TOLERANCE OF RICE CULTIVARS TO SALINITY

NAND KUMAR FAGERIA

ABSTRACT - Salinity is a serious growth-limiting factor for rice production in arid and semi-arid regions of the world. Data related to the reaction of rice cultivars to salinity are limited, especially for large numbers of cultivars. Forty rice cultivars were grown in a greenhouse in soil adjusted to different levels of salinity by applying 0.34 mol l⁻¹ of NaCl solution. The resulting salinity levels were: 0.39 (control), 5, and 10 dS m⁻¹ saturation extract conductivity. Significant varietal differences were found in relation to salinity tolerance. Based on relative dry matter yield of shoots at growth depressing salinity levels, rice cultivars were classified as tolerant, moderately tolerant, or moderately susceptible, and susceptible. The effect of salinity on concentrations and uptake of nutrients was observed. The sensitive and tolerant cultivars/lines identified may be beneficial in future breeding and physiological studies.

Index terms: electrical conductivity, nutrient uptake, Oryza sativa.

TOLERÂNCIA DE CULTIVARES DE ARROZ À SALINIDADE

RESUMO - A salinidade é um fator nocivo, por limitar a produção de arroz em regiões áridas e semi-áridas do mundo. Dados relacionados à reação de cultivares de arroz à salinidade são limitados, especialmente para grande número de cultivares. Quarenta cultivares de arroz foram testadas em casa de vegetação, em solo ajustado aos diferentes níveis de salinidade criados pela aplicação de solução de 0.34 mol l⁻¹ de NaCl. Os níveis de salinidade foram: 0.39 (testemunha), 5 e 10 dS m⁻¹ condutividade elétrica do extrato saturado do solo. Diferença significativa foi obtida em relação à tolerância de cultivares à salinidade. Baseado na redução de matéria seca da parte aérea com os altos níveis de salinidade, as cultivares foram classificadas como tolerante, ou moderadamente susceptível, e susceptível. Foi observado o efeito de salinidade na concentração de nutrientes. As cultivares/linhagens identificadas como tolerantes e sensíveis podem ser usadas nos estudos de fisiologia e melhoramento.

Termos para indexação: condutividade elétrica, absorção de nutrientes, Oryza sativa.

INTRODUCTION

Saline soils occupy about 380 million hectares of the earth's surface (Mahrous et al. 1983). Salt-affected soils are common in arid and semi-arid regions of many parts of the world where evaporation is higher than precipitation (Allison 1964, United States Salinity Laboratory Staff 1954). As a result, salts are not leached from the soil and accumulate in amounts or types detrimental to plant growth. Soils are also salinized in coastal areas due to tides. Salts generally originate from native soil and irrigation water. Successful crop production on these soils depends on the way the three components, i.e. soil, water and plants are managed.

Rice varieties differ widely in their salinity tolerance (Fageria et al. 1981, Fageria 1985). Therefore, selection for varietal tolerance to salinity is an important aspect of rice breeding programs in arid and semi-arid regions. A greenhouse experiment was conducted with the objective of evaluating rice cultivars/lines for tolerance to salinity. Promising materials may be used either directly after field testing or in breeding programs.

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MATERIALS AND METHODS

The greenhouse experiment was conducted at Brazil's National Rice and Bean Research Center, in Goiânia Goiás. The test soil was a hydromorphic (humic gley), having an initial pH of 5.1, organic matter content of 7.8%, extractable P-14.9 and K-115 mg kg⁻¹, and Ca-9.5, Mg-4.1 and Al0.2 cmol kg⁻¹. Phosphorus and K were extracted with the Mehlich I solution (0.05 mol 1⁻¹ HCl + 0.0125 mol 1⁻¹ H₂SO₄). Phosphorus was determined by colorimetry and K by flame photometry. Aluminum, Ca and Mg were extracted with 1 M KCl determined by titration with NaOH and EDTA, respectively.

Five-kg lots of air-dried soils were put in 6 kg plastic pots. Three levels of salinity were induced by treating the soil with a 0.34 mol 1⁻¹ solution of NaCl. The salinity levels included: 0.34 (unsalvanized control), 5 and 10 dS m⁻¹ electrical conductivity (ECₑ at 25⁰C). These levels were based upon a calibration curve (Fig. 1) developed on the same soil before starting the experiment. This methodology is that recommended by the International Rice Research Institute in the Philippines for rice (Ponnampalam 1976). Electrical conductivity of the saturated extract was determined by way of the method prepared by the US Salinity Laboratory (United States Salinity Laboratory Staff 1954).

