CHAPTER - 2

REVIEW OF LITERATURE

2.1 Extent and distribution of salt affected soils

The problem of soil salinity and sodicity is widespread especially in the arid and semi-arid tracts of the world. In India, about 7 million hectares of land has been estimated to be affected because of salinity and alkalinity (Abrol and Bhumbia, 1971). The salt affected soils are distributed in

1) Indo-gangetic plains of Punjab, Haryana, Uttar Pradesh, Delhi, parts of Bihar and Gwalior regions of Madhya Pradesh.

ii) Medium and deep black soils of Madhya Pradesh, Maharashtra, Karnataka and Andhra Pradesh.

iii) Arid areas in the states of Rajasthan and Gujarat.

iv) Coastal areas in the states of West Bengal, Orissa, Andhra Pradesh, Kerala, Karnataka and Maharashtra.

v) Coastal areas of Gujarat.

The state-wise distribution of salt affected soils is given in Table.

<table>
<thead>
<tr>
<th>State</th>
<th>Area under saline and alkali soils (Hundred thousand hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uttar Pradesh</td>
<td>12.95</td>
</tr>
<tr>
<td>Gujarat</td>
<td>12.14</td>
</tr>
<tr>
<td>West Bengal</td>
<td>8.50</td>
</tr>
<tr>
<td>Rajasthan</td>
<td>7.28</td>
</tr>
<tr>
<td>Punjab</td>
<td>6.89</td>
</tr>
</tbody>
</table>

......contd.
<table>
<thead>
<tr>
<th>State</th>
<th>Million Hectares</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maharashtra</td>
<td>5.34</td>
</tr>
<tr>
<td>Haryana</td>
<td>5.26</td>
</tr>
<tr>
<td>Orissa</td>
<td>4.04</td>
</tr>
<tr>
<td>Karnataka</td>
<td>4.04</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>2.24</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>0.42</td>
</tr>
<tr>
<td>Delhi</td>
<td>0.16</td>
</tr>
<tr>
<td>Kerala</td>
<td>0.16</td>
</tr>
<tr>
<td>Bihar</td>
<td>0.04</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>0.04</td>
</tr>
</tbody>
</table>

69.49 or say, 7.00 million hectares

It is apparent that about 2.5 million hectares land is located in the states of Punjab, Haryana and Uttar Pradesh which are mainly sodic (Abrol et al., 1973).

In the state of Haryana, out of total cultivation area of 4.3 million hectares, about 0.5 million hectares is affected by salinity and sodicity. The problem is particularly acute in Karnal, Rohtak, parts of Jind, Hissar and Gurgaon districts (Poonia and Bhumble, 1973).

Bhumble (1975) listed the following main causative factors for the formation of salt affected soils in the arid areas of Gujarat, Rajasthan, Punjab and Haryana as

a) The rise in the water table as a result of canal irrigation;

b) Obstruction of natural drains due to development of roads, canals etc.
a) Siltation of natural drains as a result of erosion.
d) Use of poor quality waters in areas having restricted
drainage.

2.2 Characteristics of salt affected soils

Salt affected soils are characterized by the presence
of excess soluble salts or exchangeable sodium or both, which
restrict plant growth.

2.2.1 Saline soils

The common outward feature of saline soil is the
presence of excessive white, greyish white or ash coloured
fluffy deposits of salt on the surface of land, either in
patches scattered irregularly or otherwise in blocks (Aggarwal
and Gupta, 1968). By definition, the electrical conductivity
of a saturation extract (ECe) of a saline soil is greater than
4 mhos/cm, exchangeable sodium percentage (ESP) is less than
15 and pH is usually less than 8.5 (Richards, 1954).

The salts present in saline soils consist mainly of
neutral salts, such as chlorides and sulphates of sodium, calcium
and magnesium. Sodium seldom comprises more than half of the
soluble cations and, therefore, it is not absorbed to any
significant extent in the soil exchange complex.

Because saline soils are generally flocculated, their
tillage properties and permeability to water are often equal to
or better than those of similar non-saline soils (Allison, 1964).

2.2.2 Sodic soils

Sodic soils contain sufficient exchangeable sodium to
interfere with the growth of most crop plants, but do not contain
appreciable quantities of soluble salts. By definition the ESP
is greater than 15, the ECe is less than 4 mmhos/cm. and pH is usually greater than 8.5 and sometimes as high as 10.

If carbonates are present in detectable amounts in the saturation extract, then the pH must be above 9 (Allison, 1964).

The exchangeable sodium has marked influence on the chemical and physical properties of soils. As the proportion of exchangeable sodium increased, the soil tends to become dispersed less permeable to air and water, and exhibits poor tilth. Sodic soils are usually plastic and sticky when wet and form large clods on drying. Their crusting tendency is a serious hazard to seedling emergence, and it often results in poor stand of crops, causing reduced yield (Allison, 1964). Aggarwal and Gupta (1968) reported that usually a thick and highly cemented bed of big sized kankar is found in the subsoil which is occasionally so much cemented that it appears rock-like and difficult to pierce. Water percolation is almost nil and water stagnation with high turbidity is a common land feature.

