TOLERANCE OF DWARF RICE VARIETIES TO HIGH P^H AND EXCHANGEABLE SODIUM

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ABSTRACT

Four dwarf varieties of rice were tested at different levels of exchangeable sodium percentage (ESP) viz., 10, 15, 30, 60 and 90 corresponding to a soil pH of 8.3, 8.8, 9.4, 9.9 and 10.4 respectively in a pot culture experiment. At 60 ESP, the seedlings of RP-107-11 could not survive while at 90 ESP, those of Jaya and IET 1991 too failed to survive. Panicle emergence was delayed due to alkalinity in all varieties but less so in Pusa 2-21. There was a moderate reduction in fertile tillers, panicle length, number of grains per panicle and the size of grains in all varieties up to 30 ESP. However, the effects of 30 ESP on grain yield was substantially adverse in all varieties. Genotypic differences for tolerance to alkalinity were obvious and distinct. Pusa 2-21 was identified as the most tolerant genotype by virtue of its being the only one to survive at 90 ESP and also by exhibiting lowest reduction in yields at higher levels of alkalinity. The implications of these findings for utilization and management of salt-affected lands are discussed.

INTRODUCTION

Soil toxicity caused by high pH and excessive exchangeable sodium poses special problems for crop cultivation in the Indo-Gangetic plains of India. The reclamation and management of such soils is a difficult process. Nevertheless, it has been now successfully demonstrated that these soils can be reclaimed and made nearly as productive as normal soil (ABROL & BHUMBLA, 1973; YADAV, 1973; ABROL & DARGAN, 1974). Rice is recommended as the most appropriate crop to start the reclamation and utilization of salt-affected soils (KADDAH & FAKHRY, 1961; PEARSON, 1959; VAN DE GOOR, 1966). Therefore, the identification and selection of tolerant rice varieties is of prime importance. Studies aimed at these objectives are imperative as, firstly, there is very little information on responses of recently developed high yielding dwarf varieties of rice to salinity and alkalinity (PEARSON, AYERS & EBERHARD, 1966; DARGAN, ABROL & BHUMBLA, 1974; SINHA & DATTA, 1974). Secondly, raising of tolerant varieties will not only help increase the production (MISHRA, SARIN & BHUMBLA, 1973), but may also help reduce gypsum requirement of the soil by virtue of their ability to grow even at relatively higher levels of pH, sodicity and salinity. Recent work by IRRI scientists on tolerance to salinity and alkalinity has demonstrated the existence of varietal differences among dwarf rice varieties even though the alkali levels they chose were only moderate (ANONYMOUS, 1974). The present investigation was, therefore, conducted to obtain some information on the primary effects of high soil pH and ESP on selected varieties of dwarf rice, with a view to find solution if possible, to some practical problems of the farmers willing to reclaim their land.

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MATERIAL AND METHODS

Four levels of ESP, viz. 15, 30, 60 and 90 were simulated by spraying standard aqueous solution of $NaHCO_3$ over required quantities of normal soil of 10.5 m.e./100g cation exchange capacity in a manner described by JOSHI AND SINGH (1975). The ESP of normal soil was 10 which was used as control. Adequately fertilized soils of various ESP values were then filled in round porcelain pots (28 cm × 28 cm) and fully saturated with tubewell water before transplanting. At the time of pot filling soil samples from various ESP treatments were drawn and the pH and electrical conductivity (EC) of soil and water suspension (1 : 2) were determined (Table 1). Actual ESP values of simulated soils could not be determined at the end of the experiment. Thirty-five-day-old seedlings of dwarf rice varieties, Jaya, Pusa 2-21, IET 1991 (now released as Sona) and RP-107-11 were transplanted on July 3, 1973 keeping three seedlings per hill and four hills per pot. There were four replications. Efforts were made to maintain about 5 cm of standing water throughout the active growth period of the crop. Observations were recorded on seedling survival, panicle emergence, tiller growth, grain yield and yield components.

Table 1—pH and salinity regimes of experimental soils

Exchangeable sodium percentage	pH	EC (mmhos/cm)
10	8.30	2.37
15	8.82	2.35
30	9.37	2.52
60	9.95	4.00
90	10.45	8.05

RESULTS AND DISCUSSION

SEEDLING SURVIVAL

From the visual appearance of seedlings it was noted that lower ESP levels had little or no adverse effect on seedling establishment and foliage appeared fully recovered after 3 days from transplanting. However, higher pH and ESP had adverse effect on recovery and survival. At 60 ESP, for example, foliage appeared still somewhat wilted in all varieties excepting Pusa 2-21 which had fully recovered. At this level of ESP the genotype RP 107-11 could not survive. At 90 ESP, seedlings of only Pusa 2-21 survived while other varieties could not survive and dried off four days after transplanting. Thus, Pusa 2-21 proved to be superior to other genotypes and appears to possess an ability to withstand alkali and excessive ESP. The toxicity to the plants of other varieties might have resulted from a combined effect of high pH, excessive ESP and salinity. Of the three factors, however, the most immediate effect seems to be that of high pH which has been shown to cause instant wilting in tomato (THORUP, 1969).

