Breeding for Saline-resistant Varieties of Rice

III. Response of F_1 Hybrids to Salinity in Reciprocal Crosses between Jhona 349 and Magnolia

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Synopsis. The F_1 hybrids of reciprocal crosses between Jhona 349 and Magnolia exhibited a high degree of salt resistance regarding plant height and the number of spikelets per panicle. The behavior of the delayed type panicle sterility caused by salinity suggested that Magnolia has a gene or genes for this characteristic. No cytoplasmic effect on salt resistance was observed in the reciprocal crosses.

Introduction

In rice varieties, Magnolia, Bluebonnet, IR 8 and Jhona 349, sterility caused by salinity has been classified into three types, i.e. cluster, delayed and random (AKBAR *et al.* 1972).

The seed setting percentage of these rice varieties grown under the saline conditions showed a close relationship with the frequencies of these types of sterility (AKBAR *et al.* 1972).

The delayed type panicle sterility was only present in Magnolia at the 4,000 and 5,000 ppm salinity levels, whereas it was absent in the other three varieties at the same salinity levels. Therefore, it was assumed that the delayed type the panicle sterility could possibly be under genetic control. If this assumption is correct, this type of sterility may be taken as a good criterion for the genetic analysis of salt tolerance.

The behavior of the delayed type panicle sterility in the F_1 generation of Jhona 349 $\times$ Magnolia and its reciprocal and the comparative performance of the parental varieties and their F_1 hybrids are described in this paper.

Materials and Methods

Jhona 349 had good seed setting percentage (75.3%) at the 4,000 ppm salinity level, while Bluebonnet, IR 8 and Magnolia gave 25.0, 45.5 and 18.0% at the same salinity level,

respectively (AKBAR *et al.* 1972). On the basis of the delayed type panicle sterility and seed setting percentage two varieties, Jhona 349 and Magnolia, were selected as relatively salt-resistant and salt-sensitive varieties, respectively. Reciprocal crosses between these two varieties were made in summer 1970.

Response of the F_1 hybrids, Jhona 349 $\times$ Magnolia and Magnolia $\times$ Jhona 349, together with the parental varieties to salinity was observed in the greenhouse during summer 1971 by using water-culture techniques. The general procedure of the water-culture experiment and the composition of basic nutrient solution were similar to those described previously (AKBAR *et al.* 1972).

The basic nutrient solution was kept as the control, while the 4,000 ppm salinity level was obtained by adding equal parts by weight of sodium chloride and calcium chloride to the basic nutrient solution. The mean electrical conductivity values were 0.4 and 6.8 mmho per cm at 25°C, respectively.

The pH of the solution was kept at 6. The nursery was raised in soil. The seedlings were transplanted (three plants per pot) on 8th July five weeks after sowing. Salinization was initiated two weeks after transplanting and continued till harvest. The culture solution was changed once a week during early growth period and twice a week thereafter. The water level and pH were adjusted on alternate days. The experiment was replicated four times. During the experimental

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period (July–November) the mean maximum temperature was 31.6°C and the mean minimum 19.7°C. At the end of the experiment the data regarding plant height, the number of productive tillers, root length and the number of days from seeding to heading were recorded for each plant, while data for panicle length, the number of primary branches, the number of spikelets and seed setting percentage were recorded for each panicle in the F_1 hybrids and the parental varieties in order to determine the total effect of salinity on yield components.

The pollen fertility was examined by potassium iodide method.

Root length measurement was taken on the longest root in each case.

The delayed type sterility caused by salinity (AKBAR *et al.* 1972) could easily be further classified into the following two types:

(i) Delayed type panicle sterility. The entire panicle turns whitish after heading (delayed type) and seed setting percentage is zero. In this paper, we designate such a panicle as delayed type sterile panicle.

(ii) Delayed type branch or spikelet sterility. A few primary branches or spikelets turn whitish after heading (delayed type) and seed setting percentage varies with the panicle.

Both types of sterility were used for calculating the percentage of delayed type sterility presented in Table 3.

lity presented in Table 3.

In Jhona 349, the type (i) was absent, while the type (ii) was present. In Magnolia, both types were present. For the genetic analysis the type (i) was used. The plants with one or more delayed type sterile panicles were designated as D-type plants and the percentage of D-type plants was used for interpreting the inheritance of delayed type panicle sterility.

Results

Vegetative Growth

Plant height.

From the data given in Table 1, it is evident that the parental varieties, Jhona 349 and Magnolia, in the control did not differ in plant height. The F_1 hybrids of Jhona 349 × Magnolia and Magnolia × Jhona 349 showed hybrid vigor both at the control and at the 4,000 ppm salinity level.

The difference of means of plant height between the reciprocal hybrids at the control was non-significant. Similarly, at the 4,000 ppm salinity level the difference of means between these F_1 hybrids was also non-significant, indicating the absence of any cytoplasmic effect.

