Utilization of Salt Affected Soils & Poor Quality Waters for Sustainable Biosaline Agriculture in Arid and Semiarid Regions of India

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Abstract: In this paper judicious use of salt affected soils and poor quality waters for sustainable biosaline agriculture in arid and semiarid regions of India has been discussed in brief. Results of several long term field experiments have been reported. In one long term experiment 30 forest tree species, 15 strains of *Prosopis*, and 10 fruit tree species planted on highly alkali soil (pH >10) using pit-augerhole and pit techniques of plantation using different doses of amendments were evaluated. After 7 years of experimentation , *Prosopis juliflora*, *Tamarix articulata*, and *Acacia nilotica* were found most suitable forest tree species for such soils. Among fruit trees *Ziziphus mauritiana*, *Syzygium cuminii*, *Psidium guajava*, *Emblica officinalis*, and *Carissa carandus* were the successful species showing good growth and initiated fruit setting. Among grasses *Leptochloa fusca*,*Brachiaria mutica*, *Chloris gayana*, and species of *Sporobolus* were most promising for these soils. Those forest and fruit tree species which could not withstand stagnation of water could be grown successfully on raised bunds and the inter-spaces could be utilized for growing salt tolerant crops like rice (var. CSR-10) or forages like *Leptochloa fusca* and *Trifolium alexandrinum*. In another long term experiment on waterlogged saline soils about three dozen forest tree species were raised using three methods of planting, namely, ridge-trench, subsurface, and furrow method. The furrow technique provided favorable niches and was found most economical. *Prosopis juliflora*, *Tamarix articulata*, *Casuarina glauca*, *Acacia farnesiana*, *A. nilotica*, *A. tortilis*, and *Parkinsonia aculeata* were found most promising species for such areas. Thirty tree species were evaluated for saline irrigation (ECiw 8—10 dS/m) in a highly calcareous soil in low rainfall areas. The results showed that tree species like *Acacia nilotica, A. tortilis, A. farnesiana, Azadirechta indica, Eucalyptus tereticornis, Pithecellobium dulce, Prosopis juliflora, P. cineraria, Tamarix articulata*, and *Feronia limonia* hold promise. Among grass *species Panicum laevifolium, P. antidotale, P. virgatum, P. maximum, Cenchris ciliaris, C. setigerus, and Brachiaria mutica* were found promising and an irrigation of Diw/CPE 0.4 was found optimal for saline irrigation. One field experiment was conducted on calcareous saline soil. Seven under-explored species of industrial application were raised in furrows and three irrigation treatments (T_1: irrigation with available water of very high salinity, EC_i = 18—20 dS/m; T_2: irrigation with available water of EC_i = 8—10 dS/m; T_3: alternate irrigation with above two waters) were imposed. Results after two years showed that all seven species viz. (*Cordia rothii*, *Azadirachta indica*, *Salvadora persica*, *Jatropha curcas*, *Adhatoda vasica*, *Ricinus communis* and *Catharanthus roseus* performed well under all the treatments. In a separate trial vetiver (*Vetiveria zizanoides*) showed tremendous promise for calcareous saline soils yielding 72.6 t/ha to 78.7 t/ha fresh shoot and 1.19 t/ha to 1.73 t/ha root biomass when irrigated with saline water of 10 EC_i dS/m. The medicinal Isabgol (*Plantago ovata*) produced 1.35 t/ha to 1.55 t/ha high values medicinal material when irrigated with saline water of EC_i 10 dS/m. These results show that salt affected soils and poor quality waters can judiciously be utilized for growing forest & fruit trees, forage crops and low water requiring salt-tolerant non-conventional crops of industrial application.
Keywords: salt affected soils, poor quality waters, biosaline agriculture, augerhole and furrow techniques, non-conventional crops of industrial application

