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Screening of Waterlogged Resistant Maize Varieties by Determining Root Porosity

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Abstract

In the present laboratory and field investigations we sought to ascertain the effect of water logging on root porosity maize var Suwan and Ganga Safed-2; 11-days maize seedlings under the laboratory was treated with 2, 3 and 4 days of water logging followed by 2-days recovery whereas in the field condition, treatment of 4, 5 and 6 days of water logging followed by 2-days recovery was treated in 28-and 63-days of maizeplant under both laboratory and field situations. It was observed that the porosity of root followed a decreasing trend with the increase in duration of water logging. However, 2-day recovery period improved leaf porosity following an increasing trend over their respective treatments of water logging in both the varieties, more in Suwan than Ganga Safed-2.

Key words : Maize, Root Porosity, Water logging.

Maize, being traditionally a *kharif* crop has to face several environmental stresses especially water logging due to excessive monsoon showers. Some time immediately after rains, the crop gets exposed to excessive high temperature which most often proves fatal to this crop. However, the acreage under *kharif* is gradually decreasing, mainly because of heavy loss to the farmers due to water logging situation. Water above the critical limit in maize (300 mm) causes various physiological disorders. In the field water-logged condition, after a heavy rain fall with few days of sunny weather, combining with wind, induces temporary wilting in plants (1). The effect of water logging in maize grown in *kharif* appears to be more sever in seedling stage than the adult plants (2). The flooding of soils during early stages of germination normally results in production of abnormal seedling due to arrest of normal metabolism under anoxia condition. The seedling grown under aerobic condition develop the potential to minimize the degradation of mitochondria and other organelles of coleoptiles cells even if they exposed to anoxia condition for different duration (3).

Physiological feature which limit the plant growth and yield in the prevailing climatic conditions provides quick and easy method of screen the genotypes and also facilitate the assessment of the genetic variation among these features. Relative flood tolerance appears to be correlated with the specific physiological adaptation namely, accelerated anaerobic root respiration and ability of species to oxidize their rhizosphere.

Physico-chemical characteristics of waterlogged soils, which can limit plant growth, lack of oxygen is primary, but not necessarily the most important problem. This is because of the reason that many wet land species appears to be able to avoid anoxia in their root cell by transporting oxygen from shoot to root, e.g. British bog plant (4). *Spartina alterniflora* (5), *Nyssa sylvatia* (6). In these species, oxygen diffusion through roots is facilitated by the presence of large continuous air spaces of large continuous air spaces in the cortex (aerenchyma) which may became a permanent anatomical feature of the root as in rice (7) or induced in new roots by flooding as in maize (8). The movement of oxygen through stomata stems lenticels and root aerenchyma may be great enough to cause the oxidation of rhizosphere soil around the roots (9).

Hence, it becomes essential to isolate and identify the regulatory components of plant metabolism developed in the crops exposed in anoxia conditions at differnt physiological stages of crop growth and develop to strategies to induce tolerance in crops especially in present context in maize crops against water logging.

Maize variety, Ganga Safed-2, a normal crop for *kharif* season is embedded with various problems. Being hybrids the seeds are to be changed every season which costs much and if sown late is prone to the water logging problem. Therefore, there is urgent need to evaluate new varieties which may suit and stand well against various agro-climate, soil and physio-morphological management. On the contrast, recently evolved composite, especially variety Suwan has been found to compare well with the well established hybrids Ganga Safed-2. Keeping these view the present investigation was undertaken with the objective to develop parameters for screening the varieties relatively better suited to the waterlogged situations.

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Methods

The experiment was conducted in the seed physiology laboratory, Department of Botany and Plant Physiology, Rajendra Agricultural University, Bihar, Pusa, Samastipur during 1994 and 1995. Caryopses of *Zea mays* L. biotype Suwan and Ganga Safed-2 were surface sterilized with 2% sodium hypochloride for 30 minutes followed by washing with 0.01 N HCl to avoid its any harmful effects (10). After washing with distilled water seeds were germinated on filter paper moistened with 10 ml distilled water. The experiments were carried out in completely randomized block design. By the end of 120 h of germination the germinated seeds with good vigor were transferred to the plastic pot containing soils with full strength of nutrient.

The plastic pots of 220 ml capacity having out side surface painted with black color to cut light for proper root growth in the pots to simulate a field condition. The pots were filled with nutrient solution up to marked levels. Germinated seeds were placed in the soils with roof placing down in soils. The depth of water in water logging treatment was maitained to 2 cm above soil surface. The seedlings were kept in growth chamber maintained at 30/24C ±1C temperature day/night and 70—80% relative humidity under fluorescent and incandescent light having luminous intensity15,000 Lux.

