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Floristic characterisation of alkali soils in northwestern India

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Summary Floristic composition studied in a 40 hectares representative site of alkali soils in the Indo-gangetic plains of Northwestern India revealed a remarkably restricted spectrum of natural vegetation. Soil analysis of specific niches, occupied by aggregations of different species, was employed to identify alkali halophytes. Response functions of eight prominent species to increasing levels of soil alkalinity, studied in pot culture, showed that most of them were adapted to alkali soils. Based on the computed importance value indices and observed biomass production maxima, it has been inferred that *Sporobolus marginatus*, *Sporobulus coromandelianus*, *Diplachne fusca* and *Chloris barbata*, qualify as plant indicators of high-alkali soil conditions.

Introduction

Alkali soil conditions, characterised by the presence of free sodium carbonate and bicarbonate, affect nearly three million hectares of potentially agricultural land in India. Alkali soils[3,10], distinctly different from neutral saline soils that contain excessive amounts of chlorides and sulphates, are distinguished from the latter by high pH (often reaching values of over ten), an exchangeable sodium that usually exceeds 30 percent of the soil's cation exchange capacity, precipitated calcium carbonate forming a thick nodular layer about a metre below surface, severe zinc and calcium plant nutritional deficiencies, surface crusting, low hydraulic conductivity and poor physical properties. Utilization of these deteriorated land resources presents a challenging problem in India and several other developing countries in the context of increasing demands for agricultural production[16].

Since reclamation technology and management practices for alkali and neutral saline soils are different, a precise diagnosis of the soil problem is essential. Plants are the best integrators of changes in soil status and, hence, they provide a reliable aid to defining soil problems[6,11]. One of the earliest quantitative studies of plant communities as biological indicators of alkali soils was made in the Tooele Valley in the USA[9]. Although study of grass cover in India has attracted some attention in the past[4,17] yet there is little systematic information on the native vegetation of alkali soils. The present investigation was, therefore, undertaken primarily to identify plant species indicative of alkali soil conditions and to point out as yet unexploited plant materials for direct utilization of salt-affected wastelands for agro-forestry purposes.

Methods

A study was conducted on a 40-hectares plot of virgin salt-affected land earmarked as a common grazing facility at a location that represents sub-tropical and semi-arid climatic conditions with an average annual precipitation of 700 mm, mostly monsoonal rainfall, and mean annual maximum and minimum temperatures of 32°C and 19°C respectively. Soil samples were taken periodically at depths of 0–15, 15–30, 30–60 and 60–100 cm at seven study spots. These were prepared into soil-water extracts (1:2) and analysed for pH, electrical conductivity and exchangeable sodium following methods described by Richards[13] and Darab[5]. Soil chemical analysis was done by

Table 1. Importance value indices and niche-soil characteristics of eight species growing naturally in alkali soil (based on 14 samples)

Species	IVI*	Niche-soil characteristics		
		pH_2	ECe dSm^{-1}	Situation
Chloris barbata	38.3 ± 2.3	10.0 ± 0.2	14.1 ± 1.3	Flat land
Cynodon dactylon	14.8 ± 1.0	9.1 ± 0.1	4.7 ± 0.3	Raised portions
Desmostachya bipinnata	58.1 ± 2.9	9.2 ± 0.1	5.4 ± 0.5	Raised portions
Diplachne fusca	77.4 ± 5.6	9.8 ± 0.1	10.3 ± 1.1	Low lying land
Kochia indica	26.7 ± 1.5	9.4 ± 0.1	6.5 ± 0.5	Flat land
Salsola baryosma	17.2 ± 1.3	9.5 ± 0.2	15.2 ± 2.1	Flat land
Sporobolus marginatus	191.4 ± 7.2	10.2 ± 0.2	8.1 ± 0.9	Raised portions
Sporobolus coromandelianus	39.6 ± 4.5	10.4 ± 0.2	14.6 ± 1.3	Flat land

* IVI = Importance Value Index.

procedures described by Jackson[7]. Soil analysis of specific niches, occupied by aggregations of different species, was also carried out to find out adaptive preferences. Floristic composition of naturally growing vegetation was studied employing quadrat method. Data so obtained were used for computation of importance value index (IVI = relative frequency + relative density + relative dominance) and other comparative attributes as discussed by Greig-Smith[7] and Shimwell[4]. Growth response of eight species to soil alkalinity was quantified under simulated conditions by growing them in pot culture. This experiment was conducted with five replications using four grades of alkali soils, prepared by the method adopted by Bains and Fireman[1], and also a normal soil control.

