CHAPTER - 5

DISCUSSION

Crop production is affected by both soils and saline soil conditions. Hayward and Wadleigh (1949) have described that in sodic soils the plant growth may be affected due to three causes, any one of which may become a serious limiting factor in plant growth (i) the high exchangeable sodium may depress the availability of Ca, Mg and other nutrients; (ii) toxicity of hydroxyl and carbonate ions and (iii) the adverse physical effect of sodium in reducing the permeability of soil to water and air. The effect of amendments which reduce exchangeable sodium by replacing with more favourable calcium is now well recognised as a method for overcoming adverse effects of exchangeable sodium.

The effect of graded doses of gypsum on the yield and quality of five fodder grass species was studied in a highly sodic soil in a field experiment, and effect of different ESP levels was studied in the pot experiment.

5.1 Green yield

The gypsum treatments in the field experiment were imposed late, i.e. on 7 July, 1973. Because of the time required for the establishment of the grasses and time lag between the application of gypsum and its reaction with the soil, the fodder yields in 1973 were generally low and only one cut could be taken from all the grasses in the first year. Data presented in Table 4,35 show that from among the grass species, para grass yielded the highest at all the levels of gypsum application. Anjan grass failed even to sprout in any of the plots. Bermuda grass was planted in the plots where anjan grass had failed on 13 August, 1973 and this grass appeared quite promising under sodic soil conditions as it
out that bermuda is likely to be a promising grass under sodic soil conditions. Thomas (1967) and Judd (1975) have reported that para grass grows best on moist soils and withstands prolonged water logging. Probably, due to this reason the crop is not affected under anaerobic conditions which exist in sodic soil and hence was tolerant. Mohindra (1973) also found that para grass established successfully on saline alkali soil having pH between 9.45 and 10.45 and EC in the range of 0.32 and 1.65 mmhos/cm.

The green yields of the grasses studied increased significantly with the increase in the gypsum level in both the years (Tables 4.35 and 4.36). This increase in the yield of grasses with each increase in the level up to highest gypsum level (12.50 t/ha) over the lower level may be attributed to better plant growth and higher survival percentage.

In pot experiment (Table 4.177) increasing ESP levels decreased the green yields of the grasses. Yield reduction with increasing ESP was associated with reduced number of tillers (Tables 4.162, 163 and 170) and leaf area (Tables 4.171, 172 and 173) of leaves and circumference of the stem (Tables 4,174, 175 and 176).

The effect of various gypsum treatments on the yield of fodders can be interpreted when compared to the yield which is likely to be obtained under soil conditions unaffected by sodicity. The average yields of different grasses in g/ha in normal soils in the northern India and their percentage decrease or increase at different pH values as brought down by different gypsum levels in the field experiment during 1974 is presented in Table 5.1 and Fig. 5.1.
FIG. EFFECT OF pH VALUES IN COMPARISON TO NORMAL SOIL ON THE 51 PERCENT REDUCTION OF GREEN YIELD DURING 1974.
Table 5.1 Percentage decrease or increase in the green yields of grasses at different pH values (March, 1974) as compared to normal soil.

