Potash Review

Publisher : International Potash Institute, P.O. Box 1609 - CH-4001 BASEL (Switzerland),
· Phone (41) 61 261 29 22/24 - Telefax (41) 61 261 29 25

Subject 6
Cereals
12th suite

No. 4/1993

Potassium nutrition of rice (*Oryza sativa* L.) varieties under NaCl salinity

Bohra, J.S. [1] *and Doerffling, K.*

Institute of General Botany, University of Hamburg, Ohnhorststr. 18, D-22609 Hamburg, Germany; [1] Present address and address for correspondence: Department of Agronomy, Institute of Agricultural Sciences, B.H.U., Varanasi - 221 005, India

Reprint from Plant and Soil **152**: 299-303, 1993, with kind permission of the Kluwer Academic Publishers.

Abstract

A salt-tolerant (Pokkali) and a salt-sensitive (IR28) variety of rice (*Oryza sativa* L.) were grown in a phytotron to investigate the effect of K (0, 25, 50 and 75 mg kg^{-1} K soil) application on their salt tolerance. Potassium application significantly increased potential photosynthetic activity (Rfd value), percentage of filled spikelets, yield and K concentration in straw. At the same time, it also significantly reduced Na and Mg concentrations and consequently improved the K/Na, K/Mg and K/Ca ratios. IR28 responded better to K application than Pokkali. Split application of K failed to exert any beneficial effect over basal application.

Introduction

Rice (*Oryza sativa* L.) is a salt-sensitive crop (John *et al.*, 1977). However, because of its ability to grow well in standing water, it is recommended as a desalinization crop (Bhumbla and Abrol, 1978). Yeo and Flowers (1982) reported varietal differences in rice for salinity tolerance.

As saline soils generally have higher concentrations of Na and Mg than K and Ca (Shah Muhammed *et al.*, 1986), high ionic imbalances may impair the selectivity of root membranes. This may result in passive accumulation of Na in root and shoot (Kramer *et al.*, 1977). Addition of K to a saline culture solution has been found to increase the dry weight and K content of the shoots with a corresponding decrease in Na content in rice (Shah Muhammed *et al.*, 1987).

According to Yoshida (1981) rice is sensitive to salinity especially during early seedling growth and flowering. Therefore, maintaining a low Na/K ratio in the soil during these two critical stages may benefit the rice plants. To some extent, the Na/K ratio in soil can be reduced by applying potassium-rich fertilizers. The present study aims to investigate the effect of different levels and methods of K application on the growth, yield and mineral nutrient concentrations of a salt-tolerant and a salt-sensitive rice variety.

Material and methods

Plants were grown in a phytotron at the Institute of General Botany, Hamburg, Germany. The soil was sandy loam in texture with a pH of 6.68, a conductivity (EC) of 0.31 dS m^{-1} and 2.88% organic carbon. It contained high levels of available N (555 kg ha^{-1} N) and low levels of available P (34.9 mg kg^{-1} P soil), K (58.1 mg kg^{-1} K soil) and total salts (378 mg kg^{-1} soil). The soil was air-dried and, after proper grinding and sieving, 2.5-l earthen pots were filled with 2 kg of soil.

The treatments involved two varieties (the salt-sensitive modern short strawed IR28 and the salt-tolerant tall land race Pokkali), four levels of K (0, 25, 50 and 75 mg kg^{-1} K soil) and two methods of K application (full basal and half basal plus half top dressing at flowering). The treatments were replicated three times in randomized complete block design. A basal dose of 50 mg N and 25 mg kg^{-1} P soil was applied as $(NH_4)_2SO_4$ and Flory 5 (12:60 N P complex fertilizer) to all the plots. Potassium was added as K_2SO_4. Similarly, plants were grown under normal conditions in three pots of each variety to be used as controls. These were fertilized with 50 mg N + 25 mg P + 50 mg kg^{-1} K soil each.

