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Performance of Pastoral, Silvipastoral and Silvicultural Systems in Alkali Soils of Indo-Gangetic Plains

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ABSTRACT

A field study to find out the suitable agro forestry systems in a highly alkali soil and their effect on improving the soil properties was initiated during 1995 at Central Soil Salinity Research Institute, Regional Research station, Lucknow. The soil was poor in organic matter (0.08%) and available N (94kg ha^{-1}) but high in available P (25kg ha^{-1}) and K (237.44kg ha^{-1}). The treatments include: T_1, Kallar grass (*Leptochloa fusca*) for 4 years followed by Gutton panic (*Panicum maximum*) grass (without amendments); T_2, Vilayati babul (*Prosopis juliflora*) as sole tree crop; T_3, Deshi babul (*Acacia nilotica*) as sole tree crop; T_4, Vilayati babul (*Prosopis juliflora*) + Kallar grass (*Leptochloa fusca*) for 4 years followed by berseem (*Trifolium alexendrium*) for 3 years (without amendments) and T_5, Deshi babul (*Acacia nilotica*) + Kallar grass (*Leptochloa fusca*) for 4 years followed by Rhodes grass (*Chloris gayana*) for 3 years. After 84 months of planting all the growth parameters including survival percent, plant height, diameter at breast height (DBH), diameter at stump height (DSH) and lopped biomass of *Prosopis juliflora* and *Acacia nilotica* grown in combination with inter crops of grasses were higher as compared to the sole plantation. Plant height was recorded to be 20 and14% higher in *Prosopis juliflora* and *Acacia nilotica* respectively grown in combination with grasses than the sole plantation of these species. The pH, EC and organic carbon of the surface soil (0-15cm) with *Prosopis juliflora* in combination with Kallar grass (*Leptochloa fusca*) for 4 years followed by Berseem (*Trifolium alexendrium*) for 3 years silvipastoral system has reduced to the level of 8.87. However, pH was > 9.0 in case of the remaining treatments. Vilayati Babool (*Prosopis juliflora)* + Berseem (*Trifolium alexendrium*) silvipastoral system gave highest net return (Rs. 15155ha^{-1} yr^{-1}) followed by Gutton panic (*Panicum maximum*) as sole crop (Rs.7660 ha^{-1} yr^{-1}) than the sole plantation of *Prosopis juliflora* (Rs.5610 ha^{-1} yr^{-1}) and *Acacia nilotica* (Rs.3260 ha^{-1} yr^{-1}) and appeared to be the most suitable and economically viable alternate land use system for alkali soils.

Key words: Alkali soil, Indo-Gangetic plains, Agro-forestry systems, soil improvement.

INTRODUCTION

Acacia nilotica and *Prosopis juliflora* are the most promising woody species for alkali lands in indo-gangatic plains of India. Now it is promoted as a component of silvipastoral systems but the interaction of these trees with grasses has not been adequately studied. In India there are about 8.6 million ha. salt affected soils. The indo-gangetic plains constitute a major part of salt affected soils in the country. The farmers in the Indo-gangetic plains in India have reclaimed a sizeable area of alkali lands for crop production, but still a large part of common lands either government lands or village panchayat lands are not in any productive use. In addition to this a large part of alkali soils belongs to the small and marginal farmers is also lying unproductive. Judicious use of these lands can substantially contribute in increasing demands of food, fodder, fuel and timber in the country. Silvipastoral systems have been generally promoted for hilly areas as a means for reducing soil erosion and improving soil physical and chemical properties. Introduction of tree+ grasses in alkali soils provides an alternative to control further deterioration of these soils and also maintain the soil health. Several studies have measured to increase the N status of the soil under varying N_2- fixing tree species (*Acacia spp*.). The highly salt tolerant and high biomass producing grass species include: Kallar grass (*Leptochloa fusca*), Rhodes grass (*Chloris gayana*) and Gutton panic (*Panicum maximum*) has been found most suitable fodder species. Growing of these fodder species in combination with *Prosopis juliflora* and *Acacia nilotica* for a certain period of time improved the soil health to such an extent that less tolerant but more palatable fodder species such as Berseem (*Trifolium alexendrium*) and Senji (*Melilotus*