<table>
<thead>
<tr>
<th>Hybrid napier</th>
<th>pH</th>
<th>Normal</th>
<th>10.2</th>
<th>9.9</th>
<th>9.8</th>
<th>9.5</th>
<th>9.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green yield (q/ha)</td>
<td>100</td>
<td>4.17</td>
<td>37.64</td>
<td>201.41</td>
<td>267.66</td>
<td>383.92</td>
<td></td>
</tr>
<tr>
<td>Percentage of normal yield</td>
<td>100</td>
<td>0.42</td>
<td>3.76</td>
<td>20.14</td>
<td>26.76</td>
<td>38.39</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Para grass</th>
<th>pH</th>
<th>Normal</th>
<th>10.3</th>
<th>10.0</th>
<th>9.7</th>
<th>9.6</th>
<th>9.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green yield (q/ha)</td>
<td>100</td>
<td>126.82</td>
<td>191.54</td>
<td>502.54</td>
<td>697.28</td>
<td>897.85</td>
<td></td>
</tr>
<tr>
<td>Percentage of normal yield</td>
<td>100</td>
<td>12.68</td>
<td>19.15</td>
<td>50.25</td>
<td>69.73</td>
<td>89.79</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Setaria grass</th>
<th>pH</th>
<th>Normal</th>
<th>10.1</th>
<th>10.0</th>
<th>9.9</th>
<th>9.6</th>
<th>9.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green yield (q/ha)</td>
<td>100</td>
<td>45.14</td>
<td>139.73</td>
<td>192.38</td>
<td>270.86</td>
<td>284.75</td>
<td></td>
</tr>
<tr>
<td>Percentage of normal yield</td>
<td>100</td>
<td>6.02</td>
<td>18.63</td>
<td>25.65</td>
<td>36.11</td>
<td>37.97</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Guinea grass</th>
<th>pH</th>
<th>Normal</th>
<th>10.2</th>
<th>9.8</th>
<th>9.7</th>
<th>9.6</th>
<th>9.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green yield (q/ha)</td>
<td>750</td>
<td>0.00</td>
<td>8.06</td>
<td>19.45</td>
<td>47.50</td>
<td>63.20</td>
<td></td>
</tr>
<tr>
<td>Percentage of normal yield</td>
<td>100</td>
<td>0.00</td>
<td>1.07</td>
<td>2.59</td>
<td>6.33</td>
<td>8.43</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bermuda grass</th>
<th>pH</th>
<th>Normal</th>
<th>10.3</th>
<th>9.9</th>
<th>9.7</th>
<th>9.5</th>
<th>9.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green yield (q/ha)</td>
<td>500</td>
<td>187.38</td>
<td>368.22</td>
<td>536.85</td>
<td>569.63</td>
<td>534.07</td>
<td></td>
</tr>
<tr>
<td>Percentage of normal yield</td>
<td>100</td>
<td>37.48</td>
<td>73.64</td>
<td>107.37</td>
<td>113.93</td>
<td>116.81</td>
<td></td>
</tr>
</tbody>
</table>
At the highest pH i.e. 10.2 (without gypsum), hybrid napier yielded only 0.42 per cent of average yield as obtained in the normal soil and guinea grass produced no yield. Setaria grass gave 6.02 per cent of normal yield at pH 10.1 and para and bermuda grasses 12.68 and 37.48 per cent respectively at pH 10.3. At the lowest pH 9.4 which was brought by highest gypsum level (12.50 t/ha), hybrid napier, setaria and guinea grasses showed 38.39, 37.97 and 8.43 per cent yields respectively when compared to average yield of normal soil. Para grass gave 50.25, 69.73 and 89.79% yields at pH values of 9.7, 9.6 and 9.2 respectively or at corresponding gypsum levels of 6.25, 9.37 and 12.50 t/ha as compared to normal soils. It is interesting to note that where gypsum at 6.25 t/ha and above was added, bermuda yielded as much, or even higher yield, as obtained in the normal soil.

The relationship between ESP of 0 - 15 cm soil and yield of different grasses (Fig. 5.2) shows that hybrid napier yielded negligible beyond ESP 70. The yields of guinea grass were very poor even at the lowest ESP of 20 but above ESP 40 the yield was negligible. In the case of para grass, although the yield was affected by increasing ESP levels, the effect appears to be more pronounced at ESP around 80. The figure clearly indicates that all the grasses failed to give satisfactory yields after ESP 80 but bermuda grass gave quite satisfactory yield up to ESP of approximately 85 and thus can be regarded as most tolerant among the grasses tried. Para grass also gave some yield up to about ESP 80 and beyond this it was affected very adversely but was still better than other grasses and therefore, can be rated as the next best grass under salic soil conditions.

For data from the pot experiment, where soil variability was relatively less, yield reduction was calculated at different
FIG. EFFECT OF ESP ON THE TOTAL GREEN YIELD OF 5-2 GRASSES DURING 1974.
ESP levels. Presuming green yield as 100 per cent at ESP 15.

The yield reduction in the para grass was much less than that of hybrid napier and setaria grasses (Fig. 5.3). Bermuda grass stands next in the yield reduction due to increasing ESP. Para and bermuda grasses gave 56.3 and 49.4 per cent green yields respectively at ESP 75 when compared to yield at ESP 15. At this level, hybrid napier yielded only 13.7 per cent green matter.

