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Morpho-physiological changes associated with waterlogging in rice (*Oryza sativa*)*

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Environmental factors like high rainfall consistently depress rice (*Oryza sativa* L.) yield during monsoon (*kharif*) season in Upper Brahmaputra valley zone of Assam. Waterlogging is common in poorly drained soils of the areas with high rainfall. It is established that genotypic differences exist for tolerance to waterlogging in cereal crops. Low redox potential and *p*H in waterlogged soil cause increased availability of reduced iron, which is normally toxic to the plant. Being a flood-prone area, iron toxicity is one of the major problems in the rice fields of Assam. Selection of suitable variety with proper management may be one of the economically feasible solutions for sustainable rice production under flooded condition during rainy season. Therefore, in the present

* Short note

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Table 1 Effect of waterlogging on culm height at flowering, tiller number, chlorophyll and iron content at 45 days after transplanting

Variety	Height (cm)		Tillers/ m^2		Leaf chlorophyll (mg/g fresh weight)		Shoot iron (ppm)	
	Water-logging	Normal	Water-logging	Normal	Water-logging	Normal	Water-logging	Normal
'IET 11271'	123	111	96	136	1.66	2.14	526	431
'Bogabordhan'	113	112	180	178	2.44	2.68	487	375
'IET 10016'	90	88	186	184	2.51	2.65	511	408
'IET 10021'	92	87	169	189	2.48	2.70	488	391
'IET 11188'	109	99	95	142	1.25	2.12	675	454
'Utkalprova'	111	104	128	150	2.01	2.35	509	395
'IET 11187'	89	83	76	135	1.18	2.04	684	405
'Kushal'	89	84	158	167	2.50	2.65	481	377
'Sobita'	114	110	148	165	2.14	2.43	499	386
'Neeraja'	100	92	135	158	2.11	2.41	527	384
'Moniram'	85	87	166	172	2.38	2.58	487	384
'IET 11195'	112	112	118	139	1.79	2.18	581	497
'IET 13119'	119	115	152	163	1.92	2.15	545	362
'IET 10543'	109	103	132	168	2.14	2.34	496	417
'IET 11910'	119	112	112	152	1.55	2.02	610	400
Mean	105.6	100.6	138	161	2.01	2.37	538	404
Source	*SEd* ±	*CD (P=0.05)*	*SEd*±	*CD (P=0.05)*	*SEd* ±	*CD (P=0.05)*	*SEd*±	*CD (P=0.05)*
Depth of water 'w'	0.528	2.273	5.393	0.023	0.236	1.006	4.199	18.072
Varieties 'v'	2.357	4.619	3.269	0.064	2.491	4.881	19.492	38.205
Between 2 'v' Mean at the same level of 'w'	3.333	NS	4.624	0.090	3.522	6.903	27.566	54.030
Between 2 'w' mean at the same level of 'v'	0.528	NS	5.393	0.023	0.233	1.006	4.199	18.072

NS, Non-significant

study we sought to explore the relationship between physiological disorder in terms of bronzing intensity and reduction in grain yield when rice cultivars were subjected to continuous waterlogging stress.

The field experiment was conducted during the rainy season of 1999 at Jorhat in split-plot design. Rice varieties selected were 'IET 11271', 'Bogabordhan', 'IET 10016', 'IET 10021', 'IET 11188', 'Utkalprova', 'IET 11187', 'Kushal', 'Sobita', 'Neeraja', 'Moniram', 'IET 11195', 'IET 13119', 'IET11272', 'IET 10543' and 'IET 11910'. The sandy-loam soil had organic carbon 0.58%, coarse sand 11.30%, fine sand 58.92%, silt 16.25%, clay 12.64%, available N 264 kg/ha, P 14.08 kg/ha and K 240 kg/ha. Fertilizers were applied in the field @ 40, 8.8 and 16.6 kg N, P and K/ha. Thirty-day old-seedlings were transplanted at a distance of (15 cm × 20 cm). Two levels of water depth (10 ± 5 cm and 50 ± 5 cm) were maintained 2 weeks after transplanting when seedlings have established properly in the field. Waterlogged condition (50 ± 5 cm) was maintained in the field throughout the experimental period up to flowering and in the control plot, the water was drained out as and when needed. Soil *p*H was determined with Elico model glass electrode *p*H meter. Soil Fe^{++} was determined colorimetrically by orthophenanthroline method after extracting the soil with neutral normal ammonium acetate (Jackson 1973). Iron content in the shoots of rice plant was determined colorimetrically by orthophenanthroline method after extracting with triacid mixture. Leaf chlorophyll was estimated by double beam spectrophotometric method (Anderson and Boardman 1964). Nitrogen, phosphorous and potassium contents were determined by standard methods of Jackson (1973). Culm height at flowering and harvesting was measured and the number of tillers/m^2 at 45 days after transplanting was recorded. Percentage of yellow leaf was calculated in each observation in terms of total leaves .The yellow and green leaves of 5 individual plants in each plot were counted at 45 days after transplanting. Yield and other yield-attributing parameters were estimated by standard methods.

