INTERACTIVE EFFECT OF SODIUM ABSORPTION RATIO (SAR), BORON RICH IRRIGATION WATER AND NITROGEN APPLICATIONS ON MORPHOMETRIC PARAMETERS OF PALMAROSA 
[CYMBOPOGON MARTINII VAR. MOTIA (ROXV) WATS.]

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ABSTRACT
A field experiment was conducted at Research Farm of Agricultural College, Bichpuri (Agra), to assess the effect of SAR and boron rich irrigation water with nitrogen and their interaction on morphometric parameters of Palmarosa (Cymbopogon martinii var. motia (Roxv) Wats.). The treatment consists of three types of saline-sodic water having EC₃ SAR 125 (S₁), EC₃ SAR 25 (S₂) and EC₃ SAR 37.5 (S₃). Four levels of boron i.e. B₁ to B₄ as 0, 2.5, 5.0 and 10 mg kg⁻¹ were used for irrigation of the plants. The three doses of nitrogen as 40 (N₁), 80 (N₂), and 120 (N₃) kg ha⁻¹ were tested through soil application. The plant height and number of tillers per plant were significantly reduced by SAR and boron levels in saline-sodic water but these increased significantly with higher levels of nitrogen (120 kg ha⁻¹). The mean increase in plant height and number of tillers per plant were 2.4 percent and 7.2 per cent. Interaction SAR × boron × nitrogen were found significant in case of herb yield and dry matter production at fourth harvest stage. Each increasing level of SAR and boron decreased the herb yield and dry matter production while useful effect of nitrogen could be observed at each level of SAR and boron. Each higher level of SAR and boron resulted significant reduction in oil content as 11.8 and 15.5 per cent with highest level S₃ of SAR 37.5 over lowest level S₁ of SAR 125 and B₁ level of boron in comparison to B₄ level of boron, respectively. The oil production of Palmarosa decreased significantly with each higher level of SAR and boron in saline-sodic water. At fourth harvest, the maximum oil production was recorded with N₃ level of nitrogen, which was 19.0 per cent higher in comparison to N₁ level of nitrogen. Interactions between SAR × boron × nitrogen were found significant in case of oil content and oil production at various harvest stages of Palmarosa. The increasing levels of SAR and boron generally decreased the geraniol and geranyl acetate of Palmarosa oil at fourth harvest while higher doses of nitrogen slightly improved the same in comparison to lower levels of nitrogen.

Key words: Cymbopogon martini, Morphometric parameters, Sodium absorption ratio, SAR, Boron.

INTRODUCTION
Salt affected soils are estimated to be about 6.74 million hectares (NRSA, 2006) in India. The maximum acreage of saline-alkali soils is in Uttar Pradesh state. The effects of salinity on crop growth are different from those of sodicity (Porcelli et al, 1995). Salinity causes a reduction in growth because plants expend energy on generating cellular osmolytes to generate a water potential gradient adequate to counteract the salts (Lauchli and Epstein, 1990), while sodicity affects plant growth

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negatively through its influence on physical and hydrological properties of the soils.

As per the ground water quality map of the India, about 25 per cent of ground waters are sodic and/or saline in the country. Agra region of Uttar Pradesh is well known for poor quality of water with regard to salinity, sodicity and toxic elements (Tripathi and Pal, 1980). Plants grown under such conditions show a progressive decline in crop yield. Both concentration and type of salts can affect crop growth and yield due to nutritional disorders and toxic effects (Naidu and Rangaswamy, 1993).

The excessive use of poor quality ground water for irrigation makes the soil unproductive and wastelands. The utilization of poor quality ground water and subsequent improvement of salt affected wastelands for crop production is of significant importance. Technological improvement of wastelands includes alternate strategies, such as introducing non-traditional crops to cope with such adverse problem. An attempt was made to study the effect of SAR and boron rich irrigation water with the use of nitrogen application and their interaction on morphometric parameters of Palmarosa (Cymbopogon martinii var. motia (Roxv) Wats.). Cymbopogon martinii is a species of grass in the lemon grass genus best known by the common name palmarosa. This perennial grass is native to Southeast Asia, especially India, and it is cultivated for its oil. The essential oil of this plant, which contains the active compound geraniol, is valued for its scent and for a number of traditional medicinal and household uses. Palmarosa oil has been shown to be an effective insect repellent when applied to stored grain and beans (Kumar et al., 2007), an anthelmintic against nematodes (Kumaran et al., 2003) and an antifungal and mosquito repellent (Duke and duCellier, 1993).

