Biosaline Agriculture and Salinity Tolerance in Plants
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Growth performance and nutritional value of salt tolerant plants growing under saline environments

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Socio-economic effects of salinity

Salinity is a serious problem of agriculture worldwide, particularly in arid and semi-arid regions. Most of Pakistan is arid to semi-arid with low annual precipitation and 6.3 million hectares (mha) land is affected to varying degree of salinity [1]. As a result of this, heavy losses in crop yields and plant productivity have been recorded [2]. Lands with high salinity are not cultivated and are changing into wasteland, and farmers owning these lands are migrating towards cities or towns as a result of which population load on cities is increasing day by day and deficiencies in food, feed, fodder and industrial materials are being faced. So, there is an urgent need to utilize these lands for plant production [3].

Halophytes as livestock fodder

Halophytes having economic values can be grown on salt-affected wastelands, which may bring socio-economic gains. It was observed that farmers as well as livestock of salt-affected areas face great scarcity of food, fodder and feed. The farmers of these areas often arrange fodders for their livestock from other areas at very high costs. However, if these areas are utilized for developing pastures or rangelands with salt tolerant forage plants, good economic returns can be achieved. In Pakistan, Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan, started work in the 1970s to identify the salt tolerant plants with economic values so that they may be utilized as food, fodder and industrial raw materials. Dozens of salt tolerant plants with economical value have been identified and introduced at two biosaline research stations. Some of these can be utilized as fodder; however, farmers are reluctant to use them as fodder due to their high salt content. It is necessary to have complete knowledge about the nutritive values of these plants, so that they can be recommended to the farmers for using them as fodder for their livestock.

The studies have been conducted at NIAB, Faisalabad, Pakistan, with the aim to work out the forage values and their chemical composition. On the basis of their utility as forage, these can be recommended for the livestock in saline areas and thereby salt-affected wastelands can be utilized for better economic returns. So, the present study was conducted with five halophyte forage plants, two were grasses and the other three were shrubs, i.e., *Leptochloa fusca*, *Sporobolus arabicus*, *Suaeda fruticosa*, *Kochia indica* and *Atriplex lentiformis*, respectively.

Cultivation of halophyte grasses, bushes and their chemical analysis

Studies were conducted at the Biosaline Research Station-II (BSRS-II) of Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan, situated 40 km from Faisalabad, Pakistan. The salt concentration in ground water is 4,000–6,000 ppm and the water table varies from 2.1–3.0 m, while soil salinity ranges from 12–27 dS m^{-1}. The other characteristics of soil and water are summarized in Table 1. The site has an annual average temperature of 32^{o}C. The annual average precipitation and evaporation is 320 mm and 1,100 mm, respectively. The halophyte species viz, *Leptochloa fusca* (Kallar grass), (*Sporobolus* grass), *Suaeda fruticosa* (Lana), *Kochia indica* (Kochia) and *Atriplex lentiformis* (salt bush) were grown from stubbles and seeds in plots of 10×10 m, repeated four times; side by side naturally growing plants of these species were also selected. The irrigation water was underground brackish water with high salt (the characteristics of tubewell water are summarized in Table 2). When the plants were at the feeding stage, samples were collected from cultivated plots and naturally growing plants at BSRS-II. Their fresh and dry weights were recorded and to evaluate their nutritive values, samples were oven dried. The leaves and twigs were ground and used for subsequent chemical analyses. Crude protein (Nx6.25), fibers, total minerals and total carbohydrate were determined according to AOAC [4] procedures. The above ground plant material was digested according to

Table 1. Characteristics of soil of study site, BSRS-II Pacca Anna, NIAB, Faisalabad, Pakistan

Soil characteristics	**Range**
Soil texture	Sandy loam
Clay (%)	14 ± 1.4
Silt (%)	18 ± 1.5
Sand (%)	68 ± 3.1
EC (dS m^{-1})	12–27.24
Saturation Percentage	25.36–31.45
PH	7.82–8.92
Bulk density (g cm^{-3})	1.38–1.58
$CaCO_3$ (%)	12–23
$CaSO_4.2H_2O$ (%)	2.56–4.15

