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I. Introduction

The Cholistan Desert (Figure 1) lies within the southeast quadrant of Punjab province between 27° 42' and 29° 45' North latitude and 69° 52' and 73° 05' East longitude (FAO/ADB, 1993; Arshad et al., 1995; Jowkar et al., 1996; Ahmad, 1998; 1999a; 1999b; 1999c; 2003; Ahmad et al., 2004; Ahmad, 2005a; 2005b; Ahmad et al., 2005; Ahmad, 2007a; 2007b; Ahmad and Farooq, 2007; Ahmad, 2010; 2011; 2012a; 2012b; 2013) and covers an area of 2,580,000 ha (Ahmad, 2002; 2010), out of which 1.13 million ha comprising stable as well as non-stable sand dunes, 0.95 and 0.06 million ha consist of sandy and loamy soils respectively, while 0.44 million ha are clayey in nature, locally known as *'dhars'*. About 17% of the Cholistan Desert consist of such *'dhars'* (Table 1) having flat and hard surface with salt incrustation and surrounded by sand dunes. *Dhars* are shallow to moderately deep, poorly drained with low vegetation, calcareous and having saline sodic fine to medium textured clayey soils. Except *Haloxylon recurvum*, other plant species can't survive due to salinity, compaction of soil and complete inundation during rainy season. The ponded rainwater in *'dhars'* stagnates for a period until the water evaporates (Khan et al., 1990; Ahmad, 2010).

It is judicious to utilize the land using ground saline and surface rainwater resources for growing palatable grasses. Biological approach for economic utilization of salt-affected soil is feasible and is the only viable method when the soil is sodic and sweet water is not available for irrigation (Abdullah, 1985; Ahmad, 2010).

Leptochloa fusca is high tolerant to saline and sodic conditions even irrigated by saline groundwater or ponded rainwater. After the successful cultivation of *L. fusca* in the Cholistan Desert, other palatable grasses like para grass (*Brichiaria mutica*), Rhodes grass (*Chloris gayana*), Bermuda grass (*Cynodon dactylon*) and *Sporobolus* grass species can be tested (Abdullah et al., 1990; Ahmad, 2010). The cultivation of salt tolerant grasses would not only provide much needed palatable forage for livestock but also improve the physical properties of the soil due to biological activity of grass roots.

II. Research Design and Methods

The purpose of this paper is to assess the available evidence and published arguments and to provide a constructive working synthesis of evidence about *Leptochloa fusca* in the literature. *L. fusca* is a promising grass for economic utilization and better management of sodic, high pH, saline soil and saline water resources of the Cholistan Desert. The plants respond to salinity stress in part by modulating gene expression, which ultimately leads to the restoration of cellular homeostasis, detoxification of toxins and recovery of growth (Ashraf and Harris, 2004). Salinity in soil or water is one of the major stresses and, especially in arid and semi-arid regions, can severely limit crop production (Shannon, 1997; Mansour, 2000; Ashraf and Harris, 2004; Ashraf and Foolad, 2005; Ashraf and Foolad, 2007). Several physiological responses to salinity that differ qualitatively or quantitatively between salt tolerant and sensitive species (Ashraf and Harris, 2004), and that are candidate indicators, it has not yet proved possible to find any sensitive criterion that could reliably be used by breeders to improve salt tolerance of plants (Kumar et al., 1994; Ashraf and Harris, 2004; Hamdia and Shaddad, 2010). Although the groundwater is saline but it can be used for saline agriculture to grow salt tolerant trees, vegetables, crops and fodder grasses in non-saline-non-sodic coarse textured soils with minimum adverse effects due to rapid leaching of salts

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beyond the root zone and flushing of salts from root zone by rains (Abdullah et al., 1990; Ahmad, 2010).