Kelley (1933), quoting the works of Gedroiz, Hissink and de sigmoid, points out that exchangeable sodium is the real source of trouble, sodium clays upon leaching gives rise to highly deflocculated condition due to hydrolysis of sodium. Acharya and Abrol (1975) found that an increase in the exchangeable sodium percentage was accompanied by a marked decrease in hydraulic conductivity.

Water flow can be reduced by chemical deflocculation and swelling of soil materials which results in the plugging of the water conducting pores by the dispersed or swollen material (Nakayama, 1966).
2.3 Physico-chemical characteristics of the sodic soils of Indo-gangetic plains

Leather (1893, 1897) undertook extensive investigations of the distribution and composition of salts in soils from various districts of the erstwhile North-Western Provinces (now Uttar Pradesh), Punjab and Bombay Deccan. He observed that the principal salt in near soils of Uttar Pradesh was sodium carbonate, while sodium sulphate was present in insignificant amounts in types which were more saline. Later, Leather (1914) supplemented the above study with observations on the impervious nature of sodic soils, which were found to have percolation rates of 1/10 to 1/100 that of a normal soil.

Kanwar and Bhumblr (1969) examined the soil samples from different horizons of Punjab and Haryana states and reported that the soils contained high amounts of salts with the electrical conductivity of saturation extract of the soils ranging from 4 to 40 mnhos/cm at 25°C and sodium formed the predominant cation. Carbonate and bicarbonate constituted about 50 per cent of the anions. Bhargava et al., (1972) reported that majority of the soils of Karnal district contained carbonates and bicarbonates of sodium as predominant salts. The barren lands showed a gradual decrease in salt content with depth but the cultivated ones normally showed the reverse trend. Sodium continued to be dominant exchangeable cation in the old alluviums and calcium in the recent ones.

Bhumbla (1977) has summarized the following characteristics of the sodic soils of the Indo-gangetic plains:

1) The soils have high pH, usually higher than 9.5 and high exchangeable sodium throughout the profile.

2) High salt content is confined to the upper about 60 cm and the soils invariably contain sodium carbonate and sodium bicarbonate in appreciable amounts.
iii) The soils are highly dispersed and have very low hydraulic conductivity. The upper horizon has a platy structure.

iv) There is usually a layer of clay accumulation in the sub-surface horizon. Many of these soils may contain matric horizon, usually without columnar structure.

v) The soils are usually calcareous and may have a zone of accumulation of calcium carbonate sometimes in amounts large enough to have calcic horizon. The zone of accumulation of calcium carbonate may indicate the zone of fluctuating water table.

vi) The soils also show ferro-manganese concretions interspread above the calcium carbonate layer.

vii) The water-table may be near the surface in the monsoon but recedes to about 4 m. subsequently.

viii) The common vegetation in highly sodic areas is *Sporobolus marginatus* and in low lying areas not having salt incrustation *Diplachna fusca*.

ix) The ground water in these areas has usually low salt content though may have significant proportion of sodium and bicarbonate ions.

2.4 Nutrient status of salt-affected soils

Alkali soils are deficient in nutrients particularly in nitrogen and zinc. Gupta *et al.* (1970) studied four profiles belonging to saline, saline-alkali, alkali and degraded alkali soils of Madhya Pradesh with respect to distribution of available cations viz., K, Ca, Mg, Mn, Cu and Fe. These soils were adequate in K, but deficient in
Ca, Mg and Fe as compared to normal soils. Bhumbla and Shingra (1964) reported that in highly sodic soils the availability of micronutrients like zinc, manganese and iron is very much depressed.

Saline-sodic soils may also contain boron in toxic amounts. However, boron toxicity occurs in limited, scattered areas of arid and semi-arid regions (Richards, 1954).

Warington (1923) was first to establish the essential nature of boron for plant growth. Presence of high amount of boron bearing minerals in soils, manures (Corner and Ferguson, 1920) and irrigation with high boron waters (Saton, 1935; Sastry and Vishwanath, 1946; Mathur et al., 1964) leads to accumulation of boron in soils. High amounts of boron are usually found in soils of arid and semi-arid regions which are invariably saline and sodic in nature (Satyanarayana, 1958; Kanwar, 1961; Mathur et al., 1964), Moghe and Mathur, 1966) whereas acid soils of humid regions are usually deficient in it (Asken et al., 1937). The high content of boron 1.20 to 1.28 ppm in arid zone soils of Western Rajasthan have been reported by Satyanarayana (1958), Mathur et al., (1964) and Moghe and Mathur (1966). Kanwar and Singh (1961) have found saline sodic soils of Punjab to contain much more boron (3.00 to 11.80 ppm) than normal soils (0.18 to 2.44 ppm). The saline-sodic soils of Uttar Pradesh contained 0.82 to 10.05 ppm available boron as compared to 0.10 to 1.55 ppm in normal soils (Singh and Singh, 1967).

Kanwar and Bhumbla (1969) stated that saline and sodic soils of Punjab and Haryana states contain boron in toxic amounts (4.0 - 30.0 ppm) in saturation extract. (Richards, 1954) stated that concentration below 0.7 ppm boron is probably safe for the sensitive crops, 0.7 to 1.5 ppm is marginal and more than
1.5 ppm is unsafe.

