

1 Leptochloa Fusca Cultivation for Utilization of Salt-Affected Soil 2 and Water Resources in the Cholistan Desert

3 Dr. Farooq Ahmad¹

4 ¹ University of the Punjab

5 *Received: 16 December 2012 Accepted: 1 January 2013 Published: 15 January 2013*

6

7 **Abstract**

8 In the Cholistan Desert, 0.44 million ha are salt-affected low lying and clayey in nature locally
9 known as 'dhars', where rainwater as well as saline groundwater could be utilized for growing
10 salt grasses like *Leptochloa fusca* as forage during summer. *L. fusca* is a promising candidate
11 grass for economic utilization and better management of sodic, high pH, saline soil and water
12 resources of the Cholistan Desert. *L. fusca* is known to be a versatile, halophytic, primary
13 colonizer, easily propagatable, perennial, nutritive and palatable forage plant species. The
14 grass has the good biomass producing potential and can grow equally well both under upland
15 and submerged saline soil environment.

16

17 **Index terms**— Cholistan, *Leptochloa fusca*, saline irrigation, salt-affected, soil reclamation.

18 **1 Introduction**

19 Author : Department of Geography, University of the Punjab, New Campus, Lahore, Pakistan. E-mail :
20 drylandpk@yahoo.com salt-affected soil is feasible and is the only viable method when the soil is sodic and
21 sweet water is not available for irrigation (Abdullah, 1985; Ahmad, 2010).

22 **2 II.**

23 Research Design and Methods The Cholistan Desert (Figure 1) lies within the southeast quadrant of Punjab
24 province between 27° 42' and 29° 45' North latitude and 69° 52' and 73° 05' East longitude (FAO/ADB,
25 1993; Arshad et al., 1995; Jowkar et al., 1996; Ahmad, 1998; 1999a; 1999b; 1999c; 2003; Ahmad et al., 2004; Ahmad,
26 2005a; 2005b; Ahmad et al., 2005; Ahmad, 2007a; 2007b; Ahmad and Farooq, 2007; Ahmad, 2010; 2011; 2012a; 2012b;
27 and covers an area of 2,580,000 ha (Ahmad, 2002; 2010), out of which 1.13 million ha comprising stable as well as
28 non-stable sand dunes, 0.95 and 0.06 million ha consist of sandy and loamy soils respectively, while 0.44 million
29 ha are clayey in nature, locally known as 'dhars'. About 17% of the Cholistan Desert consist of such 'dhars'
30 (Table 1) having flat and hard surface with salt incrustation and surrounded by sand dunes. Dhars are shallow to
31 moderately deep, poorly drained with low vegetation, calcareous and having saline sodic fine to medium textured
32 clayey soils. Except *Haloxylon recurvum*, other plant species can't survive due to salinity, compaction of soil
33 and complete inundation during rainy season. The ponded rainwater in 'dhars' stagnates for a period until the
34 water evaporates (Khan et al., 1990; Ahmad, 2010). It is judicious to utilize the land using ground saline and
35 surface rainwater resources for growing palatable grasses. Biological approach for economic utilization of The
36 purpose of this paper is to assess the available evidence and published arguments and to provide a constructive
37 working synthesis of evidence about *Leptochloa fusca* in the literature. *L. fusca* is a promising grass for economic
38 utilization and better management of sodic, high pH, saline soil and saline water resources of the Cholistan
39 Desert. The plants respond to salinity stress in part by modulating gene expression, which ultimately leads to
40 the restoration of cellular homeostasis, detoxification of toxins and recovery of growth (Ashraf and Harris, 2004).
41 Salinity in soil or water is one of the major stresses and, especially in arid and semi-arid regions, can severely limit
42 crop production (Shannon, 1997; Mansour, 2000; Ashraf and Harris, 2004; Ashraf and Foolad, 2005; Ashraf and