Table 2. Characteristics of Tube-well water at BSRS-II Pacca Anna, NIAB, Faisalabad, Pakistan

Characteristics	**Range**
EC (dS m^{-1})	4.97
PH	8.2
TSS	3878
SAR	40.5
SAR adj	101.25
RSC	21.60
Soluble ions (me L^{-1})	
Na^+	51.2
K^+	0.4
Ca^{2+}+ Mg^{2+}	3.21
Cl^-	13.75
CO_3	1.5
HCO_3	21.75
SO_4	17.35

Wolf [5] and cations like Na^+, K^+ and Ca^{2+} were estimated by flame photometer (FP7, Jenway, England) and from the same aliquot Mg was determined titrimetrically as described in US Salinity Lab Hand Book-60 and P using Barton's reagent [6]. The data were statistically analyzed [7].

Growth and yield of halophyte plants

The yield per plot is not shown because it is obvious that the plant with higher salt tolerance potential had higher yield and that was maximum in *Atriplex*, closely followed by *Suaeda fruticosa* and *Kochia indica* and minimum was in *Sporobolus*. The yield was higher in experimental plots than that of plants growing naturally. The pattern was almost similar in dry matter accumulation (Fig. 1a). As *Leptochloa fusca* and *Sporobolus grasses* excrete salt absorbed through the salt glands present in their leaves [8], so these species contained more water than other salt tolerant bushes [9]. The salt tolerant bushes contained more salts and less water, as a result they had more dry matter and total minerals. The palatability reports indicated that *Atriplex* and other salt bushes are not as palatable as *Sporobolus* and *Leptochloa fusca* and other grasses [9–11]. Similarly, Casson et al. [12] reported that higher dry matter in salt tolerant plants is due to high accumulation of salts, which is very clear from the present study, because the total mineral contents were very high in the salt tolerant bushes.

Mineral and nutrient values of halophytes

The total minerals were the maximum in *Atriplex lentiformis*, followed by *Suaeda fruticosa*, *Kochia indica*, *Leptochloa fusca* and *Sporo-bolus arabicus* (Fig. 1b), which