Nathani et al. (1969) reported that B levels ranged from 2.1 to 4.46 ppm water soluble B and were critical for sensitive crops. In saline sodic soils, the levels (1.68 to 2.00 ppm) were hazardous for crops.

Gupta and Harish Chandra (1972) found that use of gypsum reduced boron hazard of saline waters and a saline sodic soil. One per cent dose of gypsum for waters and eighty per cent dose of gypsum requirement for saline-sodic soil were found adequate to reduce toxic concentrations of boron to non-toxic levels.

2.5 Principles and methods of reclamation

According to Kelley (1951) for any reclamation technique to be permanent, the following three essential requirements have to be met with:

1) salts or alkali must be completely removed from the root zone;
2) the land must be prevented reverting to the original condition; and
3) the repair of the damage already done to the soil should be substantial.

2.5.1 Saline soils

Salts can be removed by leaching with water which is the chief medium for their transport. Leaching salts to lower layers beyond the root zone of shallow rooted crops can be accomplished by ponding water on the soil surface. The best time for leaching would be when the ground water table is deep or receding. In the Indo-gangetic plains the water table is deepest in June (Bhumbia, 1972).
2.5.2 Sodic soils

When the exchangeable sodium content of soil is high, application of amendments, leaching and management practices are required to improve and maintain favourable soil conditions for plant growth (Richards, 1954). In most cases, reclamation of sodic soils involves replacement of sodium on the exchange complex with calcium and improvement of the physical conditions of the soil. For the reclamation of sodic soil, amendments like gypsum, sulphur, sulphuric acid iron pyrites, iron sulphate, aluminium sulphate, press-mud, farm yard manure etc. are usually recommended. Gypsum has been used extensively for the reclamation of sodic soils because of its low cost and easy availability and recommended by many workers (Singh and Nijhawan, 1932; Yadav and Agarwal, 1961; Singh et al., 1969; Abrol et al., 1973 and Milap Chand et al., 1977).

Kanwar et al., (1965) studied ameliorative effects of gypsum, press-mud, farm yard manure and fertilizers alone and in combination and reported that gypsum improved the soil faster. Davidson and Quirk (1961) reported that the treatment with gypsum leads to a more friable soil surface, increases the rate of water entry, and results in increased yields per plant.

2.6 Gypsum requirement of the crops

The amount of gypsum to be applied and the levels to which exchangeable sodium percentage (ESP) has to be brought down would differ from soil to soil and crops to be grown.

Singh and Nijhawan (1932) recommended the application of gypsum at the rate of about 5 t/ha. Yadav and Agarwal (1961) conducted an experiment in which 7.5 t/ha gypsum was broadcast before sowing to paddy, on half of the plot daunche was also grown for six weeks and ploughed in before paddy was sown.
After a year gypsum treatment had reduced exchangeable Na percentage from 51.9 to 5, the pH from 10.2 to 8.8 and the conductivity of saturation extract from 18.99 to 4.0 mmhos/cm. Kanwar and Chawla (1963), from pot experiments on a sodic soil with graded doses of gypsum reported that application of gypsum in quantities higher than 30 per cent of gypsum requirement is not necessary. Russel and Brooker (1963) reported that the application of 50 t/ha CaSO₄ combined with proper drainage decreased conductivity of the saturation extract from 4.0 to 2 - 3 mmhos/cm, and lowered exchangeable Na from 30 to 10% permitting the establishment of Rye-grass-clover pasture on formerly unfertile soils. They further suggested that even where the heavy soils contain CaSO₄ in the lower horizons, a minimum initial application of 12.5 t/ha CaSO₄ required for reclamation.

Singh et al., (1969) tried the gypsum levels needed to bring Ca saturation to 50, 75, 85 and 100 per cent. The gypsum treatment produced more noticeable effect on barley than on paddy, and upto 50 per cent calcium saturation seems to be adequate. Kanwar and Bhunbla (1969) observed that gypsum application at 22 t/ha corresponding to 50% of G.R. increased the yields of paddy, barley, wheat, sugarbeet, berseem and sudan grass in highly saline sodic soils. Five fodder crops viz. jowar, sudan grass, Dina grass, cowpea and guara were tried at the Central Soil Salinity Research Institute, Karnal during 1970-71 with five graded levels of gypsum (0, 25, 50, 75 and 100% of gypsum requirement) and found that only jowar and sudan grass did well in gypsum applied plots while Dina grass, cowpeas and guara could not grow (Annual report of CSSRI, 1971). No crop could
grow in control plots. Rixon (1970) reported that the application of 6 t/ha CaSO₄ to irrigated grassland on slowly permeable sandy
loam (red-brown earth) increased yield and utilization of N (56 -
44.8 kg/ha), and increased recovery from 45 - 60% on the application
of 224 kg N (broadcast urea). Shumbia and Abrol (1975) reported
that for shallow rooted crops application of gypsum at the rate
of 1/4 of the gypsum requirement was adequate. They further
suggested that unlike fertilizers, gypsum is to be added only
once in the first year.