Seeds of 40 rice cultivars were germinated in nutrient solution contained in 2 liter plastic pots. The composition of the nutrient solution was similar to that developed by the International Rice Research Institute for solution culture experiments (Yoshida et al. 1976). When seedlings attained an age of 15 days, 5 seedlings were transplanted into the pots of soil with different salinity levels. The salinity treatments were applied to the soil 14 days before transplanting, when an equilibrium was attained (Fig. 1). Each treatment was replicated two times.

To maintain a uniform distribution of salt, the soil layer in the pots was kept submerged to a depth of approximately 1 cm with distilled water.

Thirty-seven days after transplanting, the seedlings in the treated pots were harvested. Plant material was dried to constant weight in a forced-draft oven at 70 to 75⁰C and ground. Ground material was digested with a 2:1 mixture of nitric and perchloric acids. Composite samples per treatment of 9 randomly selected cultivars were analyzed for N, P, K, Ca, Mg, Na, Fe, Mn, Zn and Cu. The P concentration in the digest was determined colorimetrically, while K and Na were determined by way of flame photometry. Total N was determined with a Tecator 1016 digester and 1004 distilling unit and the remaining elements were determined by way of atomic absorption spectroscopy. An analysis of variance of the data was made and Statistical Analysis System (SAS) programs were used to calculate correlation coefficients and regression equations relating growth parameters and plant nutrients status.

RESULTS AND DISCUSSION

Analysis of variance indicated a highly significant difference between cultivars and salinity levels of plant height, tillers and dry shoot weight (Table 1). The cultivars x salinity interaction was also significant for plant height and tillers, but nonsignificant for shoot dry weight.

Influences of salinity on plant height, tiller number, and shoot dry weight of 9 rice cultivars are illustrated in Table 2. Within cultivars, differences existed in the reduction of growth parameters at excess salt concentrations. On an average basis, all growth parameters were reduced with increasing salinity levels. At the 10 dS m⁻¹ level of salinity, plant
height, tiller number, and shoot dry weight were reduced by 13, 15, and 27%, respectively, as compared to the control. This means shoot dry weight is more sensitive to salinity than plant height and tiller number.

The results of Munns et al. (1982) with barley suggest that the primary cause of reduced shoot growth under NaCl salinity is located in the growing tissues and not in the mature photosynthetic tissues. The inhibition by salt of cell division or enlargement (or both) in the growing region may be indirect or direct (Maas & Nieman 1978, Setter et al. 1983). Salt may affect growth indirectly by decreasing the amount of photosynthates, water, or growth factors reaching the growing region (Maas & Nieman 1978). The amount of photosynthetic reach the growing region may decrease because of inhibition of photosynthesis due to stomatal closure (Shoe & Gale 1983) or by direct effects of salt on the photosynthetic apparatus. In addition, transport of photosynthates in the phloem may be inhibited (Maas & Nieman 1978). Water deficits in the growing region may occur by insufficient osmotic adjustment or increased resistance to water flow (Owneby & Mahall 1983). According to Kawasaki et al. (1983), salinity hazards to plant growth are mainly because of competition in uptake between nutritional and saline ions, rather than due to high osmotic pressure.

Influences of soil salinity on dry matter production and the relative yield of 40 rice cultivars is shown in Table 3. Rice cultivars differed greatly in their growth response to

**TABLE 1. F values for analysis of variance of growth parameters of 9 rice cultivars.**

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Plant height</th>
<th>Tillers</th>
<th>Shoot dry weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivars</td>
<td>7.16**</td>
<td>3.73**</td>
<td>3.96**</td>
</tr>
<tr>
<td>Salinity</td>
<td>24.55**</td>
<td>15.49**</td>
<td>29.65**</td>
</tr>
<tr>
<td>CV x Salinity</td>
<td>2.40*</td>
<td>3.82**</td>
<td>1.73NS</td>
</tr>
</tbody>
</table>

*, ** Significant at P = 0.05 and 0.01, respectively. NS = Not Significant.