6 VI. USE OF GROUND SALINE WATER FOR IRRIGATION

43 Foolad, 2007). Several physiological responses to salinity that differ qualitatively or quantitatively between salt
44 tolerant and sensitive species (Ashraf and Harris, 2004), and that are candidate indicators, it has not yet proved
45 possible to find any sensitive criterion that could reliably be used by breeders to improve salt tolerance of plants
46 (Kumar et al., 1994;Ashraf and Harris, 2004;Hamdia and Shaddad, 2010). Although the groundwater is saline
47 but it can be used for saline agriculture to grow salt tolerant trees, vegetables, crops and fodder grasses in non-
48 saline-non-sodic coarse textured soils with minimum adverse effects due to rapid leaching of salts *Leptochloa fusca*
49 is high tolerant to saline and sodic conditions even irrigated by saline groundwater or ponded rainwater. After
50 the successful cultivation of *L. fusca* in the Cholistan Desert, other palatable grasses like para grass (*Bricharia*
51 *mutica*), Rhodes grass (*Chloris gayana*), Bermuda grass (*Cynodon dactylon*) and *Sporobolus* grass species can
52 be tested (Abdullah et al., 1990; Ahmad, 2010). The cultivation of salt tolerant grasses would not only provide
53 much needed palatable forage for livestock but also improve the physical properties of the soil due to biological
54 activity of grass roots.

55 3 Growth Characteristics of *Leptochloa Fusca*

56 *Leptochloa fusca* is also known as *Diplachne fusca*, widely spread in salt affected regions of Pakistan. This forage
57 plant is locally known as "Kallar grass" (salt grass). Being a grass of sub-tropical climate, the plant follows
58 the photosynthetic CO₂ fixation process of C 4 -NAD-malic enzyme metabolism (Gate, 1972;Zafar and Malik,
59 1984;Ahmad, 2010). It is native of saline soil which gives clear indication of its halophytic character; the plant
60 is perennial or biennial in nature (Rao and Arshad, 1991;Arshad and Rao, 1993). It has been regarded as good
61 quality forage especially in saltaffected and waterlogged areas where other superior forage species may not grow
62 successfully.

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

79 IV.

80 4 Nutritional Requirements

81 V.

82 5 Role in Soil Reclamation

83 *Leptochloa fusca* behaved as a typical crypnœu-halophyte having both accumulating and excreting properties
84 (Abdullah, 1986)

85 6 VI. Use of Ground Saline Water for Irrigation

86 Dense saline-sodic soils of the Cholistan Desert (Baig et al., 1975) can be used for growing such palatable grasses,
87 which is salt tolerant and capable of surviving in soils having poor properties (Baig et al., 1980). The sandy
88 and loamy soil that is about 1 million ha can be brought under agriculture using underground saline water and
89 harvested rainwater. Experiments showed that under certain conditions plant could not only survive but also
90 even vast area of land could be irrigated with water of such high concentration. Moderately saline irrigation
91 water stimulates vegetation, assists the benevolent bacteria of the soil and improves yield and quality (Akram
92 et al., 1995) It has been observed that 3-4 cuttings of this grass could be easily taken without the addition of
93 nitrogen (N) fertilizer in salt-affected and less fertile soils. Malik (1980) demonstrated a high activity of nitrogen,
94 which indicates strong associative symbiotic relationship of N 2-fixing bacterium (*Bacillus* gram negative) in
95 the rhizosphere of *L. fusca*. Moreover, the nitrogen fixation through the growth of blue green algae and *Azolla*
96 under flooded conditions may partly contribute to the nitrogen supply and economy of the specie. It was also
97 observed that *L. fusca* contribute more stable organic matter fraction due to its slow decomposition as compared
98 to succulent plant species like *Sesbania aculeata*. Kumar (1980) reported an abrupt increase in the yield of *L.*
99 *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
100 per ha was applied in a sodic soil. Abdullah (1985) showed a definite ameliorative effect of phosphorus (P) on

101 the growth of *L. fusca* under saline environment (Hanson and Scott, 1980;Agboma et al., 1997a;Agboma et al.,
102 1997b;Díaz-Zorita et al., 2001). The application of P at the rate of 50 kg per ha gave significantly higher fresh
103 and dry matter yield at EC \leq 10 dS m $^{-1}$ than all other treatments, which was followed by 75 and 25 kg P per ha
104 at EC \leq 20 dS m $^{-1}$. The synergistic P x salinity effect was obvious at the highest P level of 75 kg per ha. Thus,
105 the specie is responded favourably to P application at all salinity levels studied i.e. EC \leq 3.5 to 30 dS m $^{-1}$,
106 indicating higher P requirements. In general, the specie is capable to accumulate trace elements (Zn, Cu, Fe, Mn)
107 in a sufficient amount to meet the dietary requirements of the livestock under saline soil conditions (Abdullah et
108 al., 1990;Ahmad, 2010). The germination capacity of different varieties of tomato, ladyfinger (bhindi), spinach
109 (palak), cowpea and zucchini (tori) at different levels EC \leq 3 to 18 mmho/cm was studied in sand culture (Akbar
110 et al., 1996;Akbar, 2002; ??ADMU, 1986;Ahmad, 2010). The germination was delayed and decreased with the
111 increase in salinity. Significant vegetables were found to fall in the order of salt tolerance: Spinach > Zucchini
112 > Cowpea > Tomato > Ladyfinger (Abdullah et al., 1988;Abdullah et al., 1990;Abdullah et al., 1991;Ahmad,
113 2010). List of some salt tolerant grasses and forages cultivated in the Cholistan Desert using saline water is given
114 in table 5.