Results

Site characterization

The soil was loamy and highly dispersed with top layer (0–15 cm) pH_2 ranging from 9.1 to 10.6 and ECe varying from 6.3 to 16.1 dS m^{-1}. Cation exchange capacity (CEC) was low (mean value 8.2 meq/100 g soil) but exchangeable sodium was very high reaching over 90% of CEC. Carbonates and bicarbonates of sodium were the predominant salts, concentrated mainly in the upper 30 cm depth.

Floristic composition

Grass cover occurred mostly in open patches, 58.6% area being completely devoid of vegetation. Besides a few trees of *Acacia nilotica*, there were some scattered shrubs of *Capparis aphylla*, *Zizyphus nummularia* and *Calotropis procera*. Halophilous species included *Chloris barbata*, *Kochia indica* and *Salsola baryosma*. Grasses comprised mainly of *Sporobolus* species, *Diplachne fusca*, *Desmostachya bipinnata* and *Cynodon dactylon*. Seven study spots measuring 15 m × 10 m each were surveyed for floristic analysis in February, May, September and November, recording frequency, density, abundance, basal area and importance value index. Twenty five quadrats of 50 cm × 50 cm were laid at random in each of the seven study spots. Data on the importance value index of some prominent herbs are presented in Table 1.

The two species of Sporobulus along with *Diplachne fusca* were found to occoupy 61.8% of vegetation cover while halophilous species of Chloris, Kochia and Salsola counted for 20.3%. *Desmostachya bipinnata* and *Cynodon dactylon* together occurred on 16.5% area while the remaining 0.4% was ascribed to the sporadic presence of a few other species of minor importance. *Sporobulus marginatus* was the dominant species, though *Diplachne fusca*, *Sporobolus coromandelianus* and *Desmostachya bipinnata* were also prominent at some places. *S. marginatus* is a highly palatable and nutritive grass with substantial potential for grazing if managed and protected properly. *Diplachne fusca* is another promising forage grass, particularly during tender stages.

Table 2. Growth response of eight species to four grades of alkali soils. Biomass production (relative to corresponding control, values averaged over five replications)

Species	Soil pH_2				LSD $P = 0.05$
	8.5	9.1	9.8	10.4	
Chloris barbata	118.1	163.7	120.5	68.4	5.4
Cynodon dactylon	56.4	21.3	0	0	6.8
Desmostachya bipinnata	112.3	79.5	32.3	6.2	4.2
Diplachne fusca	106.6	118.9	154.5	121.9	4.3
Kochia indica	116.2	144.1	119.2	43.2	5.2
Salsola baryosma	114.5	145.3	120.4	49.7	6.7
Sporobolus marginatus	108.5	139.8	146.7	101.5	4.1
Sporobolus coromandelianus	106.9	132.3	189.9	128.3	3.7
LSD ($P = 0.05$)	2.7	3.8	5.1	6.2	

Niche-soil characteristics

Most of the dominant and co-dominant species were found to occur in aggregations of nearly pure stands indicating that they had inherent adaptation to specific soil conditions within the range of alkali soils. To check on this inference, soil samples were taken from representative niches of different species and analysed for soil characteristics. The data in Table 2 show that *Sporobulus coromandelianus*, *S. marginatus*, *Chloris barbata* and *Diplachne fusca* are adapted to severely degraded and highly alkali soil conditions. Out of these *Diplachne fusca* appeared to prefer low-lying places prone to water stagnation. *Sporobolus marginatus*, on the other hand, occurred invariably on raised portions where salts, accumulated on the surface through capillary action, were frequently washed away by rainwater. Whereas *S. coromandelianus* seemed to thrive under soil conditions of high pH and considerable salt concentration, *Chloris barbata* appeared more frequently where surface soil had been disturbed such as in footpaths and cart trails.