**TABLE 2. Influence of salinity on growth parameters of 9 rice cultivars.**

<table>
<thead>
<tr>
<th>Salinity level (dS m⁻¹ at 25°C)</th>
<th>Cultivar</th>
<th>0.34 control</th>
<th>5</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Plant height (cm)</td>
<td>Tillers per 5 plants</td>
<td>Shoot dry weight (g/5 plants)</td>
</tr>
<tr>
<td>GA 4223</td>
<td>66.5a</td>
<td>15.0d</td>
<td>6.20a</td>
<td>65.2ab</td>
</tr>
<tr>
<td>CNA 3525</td>
<td>63.8a</td>
<td>15.5d</td>
<td>5.34a</td>
<td>63.4ab</td>
</tr>
<tr>
<td>CNA 4909</td>
<td>68.2a</td>
<td>15.5cd</td>
<td>6.37a</td>
<td>65.6ab</td>
</tr>
<tr>
<td>CICA 8</td>
<td>66.4a</td>
<td>19.5ab</td>
<td>6.63a</td>
<td>68.8a</td>
</tr>
<tr>
<td>METICA 1</td>
<td>65.0a</td>
<td>15.5cd</td>
<td>5.65a</td>
<td>65.8ab</td>
</tr>
<tr>
<td>CNA 4982</td>
<td>56.6a</td>
<td>18.5bc</td>
<td>6.75a</td>
<td>56.6b</td>
</tr>
<tr>
<td>CNA 3949</td>
<td>61.2a</td>
<td>16.5b-d</td>
<td>5.57a</td>
<td>59.0ab</td>
</tr>
<tr>
<td>CNA 4900</td>
<td>66.9a</td>
<td>22.0a</td>
<td>6.15a</td>
<td>55.2b</td>
</tr>
<tr>
<td>CNA 4988</td>
<td>62.2a</td>
<td>18.5bc</td>
<td>6.36a</td>
<td>62.0ab</td>
</tr>
</tbody>
</table>