In the pot experiment the highest ESP was 75 where para grass showed its superiority over bermuda grass but in the field experiment, the ESP was much higher, bermuda grass was found to be somewhat better than para grass. Thus it is seen that bermuda grass was more tolerant at higher ESP levels. Pearson (1960) described that crested wheat grass, fairway wheat grass, tall wheat grass and rhodes grass as most tolerant to exchangeable sodium.

The gypsum requirement of the grasses vary, the effect of gypsum application is greatly influenced by the seasonal variations and, therefore, there is every likelihood of the crop production also affected with the season. The performance of each of the grass studied as influenced by the levels of gypsum at various cuts during 1974 is discussed separately.

Hybrid Napier

First cut gave significantly higher yield than second cut. The first cut was taken on 12 August when there was higher rainfall, humidity, and warm temperature which appears to be congenial for the growth of hybrid napier and which resulted in higher leaf area and circumference of stem which contributed to higher yields. The yield in the second cut was lower because the cut was taken on 17 November when the minimum temperature went down to 8.6°C thus affecting various growth parameters adversely.
In the pot experiment (Table 4.177) increasing ESP resulted in significant decrease in green yield at each level up to ESP 75. The first cut was taken on 5 August and second on 21 November. Both cuts were taken under similar climatic conditions as that of field experiment and thus the yield was higher in the first cut than in the second cut.

Para grass

With every increase in the gypsum level, there was an increase in the green yield of para grass. The difference between no gypsum and 3.12 t/ha gypsum was not significant. Four cuts in the field experiment were taken on 28 June, 10 August, 9 October and 22 December. The second cut gave the highest green yield followed by the third cut. Fourth cut recorded the lowest yield. The reason for higher yield in the second cut could be due to the presence of warm and humid conditions as well as rainfall resulting in higher height, number of leaves and leaf area compared to other cuts. The lower yield in the fourth cut is apparently due to very low temperature for its proper growth (6.0°C minimum temp.) and in first cut may be higher temperature (37.9°C maximum temp.) and low humidity.

With increase in the ESP there was significant decrease in the green yield of para grass in pot experiment. Highest green yield of 478 g/pot was obtained in the first cut and lowest (161 g/pot) in the fourth cut. The cuts were taken on 18 July, 22 August, 30 September and 28 November respectively. The highest yield in first cut is apparently due to more time taken for the growth of plant, high humidity and rainfall in the month of July which resulted in greater height and number of leaves which ultimately increased the yield. The same was true for the second cut. The low yields in the third and fourth cut, in particular are related to low
FIG. EFFECT OF ESP LEVELS ON THE PER-CENT YIELD REDUCTION OF GRASSES.
temperatures and less humidity.

**Setaria grass**

The application of gypsum levels over no gypsum showed significant increase in the green yield. First cut which was taken on 3 September gave significantly higher yield than the second cut taken on 30 December.

There was decreasing effect on the green yield of setaria grass as the ESP increased from 15 to 75. The first cut taken on 28 September produced more yield than the second cut taken on 17 December.

The higher yield in the first cut in both experiments is due to the favourable climatic conditions during September.

**Guinea grass**

This grass failed in the no gypsum treatment but in the gypsum treated plots, there was progressive increase in the green yield with increasing levels of gypsum. However, the results were statistically non significant. First cut taken on 13 September resulted in higher yield as compared to second cut taken on 20 December.

This grass also failed in pot experiment completely even in the 15 ESP level.

**Bermuda grass**

Gypsum application up to 6.25 t/ha increased the green yield significantly and thereafter the yield increase was not significant. Second cut (14 July) gave significantly higher yield than the third cut (1 September) which, in turn, gave significantly more yield than the fourth (4 December) and the first cuts (6 May).

In pot experiment significant reduction in the green yield of bermuda grass at each increased ESP (up to ESP 75) was observed.
Highest green yield of 273 g/pot was obtained in the second cut followed by third and fourth cuts (174 and 131 g/pot) respectively. Lowest yield of 86 g/pot was obtained in the fifth cut. The higher yields from second cut onwards were due to the fact that these cuts were taken on 20 July, 25 August and 25 September respectively and during these months there was maximum humidity (75.5, 76.0 and 67.5 per cent respectively) desired mean temperature (29.6, 28.9, 28.4°C respectively) and high rainfall (175.7, 149.2 and 20.2 mm respectively) which are favourable for plant growth. The yields in the first (28 May) and fifth cut (25 November) were low because in the former cut there was highest maximum temperature (39.1°C) with very low humidity (31.0%) and in the later cut minimum temperature was only 8.6°C. Thus both high and low temperatures retarded plant growth.