Simultaneously, field experiments were carried out during the *kharif* seasons of 1993 and 1994 to assess the out come of the laboratory experiment at the field adjacent to the faculty of Basic Sciences and Humanities, Rajendra Agricultural University, Pusa, Bihar, Samastipur. The experimental plots was fairly uniform, with low land topography having well drained soil. The experiments was laid out in randomized block design having three replicates. The seeds of maize varieties Suwan and Ganga Safed-2 were sown in the last week of the May using all recommended package of practices in both years. The seven treatments were employed at two stages of crop growth i. e. 28 days (seedling stage), 63 days (silking stage); separately and combined in the field condition with 5 cm controlled water depth and combinations were randomly allocated in different replications. Details of the treatment are given in Table 1.

Determination of Root Porosity. One gram of sun dried maize root samples from different treatments, devoid of any soils/sand particles (dried for 12h) were packed in 20 ml graduated test tube, 10 ml of luke warm distilled water (water temperature 35C) was poured in the test tube and finally stacked in the water bath, maintained at the temperature of 35C ± 1C. After 2 minutes, the final volume was measured and the same set was left in the water bath for 60 minutes, before the final volume was recorded. Root porosity ($\varnothing_r$) was calcuated as given below,

$$\varnothing_r = \frac{V_{t2} - V_{t0}}{V_{t2} - V_{t60}}$$

Where, $\varnothing_r$ = Root porosity ($cm^3 cm^{-3}$), V_{t2} =Volume of water two minutes after root submergence, V_{t0} = Initial volume of water poured in the test tube, V_{t60} = Volume of water 60 minutes after root submergence.

Results and Discussion

Visualizing the data concerning root porosity under the laboratory experiment, it is evident that Ganga Safed-2 had relatively lower root porosity value

Table 1. Treatment for differnt duration of water logging in maize crop both at laboratory and field condition. CA=Crop age; WL= Water logging; R=Recovery.

Laboratory Condition		Field condition	
Symbol	Treatment details	Symbol	Treatment details
16CA/	Control	28CA/; 63 CA	Control
14CA/+2/WL	Two days water logging	24CA + 4/WL; 59 CA + 4/WL	Four days water logging
13CA/+ 3/WL	Three days water logging	23CA + 5/WL; 58CA+ 5/WL	Five days water logging
12CA/+4/WL	Four days water logging	22CA +5/WL; 57CA + 6/WL	Six days water logging
11 CA/+3/WL + 2/R	Three days water logging followed by two days recovery	22CA +4/WL +2/R 57 CA + 4/WL + 2/R	Four days water logging followed by two days recovery
10CA/ +4/WL+2/R	Four days water logging followed by two days recovery	21CA + 5/WL + 2/R; 56 CA + 5 WL+2/R	Five days water logging followed by two days recovery
9CA/5/WL+2R	Five days water logging followed by two days recovery	20CA + 6/WL +2/R; 55CA + 6/WL + 2/R	Six days water logging followed by two days recovery

in response to almost all the respective water logging treatment as compared to Suwan which is to a tune of 74.17% in Ganga Safed-2 and 64.43 in Suwan in 4-days of water logging in respect to their respective controls. The reduction in root porosity was by 15.45, 42.25% and 18.66, 56.69% after two and three days of water logging in Suwan and Ganga Safed-2, respectively with respect to their respective controls. Consequently, the overall analyses of the crop growthunder the field experiment when it attained 28 and 63 days of age demonstrate that there was general decrease in root porosity with the increase in water logging duration from control to 6 days in 28 and 63 days old crop in both the varieties Suwan and Ganga Safed-2. However, plants try to adapt to the water logging situations by bringing in morpho-physiological adaptation. Root and leaf porosity are important morpho-physiological adaptation which facilitate plants for keeping the flow of oxygen at relatively optimum rate just sufficient to keep the plants, growing even under waterlogged situations. Root and leaf porosity contributes in the maintenance of an oxygen concentration sufficient to activate inhibited cytochrome. The observations recorded show that the leaf and root porosity both decreased with the increase in water logging duration and intensity in both the varieties of maize, more in Ganga Safed-2 than Suwan (Table 2). It was also observed that after two

Table 2. Effect of different duration of water logging on root porosity of maize (*Zea mays*) at different stages of crop growth. CA=Crop age; WL= Water logging; R=Recovery ; 12CA +2/ WL + 2/R represents; 12 days of crop followed by two days water logging followed by two days of recovery.