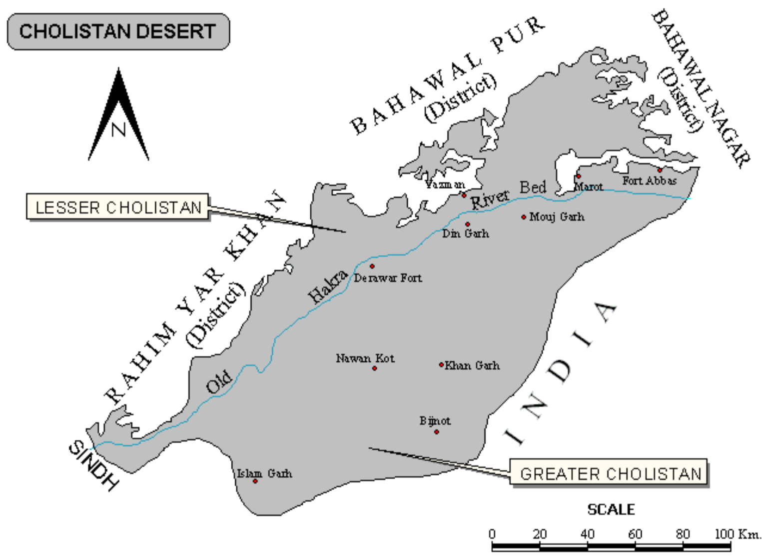

Figure 1 : Location map of the Cholistan Desert

Table 1 : Soil Types

Soil Types	Extent (Ha)	Percentage
Sand dunes	1,133,900	44.0
Sandy soils	945,500	37.0
Loamy soils	58,700	2.0
Saline sodic clayey soils (*Dhars*)	441,900	17.0
Total	2,580,000	100.0

Source: PADMU - Pakistan Desertification Monitoring Unit (1986).

III. Growth Characteristics of Leptochloa Fusca

Leptochloa fusca is also known as *Diplachne fusca,* widely spread in salt affected regions of Pakistan. This forage plant is locally known as *"Kallar grass"* (salt grass). Being a grass of sub-tropical climate, the plant follows the photosynthetic CO_2 fixation process of C_4 - NAD-malice enzyme metabolism (Gate, 1972; Zafar and Malik, 1984; Ahmad, 2010). It is native of saline soil which gives clear indication of its halophytic character; the plant is perennial or biennial in nature (Rao and Arshad, 1991; Arshad and Rao, 1993). It has been regarded as good quality forage especially in salt-affected and waterlogged areas where other superior forage species may not grow successfully.

Leptochloa fusca can be easily propagated and established through seed, stem cutting, root stumps or rhizomes. The grass can grow to a height of 1 to 1.5 meter with a high leaf production rate and can be grazed directly or cut for stall-feeding. This fodder appears highly palatable to sheep, goats, buffaloes and cattle alike and no toxic effects of this grass during long-term consumption have been diagnosed. Moreover, it is similar to other conventional fodder regarding its nutritional status and 3-4 cutting within 3 months may be easily harvested, producing 20-40 tons of green fodder per ha per year or 5-10 tons per ha per cutting in salt-affected soils (Sandhu et al., 1981; Qureshi et al., 1982; Sandhu, 1993; Ahmad, 2010). The grass grows well during the hot season from March to September with peak yields during rainy season *i.e.* July and August in Pakistan, indicating a strongly thermophilic character. The development of extensive and dense fibrous root system has been observed even in highly sodic soils (Joshi et al., 1981; Ahmad, 2010). The penetration of roots in such soils can enhance hydraulic conductivity, microbial activity, organic matter and ultimately leaching of salts. Joshi (1981) noted a decline of *L. fusca* growth due to decrease of soil sodicity, while Haq and Khan (1971) observed that *L. fusca* has a general tendency to decrease EC_e (electrolyte conductivity), SAR (sodium adsorption ratio), pH (soluble ions) and even ESP (exchangeable sodium percentage) of artificially salinized soils. Malik (1986) confirmed the utility of *L. fusca* not only as a primary colonizer of salt-affected lands but also as ameliorative plant for the soil (Ahmad, 2010).

IV. Nutritional Requirements

It has been observed that 3-4 cuttings of this grass could be easily taken without the addition of nitrogen (N) fertilizer in salt-affected and less fertile soils. Malik (1980) demonstrated a high activity of nitrogen, which indicates strong associative symbiotic relationship of N_2- fixing bacterium (Bacillus gram negative) in the rhizosphere of *L. fusca*. Moreover, the nitrogen fixation through the growth of blue green algae and *Azolla* under flooded conditions may partly contribute to the nitrogen supply and economy of the specie. It was also observed that *L. fusca* contribute more stable organic matter fraction due to its slow decomposition as compared to succulent plant species like *Sesbania aculeata*. Kumar (1980) reported an abrupt increase in the yield of *L. fusca* from 24-26 tons per ha per year without N application to 41-46 tons per ha per year, when only 40 kg N per ha was applied in a sodic soil. Abdullah (1985) showed a definite ameliorative effect of phosphorus (P) on the growth of *L. fusca* under saline environment (Hanson and Scott, 1980; Agboma et al., 1997a; Agboma et al., 1997b; Díaz-Zorita et al., 2001). The application of P at the rate of 50 kg per ha gave significantly higher fresh and dry matter yield at EC_e 10 dS m^{-1} than all other treatments, which was followed by 75 and 25 kg P per ha at EC_e 20 dS m^{-1}. The synergistic P x salinity effect was obvious at the highest P level of 75 kg per ha. Thus, the specie is responded favourably to P application at all salinity levels studied *i.e.* EC_e 3.5 to 30 dS m^{-1}, indicating higher P requirements. In general, the specie is capable to accumulate trace elements (Zn, Cu, Fe, Mn) in a sufficient amount to meet the dietary requirements of the livestock under saline soil conditions (Abdullah et al., 1990; Ahmad, 2010).