Number of productive tillers per plant.

There was no effect of salinization on the number of productive tillers per plant in the parental varieties and their F_1 hybrids. The

Table 1. Influence of salinity on vegetative growth in F_1 hybrids and parental varieties

Character	Salinity level (ppm)	Parents		F_1 hybrids	
		Jhona 349	Magnolia	Jhona 349 × Magnolia	Magnolia × Jhona 349
Plant height (cm)	Control	141.0 ± 8.61	142.3 ± 5.27	162.1 ± 10.88	167.0 ± 5.90
	4,000	120.0 ± 8.15** (85.1) ¹⁾	139.8 ± 7.15 (98.2)	160.1 ± 8.78 (98.8)	159.4 ± 8.88* (95.5)
Number of productive tillers/plant	Control	16.1 ± 9.23	11.0 ± 3.08	14.0 ± 7.12	13.3 ± 3.92
	4,000	17.0 ± 7.14 (105.6)	12.3 ± 3.14 (111.8)	14.5 ± 7.12 (103.6)	14.6 ± 6.52 (109.8)
Root length (cm)	Control	48.5 ± 7.87	39.6 ± 2.27	47.3 ± 4.55	48.1 ± 2.04
	4,000	34.7 ± 2.83** (71.5)	28.8 ± 1.06** (72.7)	36.3 ± 2.83** (76.7)	38.5 ± 2.84** (80.0)
Number of days from seeding to heading	Control	103	90	93	89
	4,000	109	99	94	91

* Difference significant from that of control at 5 per cent level.

** Difference significant from that of control at 1 per cent level.

1) Figures in parentheses denote the percentage of control.

F₁ hybrids showed a mean value close to the mid-parent both at the control and the 4,000 ppm salinity level.

Root length.

Salinization apparently inhibited the elongation of roots in the F₁ hybrids as well as their parents.

Although root length was significantly affected in the F₁ hybrids at the 4,000 ppm salinity level, the difference of the means between the F₁ hybrids, Jhona 349×Magnolia and its reciprocal, was non-significant at the 4,000 ppm salinity level, indicating that the cytoplasmic effect was absent.

Number of days from seeding to heading.

The F₁ hybrids headed earlier and were less affected by salinization than the parents.

Reproductive Growth

Data relating to reproductive growth are given in Table 2.

Panicle length.

The F₁ hybrids resembled Magnolia in panicle length. The effect of salinization was significant in the F₁ hybrids and their parents.

Number of primary branches per panicle.

The F₁ hybrids approximated to Magnolia at the control and at the 4,000 ppm salinity level. The number of primary branches per

panicle reduced significantly in Jhona 349, while the F₁ hybrids and Magnolia were not affected by salinity.

Number of spikelets per panicle.

The F₁ hybrids resembled Magnolia. The number of spikelets per panicle reduced significantly in the parental varieties, Jhona 349 and Magnolia, while the F₁ hybrids were not affected by salinization.

Panicle weight.

Panicle weight of the parental varieties, Jhona 349 and Magnolia, was reduced to 42.3 and 28.6 per cent of their controls, respectively, by salinization, while their F₁ hybrids, Jhona 349×Magnolia and its reciprocal, were highly resistant to salinization, being 100% and 84.2% of the controls, respectively.

Grain yield per plant.

The grain yield had the same tendency as that of panicle weight. The yields of the F₁ hybrids, Jhona 349×Magnolia and its reciprocal, at the 4,000 ppm salinity level were 109.1 and 89.5% of their controls, respectively, while Jhona 349 and Magnolia produced only 40.1 and 23.5% of the controls, respectively.

Seed setting percentage.

At the 4,000 ppm salinity level, the seed setting percentage of Jhona 349 was 61.4%,

Table 2. Influence of salinity on yield and its components in F₁ hybrids and parental varieties

Character	Salinity level (ppm)	Parents		F ₁ hybrids	
		Jhona 349	Magnolia	Jhona 349 × Magnolia	Magnolia × Jhona 349
Panicle length (cm)	Control	22.1 ± 1.86	28.8 ± 2.36	28.5 ± 1.95	29.3 ± 2.40
	4,000	19.6 ± 1.97** (88.7) ¹⁾	27.2 ± 2.84** (94.4)	27.1 ± 2.36** (95.1)	27.1 ± 2.43** (92.5)
Number of primary branches/panicle	Control	9.4 ± 1.43	11.3 ± 1.87	10.7 ± 1.66	10.7 ± 1.91
	4,000	8.3 ± 1.65** (88.3)	11.5 ± 1.84 (101.8)	11.2 ± 1.82 (104.7)	10.8 ± 1.84 (100.9)
Number of spikelets/panicle	Control	119.1 ± 28.81	153.5 ± 39.61	155.8 ± 39.35	158.2 ± 39.13
	4,000	94.6 ± 28.18** (79.4)	144.0 ± 38.93* (93.8)	167.6 ± 48.49 (107.6)	159.6 ± 44.56 (100.9)
Panicle weight (g)	Control	2.6	3.5	1.8	1.9
	4,000	1.1 (42.3)	1.0 (28.6)	1.8 (100.0)	1.6 (84.2)
Grain yield/plant (g)	Control	39.9	36.2	17.6	18.1
	4,000	16.0 (40.1)	8.5 (23.5)	19.2 (109.1)	16.2 (89.5)

* Difference significant from that of control at 5 per cent level.