PANICLE GROWTH AND EMERGENCE

The presence of alkalinity and excessive ESP in soil medium delayed the process of heading and was such that 30 ESP caused a delay of 3 to 5 days and 60 ESP of 5 to 8 days.

The variety Pusa 2-21 was the least affected (Table 2) and at 90 ESP where only this variety survived, the delay in its heading occurred only by 9 days. The other 3 varieties could not be assessed due to their absolute mortality at 90 ESP. The slow rate of rachis elongation during panicle development appears to be the main reason of delayed heading. It is known that the concentration of gibberellins rises sharply in barley shoot apex during stamen initiation which causes rapid elongation of plant as well as shoot apex (NICHOLLS & MAY, 1963). Changes in gibberellin content in rice panicle under stress conditions do not seem to be reported, however, it seems that either gibberellin synthesis or action or both are inhibited by such adverse soil conditions. The involvement of other naturally occurring hormones in the control of panicle growth and emergence may also be expected.

Table 2—Panicle emergence in four dwarf rice varieties as affected by various levels of exchangeable sodium

Variety	Observations on	Exchangeable sodium percentage				
		10	15	30	60	90
Jaya	Heading date	16 Sept.	17 Sept.	20 Sept.	25 Sept.	No Survival.
	Delay (day)		1	4	9	
Pusa 2-21	Heading date	24 Aug.	24 Aug.	27 Aug.	29 Aug.	1 Sept.
	Delay (day)		0	3	5	8
IET 1991	Heading date	16 Sept.	16 Sept.	21 Sept.	24 Sept.	No Survival.
	Delay (day)		0	5	8	
RP 107-11	Heading date	7 Sept.	8 Sept.	10 Sept.	No Survival	No Survival.
	Delay (day)		1	3		

TILLER FORMATION AND DEVELOPMENT

Tillers were counted at maturity and were classified as productive and non-productive. The total number of tillers reduced drastically in all varieties with increasing pH and sodicity (Table 3). Between the productive and non-productive tillers, the latter were comparatively more restricted with increasing alkalinity than the former. In the case of Jaya, however, the trend was not consistent with the other three varieties. The reduced number of tillers under alkalinity may have been due to a hindrance to the proper development of tiller primordia, their early mortality or to a lack of their initiation itself. Further, it seems that the free supply of nutrients easily available to plants under normal soil conditions is restricted by high pH and excessive sodium which might have imposed limitations on profuse tillering under sodic conditions (EPSTEIN, 1972; MATSUSHIMA, 1967).

THE NUMBER AND SIZE OF GRAIN

The number of grains in a panicle decreased with increasing levels of alkalinity (Table 5) but the size of grains as indicated by 1000-grain weight was found to be slightly heavier at 15 ESP than normal in all varieties excepting Jaya (Table 6). There was only a moderate reduction in grain size at 30 ESP beyond which the accumulation of assimilates was severely affected. The grain setting in IET 1991 was least affected and it produced

Table 3—Tiller growth and development in four dwarf rice varieties as affected by various levels of exchangeable sodium

Variety	Tillers/pot	Exchangeable sodium percentage				
		10	15	30	60	90
Jaya	Total	161.5	152.2	148.0	114.7	Nil
	Productive	95.0	88.5	84.0	71.5	Nil
	Non-Productive (%)	41.2	41.9	43.3	37.7	Nil
Pusa 2-21	Total	160.2	148.5	131.0	123.0	62.2
	Productive	108.0	104.2	93.7	98.7	52.5
	Non-Productive (%)	32.6	29.9	28.5	19.8	15.6
IET 1991	Total	171.5	162.7	136.2	127.2	Nil
	Productive	91.0	94.2	82.0	88.7	Nil
	Non-Productive (%)	47.0	42.2	39.8	30.3	Nil
RP 107-11	Total	155.0	137.5	121.2	Nil	Nil
	Productive	80.7	81.5	76.0	Nil	Nil
	Non-Productive (%)	48.0	40.8	37.3	Nil	Nil

CD (P=0.05) *for productive tillers*=5.84

CD (P=0.05) *for total tillers*=14.72

the maximum number of grains at all ESP levels it survived. In Pusa 2-21, nevertheless grain setting was possible even at 90 ESP though the number and size were both drastically reduced. High sterility of spikelets under adverse soil conditions is a common feature in rice (KADDAH, 1963; VENKATESHWARLU, RAMESAN & RAO, 1972). The panicle length was also reduced (Table 4) which too might have limited the production of grain bearing primary branches thus leading to the reduced number of grains. The seed size does not appear to have been affected by a change in sink capacity as it was not a limiting factor for seed development at ESP values exceeding 30. It is then possible that limited supply of photosynthate or inability of grains to accept photosynthate or both might have affected the development of grains (JENNER, 1974; JENNER & RATHJEN, 1975).