Means in the same column followed by the same letter are not significantly different at P = 0.05 by Duncan's Multiple Range Test.
TABLE 3. Influence of soil salinity on dry matter production of 40 rice cultivars.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Electrical conductivity (dS m⁻¹)</th>
<th>Relative yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.34 control</td>
<td>5</td>
</tr>
<tr>
<td>CIA 8</td>
<td>6.63 a-d</td>
<td>5.97a-e</td>
</tr>
<tr>
<td>METICA 1</td>
<td>5.65b-h</td>
<td>5.94a-e</td>
</tr>
<tr>
<td>FJ 10</td>
<td>5.98a-g</td>
<td>5.41b-j</td>
</tr>
<tr>
<td>GA 3922</td>
<td>6.22a-f</td>
<td>5.72a-g</td>
</tr>
<tr>
<td>GA 3879</td>
<td>6.05a-g</td>
<td>5.67a-h</td>
</tr>
<tr>
<td>GA 3852</td>
<td>5.80b-g</td>
<td>6.72ab</td>
</tr>
<tr>
<td>CNA 4</td>
<td>5.61b-h</td>
<td>5.34c-k</td>
</tr>
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<td>CNA 796019</td>
<td>6.84ab</td>
<td>5.17c-k</td>
</tr>
<tr>
<td>GA 3630</td>
<td>5.59b-h</td>
<td>6.40a-c</td>
</tr>
<tr>
<td>GA 3947</td>
<td>4.86f-h</td>
<td>5.66a-i</td>
</tr>
<tr>
<td>GA 3891</td>
<td>5.26d-h</td>
<td>5.90af</td>
</tr>
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<td>GA 3762</td>
<td>5.50b-h</td>
<td>5.24c-k</td>
</tr>
<tr>
<td>GA 3815</td>
<td>4.19h</td>
<td>4.42g-l</td>
</tr>
<tr>
<td>GA 3771</td>
<td>5.21d-h</td>
<td>5.51b-j</td>
</tr>
<tr>
<td>GA 3755</td>
<td>5.80b-g</td>
<td>5.94e-a</td>
</tr>
<tr>
<td>GA 3949</td>
<td>5.79b-g</td>
<td>6.29a-c</td>
</tr>
<tr>
<td>GA 3955</td>
<td>5.15d-h</td>
<td>4.93d-k</td>
</tr>
<tr>
<td>GA 3887</td>
<td>5.08e-h</td>
<td>4.74e-k</td>
</tr>
<tr>
<td>GA 3894</td>
<td>5.60b-h</td>
<td>5.33c-j</td>
</tr>
<tr>
<td>GA 4223</td>
<td>6.20a-f</td>
<td>6.19a-d</td>
</tr>
<tr>
<td>GA 3886</td>
<td>4.30a-f</td>
<td>4.09a-d</td>
</tr>
<tr>
<td>CNA 810230</td>
<td>4.20h</td>
<td>4.87d-k</td>
</tr>
<tr>
<td>CNA 4911</td>
<td>6.17a-f</td>
<td>5.97a-d</td>
</tr>
<tr>
<td>CNA 3525</td>
<td>5.34c-h</td>
<td>5.17c-k</td>
</tr>
<tr>
<td>CNA 4925</td>
<td>5.61b-h</td>
<td>4.32i-l</td>
</tr>
<tr>
<td>CNA 4892</td>
<td>6.00a-g</td>
<td>4.38h-l</td>
</tr>
<tr>
<td>CNA 3949</td>
<td>5.57b-h</td>
<td>5.09c-k</td>
</tr>
<tr>
<td>CNA 4897</td>
<td>5.12e-h</td>
<td>4.04kl</td>
</tr>
<tr>
<td>CNA 4917</td>
<td>4.99e-h</td>
<td>5.59b-i</td>
</tr>
<tr>
<td>CNA 4918</td>
<td>5.74b-f</td>
<td>4.57f-k</td>
</tr>
<tr>
<td>CNA 4891</td>
<td>5.52b-h</td>
<td>5.57b-g</td>
</tr>
<tr>
<td>CNA 4900</td>
<td>6.15a-f</td>
<td>5.39b-j</td>
</tr>
<tr>
<td>CNA 4191</td>
<td>7.39a</td>
<td>4.17j-l</td>
</tr>
<tr>
<td>CNA 4922</td>
<td>5.81b-g</td>
<td>5.29c-k</td>
</tr>
<tr>
<td>CNA 4898</td>
<td>6.06a-g</td>
<td>6.08a-e</td>
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<tr>
<td>CNA 4942</td>
<td>4.62gh</td>
<td>3.161</td>
</tr>
<tr>
<td>CNA 4981</td>
<td>5.16d-h</td>
<td>4.52g-k</td>
</tr>
<tr>
<td>CNA 4982</td>
<td>6.75a-c</td>
<td>6.60a-e</td>
</tr>
<tr>
<td>CNA 4988</td>
<td>6.36a-e</td>
<td>6.39a-c</td>
</tr>
<tr>
<td>CNA 4909</td>
<td>6.37a-e</td>
<td>6.98a</td>
</tr>
</tbody>
</table>

Means in the same column followed by the same letter are not significantly different at $P = 0.05$ by Duncan's Multiple Range Test.

Relative yield = \[
\frac{\text{Yield at 5 or 10 salinity level}}{\text{Yield at control}} \times 100
\]
salinity. Some cultivars produced good dry matter yields at the highest salinity level, while others could not survive.

Relative yield (percent of control) of plant species or cultivars can be used as a parameter for classification as salt tolerant or susceptible (Maas & Hoffman 1977). One group of the cultivars having relative yield approaching 90% or more may be considered as tolerant. The other group, having relative yield in the range of 0 - 50, may be considered as susceptible, and the third group of cultivars falling between these two ranges may be considered as moderately tolerant or susceptible. Based on these criteria, almost all cultivars were tolerant and/or moderately tolerant or susceptible at the 5 dS m⁻¹ salinity level (Table 3). At the 10 dS ms⁻¹ salinity level, tolerant cultivars were: GA 3922, GA 4223, GA 3886, CNA 4911, CNA 3525, CNA 4917, CNA 4891, and CNA 4909. The most susceptible cultivars at the highest salinity levels were: GA 3852, CNA 4, CNA 796019, GA 3630, GA 3947, GA 3891, GA 3762, GA 3815, GA 3771, GA 3755, GA 3887, GA 3894, CNA 4191, CNA 4922, and CNA 4942. All other cultivars were moderately tolerant or susceptible. These results showed that the best genotypes at low salt concentration may not be best at higher concentration. This means salinity screening should be done at least at three salinity levels (low, medium, and high) to fit cultivars under variable salt concentrations that normally exist under field conditions.