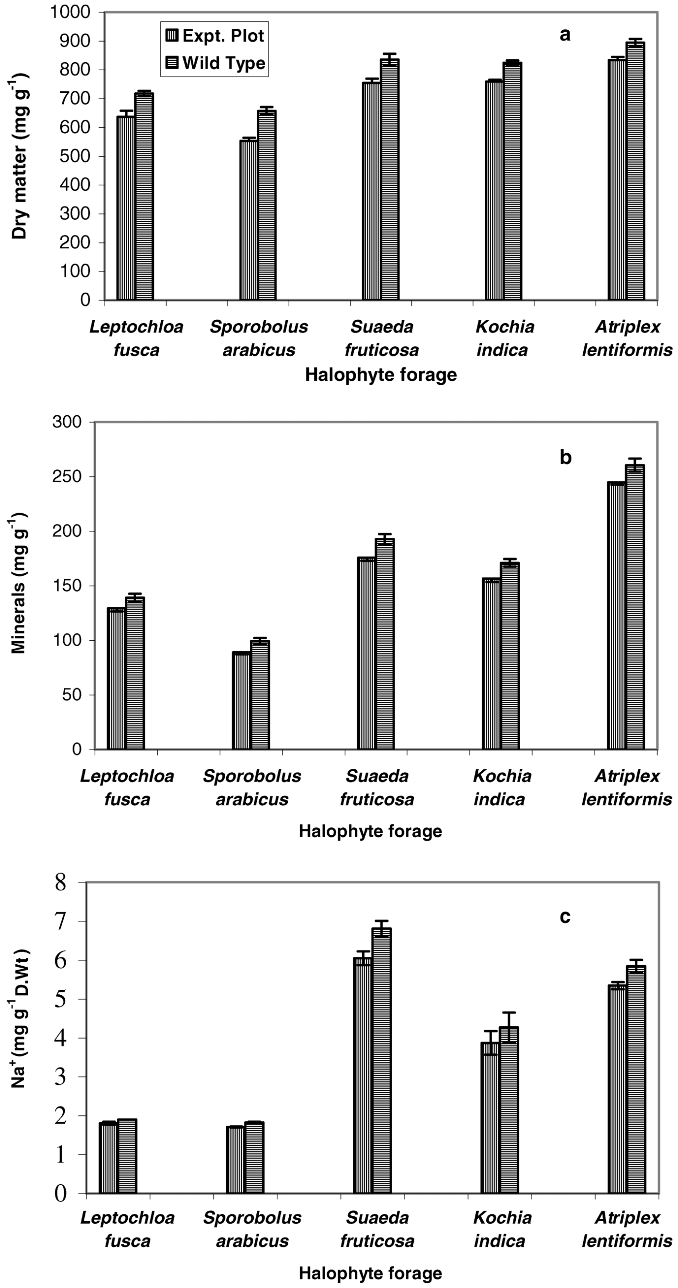

Figure 1. Growth performance and nutritional value of some halophyte forage species under saline environments (**a**) dry weight (**b**) total minerals (**c**) sodium contents

confirmed that maximum salts were accumulated in *Atriplex* and minimum in *Sporobolus*. On the basis of salt concentration, *Sporobolus* is categorized as the most palatable grass for livestock. Many reports indicated that the plants containing higher concentrations of salts are toxic for livestock and are responsible for different types of diseases and physiological disorders. The literature indicates that the animal fed on plants having higher concentrations of salts cause lesion and rashes in the stomach of the animals [13].

Chemical composition of the plants for ions like Na^+ (Fig. 1c), K^+ (Fig. 2a), Ca^{2+} (Fig. 2b) and Mg^{2+} (Fig. 2c) also varied significantly within different halophytic forage species. Maximum Na^+ was recorded in *Suaeda fruticosa* and minimum in *Sporobolus* and *Leptochloa fusca* (Fig. 1c). The literature has clearly indicated that the plants with higher concentrations of Na^+ are injurious for animal health and only the *Sporobolus* and *Leptochloa fusca* in experiment plots maintained Na^+ concentration which is near to critical limit for livestock. However, the naturally growing plants contained higher Na^+ concentrations near the critical limit necessary for livestock (Fig. 1c). So, *Sporobolus* and *Leptochloa* are more suitable as animal fodder than other salt tolerant plants. Many reports [9, 14] have suggested mixing of *Atriplex*, *Suaeda fruticosa* and *Kochia* in animal ration as a result of which Na^+ as well as other salt concentrations can be reduced in animal ration and can be made more palatable and digestible.

Potassium concentrations were higher in *Kochia*, closely followed by *Atriplex* and *Suaeda fruticosa*, while it was minimum in *Leptochloa* and *Sporobolus*. Although animals require higher K^+ concentration to maintain their optimum metabolic activities, in higher amounts it is toxic (Fig. 2a). The salt tolerant bushes contained higher amounts of K^+ than the critical limit; however, salt tolerant grasses contained K^+ up to the requirements of the animals. So these grasses can be recommended for direct grazing or feeding. However, for salt bushes, mixing with other plants is necessary.

Salt bushes also maintained relatively higher Ca^{2+} and Mg^{2+}. However, maximum Ca^{2+} was in *Atriplex*. *Suaeda fruticosa* contained the highest Mg^{2+} concentration (Figs. 2b and c). The grasses however, contained low amounts of these salts. This may be due to the excretion of salts through salt glands, which are absent in salt bushes [8]. The earlier work of NIAB scientists has demonstrated that these grasses have salt glands in their leaves to get rid of the excessive salt concentrations. This property of these plants therefore makes them more palatable and digestible. These grasses are already recommended to farmers for cultivation on salt-affected wasteland for livestock grazing. *Atriplex* and other salt bushes are also being utilized in the animal ration by mixing with other feed. Their sole use is not useful for livestock. Observations indicated that if the animals were only fed on salt bushes, they become weaker day by day and suffer from various metabolic or physiological disorders.