Kassamussen et al., (1964) reported that the application of
30 - 50 t/ha CaSO₄ greatly increased infiltration rates, but did
not increase the depth of water penetration on slick spot areas.
Scott et al., (1968) reported that the application of gypsum to a
Na clay gave improved flocculation leading to greater water
infiltration and better seedling emergence.

2.7 Crops in relation to soil sodicity

Crops differ markedly in their tolerance to salinity and
sodicity. Pearson (1960) classified the crops according to ESP
tolerance as extremely sensitive (2 - 10), sensitive (10 - 20),
moderately tolerant (20 - 40), tolerant (40 - 60) and most tolerant
(> 60). He classified crested wheatgrass, fairway, wheatgrass,
tall wheatgrass and Rhodes grass as most tolerant crops. Uppal
et al., (1961) prepared a list of crops that can be grown at
various stages of reclamation and can be categorised as high,
medium and low salt tolerant crops. Among the high salt-tolerant
crops are listed: dhaincha (Sesbania aculeata), paddy, sugarcane
in kharif and oats, berseem, lucerne, senji, methi and barley in
rabi. Medium salt tolerant crops which should be tried during
second stage of reclamation are castor, cotton, jowar, bajra
and maize for kharif and mustard and wheat for rabi. Low salt-tolerant species are moong, urd, arhar and sunnhemp in kharif, and gram, peas, linseed and sesame during rabi. As far as possible crops are to be taken in the order given above.

Hayward and Wadleigh (1949) discussed the possible causes that affect plant growth on saline-alkali soil. The effect of soil salinity may manifest itself in two ways: (i) the physical effects of salts in increasing the osmotic pressure of the soil solution thereby decreasing water availability to the plants, and (ii) toxic effect of various ions like Na⁺, Mg²⁺, K⁺, SO₄²⁻, HCO₃⁻ and NO₃⁻. Sodic soils may affect plant growth 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 exchangeable sodium.

Sodium sensitive plants such as almond, citrus and stone fruits, exhibit characteristic leaf burn symptoms when sodium accumulation in leaves becomes excessive (Martin and Bingham, 1954; Jones et al., 1957). They may become injured at ESP levels too low to give unfavourable soil physical conditions. Sodium appears to be directly toxic for these species, since no evidence was detected of calcium deficiency or other nutrient imbalance.

Plants normally tolerant to sodium may be inhibited in their growth primarily by the adverse physical conditions in sodic soils, which restricts moisture transmission and aeration, and may physically impede root elongation and seedling emergence. The sodium tolerant crops that may be primarily affected by
poor structure include beets, Rhodes grass, cotton, tomatoes and other grain crops.

Lucerne and Clover were grown (Bernstein and Pearson, 1956) on 2 soils with different exchange capacities treated with sodium bicarbonate and VAMA (Vinyl acetate maleic acid copolymer) to establish 5 levels of exchangeable sodium. The resultant decrease in dry weight yields was related to the exchangeable sodium percentage (ESP) rather than absolute level of exchangeable sodium. Increasing ESP increased sodium and decreased Ca accumulation in the tops, in tolerant plants. It is suggested that in sensitive plants e.g. beans, excessive sodium accumulation by roots may affect root function, particularly water absorption. For the five crops studied (Bains and Fireman, 1964) exchangeable sodium generally caused an increase in the absorption of sodium, nitrogen and molybdenum and a decrease in the absorption of calcium, potassium, sulphur, manganese, copper, zinc and chlorine.

Agarwal et al., (1964) found that with an increase in the ESP of the soils, there was marked increase in the tissue concentration of sodium, phosphorus and manganese in both barley and paddy crops and decrease in the calcium. Agarwal et al., (1964) studied relationship of ESP to macro and micro-nutrient element composition of paddy grown in Uttar Pradesh and reported a positive correlation between ESP of the soil and water soluble and exchangeable Na and negative one between ESP and water soluble P, ESP and water soluble and exchangeable Ca and Mg, ammonium acetate extractable Fe, Mn, Perchloric acid digestible Zn and soil
nitrogen. The plants grown in high ESP soil showed a poor growth and contained high tissue concentration of Na, Mg, Fe and B, and low amounts of K, Ca, P, N, Mn and Cu. Abrol (1968) found increased dry matter and N content of wheat plants grown on sodic sand resin mixtures with medium P and high N fertilization. Andraesi et al., reported that K contents were different in the three grasses and were higher in the wet season than in the dry season. White (1971) conducted a study of Ca, Mg, K and Na contents in blue gram, buffalo grass, western wheat grass and bromegrass and concluded that the amount of N cycled to the soil surface by these three grasses was insufficient to retard sodication of a Solonetz soil. Na, Ca and Mg contents in the plant tops were the same as roots, while tops contained more K than the roots. The ratio of Ca : Mg in the plants was less than the ratio of exchangeable Ca : exchangeable Mg in the soil. Poonia et al., (1972) reported that increasing levels of Na saturation in the substrate have a definite depressive effect on the uptake of applied as well as native Ca by the plant. The Ca content in the plant positively and Na negatively related with the yield of crop. Mehrotra and Das (1973) grew wheat, barley, oats, peas, gram, lentil and rainy season (Kharif) crops like cotton, jowar, maize, paddy on soils artificially alkalinized to varying levels of exchangeable sodium ranging from 2 to 99 per cent. The plants were analysed after one and two months and stage of maturity for cationic composition. It was observed that the total cationic uptake and absorption of sodium increased with
rise in the levels of ESP, whereas the uptake of calcium, magnesium and potassium generally exhibited a reverse trend. Values of the individual as well as the total cationic absorption, in general decreased with the progress of plant growth beyond one month stage. Inter-relationship between different cations indicate that the ratios of Ca/K, and Na/K increased whereas that of Ca/K decreased with the rise in the levels of ESP. Poonia and Bhumbla (1973) reported that total removal of Ca, Mg, K, N and P and Ca from added CaCO₃ decreased significantly in both spinach and maize crops in response to ESP. The decrease in dry matter appeared to be related to decrease in Ca and increase in Na content in plant. Bhumbla and Poonia (1973) found that with an increase in the level of exchangeable Na, there was a gradual decrease in the dry matter of barley. The Ca content of barley decreased gradually in response to ESP in both gypsum and CaCO₃ treatments. An increase in the exchangeable sodium considerably increased the Na content of barley. The total uptake of Ca, Mg, K and N/Pot decreased gradually in both the treatments in response to ESP.