Macro- and micronutrient concentrations and contents in the shoots of 9 randomly selected cultivars are presented in Tables 4 and 5. Across all the cultivars, nitrogen concentration decreased at 5 dS m⁻¹, then increased.

### TABLE 4. Influence of salinity on the concentration and uptake of macronutrients in the shoots of 9 rice cultivars.

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Soil salinity level (ds m⁻¹ at 25°C)</th>
<th>Concentration (mg.g⁻¹)</th>
<th>Uptake (mg/5 plants)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.34 (control)</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>N  P  K  Ca  Mg</td>
<td>Na  P  K  Ca  Mg</td>
<td>Na  P  K  Ca  Mg</td>
<td>Na  P  K  Ca  Mg</td>
</tr>
<tr>
<td>GA4223</td>
<td>26.9 4.6 37.0 4.0 2.5 1.0 21.5 3.7 33.3 3.4 2.4 2.4 28.1 4.0 22.0 3.5 3.0 10.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNA3525</td>
<td>28.3 4.2 38.0 3.4 2.2 1.0 27.7 3.4 36.0 3.6 2.6 2.2 29.0 3.6 28.5 3.4 2.7 6.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNA4909</td>
<td>24.0 5.4 33.5 4.3 2.2 0.9 19.2 3.8 30.0 3.8 2.0 2.0 22.6 3.3 30.0 3.3 1.9 5.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CICA 8</td>
<td>28.0 4.4 37.0 2.8 2.6 1.2 26.1 3.3 34.0 3.2 2.2 2.2 29.6 2.9 31.0 3.5 2.4 6.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metical</td>
<td>27.9 5.0 36.0 2.9 2.3 0.6 25.9 3.6 33.0 3.3 2.5 2.5 34.2 3.0 29.5 3.0 2.7 5.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNA 4982</td>
<td>27.4 4.3 33.0 3.4 2.0 0.7 27.3 2.9 30.0 4.5 2.2 1.4 28.5 3.3 25.5 3.3 2.0 6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNA 3949</td>
<td>25.4 4.7 40.0 3.6 2.2 0.5 27.6 3.8 33.5 4.4 2.3 2.3 26.8 3.0 26.0 3.8 2.3 5.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNA 4900</td>
<td>27.8 4.0 36.0 3.7 2.1 0.4 25.5 3.0 34.0 3.5 2.2 2.1 37.3 3.2 30.0 5.1 2.9 9.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNA 4988</td>
<td>38.0 4.7 35.0 4.0 2.8 0.8 22.5 3.3 34.0 3.5 2.1 1.4 32.4 3.3 28.0 3.9 2.8 6.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>28.2 4.6 36.2 3.6 2.3 0.8 24.8 3.4 33.1 3.7 2.3 2.7 29.8 3.3 27.8 3.6 2.5 6.7</td>
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<td></td>
</tr>
</tbody>
</table>

TABLE 5. Influence of salinity on the concentration and uptake of micronutrients in the shoots of 9 rice cultivars.

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Soil salinity level (ds m⁻¹ at 25°C)</th>
<th>0.34 (control)</th>
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<th>10</th>
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<tbody>
<tr>
<td></td>
<td>Fe</td>
<td>Mn</td>
<td>Zn</td>
<td>Cu</td>
</tr>
<tr>
<td>GA4223</td>
<td>100</td>
<td>1075</td>
<td>24</td>
<td>12</td>
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<tr>
<td>CNA3525</td>
<td>105</td>
<td>600</td>
<td>28</td>
<td>14</td>
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<td>CNA4909</td>
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<td>CICA8</td>
<td>120</td>
<td>675</td>
<td>29</td>
<td>18</td>
</tr>
<tr>
<td>Metical</td>
<td>105</td>
<td>975</td>
<td>28</td>
<td>16</td>
</tr>
<tr>
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<td>120</td>
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<td>13</td>
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<td>700</td>
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<td>CNA4900</td>
<td>100</td>
<td>700</td>
<td>30</td>
<td>14</td>
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<td>CNA4988</td>
<td>130</td>
<td>725</td>
<td>31</td>
<td>17</td>
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<tr>
<td>Mean</td>
<td>112</td>
<td>742</td>
<td>28</td>
<td>15</td>
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</table>