Maximum phosphorous was accumulated in *Suaeda fruticosa* and the minimum in *Sporobolus,* closely followed by *Leptochloa*. The salt bushes again contained more P than the critical limit for the livestock (Fig. 3a). P is a nutrient required in higher amounts for animals but its excessive amount may disturb the other metabolic functions of livestock. Reports have indicated [15, 16] that the salt grasses are useful for animals because they contain desirable amounts of P (Fig. 3a).

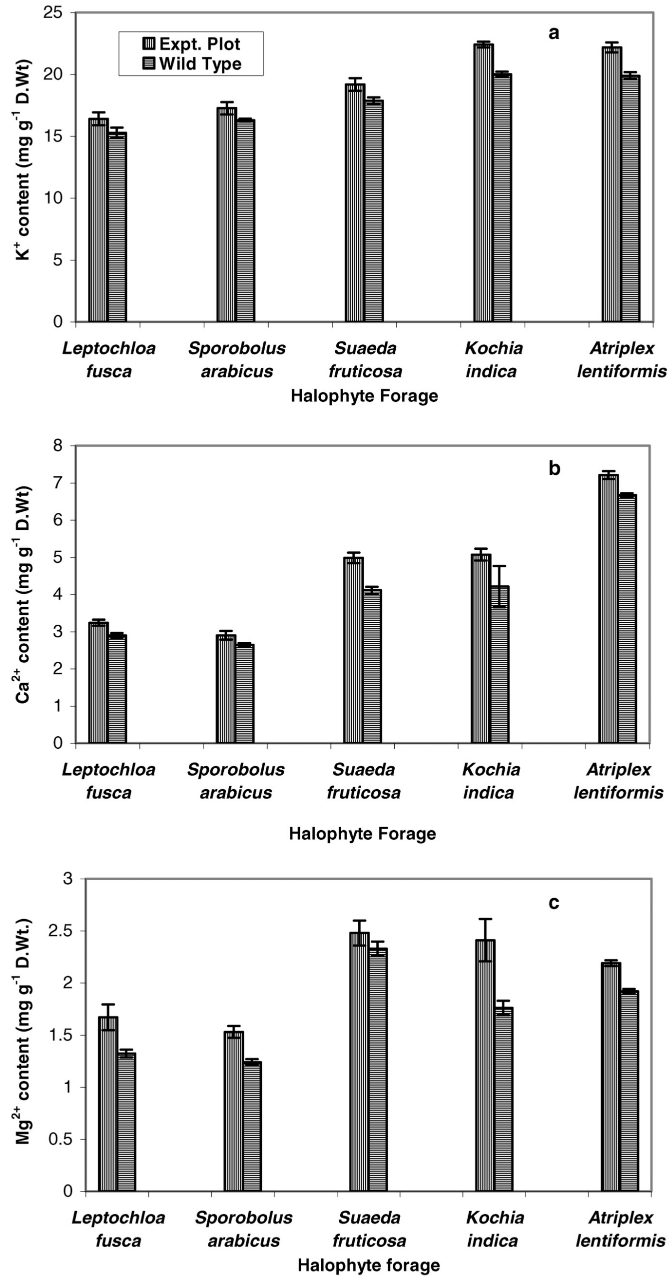

Figure 2. Nutritional value of some salt tolerant plants growing under saline environments (**a**) Potassium, (**b**) Calcium (**c**) Magnesium contents