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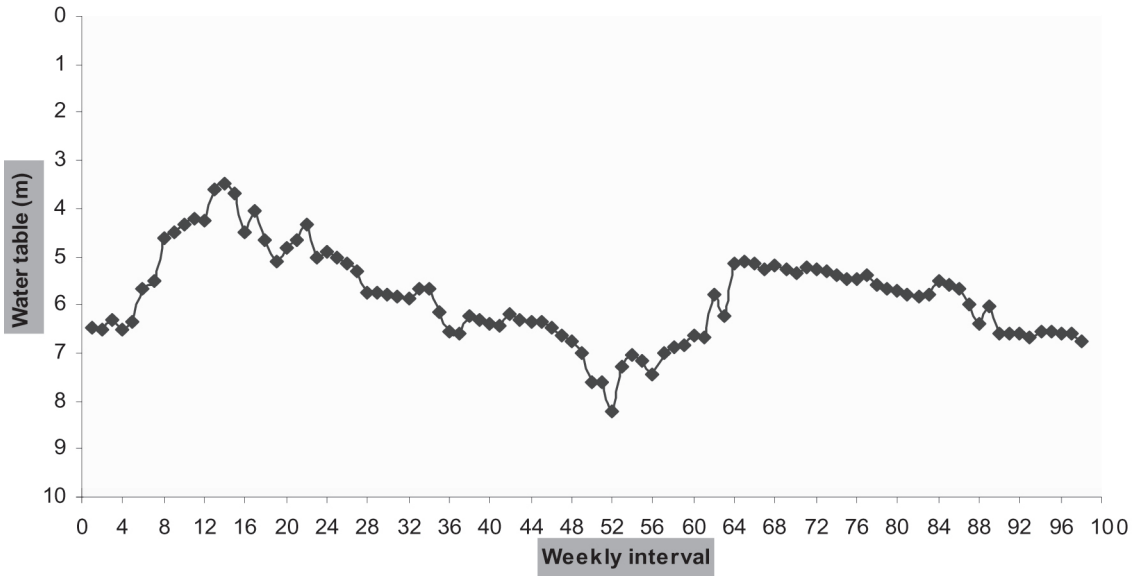
parviflora) could be grown. As the alkali soils are poor in organic carbon, the rates of organic carbon and N accumulation tends to be greatest in the first five years of plantation (Lukan and Fonda 1983). Therefore, the present study was initiated in 1995 with the twin objectives of sustainable use of highly alkali soils for fuel -fodder production and their amelioration. This study focuses on the impact of *Acacia nilotica* and *Prosopis juliflora* alone and in combination with different grass species in order to assess the effect of different combinations on growth of trees, yields of fodder grasses and improvement in soil properties.

MATERIALS AND METHODS

A field experiment was initiated during 1995 at Central soil Salinity Research Institute, Regional Research Station, Lucknow, (U.P.) (Lat. 26° 47′ N and Long. 80° 46′ E) in the Indo-gangetic plain zone of India to find out the suitable agroforestry system in highly alkali soils. The soil of the study area was having pH 10.2, EC 1.55 dSm^{-1} and ESP 89 in the upper 0-15 cm soil depth with a predominance of carbonate and by carbonate of Na+. The soil was poor in organic carbon (0.08%) but rich in available P (19.5 kg ha^{-1}) and K (388.00 kg ha^{-1}) (Table 1). The annual rainfall, mean maximum and minimum temperature and evaporation are shown in graph 1. The water table was deep fluctuating between 3-5 m in rainy season and 6-7 m in summer. Nearly 6-9 month old saplings of tree species viz. *Prosopis juliflora* and *Acacia nilotica* of uniform height, collar diameter and phenotype were planted during 1995 in auger holes of 45cm diameter at the surface and 20cm at the base and 120cm deep in a randomized block design (RBD) with 4 replications. Each auger hole was filled with a uniform mixture of original soil + 4kg gypsum+ 10kg FYM +20kg silt before planting. The trees have been planted keeping a distance of 5m between the rows and 4m between plants. Root slips of Kallar grass (*Leptochloa fusca*) at 50cm row to row and 30 cm plant to plant spacing were planted as sole crop and as inter crop with *Acacia nilotica* and *Prosopis juliflora* without any amendment for 4 years and after that Gutton panic (*Panicum maximum*), Rhodes grass (*Chloris gayana*) and Berseem (*Trifolium alexendrium*) were sown as sole and as inter crop between the rows of *Acacia nilotica* and *Prosopis juliflora* respectively for three years. Five treatments consisting T_1, Kallar grass (*Leptochloa fusca*) for 4 years followed by gutton panic (*Panicum maximum*) grass as sole crop (without amendments); T_2, Vilayati babul (*Prosopis juliflora*) as sole crop; T_3, Deshi babul (*Acacia nilotica*) as sole crop; T_4, Vilayati babul + Kallar grass for 4 years followed by Berseem (*Trifolium alexendrium*) for 3 years (without amendments) and T_5, Deshi babul (*Acacia nilotica*) + Kallar grass for 4 years followed by Rhodes grass (*Chloris gayana*) for 3 years (without amendments) were evaluated in the study. Natural grasses were allowed to grow in the treatments T_2 and T_3. The natural grasses regenerated under the trees were harvested annually and kallar grass, rhodes grass and gutton panic were harvested quarterly and used as fodder grass by the cattle. The berseem was grown during rabi season (October to April) and harvested 4-5 times during the cropping season and after that field was allowed to grow natural grasses during kharif season. All the grasses were sold in the market and prevailing market rates were considered to workout the economics of different agro-forestry systems. Lopping of side branches of trees were done during the dormant period to help the trees grow better and also improve the forage yield of inter planted grasses (Singh *et al* .1989). The

