PHYSIOLOGICAL BASIS OF SUSCEPTIBILITY AND TOLERANCE IN RICE UNDER COMPLETE SUBMERGENCE

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Abstract: A pot experiment was conducted during the Kharif season 2010-2011 with submergence tolerant varieties (NDR 9930111, Swarna Sub 1 and IR 64 Sub 1) and intolerant varieties (Mahsuri, Swarna and IR 64) rice genotypes in order to find out physiological traits associated with submergence tolerant and intolerant. Plants were raised in pots. At the age of 21 days seedling, pots were submerged in tank for 10 days. One group of plants were kept outside as non submerged control set. After 10 days submergence period, the plant were taken out from submergence tank and placed in open again for survival and recovery growth. Plant recovery was recorded 20 days after de-submergence. Tolerant genotypes had moderate elongation ability during submergence as compared to susceptible genotypes with greater elongation. Submergence tolerant genotypes NDR 9930111, Swarna Sub 1 and IR 64 Sub 1 had higher dry weight of shoot after submergence as compared to susceptible genotypes. Tolerant genotypes had higher total carbohydrate as compared to intolerant during submergence and stored carbohydrate is utilized for regeneration after de-submergence.

Keywords: Susceptibility, Rice, seedling, Kharif

INTRODUCTION

Rainfed lowland is second most important ecosystem after irrigated rice in India. In India, it is grown an area 44.5 million ha which is maximum amongst all the rice growing countries with an annual production of about 92.44 million tonnes and productivity of about 2.1 tonnes ha^{-1} (Anonymous, 2008). Uttar Pradesh is the largest rice growing state with an area of 5.63 million ha and production and productivity of 11.94 million tonnes and 2.12 tonnes ha^{-1} (Dwivedi, 2011). Rainfed lowlands constitute highly fragile ecosystem always prone to flash-floods (submergence) with an average productivity of only 1.2 t ha^{-1} in normal years and hardly 0.5 t ha^{-1} in case of submergence (Sarkar *et al*., 2006). Rainfed lowland rice grows in bunded field that become flooded for at least part of cropping seasons to depths that do not exceed 50 cm for more than 10 consecutive days (IRRI, 1993). The negative impact of flooding on terrestrial plant life is consequences of the slow diffusion rate of gases in water, compared with that in air and relatively low solubility in water (Armstrong and Drew, 2002). In non photosynthesizing tissue such as root, oxygen concentration declines strongly upon submergence (Armstrong et al, 1994).

Available physiological evidences indicate that reduce availability of oxygen causes to tissue hypoxia/anoxia which is major factor involve submergence damage. After a period of submergence, when plant are de- submerged a sudden exposure to air possibly produced free radicals of oxygen, the chloroplast being potential target of oxidative damage. Submergence induces hypoxia/anoxia shift entire metabolic pathway from aerobic to anaerobic pathway which is most insufficient producing only two adenosine tri-phosphate (ATP) molecules but in essential source of energy supply either for maintenance process associated with survival or maintenance process and growth (Greenway and Setter 1996).

High carbohydrate status prior to submergence and after de-submergence, thus has important role to play through continued supply of substrate for energy production needed for survival and recovery growth after recession of flood water (Ram et al., 2002). Considering these facts the present study, therefore, an effort was made to investigate physiological and biochemical changes associated with the submergence in tolerant and intolerant rice varieties.

MATERIAL AND METHOD

The experiment was conducted in earthen pots at the experimental site of the Department of Crop Physiology, Narendra Deva University of Agriculture and technology, Narendra Nagar Kumarganj, Faizabad (U. P.). Bold and healthy seeds of NDR R9930111, Swarna Sub 1, IR 64 Sub 1, Mahsuri, Swarna and IR 64 were surface sterilized with 1 per cent sodium hypochlorite solution before sowing. After sterilization, seeds were thoroughly washed with de-ionized water. The seeds were soaked in water for 24 hrs and then removed seeds were sown in each pot at the depth of 2 cm. The total phosphorous and potash and half dose of nitrogen was applied as basal dose at the time of sowing remaining nitrogen was applied in to equal split doses at tillering stage and at the time of ear emergence. Five plants were tagged in each replication under complete randomized design. At the age of 21 days seedling, pots were submerged in tank for 10 days. One group of plant were kept out side as non submerged control set. After 10 days submergence period, the plant were taken out from submergence tank and placed in open again for survival and recovery growth. Plant recovery was recorded 20 days after de-submergence.