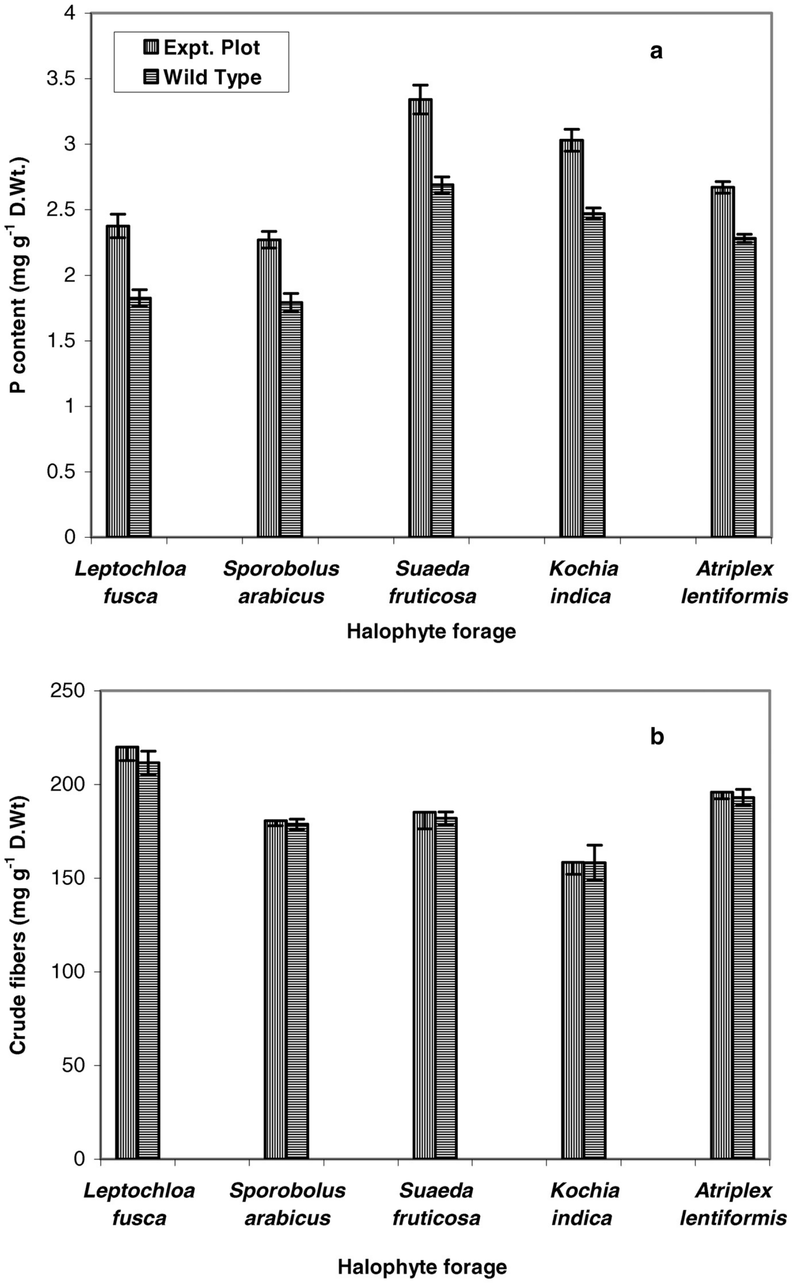

Figure 3. Nutritional value of some halophyte forage growing under saline environments (**a**) Phosphorus (**b**) Crude fiber contents