Seedlings of the two varieties were grown separately and after 18 days three seedlings were transplanted in each pot under puddled soil condition. The salinization was imposed by addition of a NaCl solution of EC 10 dS m^{-1} (Krisnamurthy *et al.*, 1987). The addition of NaCl was started two days before transplanting and continued weekly till flowering. After flowering, salinity was maintained by applying the NaCl solution fortnightly till maturity. No NaCl was applied to the control pots. The environmental conditions in the growth chamber were: 30/25°C day/night temperature, 12h photoperiod (350 µmol m^{-2} s^{-1}) by Xenon lamps and 70/80% relative humidity.

At flowering, plant height and tiller numbers were recorded and one plant in each pot was utilized to study Rfd value as an indicator of the potential photosynthetic activity of a leaf (Lichtenthaler *et al.*, 1986). The top third leaf (third from the flag leaf) was utilized for the Rfd determinations using a PAM fluorometer (Walz, Effeltrich, Germany). The shoots of the plants utilized for Rfd studies were removed and their dry weight recorded. The remaining two plants were harvested at maturity for yield studies and determination of cation concentrations in root, grain and straw by atomic absorption spectrophotometry (180/60/70/80 Hitachi Zeeman AAS).

Results and discussion

The pH and electrical conductivity of the soil at the time of harvest were 7.62 and 8.3 ds m^{-1}, respectively. Among the two methods of K application, the initial growth of both varieties was better in pots where all the K was applied as basal fertilizer. After flowering, the plants receiving their second split dose of K recovered to some extent. However, the split application of K did not have any advantage over basal application, indicating that under saline conditions all K can be applied as basal fertilizer. This may reduce the Na/K ratio of soil during the seedling stage, which appears to be more sensitive to salinity than flowering (Neue *et al.*, 1990). The data concerning the method of K application are not presented.

Rfd values

During flowering under NaCl salinity both varieties showed markedly lower Rfd values as compared to the controls (Table 1).

Table 1. The effect of salinity and K application on yield-attributing characteristics and chlorophyll fluorescence decrease ratio (Rfd).

Treatment	Panicle/plant		Filled spikelet (%)		1000-grain wt (g)		Rfd (fd/fs)[b]	
	IR28	Pokkali	IR28	Pokkali	IR28	Pokkali	IR28	Pokkali
Control (non-salinized)[a]	5.3	3.7	78.4	91.7	24.3	29.9	2.43	2.26
K levels								
(mg K kg^{-1} soil)								
0	3.8	2.8	31.1	74.0	19.3	27.1	1.59	1.89
25	4.5	3.0	37.7	81.6	22.7	29.2	1.67	1.94
50	4.5	3.2	44.8	82.2	23.4	29.5	1.76	1.99
75	4.7	3.5	44.5	82.8	23.1	29.0	1.83	1.98
LSD (0.50)								
Variety		0.52		3.73		2.65		0.08
K		NS		5.28		NS		0.12
K × Variety		NS		7.46		NS		0.17

[a] Control values are not included in analysis of variance.
[b] At flowering.
NS: Not significant.

This shows the reduction of net photosynthesis (P_N) under saline conditions (Lichtenthaler *et al.*, 1986). However, the tolerant variety Pokkali was less affected than IR28. According to Yeo and Flowers (1982), under salinity stress Pokkali maintains fewer upper leaves at low Na concentration than IR28. Yeo *et al.* (1985) observed an inverse relationship between the Na concentration in the leaf tissue and net photosynthesis. In the present investigation, with Rfd determinations made in the third youngest leaf, it is apparent that varietal differences in P_N would have been much greater in younger leaves.

Potassium application of 50 and 75 mg kg^{-1} K soil improved the Rfd values in both varieties. For IR28 the differences were significant. The improvement of the Rfd value may be due to the enhancement of the K concentration and the reduction of the Na concentration (Table 3, see also Marschner and Possingham, 1975; Muhammed *et al.*, 1987). Thus potassium application to K-deficient saline soils may be means to alleviate reductions in net photosynthesis under saline conditions.