1 Introduction

In India, about 5.50 million ha land is saline (including coastal sandy areas), 3.88 million ha alkali, and 8.53 million ha waterlogged. Further, ground water surveys indicate that poor quality waters being utilized in different states especially in Rajasthan (84%), Haryana (62%), Punjab (41%), Karnataka (38%), Andhra Pradesh (32%) and Gujarat (30%). In such areas where ground water quality is poor and fresh water is not available for agriculture, the use of poor quality waters for irrigation is inevitable. Most of the developing countries in Asia are facing a daunting challenge of managing their ever- increasing human and cattle population to meet the requirement of food, fuel wood, forage, feed, medicine, timber and shelter. The arable lands are shrinking due to developmental activities. We cannot bring these high productive lands under forests; therefore, we are left with no option other than to bring marginal and salt-affected lands under cultivation. We may utilize these lands judiciously through agroforestry practices selecting suitable salt-tolerant species using bad quality water for irrigation. This will not only utilize the unproductive land judiciously but also will increase the economic condition of the farmers and also help in improving the ecological environment. The studies conducted at CSSRI reveal that the salt affected soils can be judiciously utilized for raising forestry, forages, agricultural and horticultural crops, and non-conventional crops of high economic value using bad quality water for irrigation selecting suitable salt-tolerant species.

1.1 Utilization of alkali soils for agroforestry

The alkali soils have high pH (saturation paste > 8.2 and at times approaching to 11), exchangeable sodium percentage (ESP) > 15, and varying of electrolytic conductivity (ECe). The presence of $CaCO_3$ concretions in 30 cm—70 cm thick layer known as "*kankar*" pan at about 1 m depth causes physical impedance for root proliferation, therefore, making it difficult for tree establishment. Sometimes many of these layers are present in the soil profile. Most of the alkali or sodic lands do not support good vegetation cover, with the exception of some restricted natural flora comprising only a few highly salt-tolerant bushes. In Indo-Gangetic plains about 0.7 mha of alkali lands have been reclaimed by adopting technologies evolved by CSSRI. This area is contributing nearly 3 million tonnes of rice and wheat annually. But use of amendments is a costly preposition. Moreover, in Common Property / Community lands the use of amendments is a social problem, hence the use of agroforestry practices is the ideal solution of utilizing these lands for increasing agricultural production and diversification of crops.

1.2 Evaluation of forest and fruit trees

To find suitable forest and fruit tree species for rehabilitation of high alkali soil (pH > 10) in semiarid regions long-term experiments were conducted (Dagar *et al*., 2001). Thirty forest tree species, 15 strains of *Prosopis*, and ten fruit tree species were planted. To identify suitable and cheap technology for forest tree species establishment two methods of planting were used (1) deep augers piercing the kankar pan, and (2) shallow augers not-piercing the kankar pan. After 7 years of planting, only 13 out of 30 species survived. Out of these thirteen surviving species only *Prosopis juliflora*, *Tamarix articulata* and *Acacia nilotica* were found suitable for such soils. *Eucalyptus tereticornis* showed good survival and height but no meaningful biomass production was observed. However, *Dalbergia sissoo, Pithecellobium dulce, Terminalia arjuna, Kigelia pinnata, Parkinsonia aculeata* and *Cordia rothii* showed more than 70% survival but could not attain economically suitable biomass (Tables 1 and 2). Changes in soil properties under three successful species showed that *Tamarix articulata* ameliorated the soil most showing maximum reduction in ESP and pH values in 7 years. *Prosopis juliflora* and *Acacia nilotica* followed these. Increase in organic carbon in upper 15 cm layer under *T. articulata* was 0.23%, under *P. julflora* 0.26% and under *A. nilotica* 0.10% while on lower depths between 15 cm—30 cm the increase was comparatively low. Reduction in exchangeable sodium percentage was 50 in *T. articulata*, 33 in *P. juliflora* and 20 in *A. nilotica* in upper 15 cm depth while in lower depths the reduction ranged from 14 to 30 in these species. As the site was protected by fencing, the natural grass community dominated by *Sporobolus marginatus* also played a role in soil amelioration which was almost similar in all plantations at least for first three years of the study. Later the grasses started vanishing beneath the tree canopies of *Tamarix*, *Prosopis* and *Acacia*. However, the grasses persisted with other tree species that had no significant cover. From these studies we can draw an inference that highly alkali soils with pH > 10, may be successfully rehabilitated with *Tamarix articulata*, *Prosopis juliflora* and *Acacia nilotica* for economic fuel-wood production, forage production (from local grasses) and soil amelioration. Out of 15 strains of *Prosopis* after six years of growth it was found that *P. jullifolra* was the most superior species in terms of growth and biomass production.