Table 1. Initial soil properties of the experimental field

Soil depth (cm)	pH	EC ($ds\ m^{-1}$)	O.C. (%)	ESP (%)	G.R. ($t\ ha^{-1}$)	$CaCO_3$ (%)	Available P ($kg\ ha^{-1}$)	Av. K ($kg\ ha^{-1}$)
0-15	10.2	1.55	0.08	85	30	2.41	25.0	237.4
15-30	10.4	2.80	0.08	89	32	1.26	19.5	324.4
30-45	10.4	2.55	0.06	91	33	2.34	18.5	388.0
45-60	10.1	1.86	0.08	-	-	2.26	17.7	404.0
60-75	10.1	1.33	0.08			3.46	17.1	290.0
75-90	9.7	0.86	0.08	-	-	3.77	16.7	287.0
90-120	9.3	0.45	0.06	-	-	7.75	16.1	278.0
120-150	9.0	0.21	0.06	-	-	32.54	15.4	190.0
150-180	8.7	0.22	0.04	-	-	22.46	16.3	170.4
180-210	9.0	0.14	0.05	-	-	25.34	16.6	151.0



Graph 1. Water table fluctuation pattern of CSSRI research farm Shivri, Lucknow (U.P.)

lopped biomass of the trees was used as fuel and the prices were fixed according to the prevailing market rate of the fuel. The observations on survival %, plant height (cm), DBH (cm), DSH (cm), lopped biomass (qha^{-1}) and yields of fodder grasses viz. Kallar grass, Rhodes grass, Gutton panic, Berseem and naturally regenerated grasses, was measured on green weight basis. Soil samples collected at different growth stages were analyzed for pH, EC, and organic carbon. Soil pH in water (1:2) was measured at depths of 0-15 and 15-30cm using the method described in blakemore *et al*. (1987). The organic carbon of the soil was measured by ignition (Wang *et al*.1996) where approximately 2g of dry soil (sieved to <2mm) were placed in ceramic crucibles in a muffle furnace at 375^{0}C for 16 h. The data were analyzed statistically to find out the treatment differences following the standard methods given by Gomez and Gomez, (1984).