115 **7 VII.**

116 **8 Conclusions**

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

VIII. ^{1 2}

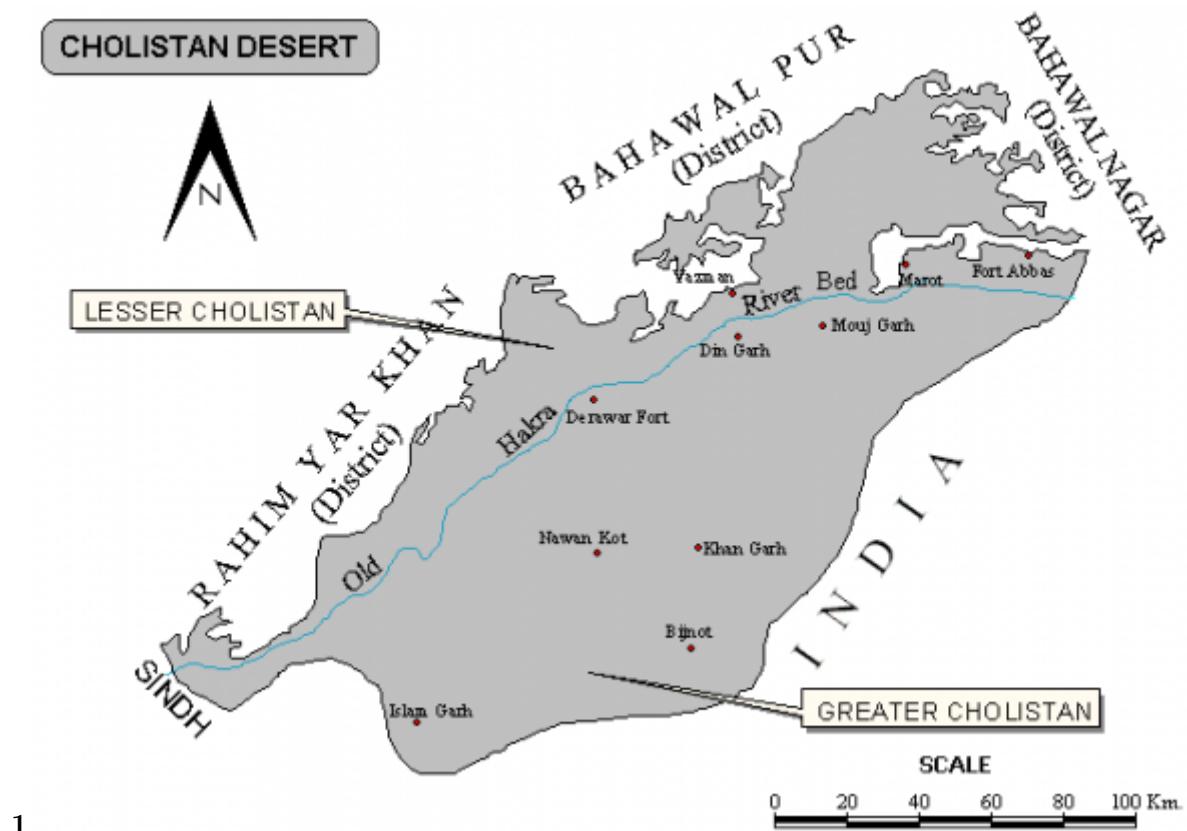


Figure 1:

124

¹© 2013 Global Journals Inc. (US)

²© 2013 Global Journals Inc. (US) Year



1

Figure 2: Figure 1 :



Figure 3:



Figure 4: Forage



Figure 5:

8 CONCLUSIONS

2435



Figure 6: Figure 2 :Figure 4 :Figure 3 :Figure 5 :

1

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

[Note: Source: PADMU -Pakistan Desertification Monitoring Unit (1986).III.]