5.2 Dry matter

The fodder is fed to animals in the green form and therefore green weight is an important parameter to judge the yield potential of a crop but daily ration of an animal is computed on dry matter basis. For this reason the dry matter production of a fodder appears to be even more significant.

In 1973, when only cut was taken from all the grasses grown, para grass yielded the maximum dry matter production followed by bermuda grass with guinea grass producing minimum dry matter yield. Higher dry matter production in para grass was chiefly due to its higher green yield. Bermuda grass which gave almost equal yield as that of hybrid napier showed more dry matter production due to its higher dry matter percentage. Among the gypsum levels, the plots of no gypsum treatment showed on an average higher dry matter percentage as compared to plots which received gypsum. However, this was more pronounced in guinea and setaria grasses which were also found to be sensitive to high sodicity. These stressed conditions created by the sodicity to these grasses might have produced more dry matter percentage.
In 1974, bermuda grass outyielded even para grass in the dry matter production inspite of its lower green yield than the para. Increased dry matter production by bermuda grass was due to its higher dry matter percentage.

Dry matter yield of a crop is the product of its green yield and per cent moisture content which is greatly affected by seasonal changes and stage of the growth. The effect of cut and gypsum levels on the dry matter yields of these grasses, therefore discussed separately.

**Hybrid napier**

The dry matter yields (Table 4.45) followed similar trend as the green yields, although the dry matter percentage was much higher in second than in the first cut.

**Para grass**

Contrary to green yields where highest yield was obtained in second cut followed by third cut, dry matter yield was found to be highest in the third cut followed by second cut. The dry matter production in the third cut was higher because of higher dry matter percentage than the second cut. The lower dry matter percentage in the second cut may be due to the fact that during the month of August when this cut was taken, more rains occurred and higher moisture was available in the soil for the plant. In other cuts the trend was similar as of green yields.

**Setaria grass**

Dry matter production of setaria grass showed similar trend as the green yield (Table 4.47).

**Guinea grass**

Dry matter yield (Table 4.48) followed the similar trend as observed in green yield.
Bermuda grass

Although second cut gave higher dry matter yield yet is
contained low dry matter percentage than any of the cuts taken.
Higher moisture availability in the soil due to frequent rains
in the month of July when grass was harvested and high humidity
resulted in low dry matter percentage in the second cut.

The above discussion was based only on per cent dry matter
in the complete plant. Data presented (Table 4.50) however show that
the leaves of the grasses, in general, contained higher per cent dry
matter than the stems. In the complete plant, the dry matter
percentage varied with grass species and cuts and almost similar
trend was maintained in leaves and stems.

In pot experiment no regular trend of dry matter percentage
in the leaves and stems of bermuda and setaria grass was noticed
with the ESP levels. However, regular trend was found in the dry
matter percentage in the stem of hybrid napier and para grass with
increasing ESP level.

5.3 Crude protein

Computation of ration on dry matter basis is one of the
criterion if applied on dry and idle animals. But, if the animals
are to be kept for production i.e. for milk, breeding purposes etc;
the fodder had to be rich in the crude protein and minerals as well.

In 1973, when only one cut was taken from all the grass species,
the trend of crude protein production was similar to the dry matter
production both amongst the grasses and the gypsum levels. On per-
cent crude protein basis also bermuda grass (10.6%) had higher crude
protein percentage. Setaria (9.0%) and hybrid napier (7.3%) showed
more crude protein percentage than para (5.9%) and guinea (5.7%).
In 1974 also, the trend of crude protein production was similar to dry matter production. The cutting effect on the crude protein production of different grasses was similar to that of dry matter production except bermuda grass where the dry matter yield was higher in the first cut than fourth cut but the crude protein yield was higher in the second cut than the first cut. Because of higher crude protein percentage in the second cut (9.7) as compared to the first (9.0), higher crude protein yield was observed in the second cut.