V. Role in Soil Reclamation

Leptochloa fusca behaved as a typical crypno-eu-halophyte having both accumulating and excreting properties (Abdullah, 1986; Abdullah et al., 1990; Ahmad, 2010). The efficient salt excretion from the shoot makes it a useful plant to deplete excessive salt from the root-zone and to provide the better root-environment for the growth of other plants. The extensive and fibrous roots of grass can open soil, increase air exchange, organic matter and hydraulic conductivity, decrease rhizosphere pH, stimulate biological activities, dissolve native $CaCO_3$, enhance leaching of salts, lower the water table of waterlogged soils, release plant nutrients and the shoot foliage can increase organic matter, humus and soil mulching, decrease surface evaporation and improve physical properties of soil with the passage of time (Haq and Khan, 1971; Joshi et al., 1981; Abdullah et al., 1986; Malik et al., 1986; Akhtar et al., 1988; Ahmad, 2010).

VI. Use of Ground Saline Water for Irrigation

Dense saline-sodic soils of the Cholistan Desert (Baig et al., 1975) can be used for growing such palatable grasses, which is salt tolerant and capable of surviving in soils having poor properties (Baig et al., 1980). The sandy and loamy soil that is about 1 million ha can be brought under agriculture using underground saline water and harvested rainwater. Experiments showed that under certain conditions plant could not only survive but also even vast area of land could be irrigated with water of such high concentration. Moderately saline irrigation water stimulates vegetation, assists the benevolent bacteria of the soil and improves yield and quality (Akram et al., 1995). Further, use of brackish water reduces soil evaporation, transpiration of plants and increases resistance to drought (Abdullah et al., 1990; Ahmad et al., 1992; Ahmad, 2010). The solution of the adverse effect is suggested (CHIDS, 1991):

- Identification and selection of species and varieties tolerant of high salinity,
- The use of brackish water of such a degree of salinity only as is compatible with help of such species and with the nature of the soil,
- The selection of irrigation with such water in areas in which soils permeable, well drained and rich in calcium and the hydrates of iron and aluminium.

Pakistan Council of Research in Water Resources (PCRWR) has planted *Eucalyptus, Acacia, Parkinsona, Zizyphus* (Beri), *Tamarix, Prosopis, Asparagus,* Date palm, Pomegranate, Jojoba and Iple Iple (*Leucaena leucocephala*). The saline water of concentration TSS (total soluble salts) 2800 ppm (part per million) and SAR (sodium adsorption ratio) 14 was being used for irrigation (Dalton et al., 1997) along with harvested rainwater (Figure 2, 3, 4 and 5) to flush the salts at certain interval (Abdullah et al., 1990; Ahmad, 2010). The calcium sulphate fertilizer was also used to neutral the adverse effects of sodium salts. The growth of some of them is given in table 2, 3 and 4.

Table 2 : Biomass of Fodder Grasses/Ha Grown at Dingarh, Cholistan Desert Using Saline Water

Fodder grass	Biomass Fresh (kg)	Biomass Dry (kg)	Carrying capacity per year			
			Camel	Goat	Sheep	Cattle
Cenchrus ciliaris	16811	15012	2	14	16	3
Panicum antidotale	22191	12407	1	11	14	3
Lasirus sindicus	25217	18247	2	17	20	4
Napier Bajra	43710	38780	4	35	42	9
Leptochloa fusca	13449	11445	1	10	13	3

Forage requirement (Dry matter per day):
1 sheep = 2.5 kg 1 goat = 3.0 kg 1 camel = 25.0 kg 1 cattle = 12.5 kg
Source: PADMU – Pakistan Desertification Monitoring Unit (1986).

Table 3 : Biomass Potential of Some Salt Tolerant Forages

Species	Green matter (kg/plant)	Dry matter (kg/plant)	Green matter yield (tons/ha)	Dry matter yield (tons/ha)	Plants/ha
Atriplex amnicola 949	4.31	1.99	2.7	1.24	625
Atriplex amnicola 971	5.37	2.39	3.4	1.49	625
Atriplex amnicola 573	6.73	3.43	4.2	2.14	625
Atriplex amnicola × *Atriplex nummularia*	5.13	2.15	3.2	1.34	625
Atriplex buburyana 1205 (Carnarvan)	3.11	1.6	7.8	4.0	2500
Atriplex buburyana 1200 (Leonora)	2.0	1.2	5.0	3.0	2500
Atriplex cinerea 524	5.0	2.35	3.1	1.46	625
Atriplex lentoformis	5.45	3.19	3.4	2.0	625
Maireana aphylla 1062	2.53	1.2	6.3	3.0	2500

Source: PADMU – Pakistan Desertification Monitoring Unit (1986).