** Difference significant from that of control at 1 per cent level.

1) Figures in parentheses denote percentage of control.

while that of Magnolia was 26.0%. It was interesting to note that there was no effect of salinization in their F_1 hybrids regarding this character. The pollen and seed fertilities of the F_1 hybrids were almost the same (30%) at the control and at the 4,000 ppm salinity level. Therefore, the low seed setting percentage in the F_1 hybrids at the control and at the 4,000 ppm salinity level should be attributed to hybrid sterility (Table 3).

Delayed type sterility.

In general, the delayed type was more frequent than the cluster and random types. The delayed type sterilities in Jhona 349 and Magnolia were 35.0 and 53.5% respectively at the 4,000 ppm salinity level. On the other hand, the reciprocal hybrids were free of the delayed type sterility (Table 3). It was rather easy to differentiate the delayed type sterile spikelets caused by salinity from the sterile spikelets which were caused by hybrid sterility. The green color of the former spikelets turned whitish after heading, while the latter spikelets retained their green color up to harvest.

Jhona 349 and the F_1 hybrids were completely free from D-type plants, whereas all the plants of Magnolia were D-type.

The absence of D-type plants in the F_1 generation shows that the delayed type panicle sterility in Magnolia is recessive (Table 4).

Cluster type sterility.

The cluster type abnormal spikelets were present in the F_1 population and their parents. But the percentage of cluster type sterility was lower in the F_1 hybrids of Jhona 349 $\times$ Magnolia (2.8%) and Magnolia $\times$ Jhona 349

(2.1%) than their parents, Jhona 349 (3.1%) and Magnolia (18.9%).

Random type sterility.

The effect of salinization could also be seen on single spikelet (Table 3). The random type sterility was negligible in the F_1 hybrids and in the parents but was helpful in classifying the effect of salinization in panicle.

Cytoplasmic effect

The study of reciprocal crosses revealed that there was no cytoplasmic effect in all the characters studied (Tables 1~3).

Discussion

Sterility due to salinity in rice is a complex character. Three types of sterility, cluster, delayed and random types, have been recognized (AKBAR *et al.* 1972). The cluster and random type sterilities appeared on each plant in the F_1 hybrids as well as the parents. Due to consistent presence of these two types of sterility it was not considered to use these parameters for the genetic analysis of salt tolerance.

The random type abnormal spikelets were few and this type can be neglected in salt tolerance studies, but they were helpful in the classification of sterility in panicle due to salinity. Although hybrid sterility appeared in the F_1 populations it was rather easy to differentiate the delayed type sterile spikelets caused by salinity from the sterile spikelets caused by hybrid sterility in the F_1 populations, because the green color of the former spikelets turned whitish after heading, but the latter spikelets remained green up to harvest. The delayed

Table 3. Various types of sterility and seed setting percentage in F_1 hybrids and parental varieties at 4,000 ppm salinity level

	Salinity level (ppm)	Seed setting (%)	Cluster type sterility (%)	Random type sterility (%)	Delayed type sterility (%)	Hybrid sterility (%)
Parents :						
Jhona 349	Control	91.2	0.0	0.0	0.0	—
	4,000	61.4	3.1	0.5	35.0	—
Magnolia	Control	87.1	0.0	0.0	0.0	—
	4,000	26.0	18.9	1.6	53.5	—
F_1 hybrids :						
Jhona 349 $\times$ Magnolia	Control	30.3	0.0	0.0	0.0	69.7
	4,000	38.5	2.8	0.4	0.0	58.3
Magnolia $\times$ Jhona 349	Control	31.3	0.0	0.0	0.0	68.7
	4,000	33.5	2.1	0.3	0.0	64.1

Table 4. Manifestation of delayed type panicle sterility in F_1 hybrids

	Total number of plants and salinity level		Number of D-type plants and salinity level	
	Control	4,000 (ppm)	Control	4,000 (ppm)
Parents :				
Jhona 349	12	12	0	0
Magnolia	12	12	0	12
F_1 hybrids :				
Jhona 349 $\times$ Magnolia	12	12	0	0
Magnolia $\times$ Jhona 349	12	12	0	0

type sterile panicle showed the symptoms of dieback. The green color of the delayed type sterile panicle changed to whitish color gradually from tip to the base. Jhona 349 and its hybrids with Magnolia were completely free from D-type plants, while all the plants of Magnolia were D-type.