There was an apparent relationship of the crude protein of complete plant with its components - leaf and stems which were taken from the top portion of the plant. The per cent crude protein was higher in the leaves as compared to stems. Bermuda grass showed higher crude protein in the leaves followed by para. The crude protein in the stem part was higher in case of setaria followed by bermuda and lowest in para grass. The crude protein in the stem part was even higher than that of complete plant in case of para, setaria and guinea grasses indicating transportation of nitrogen absorbed by the roots to the top part of the plant particularly the leaves.

The crude protein percentage of the grass species was very much affected by the age of crop or cut.

**Hybrid manfer**

The crude protein was found to be higher in second cut both in the leaves and stems as compared to first cut because the second cut was ready earlier than the first, due to which nitrogen loss from the soil as well as the plant may be less resulting in higher crude protein.
In the pot experiment, increasing ESP levels decreased the crude protein in the leaves of hybrid napier which further substantiate the results of field experiments. The results of different cuts, were contradictory to field experiment and higher crude protein was found in the first cut due to higher leaf area, less plant height and less dry matter percentage.

**Para grass**

Crude protein in the first cut was much lower than the remaining cuts, because first cut was taken after four months of its sprouting whereas other cuts were taken at shorter intervals.

Increase in ESP level (pot) had inverse relationship with crude protein of leaves and stems. Second cut gave higher crude protein.

**Setaria grass**

Crude protein in the first cut was higher than the second cut which might have resulted from low dry matter percentage in the first cut as compared to second cut.

There was sharp decline in the crude protein percentage in the leaves of setaria grass with increasing ESP levels particularly at ESP 60 and 75 showing that nitrogen uptake is inhibited more in setaria than the other grasses.

**Guinea grass**

The trend was same as for hybrid napier.

**Bermuda grass**

The crude protein in the leaves of bermuda grass was more affected by cuts. First cut gave significantly less crude protein than the remaining cuts. This may be due to higher dry matter percentage in the first cut.

Increasing ESP reduced the crude protein percentage both in the leaves and in the stems, but differences were less compared to other grasses. The trend of cuts was same as in the field experiment
but in pot studies one additional cut was taken which gave comparatively less crude protein percentage. The increase in the crude protein at increasing gypsum levels may be attributed to increased availability of nitrogen. Sodic soils have poor physical properties which result in short term oxygen deficiencies during the irrigation/rainfall cycles. There is conclusive evidence that either a deficiency of oxygen or an excess of carbon dioxide will cause a sharp decrease in the uptake of nitrogen by plant roots in culture solution (Chang and Loomis, 1945). Lawton (1945) observed a decrease in nitrogen uptake by corn as a result of compaction and that forced aeration sharply increased the nitrogen uptake. In a controlled laboratory study (Abrol, 1968), when physical soil properties were not a limiting factor in crop growth, increased nitrogen application compensated the yield reduction due to increasing levels of exchangeable sodium percentage.

5.4 Ash

Studies in the present investigation (Table 4.70) revealed that ash percentage was maximum in bermuda grass and lowest in hybrid napier. The ash content increased with the increase in the gypsum level up to the highest dose of 12.50 t/ha. The contribution of gypsum towards increase in percentage ash content was due to greater uptake of different mineral constituents such as Ca, Mg, P etc. particularly in the leaf part of the plant.

In general, the ash percentage of all the grasses increased in the second year (1974) and differed with the cuts. The increase in the ash percentage in 1974 can be attributed to more uptake of the mineral nutrients due to further soil improvement. In almost all the grasses increase or decrease of ash percentage in a particular cut was associated with the uptake of different mineral constituents.
5.5 Calcium

In 1973, bermuda grass showed the highest calcium percentage closely followed by guinea grass and with hybrid napier the lowest. Increasing level of gypsum application increased the calcium percentage of all the grasses with leaves containing higher calcium percentage than the stems (Table 4.77). The calcium percentage of both leaves and stems increased with increasing gypsum level.

In 1974, the calcium percentage of the whole plant as well as of its components i.e. leaves and stems increased tremendously even in the plots where no gypsum was applied. However, with each increase in the level of gypsum, there was progressive increase in the Ca percentage. There was marked difference in the calcium percentage with the cuts particularly in guinea grass. In general, the calcium percentage was higher in the last cut of all grasses with the exception of hybrid napier where the differences between the two cuts were negligible. Calcium percentage in para and bermuda grasses which gave four cuts each, increased with the order of cuts taken.