The toxicity symptoms of boron are characterized by burning of edges of leaves with chlorosis near the marginal areas (Moghe et al., 1966). Gandhi and Mehta (1958) reported the boron content of grasses varied from 10 to 20 ppm in normal soils. According to these workers, paddy contained 18 - 26, jowar 50, and oats 80 ppm B. In pot experiments, toxic levels of boron in soil were 2 - 4.3 ppm and in plant tissue 214 - 443, 218.33 - 416.66 for groundnut, symptoms were tip burn in gram and marginal necrosis in groundnut (Tripathi and Singh, 1968). Gupta and Macleod (1973) grew Timothy under green house
conditions at six levels of soil B and four pH values. B toxicity symptoms appeared on the leaves with application of 4 mg B/kg soil. Tissue B concentrations of > 102 ppm were associated with B toxicity symptoms and decreased yields. Liming decreased the boron concentration of leaf tissue particularly at higher rates of B.

2.8 Relative performance of grasses

2.8.1 Normal soil

Distribution, agronomic practices, utility and the chemical composition of the different grass species taken in the present investigation, is reviewed below.

**Hybrid Napier (Pennisetum purpureum x Pennisetum typhoides)**

Napier grass is native of tropical Africa. It is grown under warm and humid conditions of Transwal, Uganda, America (Florida and Southern states), Australia, Hawaii, India and to some extent in tropics and subtropics throughout the world. The crop was introduced into India and is now grown in Assam, Bengal, Bihar, Orissa, U.P., Delhi, Haryana, Punjab, Madhya Pradesh, Tamil Nadu, Karnataka, Gujarat and Maharashtra. In north India, it remains dormant in the cold months from December to February. Frost is detrimental. Napier grass is a robust perennial grass. In 1953, a cross was made between napier grass (Pennisetum purpureum) and bajra (Pennisetum typhoides) which is more succulent, leafy, fine textured, palatable, quick growing and drought resistant. This cross proved to be successful and became popular as Vishal Hathi Ghas.

Recently evolved hybrid NB 21 is higher yielding, more nutritious and quicker growing as compared to popular hybrids like B.B. 4 and Pusa Giant Napier. This hybrid is also claimed to be cold tolerant. NB 21 has additional qualities of having
high tillering, thin stemmed, large narrow leaves, non-hairy with better regeneration and low mortality and less frost damage. The hybrid is superior in quality and has high protein and calcium but low in oxalic acid content (Gupta and Sindhu, 1970).

The hybrid can be planted either by rooted slip or stem cutting. Where irrigation facilities are available, it can be planted from February to August. Under rainfed conditions, planting should be done with the break of monsoon. In the south and east India, planting can be done any time of the year. In the pre-monsoon period, rooted slips should invariably be preferred and in the post-monsoon stem cuttings can also be planted with equally good results.

First cut is ready after 75 days to 90 days and subsequent cuts can be taken after every 45 days. A stubble height of 10 - 15 cm from the ground level should be left out to avoid damage to the growing buds. In the north, five cuts can be taken till the end of November whereas in the south seven to eight cuts can be taken due to mild cold weather.

On an average about 30 to 35 tonnes of green stuff per hectare can be taken from each cut. About 120 - 150 t/ha yield can be obtained in 4 - 5 cuts in north India and 200 - 250 t/ha in 8 cuts in south India.