RESULT AND DISCUSSION

Maximum shoot elongation as well as elongation per cent was recorded in Mahsuri in submergence set while in control set maximum shoot elongation per cent was noted in IR 64 (Table 1 & 2). Plant height increased due to leaf sheath elongation irrespective of genotypes. Maximum plant height was recorded in NDR 9930111 in submerged set as well as control set (Table1). Das *et al.*, (2005) have clearly shown the beneficial effect of reduced elongation during submergence on survival of a number of rice genotypes.

In general submergence decreases plant survival and shoot dry weight in all the genotypes. The maximum reduction was observed in intolerant genotypes (Swarna, Mahsuri and IR 64) followed by moderate tolerant genotypes (NDR 9930111, IR 64 Sub 1 and Swarna Sub 1) (Table 3). Setter *et al.*, (1984) and Singh *et al.*, (2001) have also proposed similar views while working with different cultivars of rice. Submergence tolerant genotypes accumulating higher dry matter before submergence have advantage since even after reduction in dry matter during submergence they still maintain enough dry matter to sustain rapid recovery growth and development after de-submergence.

Tolerant genotypes (NDR 9930111, Swarna Sub 1 and IR 64 Sub 1) maintained higher carbohydrate content at the end of submergence period and also showed higher amount of carbohydrate at recovery phase in comparison to susceptible genotypes (Table 4). Plant gets advantage of high carbohydrate content in shoot which meet the energy requirement during submergence and after desubmergence for growth. With complete submergence, the supply of atmospheric oxygen to the plant is restricted which lowers the internal O_2 content and anaerobic respiration increases at the expense of the aerobic process (Rai and Murty, 1976 and Setter *et al.*, 1987).

The chlorophyll content in leaves generally decreased under submergence condition in susceptible and tolerant genotypes but reduction was higher in susceptible than tolerant genotypes (Table 5).

Table: 1 Effect of submergence on plant height (cm) of rice varieties

Genotypes	Before submergence	Just after de submergence			At recovery(20 days after desubmergence)		
		Control Set	Submergence Set	Mean	Control Set	Submergence Set	Mean
NDR 9930111	44.11	51.64	54.67	53.16	54.81	41.54	50.16
Swarna Sub 1	26.27	30.01	33.80	31.19	38.57	31.20	34.89
IR 64 Sub 1	24.19	32.31	33.73	33.02	47.28	26.17	36.73
Mahsuri	30.28	39.67	46.88	43.28	51.03	28.70	39.87
Swarna	29.35	38.71	43.65	41.18	48.95	25.66	37.31
IR 64	25.11	35.07	38.56	36.82	50.76	26.11	38.44
Mean	-	37.90	41.88	-	26.11	38.44	-
SEm±	1.27	S=0.69, V=1.21, SxV =1.70			S=0.61, V=1.06, SxV =1.49		
CD at 5%	3.90	S=2.03, V= 3.52, SxV = NS			S=1.78, V= 3.08, SxV = 4.36		

Table 2 Effect of submergence on shoot elongation in rice varieties

Genotypes	Control Set	Submergence Set
NDR 9930111	7.53 (17.07)	10.56 (23.94)
Swarna Sub 1	3.74 (14.23)	7.53 (28.66)
IR 64 Sub 1	8.12 (33.56)	9.54 (39.94)
Mahsuri	9.39 (31.01)	16.60 (54.82)
Swarna	9.36 (31.89)	14.3 (48.72)
IR 64	9.96 (39.66)	13.45 (53.56)
SEm±	0.37	0.58
CD at 5%	1.14	1.78

Figures in parentheses are percent increase in shoot elongation

Table 3. Effect of submergence on shoot dry weight (mg plant^{-1}) in rice genotypes