Figure 7: Table 1 :

2

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

Figure 9: Table 2 :

3

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).

Figure 10: Table 3 :

4

Name of Tree / Shrub / Bush	Age (months)	Survival (%)	Min.	Height (cm)	Max.	Canopy Cover (cm)	Min.	Mean
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								

Figure 11: Table 4 :

8 CONCLUSIONS

125 .1 Acknowledgements

- 126 The author wishes to thank Dr. Mohammad Arshad (Late), Cholistan Institute of Desert Studies, The Islamia
127 University of Bahawalpur, Pakistan for providing technical assistance during the field study of the Cholistan
128 Desert and valuable comments on a draftversion of this paper.
- 129 [Plant, Cell Environment] , *Plant, Cell & Environment* 4 (2) p. .
- 130 [Lugo and Spain (2004)] , Lugo , Spain . April 2004. United Kingdom. p. .
- 131 [Ahmad ()] 'Agro-pastoral systems in Cholistan'. F Ahmad . *Pakistan Geographical Review* 2005a. 60 (2) p. .
- 132 [Ahmad et al. ()] 'Agropastoral systems in Cholistan'. F Ahmad , F Gulzar , S A Shirazi , S Farooq , Z Ali .
133 *Proceedings of Silvopastoralism and Sustainable Land Management International Congress*, (Silvopastoralism
134 and Sustainable Land Management International Congress) 2005. p. .
- 135 [Agboma et al. ()] 'An evaluation of the effect of exogenous glycine betaine on the growth and yield of soybean:
136 timing of application, watering regimes and cultivars'. P C Agboma , T R Sinclair , K Jokinen , P Peltonen-
137 Sainio , E Pehu . *Field Crops Research* 1997b. 54 (1) p. .
- 138 [Díaz-Zorita et al. ()] 'Applications of foliar fertilizers containing glycine betaine improve wheat yields'. M Díaz-
139 Zorita , M V Fernández-Canigia , G A Grosso . *Journal of Agronomy and Crop Science* 2001. 186 p. .
- 140 [Ahmad ()] 'Archaeo-historical environ of Cholistan and significance of ancient agriculture in Pakistan'. F Ahmad
141 . *Journal of Food, Agriculture & Environment* 2007b. 5 p. .
- 142 [Hanson and Scott ()] 'Betaine synthesis from radioactive precursors in attached, water-stressed barley leaves'.
143 A D Hanson , N A Scott . *Plant Physiology* 1980. 66 (2) p. .
- 144 [Brazil for publication. The Revista Sociedade Natureza is not on the list of approved journals of Higher Education Commission,
145 'Brazil for publication. The Revista Sociedade & Natureza is not on the list of approved journals of Higher
146 Education Commission, Pakistan. The author obtained N.O.C. from the editor Revista Sociedade &
147 Natureza, Prof. Dr. Sílvio Carlos Rodrigues and re-submitted the revised and modified text alongwith
148 the N.O.C. to the Editor-in-Chief Dr'. The author submitted the text of the paper to Revista Sociedade &
149 Natureza, Instituto de Geografia, Universidade Federal de Uberlândia (Vivek Dubey, Global Journals Inc.,