**MATERIALS AND METHODS**

The germplasm of Cymbopogon martini var. motia (Roxv) Wats. was collected from nearby places of Maharashtra and planted vegetatively through tussocks at research farm of Agriculture College, Agra having saline-alkali soils. The research farm lies at 27°42' latitude (N) and 77° longitude (E) having altitude 170 meter above mean sea level. The experimental soil was sandy loam in texture having EC, 1.5 dSm⁻¹, pH 7.9, organic carbon 0.12 per cent, available nitrogen 172 kg ha⁻¹, available phosphorus 11.7 kg ha⁻¹, available potassium 220 kg ha⁻¹ and available zinc 0.41 mg kg⁻¹. Three types of saline-sodic water having EC₈ and SAR₁₂.₅ (S₁), EC₈ and SAR₂₅ (S₂) and EC₈ and SAR₃₇.₅ (S₃) with four levels of boron as 0 (B₁), 2.5 (B₂), 5 (B₃) and 10 mg kg⁻¹ (B₄) were used for irrigating plants. A basal dose of 40 kg nitrogen, 40 kg P₂O₅ and 30 kg K₂O per hectare were applied at the time of planting and remaining 40 kg nitrogen per hectare were applied after 30 days of planting. The different types of irrigation water were artificially prepared by dissolving NaCl, NaHCO₃, Na₂SO₄, MgCl₂ and CaCl₂ salts in tube-well water having EC 2.4 dSm⁻¹. The treatments were replicated four times in factorial randomize block design (RBD). The seedling of Palmarosa were planted at 45 x 45 cm distance and irrigated with tubewell water to establish them, and later on treatments were given as and when irrigation required. Ten plants per replication were harvested at different phenophases for recording morphoeconomic parameters along with determination of essential oil yield per plant and essential oil quality as geraniol per cent, Geranyl acetate per cent and linalool per cent.

**Isolation of essential oils:** The essential oils were obtained from the aerial parts of the plants by hydrodistillation method using a Clevenger-type apparatus. Triplicate distillations were performed in succession for each sample of 500 g of fresh herbage of each leafing stage/growth stage. Oils obtained at each growth stages were dried over anhydrous Na₂SO₄ and stored at 4° C until used for chemical analysis.

**Analysis of essential oils:** The chemical composition of the oil was analyzed by GLC using...
a Perkin Elmer 3920 gas chromatograph equipped with TCD and a 2m x 1/8" S. S. column packed with K-20 M. Hydrogen gas was used as a carrier at a flow rate of 25 ml/mt and the isothermal operation was performed at 145. The peaks were compared with those produced by authentic sample sand reported in literature (Adams 1995; Jennings and Shibamoto, 1980).

RESULTS AND DISCUSSIONS

Plant height and tillers per plant: The plant height and tillers per plant were significantly affected by SAR levels as evidenced by its linear reduction with increasing levels of SAR in saline-sodic water at all the four harvests. Data indicates (Table 1) that each higher level of SAR significantly reduced the plant height and number of tillers per plant in comparison to lower levels of SAR. The mean reduction in plant height and tillers per plant were noted as 4.9 and 28.3 per cent per plant respectively with high level $S_3$ of SAR$^{3.75}$ as compared to lowest level $S_1$ of SAR$^{1.25}$ at fourth harvest. The reduction in plant height and poor number of tillers might be due to higher concentration of sodium around root zone which adversely affected the nutrient supply and a decrease in osmotic potential and soil matric potential as a result of more salt concentration in the sodic soil solution developed by the applied saline-sodic water. Similar adverse effects of sodicity have been reported by Singh and Pal (1999) in Palmarosa (C. martinii var. motia).

The plant height and number of tillers per plant was significantly affected by boron levels in saline-sodic water. The mean reduction in plant