Plant growth

The plant growth observations recorded at flowering stage (data not reported) revealed that the plant height, number of tillers per plant and shoot dry weight were distinctly reduced under salinity stress in both varieties. However, the two varieties differed considerably in their growth habits. Pokkali was taller and had 34 and 55% more shoot dry weight than IR28 under unstressed and stressed conditions, respectively. In general, IR28 had better tiller production than Pokkali. Nevertheless, the percentage of effective tillers (panicle-bearing tillers) was higher in Pokkali. This indicates that under salinity stress IR28 wasted more energy than Pokkali in producing ineffective tillers.

Increasing levels of K application improved plant height, tiller numbers and shoot dry weight at flowering. However, significant differences were observed only in the sensitive variety IR28, where K_{50} and K_{75} produced significantly higher values than K_0. The beneficial effect of K application on plant growth under saline conditions may be attributed to its influence on Rfd value/net photosynthesis (Table 1).

Yield-attributing characteristics and yield

Table 1 shows that under salinity stress all yield-attributing characteristics were adversely affected in IR28. The tolerant variety Pokkali was less affected. Similar effects on the grain and straw yields were observed (Table 2). These results confirm the higher salt tolerance of Pokkali. The panicle number per plant was significantly higher in IR28 than in Pokkali. Nevertheless, Pokkali recorded a significantly higher percentage of filled spikelets and 1000-grain weight, suggesting that these contribute more to the grain yield of rice under saline conditions than panicle number.

Table 2. The effect of salinity and K application on grain and straw yield.

Treatment	Grain yield (g/plant)		Straw yield (g/plant)	
	IR28	Pokkali	IR28	Pokkali
Control (non-salinized)[a]	5.14	5.60	6.26	6.9
K levels				
(mg kg^{-1} K soil)				
0	1.1	3.8	4.8	5.5
25	1.7	4.6	5.6	6.1
50	2.1	4.7	5.9	6.2
75	2.1	4.8	6.0	6.4
Mean	1.8	4.5	5.6	6.1
LSD (0.50)				
Variety		0.32		0.19
K		0.45		0.27
K × Variety		0.64		0.38

[a] Control values are not included in analysis of variance.

All the yield attributing characteristics were improved by K application. However, the differences were only significant for the percentage of filled spikelets where K_{50} and K_{75} produced significantly higher values than K_0. Similarly, grain as well as straw yield increased with increasing levels of K application. These improved yields are most likely a consequence of the increased K/Na ratio in the straw (Table 3). This provides an improved nutritional balance, improved Rfd values (Table 1) and thereby a better translocation of photosynthates to the sink (Lips *et al.*, 1987).

The tolerant variety Pokkali recorded markedly higher grain yield than IR28 at all K levels. The biggest difference was 245% at K_0 and it declined with increasing K levels up to K_{50}. There was little variation between K_{50} and K_{75}. The good performance of Pokkali can be attributed to its inherent capacity to accumulate K (Table 3). Nevertheless, the sensitive variety IR28 responded better to applied K, particularly at K_{50}.

Mineral composition

The grain, straw and root samples were analyzed for Na, K, Ca and Mg contents at harvest. Obvious differences were only observed in the mineral composition of the straw, particularly for K and Na contents. Therefore, only the data on K and Na concentrations and the K/Na ratio of straw are presented (Table 3).

Under salinity stress the Na concentration in straw increased while that of K declined. These observations are in agreement with the findings of John *et al.* (1977) and Kuiper (1984).

The two varieties differed widely in cation concentrations. Under saline conditions, Pokkali recorded 49% more K than IR28. The Na concentration in Pokkali was 6.6% lower, while the Na uptake was slightly higher (data not reported). We agree with Yeo and Flowers (1984) that Pokkali has no better control mechanism for Na uptake than IR28, and the slightly lower concentration of Na in Pokkali is attributed to its increased growth.

Thus the higher concentration of K in Pokkali may enable it to maintain a considerably higher ratio of K/Na (Table 3).