The results of pot experiment did not match with the field experiment in relation to different grass species. Bermuda grass which was found to contain the highest calcium percentage on the basis of overall average gave less calcium percentage than para and setaria grasses. Calcium percentage of all the grasses declined with increasing ESP levels, with more pronounced decline in setaria and hybrid napier and very little in bermuda grass both in the leaves and stems. Calcium percentage of all the grasses suddenly depressed at ESP 75.

The increase of calcium percentage with increasing gypsum levels in the different grass species is attributed to the improvement of the calcium status of soil as apparent from Table 4.3. In 1973,
calcium percentage of the grasses was low because the gypsum was applied in the month of July and grasses were harvested from October to mid of November. This period was not sufficient for complete reaction of gypsum in the soil. The calcium in the soil improved even where gypsum was not applied due to leaching and calcium contained in the irrigation water. For this reason the calcium percentage of the grasses increased even in these plots. Higher calcium percentage in the later cuts particularly the last ones, was due to fact that the solubility of gypsum is very low and the soil calcium status improved with time as a result of irrigation. (Table 4.3).

Ca content of the grasses decreased with increasing ESP due to decreased Ca availability. (Table 4.155). The results are in agreement with the findings of Bernstein and Pearson (1956), Bains and Fireman (1964), Agarwal (1964), Poonia et al (1972), Mehrotra and Das (1973), Bhunbla and Poonia (1973) who reported a decrease in the uptake of Ca in different crops with increasing ESP.

5.6 Magnesium

The magnesium percentage followed a similar trend as that of calcium percentage.

In pot experiment the depression in the magnesium was also found with the increasing ESP level but cuts showed little effect on the magnesium percentage. The increase in the magnesium percentage of the grasses with increasing gypsum levels can be related with the increase of magnesium content (Table 4.4), of the soil at increasing gypsum levels in field experiment, and decrease with the increasing ESP levels with the decrease in Mg content (Table 4.156) of soil in pot experiment. Agarwal et al (1964) also found negative correlation between ESP of soil and magnesium.
Mehrotra and Das (1973) grew wheat, barley, oats, peas, gram, lentil and rainy season crops like cotton, jowar, maize, paddy on soils alkalinized to varying levels of exchangeable sodium ranging from 2 to 99 per cent and observed that uptake of magnesium decreased with the rise in ESP.

5.7 Sodium

During 1973, amongst the grasses, setaria and guinea had higher sodium percentage, approximately double than that of para and bermuda grasses and similarly para and bermuda grasses contained more than double sodium per cent compared to hybrid napier (Table 4.99). Sodium percentage of all the grasses decreased with each increase in the gypsum level. When the sodium percentage of leaves and stems is compared (which were taken from the top) with whole plant, leaves and stems contained comparatively low sodium and the difference was particularly large in hybrid napier. Stem part of the grasses, on an average, showed slightly more sodium than leaves.

The sodium percentage during 1974 increased tremendously in all the grasses and differed with the cuts. In general, the sodium percentage was higher in first cut than the later cuts.

The field results are not comparable with the results of pot experiment. Hybrid napier showed minimum sodium percentage in field experiment. But in pot experiment the difference with bermuda grass was very small, rather showed higher sodium percentage than bermuda at the highest ESP level. Para grass which showed almost equal sodium percentage as of bermuda grass in field experiment, gave more than double of it in pot experiment. There was an increase in the sodium percentage of leaves and stems with the rise in the ESP.