150 USA for republication)
- 151 [Fao/Adb ()] 'Cholistan area development project'. Fao/Adb . No. 59/53 ADB-PAK 58. *Food and Agriculture
152 Organization (FAO)*, (Rome, Italy) 1993. (Report) (Final version)
- 153 [Akbar et al. ()] 'Cholistan desert'. G Akbar , T N Khan , M Arshad . Pakistan. *Rangelands* 1996. 18 (4) p. .
- 154 [Arshad et al. ()] 'Cholistan desert in a state of flux'. M Arshad , Rao , Altaf-Ur-Rehman , G Akbar . *UNEP:
155 Desertification Control Bulletin* 1995. 26 p. .
- 156 [Joshi et al. (ed.) ()] *Cholistan Institute of Desert Studies, The Islamia University of Bahawalpur, Pakistan. and
157 glycophytes. Annual report for*, Y C Joshi , A Qadir , S K Sharma . Arshad, M. (ed.) 1981. 1980. Karnal,
158 India. p. . Central Soil Salinity Research Institute (People's participation in the management of resources in
159 arid lands)
- 160 [Ahmad and China (1998)] 'Combating desertification: Role of rainwater harvesting in Cholistan'. F ; P R
161 Ahmad , China . *Proceedings of an International Symposium & 2nd Chinese National Conference on
162 Rainwater Utilization*, (an International Symposium & 2nd Chinese National Conference on Rainwater
163 UtilizationXuzhou) 1998. 8-14 September 1998. p. .
- 164 [Desertification process in Cholistan desert ()] *Desertification process in Cholistan desert*, PADMU 7/86. 1986.
165 PCRWR Publication. p. . PADMU
- 166 [Ahmad et al. ()] 'Developing Cholistan desert -a perspective'. T F Ahmad , G Akbar , M B Tahir , I Ahmad .
167 *Progressive Farming* 1992. 12 (6) p. .
- 168 [Qureshi et al. ()] 'Diplachne Fusca: An Australian salt tolerant grass used in Pakistan'. R H Qureshi , M Aslam
169 , M Abdullah , M G Pitman . *Journal of Australian Institute for Agricultural Science* 1982. 48 (4) p. .
- 170 [Ahmad ()] 'Eco-regeneration and runoff collection in Cholistan'. F Ahmad . *UNEP: Desertification Control
171 Bulletin* 1999b. 35 p. .
- 172 [Gate ()] 'Ecological response of Australian native species Acacia harpophylla and Atriplex mummularia to soil
173 salinity, effect on water content, lead area and transpiration rate'. C T Gate . *Australian Journal of Botany*
174 1972. 20 p. .
- 175 [Ahmad ()] 'Ecological restoration in Cholistan'. F Ahmad . *Journal Geographic* 1999a. 2 (1) p. .
- 176 [Agboma et al. ()] 'Effect of foliar application of glycine betaine on yield components of droughtstressed tobacco
177 plants'. P C Agboma , P Peltonen-Sainio , R Hinkkanen , E Pehu . *Experimental Agriculture* 1997a. 33 (3)
178 p. .
- 179 [Akhtar et al. (1985)] 'Effect of kallar grass growth on water transmission characteristics of salt-affected lands'.
180 J Akhtar , R A Waheed , K A Malik , M I Haq . *Proceedings of First National Congress on Soil Sciences*,
181 (First National Congress on Soil SciencesLahore, Pakistan) 1988. 6-8 October 1985. p. .