A marked effect of K application was observed on the cation concentrations in rice straw. In general, the K concentration increased with increasing levels of K application, whereas the reverse trend was observed for Na, Ca and Mg concentrations (Ca and Mg data not reported). This exemplifies the antagonism between K and other cations resulting in increased K/Na, K/Ca and K/Mg ratios with increasing K levels. However, the K concentration in both varieties, even at K_{75}, was very low as compared to their respective non-salinized control. In agreement with Wyn Jones and Lunt (1967) we attribute this to the low Ca/Na ratio of the soil adversely affecting the selective transport of K^+ across membranes.

The results presented here highlight the importance of K nutrition of rice under saline conditions, especially in soils with low available K. Further research is needed to investigate this effect under field conditions, where the problem is more complex.

Table 3. The effect of salinity and K application on mineral content and K/Na ratio of straw at harvest.

Treatment	K (mmol kg^{-1} dry wt)			Na (mmol kg^{-1} dry wt)			K/Na		
	IR28	Pokkali	Mean	IR28	Pokkali	Mean	IR28	Pokkali	Mean
Control (non-salinized)[a]	656	823	-	22	22	-	29.8	37.4	-
K levels (mg K kg^{-1} soil)									
0	292	449	371	413	378	396	0.71	1.18	0.95
25	321	482	402	396	365	381	0.81	1.32	1.07
50	331	492	412	374	357	366	0.89	1.38	1.14
75	338	490	414	365	352	359	0.93	1.39	1.16
Mean	321	478	-	387	363	-	0.84	1.32	-
LSD (0.50)									
Variety			12.8			21.7			0.08
K			20.5			34.8			0.11
K × Variety			28.2			NS			0.15

[a] Control values are not included in analysis of variance.
NS: Not significant.

Acknowledgements

We are grateful to Dr. Dietrich Lorch for providing AAS facilities and to Mr. Ruediger Kopp for his assistance in AAS measurements. We also thank Mr. Mathias Bohn for critical reading of the manuscript.

References

Bhumbla, D.R. and Abrol, I.P. (1978): *In*: Soils and Rice. IRRI, Los Baños, Philippines. pp. 719-734.

John, C.D. *et al.* (1977): J. Exp. Bot. 28, 133-141.

Kramer, D. *et al.* (1977): Ann. Bot. 41, 1031-1040.

Krishnamurthy, R. *et al.* (1987): Oryza 24, 66-69.

Kuiper, P.J.C. (1984): *In*: Salinity Tolerance in Plants. Eds. R.C. Staples and G.H. Toenniessen. pp. 77-91. Wiley-Interscience, New York.

Lichtenthaler, H.K. *et al.* (1986): Radiat. Environ. Biophys. 25, 297-308.

Lips, S.H. *et al.* (1987): *In*: Inorganic Nitrogen Metabolism. Eds. W.R. Ullrich *et al.* pp. 233-239. Springer-Verlag, Berlin, Heidelberg, New York.

Marschner, H. and Possingham, J.V. (1975): Z. Pflanzenphysiol. 75, 6-16.

Muhammed S. *et al.* (1987): Plant and Soil 104, 57-62.

Muhammed S. *et al.* (1986): The 2nd annual meeting of the FCSSP at Benguet State University, La Trinidad, Benguet. p. 28.

Neue, H. *et al.* (1990): Transactions of 14th International Congress of Soil Science. Kyoto, Japan. pp. IV 50-IV 55.

Wyn Jones, R.G. and Lunt, O.R. (1967): Bot. Rev. 33, 407-426.

Yeo, A.R. and Flowers, T.J. (1982): Physiol. Plant 56, 343-348.

Yeo, A.R. and Flowers, T.J. (1984): *In*: Salinity Tolerance in Plants. Eds. R.C. Staples and G.H. Toenniessen. pp. 151-170. Wiley-Interscience, New York.

Yeo, A.R. *et al.* (1985): J. Exp. Bot. 36, 1240-1248.

Yoshida, S. (1981): Fundamentals of Rice Crop Science. International Rice Research Institute, Manila, 269 p.