Among the fruit tree species two methods of planting (i.e. auger hole and pit-methods-pits of 90 cm × 90 cm × 90 cm size) were tested using 5 kg and 10 kg of gypsum in each auger hole and 10 kg and 20 kg of gypsum in each pit as soil amendments. After 7 years, it was found that *Ziziphus mauritiana, Syzygium cuminii, Psidium guajava, Emblica officinalis* and *Carissa carandus* were successful species for these soils showing good growth (Table 3) and also initiated fruit setting. At the establishment stage during two methods of trial there was no significant difference in growth up to 2 years but later the growth was better in pits.

Table 1 Survival, height and diameter at stump height of forest trees on highly alkali soil after 7 years of planting

Species	Survival (%)		Height (m)		Diameter (cm)	
	Deep Auger	Shallow Auger	Deep Auger	Shallow Auger	Deep Auger	Shallow Auger
Prosopis juliflora	97.4	86.0	3.98	2.59	8.3	5.3
Acacia nilotica	81.7	76.7	3.66	2.31	8.6	6.4
Tamarix articulata	89.4	74.4	3.24	2.56	7.3	5.4
Eucalyptus tereticornis	89.9	76.0	4.13	3.41	6.0	5.1
Dalbergia sissoo	86.3	83.5	1.99	1.87	6.1	5.3
Pithecellobium dulce	86.7	69.7	1.70	1.62	5.4	4.2
Terminalis arjuna	92.0	86.6	1.51	1.45	5.1	4.8
Kigelia pinnata	93.3	85.7	1.43	1.10	5.2	5.0
Cordia rothii	78.9	76.2	1.04	0.92	4.0	3.2
Parkinsonia aculeata	80.3	76.7	2.36	1.89	4.1	3.3
Anthocephalus cadamba	71.0	68.0	0.72	0.68	4.2	3.7
Acacia leucophloea	59.3	45.3	2.24	1.77	4.8	4.7
Tamarindus indica	26.5	15.3	1.30	1.29	4.1	3.6
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LSD (*P*=0.05)	Survival (%)	Height (m)	Diameter (cm)
Main (auger depth)	9.43	0.48	0.36
Sub (species)	14.22	0.46	1.11
Main × Sub (interaction)	20.11	0.65	NS

NS = Not significant Source: Dagar *et al.* (2001)

Table 2 Average air-dried biomass ($t \cdot ha^{-1}$) of some tree species after 7 years of growth on alkali soil

Species	Deep augerholes	Shallow augerholes
Tamarix articulata	97.33	31.71
Acacia nilotica	69.78	39.09
Prosopis juliflora	51.27	22.06
Eucalyptus tereticornis	14.38	5.20
Pithecellobium dulce	3.96	2.14
Terminalia arjuna	2.68	1.76
Dalbergia sissoo	1.75	1.18
Cordia rothii	1.48	0.62
Kigelia pinnata	1.17	0.49
Parkinsonia aculeata	1.15	0.90

LSD ($P \leq 0.05$): Between auger depths = 1.17; Between species = 5.94; Interactions (auger × species) = 3.70

Planting cost per hectare using the pit method (Rs. 42214) was almost double that of the pit-cum-augerhole method (Rs. 20396) as calculated based on 1992 prices. Regarding forest tree species, the cost of plantation was slightly less as compared to the pit-cum-auger hole method of fruit tree establishment. The expenditure of the forest tree plantation establishment was Rs. 15645 ha^{-1}. Although the number of plants per hectare was greater for the forest species, the cost on inputs and plant material was lower as compared to the fruit trees.