The plants have remarkable differences in their ability to accumulate or exclude sodium ion. Some plants are highly effective accumulators of sodium while others exclude it almost completely from their shoots. The latter group of plants may accumulate large
quantities in their roots. Hayward and Wadleigh (1949) reported that more tolerant species normally take up large amounts of sodium while sensitive ones may exclude it and do so at the expense of Ca, Mg and K. Thus, the main limitation of sensitive plants, is their ability to regulate the ions while Pearson and Bernstein (1948) ascribed the reason of depressed plant yield to abnormal root functioning on excessive accumulation of sodium in such a soil. In the present experiment hybrid napier which was found to be sensitive, had very little sodium in its leaves and stems but higher in the complete plant which indicates that more sodium was accumulated in the lower part. Bernstein et al. (1956), LeHaye and Epstein (1971), Hains (1969) and Wallace et al., (1965) have also reported that non halophytes accumulate less sodium in roots and transfer little to leaves. Most of the sodium that is absorbed is retained in roots and lower part of stem. Setaria and guinea grasses accumulated high amounts of sodium in the leaves and stems which may be directly toxic, and might have affected the normal metabolic functioning of these grasses. Salts may disrupt the structure of enzymes or other macromolecules (Hauser and Hanson, 1966; Warren and Cheatum, 1966), which may damage cellular organelles (Blumenthal-Goldschmidt and Poljakoff-Mayber, 1968). The present findings are in agreement with the findings of Martin and Bingham (1954) and Jone et al. (1957) who reported that sodium sensitive plants such as almond, citrus and stone fruits, exhibit characteristic leaf burn symptoms when accumulated sodium in leaves becomes excessive. Para and bermuda grasses were tolerant, possibly due to the fact that in these grasses the sodium accumulation was only moderate. Decrease in the sodium percentage in the grasses was expected because with the application of gypsum the replacement of sodium on the exchange complex with calcium takes place leading to decreased exchangeable sodium percentage (Table 4.5). The increase of sodium during 1974 in all the grasses can be ascribed to more favour-
able conditions of ions uptake due to improvement in the physical properties of soils due to gypsum application. Higher uptake of sodium in pot experiment can be explained by a similar reasoning. In pot experiment the pots were tilled from time to time for aeration and watered daily or even twice a day which helped in maintaining better soil physical conditions and resulted in greater uptake of ions including sodium. It can be seen from the data (Tables 4, 153 and 154) that pH and ESP in pot experiment decreased more rapidly as compared to field because of more uptake of sodium by plants. In a pot experiment Ghahra and Abrol (1977) attributed intensive biological action of plant roots in the limited space available in pots as responsible for solubilizing soil calcium carbonate resulting in decrease in soil ESP. Increase in the sodium percentage of many crops due to increasing ESP have been reported by Bains and Fireman (1964), Agarwal et al (1964), Poomia et al (1972), Bhumib and Poomia (1973).

5.8 Potassium

Para and hybrid napier grasses contained comparatively more potassium than the other grasses studied. There was an increase in the potassium percentage of grasses with increasing gypsum levels. Higher potassium was noticed in leaves and stems in comparison to complete plant which indicated that more potassium was retained in the top than in the lower portion. On an average the stems of the grasses contained more potassium than their leaves. The results obtained by White (1971) on K contents in blue grama, buffalograss, Western wheat grass and brome grass and brome grass are in agreement that tops contained more K.

In 1974, the potassium percentage was more than in 1973. The reasons appear to be similar as described for sodium. The potassium content varied with cuts. The first cut in the grasses, except para grass, contained higher potassium than later cuts,
possibly due to more potassium present near root zone in the first cut because of the application of muriate of potash at the beginning of fresh growth. Para grass contained higher potassium in the second cut which was taken in the month of August when the rains occur quite frequently. First cuts of hybrid napier, setaria and guinea grasses also coincided with the rainy season and also showed higher potassium, which indicates that proper moisture supply favoured K uptake. Andreaśi et al (1970) also reported that *Panicum maximum*, *Hyparrhenia rufa* and *Laminia minutiflora* contained higher K in wet season than dry season.

With increase in ESP there was a decrease in potassium percentage of the grasses. The decrease was caused by decrease of potassium in the soil with increasing ESP (Table 4, 158). The results are in conformity with the results of Bains and Fireman (1964), Mehrotra and Das (1973) who have reported that exchangeable sodium generally caused a decrease in the absorption of potassium. Bhumbla and Poonia (1973) also reported that total uptake of K decreased gradually in response to ESP.

In sodic soils, sodium is the dominating cation which influences the uptake of sodium by the plants, and sodium in turn the uptake of other cations. Among other cations, potassium and calcium are of importance as they are required in relatively large quantities for crop growth.