Chemical Composition

Des Raj and Mudgal (1968) found the per cent chemical composition of hybrid napier at different stages of growth on
dry matter basis as follows:

<table>
<thead>
<tr>
<th>Constituents</th>
<th>60 cm</th>
<th>120-135 cm</th>
<th>180 cm</th>
<th>Flowering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>17.44</td>
<td>18.04</td>
<td>23.50</td>
<td>35.60</td>
</tr>
<tr>
<td>Organic matter</td>
<td>82.28</td>
<td>82.45</td>
<td>84.50</td>
<td>85.02</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>17.35</td>
<td>21.38</td>
<td>29.09</td>
<td>36.13</td>
</tr>
<tr>
<td>Nitrogen-free extract</td>
<td>52.88</td>
<td>51.55</td>
<td>48.41</td>
<td>44.09</td>
</tr>
<tr>
<td>Crude protein</td>
<td>8.72</td>
<td>7.10</td>
<td>4.78</td>
<td>3.37</td>
</tr>
<tr>
<td>Ether extract</td>
<td>3.33</td>
<td>2.42</td>
<td>2.29</td>
<td>1.43</td>
</tr>
<tr>
<td>Total ash</td>
<td>17.72</td>
<td>17.55</td>
<td>15.50</td>
<td>14.98</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.75</td>
<td>0.55</td>
<td>0.49</td>
<td>0.31</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.68</td>
<td>0.46</td>
<td>0.31</td>
<td>0.20</td>
</tr>
<tr>
<td>Total Oxalic acid</td>
<td>3.44</td>
<td>3.31</td>
<td>1.70</td>
<td>1.63</td>
</tr>
</tbody>
</table>

Para grass (*Brachiaria mutica* (Forsk))

Originally a native of the tropics of Africa and south America, it is now distributed as a fodder crop in India, east Pakistan, Ceylon, Burma, south east Asia, far-east and southern and central United States (Judd 1975, Relwani 1971).

Para grass is adaptable to cultivation in many parts of the country and has gained considerable popularity with dairy farmers. The grass is extensively grown in Maharashtra, Tamil Nadu, Karnataka, Kerala, Assam, Bihar and Manipur states (Thomas, 1967).

The grass grows best on moist soils and withstands prolonged water flooding or water-logging, but makes little growth during dry weather (Thomas, 1967; Judd, 1975).
Judd (1975) reported that para grass can be used for green soilage, hay or pasture and should be grazed rotationally as it will not withstand heavy continuous use.

It can be propagated by rooted setts or stem cuttings with at least two or three joints or nodes, allowing one node above ground. Where available, seeds should be used to establish para grass as it is by far the easiest method of obtaining a stand (Cameron and Kelley, 1970). In the north India, it can be planted from mid February to end August and in the eastern, western and southern regions all the year round except January (Kalwani, 1971).

The first cut is generally available after 90 days of planting and subsequent cuts after every 30 - 45 days. In the early stages the grass has prostrate habit of growth and later on it grows erect. In the north India, only 4 - 5 cuttings can be obtained in a year. In the humid areas of south, east and west about 10 cuttings can be taken easily. Each cut on an average gives about 15 t/ha of green yield. Thus a total yield of about 75 t/ha can be obtained per year under average fertility and environmental conditions. With more favourable conditions yields up to 200 - 250 t/ha can be obtained with cattle shed washings, and city sewage under sedimentation and dilution (Kalwani, 1971).

Among the non-legumes, para grass stands as high as a palatable and nutritious fodder (Thomas, 1967).
I & digestible nutrient per 100 lb. on dry matter basis | Digestible nutrient per 100 lb. on green basis
---|---
| D.C.P. | T.D.N. | D.C.P. | T.D.N. |
Para grass | 8.11 | 59.54 | 1.65 | 11.40 |
Guinea grass | 5.83 | 65.09 | 1.46 | 16.36 |
Elephant grass | 3.85 | 55.39 | 0.46 | 13.86 |
Sudan grass | 1.57 | 44.41 | 0.39 | 11.14 |

Sen and Ray (1971) reported the chemical composition of para grass on dry matter basis as crude protein - 11.98%, crude fibre - 28.22%, nitrogen free extract - 45.70%, ether extract - 2.89%, total ash - 11.21% and calcium - 0.36%.

*Setaria grass (Setaria sphacelata)*

The grass is grown in the tropical and subtropical areas of east, south and central Africa, New South Wales and parts of Queensland (Australia), Taiwan, New Guinea, Phillipines, Israel, Brazil and India.

It prefers warm and humid conditions with rainfall higher than 750 mm. It can tolerate short spells of drought and heat but suffers a severe setback when prolonged hot and dry weather persists. The crop remains on the land for 3-4 years.

The seeds can be sown directly in the field by drilling or broadcasting. Planting can also be done by rooted slips.

The grass becomes ready for first cut in about 90 days. Afterwards cut can be taken every 40 - 50 days. In all, about 7 - 8 cuts can be taken in a year in the south and 4 - 5 cuts in the north. At each cut a stubble height of about 12 - 15 cm should be left for better regeneration (Selwani, 1971).
About 15 - 20 t/ha of green grass can be harvested in every cut and an annual yield of 125 t/ha in the south and about 75 t/ha in the north, could be obtained.

*Guinea grass (Panicum maximum Jacq.)*

The grass is a native of tropical and subtropical Africa, now found growing in the more humid tropics and subtropics throughout the world. This grass is shade tolerant and grows well under trees (Judd, 1974). It is most suited to southern and eastern regions of India.

Bor (1973) reported it one of the best fodder grasses which is eaten greedily by cattle. Judd (1974) reported that this grass is valuable for grazing, green soiling, hay and silage.

The grass can be propagated by rooted slips or stem cuttings. However, during the summer season rooted slips should essentially be used for easy establishment.