Uptake (mg/5 plants)

<table>
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<tr>
<th>Cultivars</th>
<th>GA4223</th>
<th>CNA3525</th>
<th>CNA4909</th>
<th>CICA8</th>
<th>Metical</th>
<th>CNA4982</th>
<th>CNA3949</th>
<th>CNA4900</th>
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<th>Mean</th>
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<td>796</td>
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<td>6665</td>
<td>3204</td>
<td>4141</td>
<td>4475</td>
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<td>3881</td>
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<td>Zn</td>
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<td>223</td>
<td>192</td>
<td>158</td>
<td>135</td>
<td>139</td>
<td>185</td>
<td>197</td>
<td>170</td>
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<tr>
<td>Cu</td>
<td>74</td>
<td>75</td>
<td>83</td>
<td>119</td>
<td>90</td>
<td>88</td>
<td>89</td>
<td>86</td>
<td>108</td>
<td>90</td>
</tr>
<tr>
<td>Fe (mg kg⁻¹)</td>
<td>526</td>
<td>646</td>
<td>768</td>
<td>657</td>
<td>743</td>
<td>758</td>
<td>611</td>
<td>647</td>
<td>575</td>
<td>659</td>
</tr>
<tr>
<td>Mn (mg kg⁻¹)</td>
<td>7892</td>
<td>3878</td>
<td>4886</td>
<td>4029</td>
<td>5940</td>
<td>3636</td>
<td>3945</td>
<td>3773</td>
<td>3834</td>
<td>4646</td>
</tr>
<tr>
<td>Zn (mg kg⁻¹)</td>
<td>155</td>
<td>196</td>
<td>244</td>
<td>197</td>
<td>172</td>
<td>218</td>
<td>183</td>
<td>194</td>
<td>166</td>
<td>192</td>
</tr>
<tr>
<td>Cu (mg kg⁻¹)</td>
<td>105</td>
<td>103</td>
<td>105</td>
<td>125</td>
<td>101</td>
<td>194</td>
<td>122</td>
<td>113</td>
<td>121</td>
<td>121</td>
</tr>
</tbody>
</table>

Uptake decreased with increasing levels of salinity because of sharp declines in dry matter production. Concentration, as well as uptake of P and K decreased with increasing salinity. The decrease in K may be related to and increase in Na availability (Bange 1959, Hassan et al. 1970). Similarly, uptake of Ca and Mg was decreased at the highest salinity level. Tissue concentration and uptake of Na increased with increasing salinity as expected. The concentrations of Fe, Mn, Zn and Cu increased with increasing salinity. With respect to uptake, there were no definite trends. Iron uptake decreased with increasing levels of salinity while Mn, Zn, and Cu increased at 5 dS m⁻¹ salinity treatment, but decreased at 10 dS m⁻¹ salinity level.

Coefficients for linear correlations between growth parameters and nutrient concentration, uptake and uptake efficiency are presented in Table 6. Concentrations of all nutrients but P and K were negatively correlated with the growth parameters. Uptake of almost all the macronutrients was highly correlated with all three growth parameters. Among micronutrients, Fe and Mn showed significant correlation. As far as nutrient efficiency is concerned, there was a positive significant correlation with N, Ca, Mg and Na. Correlations of P and K and with all three growth parameters were negative.

The combined influence of nutrient concentrations and uptake of plant growth parameters of rice cultivars were evaluated using...
TABLE 6. Coefficient of linear correlation between growth parameters and nutrient concentration, nutrient uptake, and nutrient uptake efficiency by shoots in 9 rice cultivars.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Plant height</th>
<th>Tillers</th>
<th>Shoot dry weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant ht.</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>Tillers</td>
<td>0.46**</td>
<td>0.68**</td>
<td>1.00</td>
</tr>
<tr>
<td>Shoot dry wt.</td>
<td>0.75**</td>
<td>0.68**</td>
<td>1.00</td>
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** Nutrients conc.**