Table 3 Effect of site preparation techniques and amendments on performance of fruit species after 7 years of growth on highly alkali soil

Species	Site preparation techniques											
	Augerhole						Pit					
	5 kg gypsum			10 kg gypsum			10 kg gypsum			20 kg gypsum		
	Survival (%)	Height (m)	DSH (cm)	Survival (%)	Height (m)	DSH (cm)	Survival (%)	Height (m)	DSH (cm)	Survival (%)	Height (m)	DSH (cm)
Syzygium cuminii	100	2.76	9.8	100	2.90	10.7	98	3.17	11.7	100	3.98	12.6
Ziziphus mauritiana	96	3.38	5.9	96	3.46	6.2	98	3.52	7.1	100	3.70	7.4
Psidium guajava	100	2.70	8.5	98	2.72	8.7	100	3.20	10.1	98	3.52	10.7
Emblica officinalis	68	3.23	7.7	84	3.51	8.3	86	3.58	8.5	88	3.70	9.3
Carissa carandus	78	1.16	5.6	78	1.58	5.5	86	1.71	5.4	88	1.72	5.6
Tamarindus indica	98	2.73	6.7	98	2.82	6.7	98	2.79	6.9	100	2.90	7.1
Phoenix dactylifera	34	1.77	12.1	34	1.85	12.8	36	2.13	13.4	38	2.51	15.7
Morus alba	82	1.86	3.8	82	1.95	4.6	86	2.10	4.7	88	2.4	4.8

LSD($P \leq 0.05$)	Survival (%)	Height (m)	*DSH* (cm)
(1)Between planting techniques (A)	2.94	0.35	1.05
(2) Between amendment doses (B)	NS	NS	0.56
(3) Between species (C)	5.57	0.28	0.81
(4) interactions A×B	NS	NS	NS
(5) interactions A×C	NS	NS	1.15
(6) interactions B×C	NS	NS	1.15
(7) interactions A×B×C	NS	NS	NS

Source: Dagar *et al.* (2001).

1.3 Silvipastoral model for highly alkali soils

As mentioned above the most promising woody species for alkali soils are *Prosopis juliflora, Acasia nilotica,* and *Tamarix articulata.* Highly salt tolerant and high biomass producing grass species include *Leptochloa fusca, Chloris gayana, Brachiaria mutica* and species of *Sporobolus & Panicum.* Kumar (1998*)* reported respectively 40 t/ha, 50 t/ha, 25 t/ha, 40 t/ha, 20 t/ha, and 35 t/ha fresh forage yield by *Brachiaria mutica, Chloris gayana, Cynodon dactylon, Leptochloa fusca, Panicum antidotale, and P. maximum, when grown on an alkali soil with* pH *10.4 and ESP 90.* Mesquite *(Prosopis juliflora*) and *Kallar* grass (*L. fusca*) silvi-pastoral practice has been found most promising for firewood & forage production and soil amelioration. *Kalla*r grass in association with mesquite produced 46.5 t/ha green fodder in 15 cuttings over a period of 15 months without applying any fertilizer and amendment. Mesquite could produce 160 t/ha air-dried firewood in 6 years when planted at 2m × 2m spacing (Singh *et al.,* 1993). This system could improve the soil to greater extent after 6 years. More palatable fodder species such as shaftal (*Trifolium resupinatum*), berseem (*Trifolium alexandrium*) and senji (*Melilotus parviflora*) could be grown with mesquite after harvesting *kallar* grass even after a period of 4 years.

1.4 Raised and sunken bed technique for raising agroforestrytrees & crops on highly lkali soils

Many forest tree and fruit species can be raised on highly alkali soil (pH > 10) but some of them such as pomegranate (*Punica granatum*) are unable to tolerate water stagnation. To avoid water stagnation problem during monsoon “raised and sunken bed technique” has been found quite suitable for agroforestry practices on highly alkali soil. One fruit yielding (*Punica granatum*) and one oil-yielding (*Salvadora persica*) plantation species were successfully grown on raised bunds to avoid water stagnation and rice-wheat and berseem-kallar grass rotation on sunken-bed constructed for the purpose. The experiment was initiated in 1996 and above two crop rotations was followed for two consecutive years starting from *kharif* season. Results of these experiments (Dagar *et al.*, 2001) have shown that besides good growth of plantations on an average 4.33 t/ha to 4.90 t/ha rice (salt tolerant var. CSR-10) and 1.21 t/ha to 1.43 t/ha wheat (KRL 1-4) was obtained in sunken beds. In another rotation 21.31 t • ha^{-1} to 36.81 t • ha^{-1} fresh forage of *kallar* grass (*Leptochloa fusca*) and 44.86 t/ha to 47.76 t/ha fresh forage of *berseem* (*Trifolium alexandrium*) was obtained. After two years of experimentation soil amelioration in terms of reduction in soil pH was significant.