8 CONCLUSIONS

- 182 [Dalton et al. ()] 'Effect of root temperature on plant response functions for tomato: comparison of static and
183 dynamic salinity stress indices'. F N Dalton , A Maggio , G Piccinni . *Plant and Soil* 1997. 192 (2) p. .
- 184 [Akbar ()] 'Feasibility of silvo-pastoral model for saline -sodic soils in arid climate'. G Akbar . *Science Vision*
185 2002. 8 (1) p. .
- 186 [Kumar et al. ()] 'Forage yield of sorghum and winter clovers as affected by biological and chemical reclamation
187 of a highly alkaline soil'. A Kumar , L Batra , R Chhabra . *Experimental Agriculture* 1994. 30 (3) p. .
- 188 [Ahmad ()] 'Geoinformatics application to investigate agricultural potential in Cholistan desert'. F Ahmad .
189 *Journal of Food, Agriculture & Environment* 2007a. 5 (2) p. .
- 190 [Ahmad (2003)] 'GIS application for range development in Cholistan'. F Ahmad . *Proceedings of VII International*
191 *Rangelands Congress*, (VII International Rangelands CongressDurban, South Africa) 2003. 26 July to 1
192 August 2003. p. .
- 193 [Ahmad ()] 'Historical and archaeological perspectives of soil degradation in Cholistan'. F Ahmad . *Journal*
194 *Geographic* 2005b. (10) p. .
- 195 [Abdullah et al. (1990)] 'Internal water resources management by plants under various root environment stresses
196 with special reference to kallar grass Leptochloa Fusca'. M Abdullah , M Akram , A D Khan , R H Qureshi
197 . *Proceedings of the National Seminar on Water Resources Development and its Management in Arid Areas*,
198 (the National Seminar on Water Resources Development and its Management in Arid AreasQuetta, Pakistan)
199 1990. 6-8 October 1990.
- 200 [Malik et al. ()] 'Kallar Grass -A plant for saline land'. K A Malik , Z Aslam , M Naqvi . *Nuclear Institute for*
201 *Agriculture and Biology* 1986. NIAB. p. 93.
- 202 [Kumar et al. ()] 'Karnal grass grows well in sodic soils'. A Kumar , I P Abrol , K S Dargan . *Indian Farming*
203 1980. 30 (3) p. .
- 204 [Ahmad ()] 'Landsat ETM+ and MODIS EVI/NDVI data products for climatic variation and agricultural
205 measurements in Cholistan Desert'. F Ahmad . *Global Journal of Human Social Science: Geography &*
206 *Environmental Geo-Sciences* 2012b. 12 (13) p. .
- 207 [Ahmad ()] 'Leptochloa Fusca cultivation for utilization of salt-affected soil and water resources in Cholistan
208 desert'. F Ahmad . *Revista Sociedade & Natureza* 2010. 22 (1) p. .
- 209 [Abdullah et al. ()] *Leptochloa Fusca: A high yielding candidate grass for utilization of salt-affected soil and water*
210 *resources in Cholistan desert*, M Abdullah , M Akram , A Majeed , M A Butt , R H Qureshi , M Arshad .
211 1991. Pakistan. p. . Cholistan Institute of Desert Studies, The Islamia University of Bahawalpur (Proceedings
212 of seminar: People's participation in the management of resources in arid lands)
- 213 [Ahmad et al. (2004)] 'Leptochloa Fusca: A high yielding grass for utilization of salt-affected soil and water
214 resources in Cholistan'. F Ahmad , F Gulzar , S A Shirazi , S Farooq , Z Ali . *Fourth International Conference*
215 *on Land Degradation*, (Murcia, Spain) 2004. September 2004. p. 434.
- 216 [Mansour ()] 'Nitrogen containing compounds and adaptation of plants to salinity stress'. M M F Mansour .
217 *Advances in Agronomy* 2000. 1997. 43 (4) p. . (Biologia Plantarum)
- 218 [Malik et al. ()] 'Nitrogenase activity in the rhizosphere of kallar grass Diplachne Fusca'. K A Malik , Y Zafar ,
219 A Hussain . *Biologia* 1980. 26 (1-2) p. .
- 220 [Arshad et al. ()] *Plant genetic resources of Cholistan desert and their utilization*, M Arshad , Rao , Altaf-Ur-
221 Rehman . 1993. Pakistan. Cholistan Institute of Desert Studies, the Islamia University of Bahawalpur
- 222 [Baig et al. ()] 'Possibilities for range development in Cholistan desert as reflected by its physiography and soils'.
223 M S Baig , M Akram , M A Hassan . *The Pakistan Journal of Forestry* 1980. p. .
- 224 [Ashraf and Harris (2004)] 'Potential biochemical indicators of salinity tolerance in plants'. M Ashraf , P J
225 C Harris . <http://nhjy.hzau.edu.cn/kech/ssyy/qysd/njsl/21.pdf>. (Accesssedon *Plant Science*
226 2004. July 20. 2013. 166 (1) p. .
- 227 [Ashraf and Foolad ()] 'Pre-sowing seed treatment-A shotgum approach to improve germination, plant growth,
228 and crop yield under saline and non saline conditions'. M Ashraf , M R Foolad . *Advances in Agronomy* 2005.
229 88 p. .
- 230 [Rao ()] *Proceedings of seminar: People's participation in the management of resources in arid lands*, Altaf-Ur-
231 Rehman Rao , Arshad , M . 1991. Pakistan. p. . Cholistan Institute of Desert Studies, The Islamia University
232 of Bahawalpur (Perennial grasses of Cholistan desert and their distribution)
- 233 [Khan et al. (1990)] 'Rainwater harvesting in Cholistan desert'. A D Khan , M Akram , M Abdullah . *Proceedings*
234 *of the National Seminar on Water Resources Development and its Management in the Arid Areas*, (the National
235 Seminar on Water Resources Development and its Management in the Arid AreasQuetta, Pakistan) 1990.
236 6-8 October 1990. p. .