Table 2 Effect of waterlogging on N, P and K content in shoots of rice after harvest

Variety	N%		P%		K%	
	Water-logging	Normal	Water-logging	Normal	Water-logging	Normal
'IET 11271'	1.60	1.68	0.22	0.30	1.38	1.53
'Bogabordhan'	2.09	1.90	0.32	0.37	1.69	1.74
'IET 10016'	2.12	1.84	0.30	0.33	1.61	1.74
'IET 10021'	2.07	1.80	0.33	0.35	1.58	1.65
'IET 11188'	1.52	1.57	0.17	0.31	1.13	1.45
'Utkalprova'	1.72	1.60	0.28	0.30	1.37	1.58
'IET 11187'	1.50	1.61	0.17	0.28	1.00	1.41
'Kushal'	1.83	1.78	0.29	0.32	1.52	1.57
'Sobita'	1.64	1.66	0.24	0.30	1.45	1.64
'Neeraja'	1.70	1.63	0.21	0.27	1.41	1.46
'Moniram'	1.82	1.65	0.27	0.29	1.52	1.61
'IET 11195'	1.65	1.60	0.20	0.29	1.28	1.45
'IET 13119'	1.84	1.77	0.28	0.36	1.50	1.71
'IET 10543'	1.62	1.48	0.21	0.29	1.37	1.57
'IET 11910'	1.58	1.75	0.19	0.27	1.20	1.46
Mean	1.75	1.69	0.24	0.30	1.40	1.56
Source *SEd* ±			*SEd*±		*SEd*±	
	CD (P=0.05)		*CD (P=0.05)*		*CD (P=0.05)*	
Depth of water 'w'	1.019	0.043	2.012	0.008	1.030	0.044
Varieties 'v'	5.434	0.106	2.074	0.040	4.065	0.079
Between 2 'v'mean at the same level of 'w'	0.076	0.150	2.934	NS	5.750	0.112
Between 2 'w'mean at thesame level 'of v'	1. 019	0.043	2.012	NS	1.030	0.044

NS, Non-significant

There was significant reduction in tiller number in 7 varieties due to waterlogging. 'IET 10021' and 'Bogabordhan' produced relatively higher number of tillers (Table 1). Under waterlogged condition, culm height was maximum in 'IET 11910', 'IET 112 72', 'IET 11271', 'IET 13119' and 'IET 11195'. Waterlgging causes reduction in plant growth at their early stages along with lower number of functional leaves due to inundation (Venkateswarlu 1978). At the initial stage of waterlogging, the drop in soil *p*H (4.8) was due to accumulation of organic acid and CO_2 and thereafter the subsequent increase in *p*H (5.45) is associated with soil reduction. Increased uptake of iron by the plants was observed under waterlogged condition. 'IET 10016', 'IET 11188', 'IET11187' and 'IET 11910' possessed more tissue iron content than 'Bogabordhan', 'IET 10021', 'Kushal' and 'Moniram' under waterlogged condition (Table 1). These findings confirm those of Baruah and Nath (1997).

Under waterlogged condition, nitrogen content increased with the decrease in phosphorous and potassium content (Table 2). Decrease in phosphorous content is due to conversion of a part of water-soluble P to insoluble ferric phosphate with the increase in the concentration of iron under waterlogged condition (Singh and Singh 1976). 'Bogabordhan', 'IET 10016' and 'IET 10021' recorded a higher level of phosphorus under waterlogged condition than 'IET 11188' and 'IET11187'. The cultivars 'IET 10016', 'Bogabordhan' and 'IET 10021' recorded higher N content in the shoot compared to the other varieties. Higher K content in the tissue may prevent intrusion of Fe^{++} to the shoot and this may be one of the reasons for better performance of some of the varieties at waterlogged situation. Higher concentration of tissue iron was found in 'IET 11187', 'IET 11188', 'IET11195', 'IET 11910' and ' Neerja' than the other varieties. Higher concentration of

Table 3 Effect of waterlogging on dry matter content (leaf + stem), number of panicles/m^2, filled grain (%) and yield (tonnes/ha) at harvest