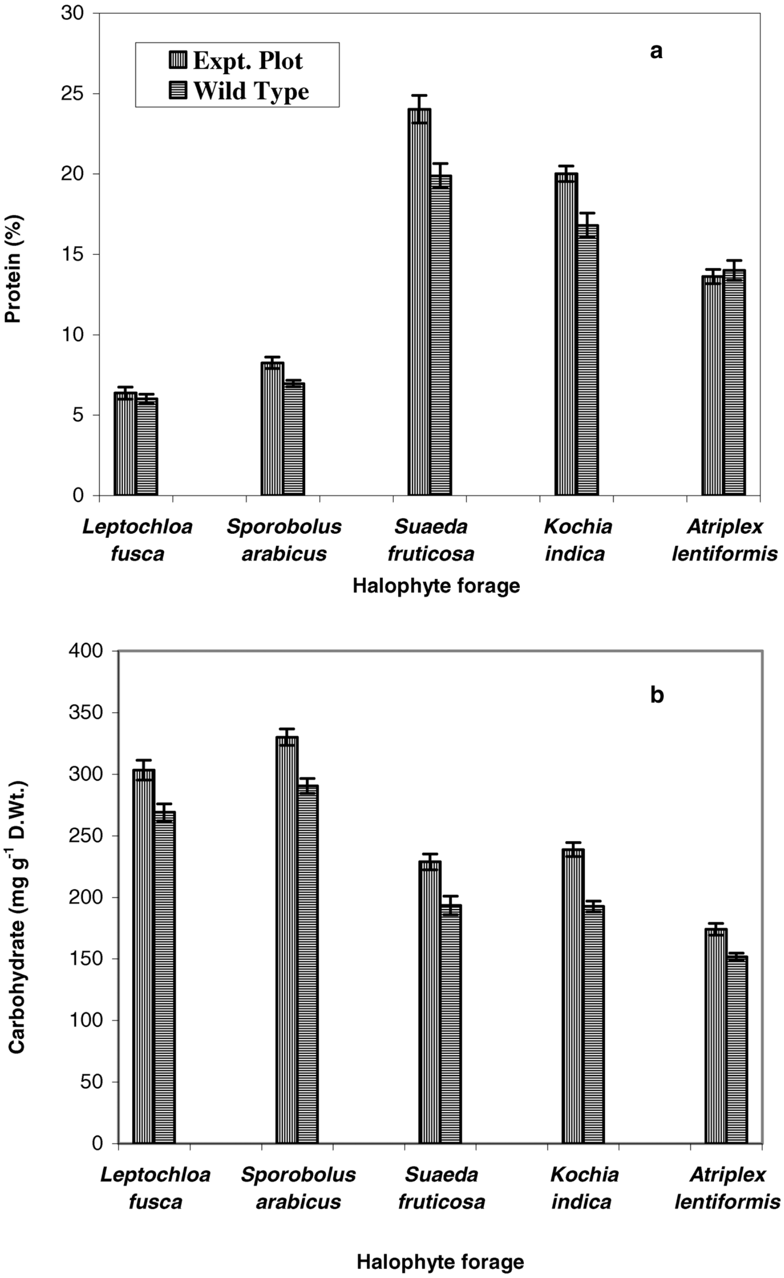

Figure 4. Nutritional value of some salt tolerant plants growing under saline environments (**a**) Protein (**b**) Carbohydrate contents

The results regarding *protein* contents of plants (Fig. 4a) also indicated that salt bushes had more protein than salt tolerant grasses, while reverse was the case for crude fibers (Fig. 3b). As regards the carbohydrates, they were the highest in *Sporobolus arabicus,* closely followed by *Leptochloa fusca* and minimum in *Atriplex lentiformis* (Fig. 4b). These findings also proved that *Sporobolus* and *Leptochloa* grasses are useful for animal health and contain nutrients up to the limit required by the livestock, while salt bushes contained more salts, which could create other metabolic disorders.

Recommendations

From the findings of the present investigation, it was also very clear that the cultivated plants contained less amounts of salts than ones growing naturally. This may be due to proper irrigation as a result of which they were able to contain reasonable amounts of water that caused dilution of salts, and plants became more suitable as animal fodder.

The palatability checked at NIAB [17] and at other places of the world also indicated that the *Atriplex*, *Suaeda fruticosa* and *Kochia indica* are not as suitable as the *Sporobolus* and *Leptochloa fusca*. The Animal Section of the Biological Chemistry Division of this institute has also conducted the digestibility studies of these species using the Nylon bag technique. It indicated that salt tolerant grasses had more digestibility values than salt bushes. So, on the basis of the above results *Sporobolus arabicus* and *Leptochloa fusca* are more useful and seem close to the normal fodder for livestock. The findings of the Animal Section of the Biological Chemistry Division of this institute has also showed that feeding of *Leptochloa* or *Sporobolus* grass had no adverse effects on health and reproduction of dwarf goats. Thus, they should be cultivated preferably on salt-affected wastelands to produce large amounts of fodder for livestock. The salt tolerant bushes should also be grown, but should be fed by mixing with other fodders containing lesser amount of salts.

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