The parental variety Magnolia had dominant characters such as panicle length, the number of primary branches per panicle and the number of spikelets per panicle. The F_1 hybrids were highly resistant to salinity regarding seed setting. The pollen and seed fertilities in the F_1 hybrids were almost the same (30%) at the control and at the 4,000 ppm salinity level.

Therefore, the low seed setting percentage in the F_1 hybrids at the control and at the 4,000 ppm may safely be attributed to hybrid sterility. The absence of the delayed type panicle sterility in the F_1 hybrids of reciprocal crosses between Jhona 349 and Magnolia indicates that this type of sterility is governed by a recessive gene or genes.

The results of the present study clearly provide the evidence that the F_1 hybrids have the ability to cope with the salinity problems better than the parents. The F_1 hybrids showed hybrid vigor in plant height. The F_1 hybrids were highly resistant to salinization than their parents regarding the number of spikelets per panicle, panicle weight, and grain yield per plant.

Only in cases of panicle length and root length, the F_1 hybrids were significantly affected by salinity, almost to the same magnitude, as their parents. Proper root development is essential for optimum plant growth, and any adverse effect on panicle growth may ultimately affect grain yield.

However, from this study, it is difficult to say whether the same mechanism is responsible for reductions of root length and panicle length.

The salinity effects on these two characters particularly in the F_1 hybrids, where other characters did not show any appreciable influence of salinity, are worth consideration.

The reduction in root length may be due to the fact that the roots are in immediate contact with saline solution and as such the first effect of salinity is manifested in the suppression of the elongation of roots. An inhibition of root emergence and decrease in the number of roots per seedling in rice varieties under saline condition have also been reported (AKBAR and YABUNO 1974). Reduction of mitotic activity by salinity has been reported by AVILOVA and MATUKHIN (1967) and STROGOV (1964) in barley and cotton, respectively.

Summary

The behavior of the F_1 hybrids of reciprocal crosses between Jhona 349 and Magnolia along with these parental varieties to salinization (4,000 ppm) was observed during summer 1971 in greenhouse using water-culture techniques. The F_1 hybrids showed hybrid vigor for plant height both at the control and the 4,000 ppm salinity level. The parental variety Magnolia had dominant characters such as the number of days from seeding to heading, panicle length, the number of primary branches per panicle and the number of spikelets per panicle.

The delayed type panicle sterility was only present in Magnolia at the 4,000 ppm salinity level, whereas it was absent in Jhona 349 and their F_1 hybrids at the same salinity level, indicating that the parental variety Magnolia carries a gene or genes responsible for the delayed type panicle sterility.

Literature Cited

- AKBAR, M., T. YABUNO and S. NAKAO 1972. Breeding for saline-resistant varieties of rice, I. Variability for salt tolerance among some rice varieties. Japan. J. Breed. 22 : 278~284.

- AKBAR, M. and T. YABUNO 1974. Breeding for saline-resistant varieties of rice, II. Comparative performance of some rice varieties to salinity during early development stages. Japan. J. Breed. 24: 176~181.
- AVILOVA, L. D. and G. R. MATUKHIN 1967. Change of mitotic activity in plant roots under conditions of salinity. Cytology 9: 478~480 (Russian).
- STROGONOV, B. P. 1964. Physiological basis of salt-tolerance of plants (Translated from Russian). I. P. S. T., Jerusalem.

耐塩性イネ品種の育種

III. 水稻品種 Jhona 349 と Magnolia との正逆交雑による F_1 雑種の塩処理に対する反応

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水稻品種 Jhona 349 と Magnolia 間の正逆交雑による F_1 雑種と両親品種の塩処理に対する反応を比較した。供試材料の栽培は 1971 年, ガラス室内でポット水耕法によった。基本培養液のみの対照区と基本培養液に塩化カルシウムと塩化ナトリウムが等量ずつ添加された塩濃度 4,000 ppm の処理区を設けた。

草丈について F_1 個体は対照・塩処理両区で雑種強勢の現象を示した。出穂期・穂長・穂当りの第 1 次枝梗数・穂当りの小穂数についての Magnolia の特徴は雑種 F_1

世代に優性的に発現した。

塩処理区で遅発性全穂不稔性が Magnolia の全供試個体に発現したが, Jhona 349 と雑種 F_1 には発現しなかった。この現象は Magnolia が塩処理によって示す遅発性全穂不稔性を支配する劣性遺伝子の存在を暗示している。供試両品種間の正逆交雑による F_1 雑種の全調査形質に示された塩処理に対する反応には細胞質の影響は認められなかった。