Genotypes	Before submergence	Just after de submergence			At recovery		
		Control Set*	Submergence Set	Mean	Control Set**	Submergence Set**	Mean
NDR 9930111	432.11	2369.89 (5.48)	299.66	1334.78	3919.24 (1.65)	375.33 (25.25)	2147.29
Swarna Sub 1	316.78	1655.56 (5.22)	306.11	980.84	2912.11 (1.75)	358.22 (17.02)	1638.67
IR 64 Sub 1	393.11	1218.33 (3.09)	290.89	804.61	3561.11 (2.92)	360.11 (23.79)	1965.11
Mahsuri	304.11	2511.67 (8.25)	129.89	1320.78	4264.78 (1.69)	208.33 (60.38)	2236.56
Swarna	300.73	1465.89 (4.88)	180.89	823.39	3419.11 (2.33)	291.33 (61.05)	1855.22
IR 64	381.00	2003.33 (5.25)	153.11	1078.22	3164.44 (1.57)	234.22 (57.97)	1699.33
Mean	-	180.78	243.43	-	3540.13	307.26	-
SEm±	14.64	S=16.64, V=28.81, SxV =40.75			S=27.51, V=47.66, SxV =67.89		
CD at 5%	45.11	S=48.56, V= 84.10, SxV =118.94			S=80.31, V= 139.10, SxV =192.72		

*Figures in parentheses are folds increase in shoot dry weight.
**Figures in parentheses are per cent increase over just after de-submergence at recovery.

Table 4: Effect of submergence on total carbohydrate (mg g^{-1} dry wt.) in leaf of rice varieties

Genotypes	Before submergence	Just after de submergence			At recovery		
		Control Set**	Submergence Set*	Mean	Control Set**	Submergence Set**	Mean
NDR 9930111	78.81	85.56 (8.5)	38.25 (51.46)	61.91	94.90 (10.9)	65.60 (71.5)	80.25
Swarna Sub 1	67.17	76.78 (14.3)	46.49 (30.78)	61.64	82.92 (7.9)	59.68 (28.4)	71.30
IR 64 Sub 1	54.37	61.43 (12.9)	43.31 (20.34)	52.37	68.47 (11.4)	50.76 (17.2)	59.62
Mahsuri	48.59	68.15 (40.2)	22.93 (52.8)	45.54	77.11 (8.7)	35.01 (52.6)	54.56
Swarna	58.44	66.90 (14.4)	24.86 (57.4)	45.88	79.47 (18.7)	39.60 (59.3)	59.54
IR 64	46.46	68.70 (47.8)	25.92 (44.2)	47.31	71.73 (4.4)	34.23 (32.1)	52.98
Mean	-	71.25	33.63	-	78.60	47.48	-
SEm±	2.56	S=1.01, V=1.75, SxV =2.47			S=1.19, V=2.07, SxV =2.93		
CD at 5%	7.89	S=2.95, V= 5.12, SxV =7.22			S=3.49, V= 6.05, SxV =8.56		

*figures in parentheses are % decrease over corresponding value before submergence.
**figures in parentheses are increase over corresponding values just after de-submergence at recovery.

Table 5. Effect of submergence on total chlorophyll content (mg g^{-1} fresh wt.) in rice varieties

Genotypes	Before submergence	Just after de submergence			At recovery		
		Control Set	Submergence Set	Mean	Control Set	Submergence Set	Mean
NDR 9930111	2.26	2.41	1.79	2.10	2.72	2.60	2.66
Swarna Sub 1	2.67	2.97	2.12	2.55	3.02	3.98	3.50
IR 64 Sub 1	2.18	2.25	2.00	1.99	2.47	3.46	2.97
Mahsuri	2.16	1.47	1.62	1.55	2.59	3.76	3.18
Swarna	2.46	2.57	1.73	2.29	2.20	3.22	2.71

IR 64	1.65	1.96	1.08	1.52	2.65	3.09	2.87
Mean	-	1.72	2.00	-	2.61	3.35	-
SEm±	0.05	S= 0.03, V=0.05 , SxV =0.07			S= 0.05, V=0.09 , SxV =0.12		
CD at 5%	0.17	S=0.08 , V=0.14, SxV =0.20			S=0.14, V=0.25, SxV = 0.35		

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