The first cut is generally ready after 75 - 90 days. Subsequently, cuts can be taken at the interval of 45 - 60 days. It also has the highest proportion of leaves and maximum calcium of the grasses tested. Nutritive value is high when leafy and young (13% crude protein), but this falls down rapidly with increasing maturity. A 15 - 22 cm stubble of growth should always be left on pasture (Judd, 1974).

It provides, on an average about 15 t/ha of grass per cut. Thus under rainfed conditions about 75 t/ha of green fodder can be obtained in about 5 cuts. Total yields of 200 to 250 t/ha can be obtained in southern and eastern India in about 10 cuts.

Sen and Fay (1971) has reported the chemical composition of guinea grass as crude protein - 5.22%, crude fibre - 36.38%,
ether extract = 1.55%, nitrogen free extract = 44.70%, total
ash = 12.15%, calcium = 1.81% and phosphorus = 0.26%.

Anjan grass (*Cenchrus ciliaris* Linn)

The grass grows in the natural pastures and rangelands
of the arid and semi-arid regions of the world and predominates
in Tanganyika, Nairobi, Uganda, Ghana, northern Rhodesia, Morrocco,
Senegal, Libya, U.A.R. (Africa), Queensland and South Wales
(Australia), Iran, Afghanistan, west Pakistan, southern Arabia,
India, Indonesia and to some extent in U.S.A. In India, it is
grown in the states of Punjab, Haryana, Uttar Pradesh, Rajasthan,
western Madhya Pradesh, Gujarat, Maharashtra and Tamil Nadu.

This grass is usually concentrated in the hot and dry
tracts with an annual rainfall from 250 to 750 mm. It can withstand
temperature up to 46 - 48°C. The grass can be established either by
direct sowing of seeds or by transplanting the rooted slips.

The grass should not be cut at early stages as it adversely
affects the root and shoots growth. Sometimes only one cut is
taken during the first year. Similarly grazing should not be
allowed during the first year and lightly done in the second year.
Rotational grazing should be done from third year onwards. The
grass generally gives about 15 t/ha green fodder per year.

Sen and Ray (1971) have given the per cent chemical
composition of anjan grass as crude protein - 5.73, crude fibre -
36.69, and nitrogen free extract - 44.25%.

Bermuda grass (*Cynodon dactylon* (L) Pers.)

Bermuda grass is found throughout the tropical and
subtropical parts of world and extends into temperate zones
as well (Sor, 1973 and Judd, 1975). In the tropics it is most
common in the areas from 625 - 1750 mm of rainfall and is adapted to a wide range of soils from sandy to heavy clay. This is the most important pasture grass in the south-eastern parts of the United States. It is considered the most important pasture grass in India and is used for permanent pastures in Rhodesia (Judd, 1975). Harlan (1970) reported that *Cynodon dactylon* is important in controlling erosion and as a turfgrass, but is almost never cut for hay. Hoveland (1960), Alexander *et al.*, (1961); Elder and Murphy (1961) appraised bermuda as a forage to be a grass with a high production potential per unit area and a modest to low production potential for grazing animals. Elder and Murphy (1961) and Burton *et al.*, (1969) reported that bermuda grass is adequate in protein content which ranges between 12 and 18%. Judd (1975) indicated that this is a troublesome weed of arable land and unsuitable for rotation pastures, as it is most difficult to eradicate. Valuable for permanent pastures, very resistant to grazing and trampling.

It is warm-season grass with little growth during cold weather and quickly damaged by frost, but sprouts again in spring from dormant buds on underground rhizomes. The grass withstands long periods of drought, but produces little growth during dry weather and is relatively unproductive on poor dry soils. It is somewhat alkali tolerant and is often used to reclaim alkali soils in the south-west (Judd, 1975). Ackerson and Youngner (1975) and Mass and Hoffman (1977) reported that bermuda grass (*Cynodon spp.*) is salt tolerant grass, valuable for forage and turf.

Bermuda is essentially a pasture grass but can also be taken as soilage. In north India the grass remains dormant after
November and hence available after the pre-monsoon showers in the middle of June up to middle of November. Clipping after 45 - 55 days can thus provide about three cuts. If two irrigations can be provided by early May and June, five clippings can be taken during the season.

In south India where the temperatures remain much above the freezing point throughout the year, 6 - 7 cuttings can be taken.

About 8 - 10 tonnes of green grass can be obtained per cut. Higher yields are produced during the rainy season and the lowest in the hot and dry months of May - June. On an average about 30 - 40 t/ha of green grass can be obtained in north India in one year as against 60 - 70 t/ha in the south India.

