.3(17)	19.4(24.4)
BAU-15-122	16.3	14.2(13.3)	14.9(8.5)	13.0(20.1)
BAU-15-87	31.3	28.5(9.2)	27.2(13.2)	24.9(20.5)

Root length (RL)

In TRT1 maximum RL reduction was observed in BAU-15-122 (13.3%) and minimum in BAU-15-102(3.6%). In TRT2 maximum reduction was found in BAU-15-87 (13.2%) and minimum in BAU-15-102(5.1%). In TRT3 maximum reduction was found in BAU-15-87 (20.5%) and minimum in BAU-15-102(8.2%). These findings can be supported by the reports of Jensen *et al.,* (1967). Data are presented in table 11.

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