Table 4 : Survival Percentage and Canopy Cover of Some Plants Grown in the Cholistan Desert

Name of Tree / Shrub / Bush	Age (months)	Survival (%)	Height (cm)			Canopy Cover (cm)		
			Min.	Mean	Max.	Min.	Mean	Max.
Eucalyptus *(Camddulensis)*	24	76	90	156	223	66	113	161
Tamarix	24	48	59	106	154	52	112	173
Acacia	24	67	66	125	193	55	126	197
Beri *(Zizyphus)*	24	43	55	118	181	38	82	126
Jojoba *(Simmondsia chinensis)*	18	76	20	60	110	08	48	89
Atriplex halimus (Local)	11	65	--	77	---	--	45	---
Atriplex amnicola 573	11	40	--	48	---	--	08	---
Atriplex amnicola 197	11	80	--	74	---	--	15	---
Atriplex amnicola 223	11	25	--	47	---	--	09	---
Atriplex bunburyana 1041	11	60	--	51	---	--	07	---
Atriplex bunburyana 1036	11	70	--	66	---	--	13	---
Atriplex cincerea	11	40	--	28	---	--	02	---
Atriplex lintiformis	11	60	--	76	---	--	26	---
Atriplex commercial	11	25	--	44	---	--	13	---
Maireana aphylea	11	85	--	35	---	--	30	---

Source: PADMU - Pakistan Desertification Monitoring Unit (1986).

Figure 2 : Wild oats grown by highly saline irrigation at PCRWR research station at the Cholistan Desert (Pakistan). Ahmad, Farooq 2008

Figure 4 : Frost trees grown by highly saline irrigation at PCRWR research station at the Cholistan Desert (Pakistan). Ahmad, Farooq 2008

Figure 3 : Innovative approach for mustard crop cultivation with saline irrigation on sandy desert at the Cholistan (Pakistan). Ahmad, Farooq 2008

Figure 5 : Innovative approach for development of grassland with saline irrigation on sandy desert at the Cholistan (Pakistan). Ahmad, Farooq 2008

Table 5 : Salt Tolerant Plants Cultivated in the Cholistan Desert Using Saline Water

Forage Crop/Grass/Bush	Tolerance ($EC_e \times 10^6$) 4000 – 18000
Alkali grass *(Puccinellia airoides)*	High
Bermuda grass *(Cymodon dactylon)*	High
Kallar grass *(Leptochloa fusca)*	High
Salt grass *(Distichlis stricta)*	High
Desert wheat grass *(Agropyron cristatum)*	High
Barley *(Hordium vulgare)*	High
Rape *(Brassica napus)*	Medium
Clover *(Melilotus)*	Medium
Alfalfa *(California common)*	Medium
Oats *(Hay)*	Medium
Atriplex spp.	High

Source : PADMU – Pakistan Desertification Monitoring Unit (1986).

The germination capacity of different varieties of tomato, ladyfinger (*bhindi*), spinach (*palak*), cowpea and zucchini (*tori*) at different levels EC_e 3 to 18 mmho/cm was studied in sand culture (Akbar et al., 1996; Akbar, 2002; PADMU, 1986; Ahmad, 2010). The germination was delayed and decreased with the increase in salinity. Significant vegetables were found to fall in the order of salt tolerance: Spinach > Zucchini > Cowpea > Tomato > Ladyfinger (Abdullah et al., 1988; Abdullah et al., 1990; Abdullah et al., 1991; Ahmad, 2010). List of some salt tolerant grasses and forages cultivated in the Cholistan Desert using saline water is given in table 5.

VII. Conclusions

The growth factors such as easy propagation, high spreading rate, colonizing ability, vigorous growth, yield, palatability, nutritional value, long term survival and high adaptability to environmental stress make *L. fusca* an excellent and versatile specie that can be cultivated using brackish water and salt-affected land of the Cholistan Desert for economic exploitation. *L. fusca* develop succulence, which dilute the level of salt in the plant and stores water for use during dry period. The specie has great promise for the economic utilization of sodic, high pH, waterlogged and saline soils. Similarly, high saline-sodic water can be used for successful cultivation of *L. fusca*.

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