5.9 Phosphorus

In 1973, when only one cut was taken from all the grass species, guinea grass contained highest phosphorus percentage and other grasses had almost equal phosphorus content (Table 4, 123).
When we compare the leaves and stems, leaves had higher phosphorus percentage than the stems. The leaves of guinea and bermuda grasses showed higher phosphorus than other grasses whereas the stems of hybrid napier and para grasses contained higher per cent phosphorus than remaining grasses. Guinea grass which showed higher phosphorus in the complete plant and leaves had minimum phosphorus percentage in the stems. The phosphorus percentage of complete plant as well as of leaves and stems increased with increasing levels of gypsum. During 1974, there was an appreciable increase in phosphorus content of the grasses and the phosphorus percentage varied from cut to cut. In general, higher phosphorus percentage was found in the first cut of the grasses except of para grass which showed higher phosphorus in the fourth cut.

In pot experiment bermuda grass showed higher phosphorus followed by hybrid napier. As in field experiment, the phosphorus percentage in pot experiment was also more in the first cut of all the grasses. There was no regular trend of phosphorus with the increasing ESP levels. This is contrary to the findings of Agarwal et al (1964) who found an increase in phosphorus concentration in barley and paddy with an increase in ESP.

The reason of low phosphorus in the control plots can be explained by the overall poor plant growth due to high soil sodicity. It is also likely that in soil of high pH, as obtained in the present experiment, phosphorus is present in the form of sodium phosphates which is not available to the plants. As the pH comes near to neutral, availability of phosphorus increases. Gypsum caused a decrease in the soil pH (Table 4-1) and improved physical conditions of the soil which resulted in increased phosphorus
content of the grasses. Regarding the cuts, the phosphorus content of a plant depends upon the age of plant, climate and the availability of the phosphorus in the soil. Higher phosphorus in the first cut might be due to the fact that phosphorus was applied only once at the start of fresh growth due to which more uptake might have taken place in the initial stage. Higher phosphorus in fourth cut of para grass may be because of less vegetative growth in the last cut.

5.10 Boron

In 1973 when only one cut was taken, bermuda grass showed higher boron content and para and hybrid napier the lowest. There was progressive reduction in the boron content with increasing gypsum levels. In 1974, differential cuts were taken and on average basis it found that hybrid napier contained maximum boron content followed by bermuda grass. The boron content of para grass increased whereas of setaria and guinea decreased as compared to 1973. These variations might have been caused due to fact that in 1973, the grasses faced moist conditions most of the time as the planting of grasses except bermuda grass was done in the month of July. Bermuda grass was planted in the second fortnight of August which faced more of dry conditions, resulting in higher boron content. In 1974 also, the boron content of the grasses decreased with the increasing levels of gypsum. This was so because the boron status of soil decreased with the application of gypsum (Table 4.7). Boron is present in toxic concentration in the form of sodium metaborate, particularly in the soils having pH higher than 9.2. Sodium metaborate reacts with gypsum and form sodium sulphate and calcium
metaborate. The solubility of calcium metaborate is very low (0.4 per cent) as compared to sodium metaborate whose solubility is 26 and 36 per cent in temperature range of 20 to 35°C. The large difference in the solubility renders boron insoluble resulting in reduction in boron content of plants. Gupta and Harish Chandra (1972) found that 80 per cent dose of gypsum requirement for a saline-sodic soil is adequate to reduce toxic concentration of boron to non-toxic levels. In general, higher boron content was either found in the first or the last cut of grasses. Boron content in the first cut may be higher because plants grew most of time in the dry and hot weather conditions of March, April, May and in most cases June also during which concentration of salts present in the soil becomes high, resulting in more uptake.

In pot experiment, there was no regular trend of boron in plants with ESP, particularly in the stems of grasses. In leaves part, however, some increase in hybrid napier, para and setaria was observed. This may be due to the fact that different ESP levels were established artificially using a normal soil which had low boron (Table 4.160), content than the sodic soil (field experiment) (Table 4.7).

5.11 ADF

During 1973, hybrid napier showed the highest ADF percentage followed by guinea grass. Bermuda grass had the lowest ADF content. The ADF percentage of the grasses decreased in 1974 in comparison to 1973. There was decreasing trend of ADF percentage with the increasing level of gypsum. The higher ADF percentage in 1973 could be due to higher leaf stem ratio (less leaf and more stem) and less uptake of the nutrients when compared to 1974.