<table>
<thead>
<tr>
<th>Treatments (S)</th>
<th>Plant height (cm)</th>
<th>Tillers/plant</th>
<th>Herb yield (q/ha)</th>
<th>Dry matter production (q/ha)</th>
<th>Oil content (%)</th>
<th>Oil production (Kg/ha)</th>
<th>Geraniol %</th>
<th>Geranyl acetate %</th>
<th>Citral %</th>
</tr>
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<tbody>
<tr>
<td>SAR Levels</td>
<td></td>
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<tr>
<td>$S_1$</td>
<td>151.7</td>
<td>46.0</td>
<td>159.0</td>
<td>60.7</td>
<td>0.68</td>
<td>109.1</td>
<td>63.0</td>
<td>13.1</td>
<td>11.1</td>
</tr>
<tr>
<td>$S_2$</td>
<td>147.5</td>
<td>39.3</td>
<td>140.4</td>
<td>53.6</td>
<td>0.66</td>
<td>93.0</td>
<td>62.1</td>
<td>12.0</td>
<td>8.1</td>
</tr>
<tr>
<td>$S_3$</td>
<td>144.3</td>
<td>33.9</td>
<td>128.9</td>
<td>49.0</td>
<td>0.60</td>
<td>78.0</td>
<td>58.0</td>
<td>10.1</td>
<td>6.2</td>
</tr>
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<td>11.1</td>
</tr>
<tr>
<td>S. E. m±</td>
<td>0.754</td>
<td>0.060</td>
<td>0.0569</td>
<td>0.0216</td>
<td>0.0019</td>
<td>0.3359</td>
<td>0.008</td>
<td>0.006</td>
<td>0.005</td>
</tr>
<tr>
<td>C. D. (5 %)</td>
<td>0.209</td>
<td>0.1669</td>
<td>0.1559</td>
<td>0.0599</td>
<td>0.0053</td>
<td>0.9311</td>
<td>0.006</td>
<td>0.007</td>
<td>0.002</td>
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<tr>
<td>Boron Levels</td>
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</tr>
<tr>
<td>$B_1$</td>
<td>153.7</td>
<td>41.4</td>
<td>154.3</td>
<td>59.7</td>
<td>0.71</td>
<td>109.6</td>
<td>70.1</td>
<td>11.4</td>
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</tr>
<tr>
<td>$B_2$</td>
<td>153.0</td>
<td>40.4</td>
<td>151.8</td>
<td>57.6</td>
<td>0.66</td>
<td>100.2</td>
<td>65.2</td>
<td>11.4</td>
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<td>$B_3$</td>
<td>142.9</td>
<td>43.0</td>
<td>135.5</td>
<td>51.3</td>
<td>0.64</td>
<td>85.7</td>
<td>58.5</td>
<td>13.1</td>
<td>5.6</td>
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<tr>
<td>$B_4$</td>
<td>141.7</td>
<td>34.2</td>
<td>129.5</td>
<td>49.2</td>
<td>0.60</td>
<td>77.7</td>
<td>53.9</td>
<td>10.2</td>
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<tr>
<td>S. E. m±</td>
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<td>0.0649</td>
<td>0.0250</td>
<td>0.0022</td>
<td>0.3879</td>
<td>0.001</td>
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<tr>
<td>C. D. (5 %)</td>
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<td>0.192</td>
<td>0.180</td>
<td>0.0692</td>
<td>0.0061</td>
<td>1.0751</td>
<td>0.002</td>
<td>0.012</td>
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<tr>
<td>Nitrogen Levels</td>
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</tr>
<tr>
<td>S. E. m±</td>
<td>0.0754</td>
<td>0.0602</td>
<td>0.0562</td>
<td>0.0216</td>
<td>0.0019</td>
<td>0.3359</td>
<td>0.006</td>
<td>0.0023</td>
<td>0.0038</td>
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<td>C. D. (5 %)</td>
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<td>0.1559</td>
<td>0.0599</td>
<td>0.0053</td>
<td>0.9311</td>
<td>0.029</td>
<td>0.0036</td>
<td>0.0046</td>
</tr>
</tbody>
</table>
height and number of tillers per plant were noted as 7.8 per cent and 17.3 per cent at fourth harvest with highest level B4 of boron i.e. 10 mg kg⁻¹ as compared to lowest level B1 of boron i.e. in the absence of boron. The enhanced concentration of boron in irrigation water suppressed plant height due to decreased cell size and adversely affected the phloem of plants. The similar results were also reported by Gupta (1998) and Singh and Pal (1996) in Lemongrass (Cymbopogon flexuosus).

Each higher level of nitrogen increased significantly the plant height in comparison to preceding lower levels of nitrogen. The mean increase in plant height and number of tillers per plant were 2.4 and 7.2 per cent, respectively. The increase in plant height may be due to enlargement in cell size by increased level of nitrogen.

Interaction between SAR x boron x nitrogen were found to be significant in case of herb yield and dry matter production at fourth harvest stage of Palmarosa (Table 2).

**Oil content (per cent) and oil production (kg ha⁻¹):**

Each higher level of SAR and boron resulted significant reduction in oil content. The per cent reduction recorded was 11.8 with highest level S3 of SAR and SAR37.5 over lowest level of S1 of SAR12.5 and 15.5 per cent reduction at B4 level of boron in comparison to B1 level of boron (Table 1). The nitrogen level affected markedly the oil content of Palmarosa, the maximum with N3 level of nitrogen which is significantly higher than other levels of nitrogen. The oil production of Palmarosa decreased significantly with each higher level of SAR and boron in saline-sodic water. The maximum oil production was recorded with N3 level of nitrogen, which was 19.0 per cent higher at fourth harvest as compared with N1 level of nitrogen.

Interaction between SAR x boron, SAR x nitrogen, boron x nitrogen and SAR x boron x nitrogen were found to be significant in case of herb yield and dry matter production at fourth harvest stage of Palmarosa (Table 2).
nitrogen were found significant in case of oil content (%)
and oil production (kg ha$^{-1}$) at fourth harvest
stages of Palmarosa (Table 2).

**Effect on oil quality:** Each higher level of SAR and
boron generally decreased geraniol, geranyl acetate and
citral content of Palmarosa oil at second and fourth
harvests while higher doses of nitrogen slightly improved
the same in comparison to lower levels of nitrogen.
The nitrogen application improved the overall quality
of oil as reported by Munsi *et al.* (1995).

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