RESULTS AND DISCUSSION

Tree growth

From the study, it is observed that the maximum survival percent up to 60 months of planting was recorded with *Prosopis juliflora* planted as sole. However, after 84 months of planting maximum survival was observed in *Prosopis juliflora* planted with inter crops of grasses. Higher plant mortality was observed in sole plantation up to 60 months of plantation and after that no mortality was observed in the trees grown in combination with grasses. Maximum plant height at 60 months crop growth stage was observed with *Acacia nilotica* grown in combination with kallar grass (*Leptochloa fusca*) as compare to the sole plantation. However, at 84 months growth stage *Prosopis juliflora* grown in combination with Berseem (*Trifolium alexendrium*) a nitrogen fixing fodder crop attains maximum plant height because of availability of additional moisture and nutrients to the plants but the difference between the treatments was not significant (Table 2). Similarly diameter at breast height (DBH) and diameter at stump height (DSH) of *Prosopis juliflora* (10.10 and 15.57cm) and *Acacia nilotica* (8.22 and 13.49cm) species at 60 and 84 months after planting stages were higher with the trees grown in combination with inter crops of fodder grasses over the sole plantation of these species. After 60 months of planting, *Acacia nilotica* grown as sole crop produced significantly higher lopped biomass (25.10q ha^{-1}) as compared to *Prosopis juliflora* and *Acacia nilotica* grown in combination with different grasses species. However, at 84 months growth stage significantly higher lopped biomass (33.55q ha^{-1}) was obtained from the *Prosopis* + Berseem intercrop. Singh *et al*. (1989a) reported that the plant height of *Prosopis juliflora* was significantly increased with lopping of trees in highly alkali soils. Lopping of side branches of trees during the dormant period helps the trees grow better and also improve the forage yield of inter planted grasses (Singh *et al*. 1989).

Fodder yields

Observations on fodder yields obtained from natural grasses regenerated under the sole plantation of *Prosopis juliflora* and *Acacia nilotica* and

Table 2. Performance of tree species under different agro-forestry systems.

Treatments	60 months after planting					84 months after planting				
	Survival (%)	Height (m)	DBH (cm)	DSH (cm)	Lopped biomass (q ha^{-1})	Survival (%)	Height (m)	DBH (cm)	DSH (cm)	Lopped biomass (q ha^{-1})
Prosopis (sole)	100	4.33	5.78	11.92	13.25	93	4.83	6.82	12.84	29.40
Acacia (sole)	85	4.35	6.26	11.46	25.10	81	4.53	7.51	12.21	32.00
Prosopis + fodder grass	95	4.97	6.47	12.97	16.70	95	5.21	10.10	15.57	33.55
Acacia + fodder grass	90	5.11	6.41	11.25	18.50	90	5.16	8.22	13.49	25.60
CD (P=0.05)	NS	NS	NS	NS	2.78	NS	NS	NS	NS	2.20

Table 3. Green fodder yields under different agro-forestry systems at different growth stages

Treatments	Green fodder yields (q ha^{-1}) obtained after			
	48 months of planting	60 months of planting	72 months of planting	84 months of planting
T_1- Grasses (Sole)	103.0	174.74	207.44	219.43
T_2-Prosopis (sole)	34.82	54.82	79.00	47.40
T_3-Acacia (sole)	41.67	71.43	85.00	88.00
T_4-Prosopis+ Karnal grass-Berseem	74.65	158.19	49.75	222.55
T_5-Acacia+ Karnal grass-Rhodes grass	61.25	56.50	112.60	162.00

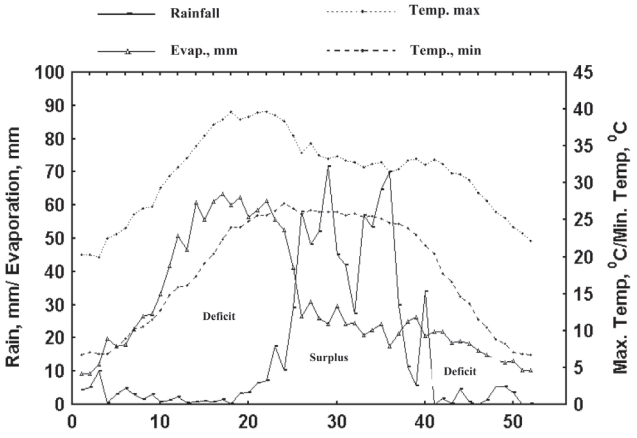


Fig. 1. Annual weather parameters of CSSRI, Research farm, Shivri

from the planted grass species like *Leptochloa fusca*, *Chloris gayqna, Trifolium alexendrium* and *Panicum maximum* planted as sole and as inter crop were taken at regular interval and it was found that the fodder yields in case of sole plantation as well as inter crop increased with every increase in time interval. Maximum fodder yield at 48 months of planting was obtained from the sole crop of *Leptochloa fusca* as compared to the yields obtained from the inter crops. Similar trend was also observed up to 72 months planting stages and after that the fodder yields under *Prosopis juliflora* increased as compared to other silvipastoral systems. The increments in fodder yields between 48 and 84 months of planting were higher in case of tree + grass cropping system as compared to the grass yields obtained from sole tree plantation and sole grass cropping systems because of more improvement in soil health with tree and grass combination system. Kumar *et al*. (1990-91) has found that under all tree canopies berseem yield was less affected as compared to other fodder crops (Table 3). Lopping of side branches of trees during dormant period helps the trees to grow better and also improve the forage yield of inter planted grasses. When large canopy-forming trees like *Posopis* and *Acacia* are pruned of side branches, light penetrates through the cavities owing to their removal and increases productivity of under-story vegetation.