Sen and Ray (1971) reported the following per cent chemical composition of bermuda grass at different stages of growth:

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Young</th>
<th>Prime</th>
<th>Hype</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>21.94</td>
<td>10.94</td>
<td>4.90</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>18.63</td>
<td>31.89</td>
<td>39.74</td>
</tr>
<tr>
<td>Nitrogen free-extract</td>
<td>44.14</td>
<td>44.00</td>
<td>46.07</td>
</tr>
<tr>
<td>Ether extract</td>
<td>2.71</td>
<td>1.42</td>
<td>1.21</td>
</tr>
<tr>
<td>Total ash</td>
<td>12.58</td>
<td>12.05</td>
<td>8.08</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.58</td>
<td>0.58</td>
<td>0.36</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.36</td>
<td>0.28</td>
<td>0.10</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.27</td>
<td>0.25</td>
<td>0.12</td>
</tr>
<tr>
<td>Sodium</td>
<td>0.11</td>
<td>0.21</td>
<td>0.13</td>
</tr>
<tr>
<td>Potassium</td>
<td>1.96</td>
<td>1.04</td>
<td>0.70</td>
</tr>
</tbody>
</table>
2.8.2 Saline-Sodic Soil

The knowledge on the tolerance of forage crops and grasses to saline sodic conditions is very meagre. Forage plants, grasses and legumes as a rule exhibit the highest degree of salt tolerance on saline lands (Harris, 1920; Kearney and Schofield, 1936; Magistad and Christiansen, 1944) but there are marked differences in this regard. The grasses are more resistant than the legumes, outstanding species being alkali sacaton (Sporobolus airoides), salt grass (Distichlis spicata), nuttal alkali grass (Puccinellia nuttalliana), bermuda grass (Cynodon dactylon), rhodes grass (Chloris gayana) (Havward and Wadleigh, 1949).

Duthie (1896) reports on usar reserves in Ghizerat and Gursikran of Aligarh district that the grass called as bat (Diplachne fusca) was observed to be more useful than usar grass (Sporobolus paddicus) on the low lying regions, where water was able to accumulate for any length of time. The former grass was nutritious and was much liked by buffaloes. Other grasses suited to the area are dub, Janewar (Andropogon annulatus), Anjan (Cenchrus pennisetiformis), gandir or musel (Anthistiria prostrata) etc. Reheja et al. (1962) classified the grasses according to salt-tolerance capacity as follows:

1. High salt tolerance: Sporobolus Son., Chloris gayana (Rhodes grass), Cynodon dactylon (bermuda or dub grass) and Paspalum notatum.
2. Medium salt tolerance: Brachiaria mutica (Para grass) and Cynodon plectostachya (giant star).
3. Low salt tolerance: Panicum antidotale (blue panic), Cenchrus ciliaris, Cenchrus setigerus and Dicanthium annulatum.

Rage and Tamhane (1964) reported the areas that cannot be economically reclaimed could be used for grasses, bushes and
trees and a list of salt tolerant plants has been given. Highly tolerant grasses are (*Chloris gayana*), *Cynodon dactylon* (bermuda), *Paspalum notatum*, *Sporobolus arboecus*, *Sporobolus pallidus* and trees are *Acacia arabica*, *Acacia spirocarpa*, *Cassia articuleata*, *Dalbergia sissoo*, *Horus alba*, *Prosopis juliflora*, *Salvadora persica* and *Tamarix articulata*. Pande (1966) stated that prolonged fencing resulted in good growth of grass cover and brought about some improvement of the soil at Makhdoompur near Lucknow.

Gausman and Barton (1954) tested the tolerance of five grasses (*Rhodes grass* (*Chloris gayana*), blue panicum (*Panicum antidotata*), coastal bermuda grass (*Cynodon dactylon*), angleton (*Andropogon nodosus*) and buffel (*Pennisetum ciliare*) to the application of irrigation water salinized with different quantities of CaCl₂ or NaCl₂. The tolerance of the grasses to artificial salinization in decreasing order was rhodes, coastal bermuda, blue panic, buffel and Angleton. Lunt et al., (1964) studied the growth of *Puccinellia distans*, seaside bent grass, *Alta fescue*, kentucky blue grass and bermuda grass as influenced by exchangeable sodium percentage in soil using both untreated and VAMA treated soils. *Puccinellia distans* and seaside bent grass exhibited good tolerance and only moderate reduction in growth was found at ESP values to 26 to 28. The other grasses were reduced in growth by about one third one half in this range that showed only slight reduction in growth at ESP values of 11 or 12. Thorne and Benett (1952) list bermuda grass (*Cynodon dactylon nera*) as tolerant. Gausman et al., (1954) observed yield reduction of about 50% in bermuda grass at an Eoe of 9 mmhos/cm. Kelley (1937)
as quoted by Agarwal and Gupta (1968) reported that the
growth of bermuda grass reduced exchangeable Na and
increased exchangeable Ca and Mg. Mohindra (1973) tried
a number of exotic and indigenous grasses and legumes viz.
para grass, Pusa Giant Napier, Dicanthium annulatum, Pennisetum
orientale, Rhodes grass, para grass, berseem, senji and lucerne
etc. on saline-sodic soil having pH between 9.45 and 10.45
and EC in the range of 0.32 and 1.65 mmhos/cm. Rhodes grass
and para grass established successfully.

Recently Maas and Hoffman (1977) reviewed extensive
literature on salinity tolerance of the grasses and classified
the crops into sensitive, moderately sensitive, moderately
tolerant and tolerant. The mechanism by which the crop yield
is reduced in the saline soils, is entirely different than
that of the sodic soils. It is apparent from the literature
cited that no serious efforts have been made to study the
tolerance of crops in relation to soil sodicity of the
forage crops and grasses, in particular.