	Laboratory situation			
Treatments	Suwan	Percent change over control	Ganga safed-2	Percent change over control
16CA/ (Control)	61.72	—	51.66	—
14CA + 2/WL	52.18	−15.45	42.02	−18.66
13CA + 3/WL	35.64	−42.25	22.37	−56.69
12CA + 4/WL	21.95	−64.43	13.34	−74.17
12CA +2/WL + 2/R	54.99	+ 5.38	42.55	+ 3.69
11CA +3/WL + 2/R	43.66	+ 22.50	25.57	+ 14.30
10CA +4/WL + 2/R	28.49	+ 29.79	16.12	+20.83
SE ±	0.788	—	0.716	—
LSD (0.05)	2.391	—	2.171	—

Table 2. Continued.

		Field situation								
Treat-ments	Treat-ments	Suwan	Percent change over control	Ganga safed-2	Percent change over control	Treat-ments	Suwan	Percent change over control	Ganga safed-2	Percent change over control
16CA/ (Control)	28CA/ (Control)	73.53	—	66.29	—	63CA/ (Control)	93.27	—	86.86	—
14CA +2/WL	24CA +4/WL	61.92	−15.86	54.00	−18.54	59CA +4/WL	80.30	−13.90	72.56	−16.46
13CA +3/WL	23CA +5/WL	43.84	−40.42	36.97	−44.68	58CA +5/WL	64.78	−30.54	54.51	−37.24
12CA +4/WL	22CA +6/WL	34.05	−53.73	29.31	−55.78	57CA +6/WL	46.81	−50.22	42.05	−51.58
12CA+ 2/WL+2/R	22CA + 4/WL+2/R	66.65	+ 7.63	56.90	+ 5.37	57CA+ 4/WL+2/R	85.44	+ 6.36	75.97	+ 4.69
11 CA + 3/WL +2/R	21CA + 5/WL+2/R	48.85	+ 11.42	38.97	+ 5.40	56 CA + 5/WL+2/R	70.84	+ 9.35	55.18	+ 1.22
10CA + 4/WL+ 2/R	20CA + 6/WL + 2/R	39.47	+ 15.91	31.84	+ 8.63	55CA + 6/WL +2/R	54.16	+ 15.38	46.25	+ 8.98
SE ±	SE ±	0.861	—	0.779		SE ±	0.800	—	0.722	—
LSD (0.05)	LSD (0.05)	2.612	—	2.368		LSD (0.05)	2.426		2.189	—

days recovery the increase in root porosity was by 5.38, 22.50, 29.79% and 3.69, 14.30, 20.83% in respect to 2, 3 and 4-days of water logging in Suwan and Ganga Safed-2, respectively. During recovery period of two days there was little improvement in the leaf and root porosity, relatively higher rate in variety Suwan than in Ganga Safed-2. On the other hand, leaf porosity was affected with the increasing duration of water logging. Maximum reduction in leaf porosity was observed in Ganga Safed-2 which was 75.57% over control where as in Suwan the reduction was by 65.81% both in 4-days of water logging treatment over their respective control. After two days recovery of respective water logging treatments, it was observed that 2.66, 38.49, 16.31% and 4.86, 43.50, 22.77% increase in Ganga Safed-2 and Suwan respectively to their respective water logging treatments of 2,3 and 4-days of water logging. As such in the field experiment, 2-days recovery of water logging treatment of 4,5 and 6 days showed an increase in root porosity in both the varieties Suwan and Safed-2 but the percent enhancement in recovery was observed higher in Suwan than Ganga Safed-2 (Table 2) which shows more stability in varity Suwan toward water logging situations. Crawford (11) has also reported a close relationship between soil water content and air space in the plant system.Many monocotyledonous plants have a well developed aerechyma which allow them to facilitate oxygen diffusion that is provided by large air spaces (12). Ethylene is gaseous growth hormone has been linked with the stimulation of the production of aeranchyma in maize (13,14). On the critical evaluation of data collected in the present investigation, it is evident that there exist a close relationship with the status of ethylene evolution and the root porosity. Armstrong and Bechett (15) also reported relatively higher tissue porosity in waterlogged resistant plant.

Conclusion

It is pertinent to note that water logging situations create anaerobiotic environment, which make the crop of maize difficult to survive. However, there are certain biochemical adjustment in plants which get triggered under high moisture stress conditions and keep the plants healthy to respond to the recovery period. The porosity of root followed decreasing trend with the increase in duration of water logging and 2-day of recovery period had improved root porosity following an increasing trend over their respective treatment of water logging in both the varieties, Suwan and Ganga Safed-2.

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