- 237 [Ahmad (1999)] 'Rainwater utilization and ecological restoration in Cholistan'. F Ahmad . *Proceedings of VI*
238 *International Rangeland Congress*, (VI International Rangeland CongressTownsville, Australia) 1999c. 19-23
239 July 1999. p. .
- 240 [Haq and Khan ()] 'Reclamation of saline and alkaline soil by growing kallar grass'. M Haq , M F A Khan . *The*
241 *Nucleus* 1971. 8 (4) p. .
- 242 [Baig et al. ()] 'Reconnaissance soil survey of Cholistan'. M S Baig , E H Khan , M R Zaheer , M Ahmad . *Soil*
243 *Survey of Pakistan* 1975.
- 244 [Akram et al. (1993)] 'Rehabilitation of Cholistan desertified lands for sustained production'. M Akram , W
245 A Khan , B A Sheikh , M Abdullah , A D Khan . *Proceedings of the 6th All Pakistan Geographical*
246 *Conference*, (the 6th All Pakistan Geographical ConferencePakistan) 1995. 26-29 December 1993. p. . The
247 Islamia University of Bahawalpur
- 248 [Abdullah et al. ()] 'Responses of Leptochloa Fusca to various types of substrate salinities'. M Abdullah , R H
249 Qureshi , N Ahmad . *Proceedings of Pak.-US. Biosaline research Workshop*, (Pak.-US. Biosaline research
250 WorkshopKarachi, Pakistan) 1986. September 1985. p. .
- 251 [Ahmad and Farooq (2007)] 'Role of rainwater harvesting in reducing rural poverty in Cholistan Desert'. F
252 Ahmad , S Farooq . *Abstract in 12th All Pakistan Geographical Conference*, (Lahore, Pakistan) 2007. 19-
253 21 March 2007. p. 24.
- 254 [Ashraf and Foolad ()] 'Roles of glycine betaine and proline in improving plant abiotic stress resistance'. M Ashraf
255 , M R Foolad . *Environmental and Experimental Botany* 2007. 59 (2) p. .
- 256 [Ahmad ()] 'Run-off farming in reducing rural poverty in the Cholistan Desert'. F Ahmad . *Global Journal of*
257 *Human Social Science: Geography, Geo-Sciences, Environmental Disaster Management* 2013. 13 (5) p. .
- 258 [Abdullah et al. ()] 'Salt tolerance mechanisms in desert plants'. M Abdullah , R H Qureshi , M Akram . *Pakistan*
259 *Journal of Water Resources* 1988. 41 (1) p. .
- 260 [Hamdia and Shaddad ()] 'Salt tolerance of crop plants'. M Hamdia , M A K Shaddad . *Journal of Stress*
261 *Physiology & Biochemistry* 2010. 6 (3) p. .
- 262 [Abdullah ()] *Salt tolerance studies on Leptochloa Fusca*, M Abdullah . 1985. Faisalabad, Pakistan. p. 286.
263 University of Agriculture (Ph.D. dissertation)
- 264 [Ahmad (2002)] *Socio-economic dimensions and ecological destruction in Cholistan*, F Ahmad . <http://eprints.hec.gov.pk/801/01/517.html.htm> 2002. May 08. 2013. Pakistan. Department of Geography,
265 University of Karachi (Ph.D. dissertation)
- 266 [Jowkar et al. ()] 'Socioeconomic dimensions of resource management in Cholistan'. F Jowkar , M A Khan , M
267 Khan . *Institute for Development Anthropology (IDA)*, (Binghamton, New York) 1996.
- 268 [Ahmad ()] 'Soil classification and micromorphology: A case study of Cholistan desert'. F Ahmad . *Journal of*
269 *Soil Science and Environmental Management* 2011. 2 (11) p. .
- 270 [Ahmad ()] 'Spectral vegetation indices performance evaluated for Cholistan Desert'. F Ahmad . *Journal of*
271 *Geography and Regional Planning* 2012a. 5 (6) p. .
- 272 [Sandhu ()] *Sustainable agriculture: A Pakistan National Conservation Strategy Sector Paper No. 2. Environment*
273 *and Urban Affairs Division, Government of Pakistan and IUCN -The World Conservation Union*, G R Sandhu
274 . 1993. Pakistan.
- 275 [Sandhu et al. ()] *The effect of salinity on the yield and composition of Diplachne Fusca*, G R Sandhu , Z Aslam
276 , M Salim , A Sattar , R H Qureshi , N Ahmad , Wyn Jones , RG . 1981. (Kallar grass)
- 277 [Zafar and Malik ()] Y Zafar , K A Malik . *Photosynthetic system of Leptochloa Fusca*, 1984. 16 p. .
- 278