Soil improvement

With the introduction of trees, tree + grasses and grasses only under highly sodic soil conditions, it was found that there was remarkable improvement in soil properties. After 84 months of continuous observations, it was observed that the *Prosopis juliflora* + Kallar grass for 4 years followed by berseem silvipastoral system found most promising for reclamation of alkali soils. With this treatment combination, the pH of surface soil reduced to the level of 8.87 however, the pH with other treatments was > 9.0. Abrol and Prasad, 1985, Singh *et al* .1993 and Singh, 1995 have also reported similar results. The organic carbon content of

Table 4. Improvement in soil properties under different agro- forestry systems at different tree growth stages.

Treatments	Soil depth	60 months after planting			84 months after planting		
	(cm)	pH	EC	O.C. (%)	pH	EC	O.C. (%)
T_1- Karnal grass-Gutton panic (Sole)	0-15	9.60	0.84	0.24	9.20	0.63	0.28
	15-30	10.20	1.20	0.17	9.76	0.87	0.11
T_2-Prosopis (sole)	0-15	9.50	0.84	0.14	9.00	0.29	0.26
	15-30	9.91	1.21	0.10	9.85	1.03	0.17
T_3-Acacia (sole)	0-15	10.0	1.03	0.14	9.21	0.86	0.27
	15-30	10.15	1.73	0.10	9.84	1.20	0.13
T_4-Prosopis+Karnal grass-Berseem	0-15	9.56	0.59	0.28	8.87	0.63	0.44
	15-30	10.03	1.23	0.19	9.51	0.87	0.23
T_5-Acacia+ Karnal grass-Rhodes grass	0-15	9.60	0.83	0.12	9.20	0.23	0.35
	15-30	9.95	1.37	0.10	9.68	0.62	0.22

Table 5. Cost economics of different agro- forestry systems.

Treatments	Fodder yield (q ha^{-1})	Fuel yield (q ha^{-1})	Cost of Production (Rs.ha^{-1})	Gross income (Rs.ha^{-1})	Net return (Rs.ha^{-1} $year^{-1}$)
T_1- Karnal grass-Gutton panic (Sole)	219.43	-	2340	10971	8631
T_2-Acacia (sole)	87.40	29.40	1700	7310	5610
T_3-Acacia (sole)	88.0	32.00	1700	4960	3260
T_4-Prosopis+Karnal grass-Berseem	222.55	33.55	8000	23155	15155
T_5-Acacia+ Karnal grass-Rhodes grass	242.14	25.60	3000	10660	7660

surface soil (0-15 cm) has also increased more than 300% from the treatment in which *Prosopis* + Kallar grass for 4 years followed by Berseem was grown (Table 4). This might be due to production of certain allelo-chemicals/mixture of acids released from tree biomass as well as from root and shoot biomass of grasses. Gill *et al*. (1987) and Lal (1998) has also reported three and two fold increase in organic carbon of surface (0-15cm) soil in a span of 5 years under *Acacia nilotica* and *Eucalyptus territicornis* respectively. From the study it was also observed that the improvement in soil properties with *Acacia* (sole) and *Acacia* in combination with Kallar grass for 4 years followed by rhodes grass does not make any significant difference in soil pH at surface level however, at 15-30 cm soil layer *Acacia* + Rhodes grass silvipastoral system improved the soil more than *Acacia* as sole. The concentration of almost all nutrients in plant parts of *Prosopis juliflora* was more under tree + grass treatment than in sole crop. Total nutrient removal from the soil was higher in *Prosopis* + grass treatments compared with *Prosopis* and *Acacia* as sole. Even after such higher removal of nutrients in tree + grass treatments, the organic carbon and available N status of the soil was still better than the sole plantation of trees and grasses astoral treatments. The similar observations were also reported by Singh *et al*. 1987.