Table 4—Length of panicle (cm) of main shoot in four dwarf rice varieties as affected by various levels of exchangeable sodium

	Exchangeable sodium percentage				
Variety	10	15	30	60	90
Jaya	26.2	25.8	24.7	21.0	Nil
Pusa 2-21	22.5	22.0	20.9	19.8	14.5
IET 1991	27.2	26.5	25.1	24.4	Nil
RP 107-11	25.6	24.5	23.6	Nil	Nil

CD (P=0.05)=4.12

Table 5—Number of grains/panicle of main shoot in four dwarf rice varieties as affected by various levels of exchangeable sodium

Variety	Exchangeable sodium percentage 10	15	30	60	90
Jaya	192.0	181.2	147.5	122.2	Nil
Pusa 2-21	186.7	180.2	155.2	128.0	68.0
IET 1991	246.5	237.0	230.8	197.7	Nil
RP 107-11	173.2	167.0	156.7	Nil	Nil

CD (P=0.05)=2.74

Table 6—1000-grain weight (g) of main shoot of four dwarf rice varieties as affected by various levels of exchangeable sodium

Variety	Exchangeable sodium percentage 10	15	30	60	90
Jaya	26.6	26.5	24.9	20.7	Nil
Pusa 2-21	23.6	25.3	22.1	16.0	6.7
IET 1991	18.5	20.7	17.2	12.1	Nil
RP 107-11	24.4	28.1	21.0	Nil	Nil

CD (P=0.05)=1.53

GRAIN YIELD

Varietal differences in yield with respect of ESP tolerance were obvious and distinct. The yield level of different varieties did not significantly decline at 15 ESP as compared to 10 ESP except in case of IET 1991 (Table 7). However, further reductions were sig-

Table 7—Grain yield (g/pot) of four dwarf varieties of rice as affected by various levels of exchangeable sodium

Variety	Exchangeable sodium percentage 10	15	30	60	90
Jaya	236.8	223.9	187.4	57.2	Nil
Pusa 2-21	245.2	227.3	175.8	133.5	27.1
IET 1991	213.6	179.4	154.9	89.7	Nil
RP 107-11	179.5	161.3	141.8	Nil	Nil

CD (P 0.05)=18.4

nificant and substantial for all varieties, especially beyond 30 ESP. RP 107-11 did not survive at 60 ESP while Pusa 2-21 was the only variety to record any yield at 90 ESP. While the three varieties of rice suffered severe loss of yield at 60 ESP i.e., 58 to 100 per cent, Pusa 2-21 suffered 46 per cent loss in comparison with normal (Table 8). It was, therefore, easy to single out Pusa 2-21 as the most tolerant genotype among the test strains. It was followed by Jaya, IET 1991, and RP 107-11 in that order. The implications of these findings are discussed below.

Table 8—Reductions in grain yield (% of control) of four dwarf varieties of rice as affected by various levels of exchangeable sodium

	Exchangeable sodium percentage				
Variety	10	15	30	60	90
Jaya	0	5.5	20.9	75.9	No survival
Pusa 2-21	0	7.3	28.4	45.6	89.0
IET 1991	0	15.1	27.5	58.1	No survival
RP 107-11	0	14.1	21.4	No survival	No survival

The suitability of rice crop for salt-affected soil is well recognised, as the standing water in the field not only fulfils the water requirement of rice but also helps to bring down the salinity, pH and ESP through dilution and leaching (PEARSON, 1959; PEARSON & BERNSTEIN, 1959). Dissolution of CO_2 evolved by plant roots and soil microbial activities further confers added advantage in bringing down the pH and thus improving soil physical conditions (VAN DE GOOR, 1966). However, at a very high soil pH (10 and above) as often is the case in sodic soils, it is impossible to grow successfully even a rice crop. Therefore, the use of some kind of soil amendments preferably gypsum has been recommended (ABROL & BHUMBLA, 1973; ABROL & DARGAN, 1974). But the rising costs of amendments and difficulty in their availability have recently created some problems for farmers wiling to reclaim their land. Identification of tolerant high yielding dwarf rice varieties is, therefore, essential to partly meet this difficulty on short term basis. The present findings clearly bring out that the genotype Pusa 2-21 could be a better choice for alkali soils. This variety, for example, surpassed all remaining varieties and gave the highest yield beyond 30 ESP. This variety also had highest survival, capacity to produce relatively more productive tillers as well as early maturity. It can therefore be recommended for cultivation at the outset during alkali soil reclamation programme. This may also help reduce the quantity of gypsum or other ammendment to be added to soil. Its early maturity constitutes further advantage as it allows adequate and safe margin of time for *rabi* field preparations. Soil and seedbed preparation for wheat under north India conditions is more critical for alkali soils than normal soil. The alkali soils have relatively poor permeability and hydraulic conductivity and take much longer to come to proper moisture condition. Also, the period during which they retain optimum moisture for seed planting is much shorter. Therefore, early harvest of paddy which is possible by growing a tolerant variety like Pusa 2-21 is very much desirable.

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