<table>
<thead>
<tr>
<th>N</th>
<th>-0.51**</th>
<th>-0.33NS</th>
<th>-0.60**</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>0.50**</td>
<td>0.19NS</td>
<td>0.49**</td>
</tr>
<tr>
<td>K</td>
<td>0.45*</td>
<td>0.35NS</td>
<td>0.38*</td>
</tr>
<tr>
<td>Ca</td>
<td>-0.48**</td>
<td>-0.26NS</td>
<td>-0.33NS</td>
</tr>
<tr>
<td>Mg</td>
<td>-0.22NS</td>
<td>0.52**</td>
<td>-0.48*</td>
</tr>
<tr>
<td>Na</td>
<td>-0.61**</td>
<td>-0.52**</td>
<td>-0.71**</td>
</tr>
<tr>
<td>Fe</td>
<td>-0.57**</td>
<td>-0.30NS</td>
<td>-0.54**</td>
</tr>
<tr>
<td>Mn</td>
<td>-0.04NS</td>
<td>-0.08NS</td>
<td>-0.03NS</td>
</tr>
<tr>
<td>Zn</td>
<td>-0.59**</td>
<td>-0.43*</td>
<td>-0.77**</td>
</tr>
<tr>
<td>Cu</td>
<td>-0.74**</td>
<td>-0.44*</td>
<td>-0.69**</td>
</tr>
</tbody>
</table>

** Nutrients uptake**

<table>
<thead>
<tr>
<th>N</th>
<th>0.47*</th>
<th>0.51**</th>
<th>0.64**</th>
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</thead>
<tbody>
<tr>
<td>P</td>
<td>0.70**</td>
<td>0.48**</td>
<td>0.83**</td>
</tr>
<tr>
<td>K</td>
<td>0.73**</td>
<td>0.65**</td>
<td>0.88**</td>
</tr>
<tr>
<td>Ca</td>
<td>0.48*</td>
<td>0.49**</td>
<td>0.79**</td>
</tr>
<tr>
<td>Mg</td>
<td>0.73**</td>
<td>0.38NS</td>
<td>0.78**</td>
</tr>
<tr>
<td>Na</td>
<td>-0.35NS</td>
<td>-0.35NS</td>
<td>-0.42*</td>
</tr>
<tr>
<td>Fe</td>
<td>0.46*</td>
<td>0.55**</td>
<td>0.73**</td>
</tr>
<tr>
<td>Mn</td>
<td>0.59**</td>
<td>0.05NS</td>
<td>0.46*</td>
</tr>
<tr>
<td>Zn</td>
<td>0.35NS</td>
<td>0.37NS</td>
<td>0.33NS</td>
</tr>
<tr>
<td>Cu</td>
<td>-0.07NS</td>
<td>0.14NS</td>
<td>0.18NS</td>
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</tbody>
</table>

** Nutrients uptake efficiency**

<table>
<thead>
<tr>
<th>N</th>
<th>0.46*</th>
<th>0.34NS</th>
<th>0.60**</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>-0.51**</td>
<td>-0.12NS</td>
<td>-0.52**</td>
</tr>
<tr>
<td>K</td>
<td>-0.37NS</td>
<td>-0.36NS</td>
<td>-0.36NS</td>
</tr>
<tr>
<td>Ca</td>
<td>0.42*</td>
<td>0.23NS</td>
<td>0.27NS</td>
</tr>
<tr>
<td>Mg</td>
<td>0.18NS</td>
<td>0.54**</td>
<td>0.49**</td>
</tr>
<tr>
<td>Na</td>
<td>0.39*</td>
<td>0.46*</td>
<td>0.46*</td>
</tr>
</tbody>
</table>

Nutrient conc. = Nutrient content per unit of dry matter; Nutrient uptake = nutrient conc. x dry matter; Nutrient uptake efficiency = mg dry matter/mg nutrient absorbed.

*, ** = Significant at the 5% and 1% level of probability, respectively. NS = Not significant.

stepwise multiple regression analysis (Table 7). Plant height was best explained by tissue concentrations of Ca, Na, Ca, and Mn and uptake of Zn.

** Tiller numbers were mainly influenced by uptake of N, K, Zn and Mg uptake efficiency. As far as shoot dry weight is concerned, 99% (R² = 0.99**) variation was due to K concentration, uptake of K, Ca, Na and uptake efficiency of Ca and Mg.**

REFERENCES


UNITED STATES SALINITY LABORATORY STAFF. Diagnosis and improvement of saline and alkali soil. [S.I.:s.n.], 1954. (USDA Handbook, 60).