Economics

Economical interaction among pastoral, silvipastoral and silviculture systems was considered in order to assess their compatibility and economic viability, for alkali soils. The income from the different trees, grasses and Tree + grass intercropping systems started flowing from the first growing season, in the form of fodder and fuel. The income obtained from different combinations indicated that the *Prosopis juliflora* + *Kallar* grass *(Leptochloa fusca)* for 4 years followed by Berseem (*Trifolium alexendrium*) gave the maximum (Rs.15155 ha^{-1} yr^{-1}) net return as compared to rest of the treatment combinations because of great demand and higher market price of Berseem for fodder during the winter season when there is scarcity of green fodder (Table 5). However, Acacia as sole crop gave lowest (Rs. 3260 ha^{-1} yr^{-1}) net return. After harvesting of Berseem, natural grasses are allowed to grow under the *Prosopis juliflora* trees during the kharif season and harvested in the month of October. Abrol and Joshi (1984) have also reported the maximum benefit: cost ratio for intercropping of fodder grasses with trees in highly alkali soils.

CONCLUSION

After seven years of comparative evaluation of trees, grasses and tree + grasses combinations in

highly alkali soils, the survival of *Acacia* and *Prosopis* in case of tree + grasses combination was 12.06 and 3.22 percent more over the sole plantation of these trees respectively. The height in case of trees grown in combination with fodder grasses were more as compared to the sole plantation because of moisture conservation and suitable hydrothermal conditions developed in the soil for better plant growth. *Prosopis juliflora* in combination with kallar grass*(Leptochloa fusca)* during the initial 4 years has reduced the soil pH to the level of 9.5 and after that less tolerant but more palatable fodder species such as Berseem (*Trifolium alexandrium*) can be grown successfully and gave higher fodder yields (22.25Mg ha^{-1}) and net returns (Rs. 15155 ha^{-1}). Thus it can be inferred that the *Prosopis juliflora* + kallar grass *(Leptochloa fusca)* for 4 years followed by Berseem for 3 years silvipastoral system has been found most promising for firewood and forage production and also for amelioration of alkali soils.

REFERENCES

Abrol, I.P. and Joshi, P.K. 1984. Economic viability of reclamation of alkali lands with special reference to agriculture and forestry. *Proceedings of seminar on Economics of Wastelands development*. New Delhi, pp.19-30.

Abrol, I.P. and Prasad, R. 1985. Karnal grass for reclaiming alkali soil. Better farming in salt affected soils No. 5 CSSRI, Karnal, Haryana.

Gomez K.A. and Gomez, A.A. 1984. *Statistical procedures for agricultural research*. John wily and sons, New York, 80 pp.

Gill, H.S., Abrol, I.P.and Samra, J.S. 1987. Nutrient recycling through litter production in young plantations of *Acacia nilotica* and *Eucalyptus teriticornis* in a highly alkali soil. *Forest Ecology Management* **22**: 57-59.

Kumar, Ashok., Singh, N.T. and Batra, Lalita 1990-91. Tree canopy inter-crop relationships in an agroforestry system. Report 1990-91, CSSRI, Karnal, pp 106-8.

Luken, J.O., and Fonda, R.W. 1983. Nitrogen accumulation in a chronosequence of red alder communities along the Hoh river. Olympic National park, Washington. *Canadian Journal of Forest Research* **13**: 1228-1237.

Lal, B. 1998. Comparative performance of forage grasses with amendments and row spacing on saline sodic soils. In Ist Agronomy Congress: Agronomy, Environment and food security for 21st Century Nov.23-27, 1998, New Delhi.

Singh, Gurbachan, Abrol, I.P. and Cheema, S.S. 1989. Effect of spacing and lopping on *Prosopis +Kallar grass*. Agroforesty systems in a sodic soil. *Exp. Agric.* **25**: 401-8.

Singh, Gurbachan., Abrol, I.P. and Cheema, S.S. 1989a. Effect of management practices on mesquite (*Prosopis chilensis*) in a highly alkaline soils. *Indian Journal of Agricultural Science* **59**: 1-7.

Singh, Gurbachan and Singh, N.T. 1993. Mesquite for the vegetation of salt lands. 24 pp.Bull. No. 18, CSSRI, Karnal.

Singh, Gurbachan 1995. An Agroforestry practice for the development of salt lands using *Prosopis juliflora* and *Laptocloa fusca*. *Agro Forestry Systems* **29**: 61-75.