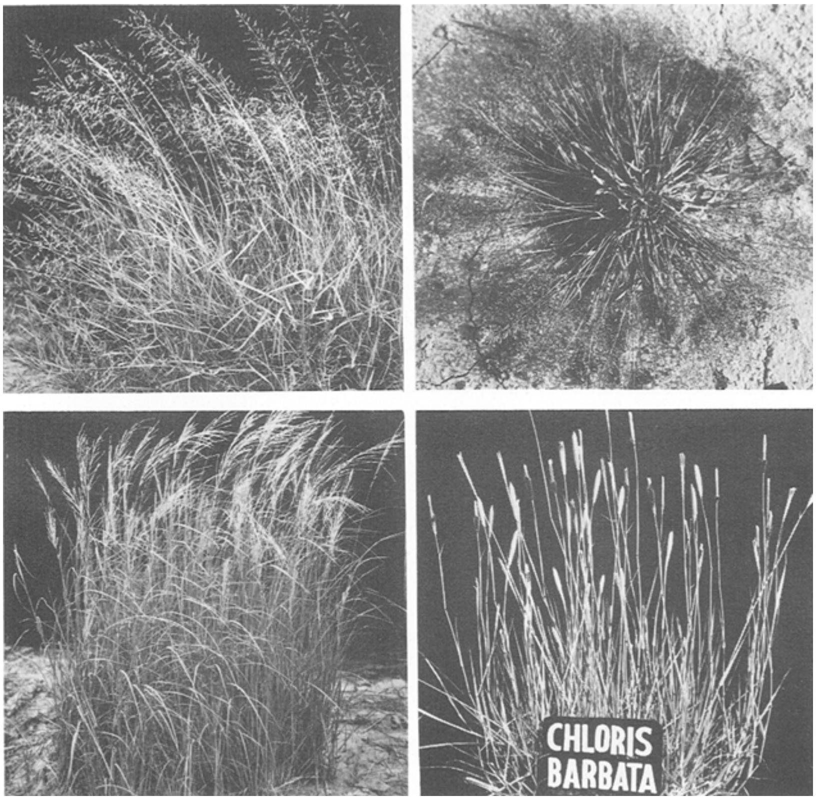
Growth response to soil alkalinity

Data on the growth of different species at various levels of alkalinity in pots, presented in Table 2, supported the inferences drawn on the basis of niche-soil analysis. At the highest pH level (10.4), performance of both species of Sporobulus, *Diplachne fusca* and *Chloris barbata* was superior to that of the rest. *Cynodon dactylon* was least tolerant followed by *Desmostachya bipinnata*. Biomass production maxima were found to be pH 9.8 for *Sporobolus* as well as *Diplachne* species and pH 9.1 for *Chloris*, *Kochia* and *Salsola* species. *Desmostachya bipinnata* showed a positive response to slightly alkali soil conditions but *Cynodon dactylon* seemed to be adapted to non-alkali soil conditions.

Discussion

Results of the present study show that native vegetation of highly degraded alkali soils of Northwestern India is characterised by a restricted spectrum with a few species dominating the floristic composition. Furthermore, the plant cover in these soils occurs in distinct patches because the species seem to be so highly adapted to specific soil conditions that they form nearly pure stands. Topographical microreliefs and changes in the soil status, whether deteriorating or ameliorating, lead to shifts in vegetation pattern. Thus, plant-soil climatic factors together form a dynamic and integrated system under edaphic stress conditions.

Computation of importance value indices of various species, niche-soil analysis and data on growth response to different levels of soil alkalinity have shown specific adaptation to severe alkali soil conditions of *Sporobolus marginatus* (Fig. 1), *S. coromandelianus* (Fig. 2), *Diplachne fusca* (Fig. 3) and *Chloris barbata* (Fig. 4) inferring that these species could be reliably used as indicators of such soils.



Plant indicators of alkali soil conditions

Fig. 1. *Sporobolus marginatus* Hochst. (top, left)

Fig. 2. *Sporobolus coromandelianus* (Retz.) Kunth. (top, right)

Fig. 3. *Diplachne fusca* (Linn.) Beauv. (bottom, left)

Fig. 4. *Chloris barbata* Sw. (bottom, right)

It will, however, be more realistic to judge soil status on the basis of plant cover as a whole rather than on mere presence or absence of individual species. Distribution and frequency of dominant and codominant species need to be given major weightage since they alone receive the full impact of the habitat conditions[2,6]. Associated less tolerant species, such as *Cynodon dactylon* in the present study, are able to survive and grow under somewhat favourable conditions perhaps brought out by the more tolerant pioneer species that establish themselves under hostile conditions[2,6]. Associated less tolerant species, such as *Cynodon dactylon* in the present study, are able to survive and grow under somewhat favourable conditions perhaps brought out by the more tolerant pioneer species that establish themselves under hostile conditions. Abundance of *Desmostachya bipinnata* appears to signify the transitional stage when soil conditions take a decisive turn towards deterioration or amelioration. The halophilous species of Kochia and Salsola indicate saline-alkali soil conditions. Their importance value indices, however, remain low as compared to those of alkali-loving species.

Among the indicator key species of alkali soils identified by this study, *Diplachne fusca* deserves special consideration since it occurs in lowlying alkali lands only and disappears gradually when alkali soils get reclaimed[12,15]. This grass never occurs as a weed in non-alkali soils. It thus provides a visible measure of the progress of soil reclamation processes.

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