Variety	Dry matter (g/m^2)		Panicle		Filled grain (%)		Yield (tonnes/ha)	
	Water-logging	Normal	Water-logging	Normal	Water-logging	Normal	Water-logging	Normal
'IET 11271'	556	612	133	127	76	81	1.69	2.79
Bogabordhan'	680	683	201	217	97	96	4.32	4.39
'IET 10016'	718	712	187	203	92	94	4.74	4.81
'IET 10021'	702	690	191	199	92	95	4.49	4.63
'IET 11188'	536	634	95	120	73	86	1.36	2.82
'Utkalprova'	583	647	147	160	79	89	2.25	3.70
'IET 11187'	512	638	78	118	72	79	1.10	2.64
'Kushal'	615	672	173	179	90	92	4.20	4.49
'Sobita'	598	685	116	127	83	89	2.84	3.22
'Neeraja'	592	643	150	161	86	88	3.17	4.00
'Moniram'	610	652	162	190	90	92	4.09	4.50
'IET 11195'	598	634	120	127	82	84	1.68	3.11
'IET 13119'	605	683	165	173	91	95	4.01	4.08
'IET 11272'	647	669	137	150	84	91	2.37	3.55
'IET 10543'	596	678	117	98	80	92	2.01	3.92
'IET 11910'	588	684	107	113	70	83	1.24	3.72
Mean	608	664	142	154	83.5	89.1	2.85	3.77
Source	*SEd*±	*CD (P=0.05)*	*SEd*±	*CD (P=0.05)*	*SEd*±	*CD (P=0.05)*	*SEd*±	*CD (P=0.05)*
Depth of water 'w'	0.754	3.247	1.930	8.307	0.218	0.940	0.0127	0.0548
Varieties 'v'	4.630	9.075	5.876	11.518	0.816	1.599	0.0440	0.0862
Between 2 'v" mean at the same level of 'w	6.548	12.834	8.310	16.289	1.154	2.262	0.0622	0.1220
Between 2 'W' mean at the same level of 'v'	0.754	3.247	1.930	8.307	0.218	0.940	0.0127	0.0548

tissue iron was reported to be the cause of yellowing in rice under waterlogged condition and less intensity of bronzed leaves in the resistant varieties is due to the root oxidizing ability of these varieties leading to less metabolically active Fe absorption mechanism (Ottow *et al.* 1982). Waterlogging causes reduction in total chlorophyll content (Table 1). But the variety 'Bogabordhan', 'IET 10016', 'IET 10021', 'Kushal' and 'Moniram' maintained higher level of chlorophyll compared with the other tested varieties. Adakand and Das Gupta (2000) reported similar type of results and stated that chlorophyll content reduces proportionately with increase in submergence period and more so in susceptible varieties due to inhibition of RUBP carboxylase activity. Panicles/m^2 and dry matter in leaves decreased under waterlogged condition (Table 3). 'Bogabordhan', 'IET 10016' and 'IET 10021' performed better than the other varieties. The results confirm the findings of Chaudhary and Das Gupta (1985). Under waterlogged condition percentage of filled grain, grain yield and harvest index were reduced significantly due to reduction in functionally active leaves and panicles. Appearance of bronzing due to higher concentration of soluble Fe^{++} may be one of the factors of reduction in grain yield under waterlogged condition as reported by Verma (1991). 'IET 10016' followed by 'IET 10021', 'Bogabordhan', 'Kushal', 'Moniram' and 'IET 13119' recorded higher grain yield than the other varieties (Table 3).

SUMMARY

A field experiment was conducted to investigate the physiology of waterlogging tolerance and associated physiological disorder in 16 varieties of rice (*Oryza sativa* L.) during the rainy season of 1999. Two water depths (10 ± 5 and 50 ± 5 cm) were maintained continuously up to the flowering stage of the crop. Occurrence of bronzing was observed in plants grown under waterlogged condition. 'IET 11187', 'IET 11188' and 'IET 11910' recorded higher number of bronzed leaves. Intensity of bronzing was less in 'Bogabordhan', 'IET 10016', 'IET 10021' and 'Kushal'. Significant reductions in chlorophyll content (1.18 mg/g fresh weight) of leaves were observed. Panicles (78/m^2), dry matter production (512 g/m^2), grain filling (70%) were significantly reduced under waterlogged condition, resulting in yield less (1.10 tonnnes/ha). 'Bogabordhan', 'IET 10016', 'IET 10021'and 'Kushal'performed relatively better than the tested varieties under waterlogged condition in terms of bronzing and yield potential. 'IET 11187', 'IET

11188' and 'IET 11910' were very sensitive to waterlogged condition.

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