1.5 Agroforestry systems for partial reclaimed soils

Viewing agroforestry as a viable proposition, many progressive farmers like to grow trees and inter-crops simultaneously in early phase of reclamation. In this approach, the trees of commercial value are planted in wider space with the standardized auger-hole technique and the inter-space between the rows of trees is reclaimed with amendments like gypsum or pyrites. For higher returns and speedy reclamation of the soil, crops demanding high water like rice are advocated during initial years of reclamation. One experiment was conducted in CSSRI on a moderately alkali soil (pH<9.2) for 6 years (Singh *et al*., 1997). Three commercial trees viz. Poplar (*Populus deltoides*), eucalyptus (*E. tereticornis*) and kikar (*Acacia nilotica*) were planted on either sole or in association with a sequences of crops. The crop sequences were: rice-wheat for four years followed by guinea grass (*Panicum maximum*)-oats (*Avena sativa*) for two years, rice-berseem for 4 years followed by cowpea -berseem for two years, pigeonpea/sorghum-mustard for three years followed by turmeric for three years, and no inter-crop (only trees). *Eucalyptus* and poplar gained maximum height, girth and woody biomass in six years when they were inter-cropped with rice crops in sequences 1 and 2. *Acacia* attained maximum growth in the absence of inter-crops. Soil amelioration during five years followed the order: *Acacia* based system > poplar > *Eucalyptus* >sole crops. The benefit-cost ratio was highest (2.88) in poplar based system and minimum (1.86) in Acacia based system. The studies indicated that growing trees and agricultural crops together is a better land use option in terms of productivity, maintenance of soil conditions and economics.

2 Agroforestry of saline waterlogged soils

Saline soils contain excess neutral soluble salts, mainly chlorides and sulphates of sodium, magnesium and calcium, in quantities sufficient to affect plant growth adversely. The water-saturated paste extract of these soils has an electrical conductivity of 4 dS/m and above and pH less than 8.2. When chlorides and sulphates of Ca and Mg predominate soluble salts, the sodium absorption ratio (SAR) in the saturation extracts is usually less than 15. However, salinization with neutral soluble salts of na invariably results in SAR greater than 15. The plant growth in saline soils is adversely affected, chiefly, due to the osmotic effects of excess salts on the availability of soil water, and the toxic effect of specific ions e.g., chloride, sulphate and boron is often an additional factor determining plant-growth relationships in saline soils. Surface drainage is the viable remedy to reclaim these soils but it is highly costly technique and can not be accomplished without the Government's help. Therefore, raising salt-tolerant trees and crops remains the ideal option of rehabilitation of these lands.

2.1 Tree species for saline waterlogged soils

Afforestation programmes for saline waterlogged soils require the proper selection of tree species and planting technique. As the main problems of these soils are: high water table, high salinity of soil and underground water, impeded drainage and less soil aeration for tree growth, tree species should be those which can tolerate these multiple stresses. It is equally important that suitable planting method is adhered for making successful afforestation of highly saline waterlogged soils. It has been observed that by way of furrow planting technique, it is possible to keep salt concentrations relatively low in the rooting zone of tree saplings such that they are able to escape the adverse effect of high salinity. Tree species like *Acacia farnesiana, Parkinsonia aculeata, Prosopis juliflora, Salvadora persica, S. oleoides* and *Tamarix sp.* could be rated the most promising which could be grown satisfactorily on waterlogged saline soils with ECe > 25 dS / m in their active root zone whereas tree species such as *Acacia nilotica* , *A . tortilis* , *Casuarina glauca* 13,987 , *C. glauca* 13,144 and *C.obesa* 27 were observed as moderately tolerant. The experimental observations indicated that the survival and growth of tree species were markedly improved with furrow planting when compared with sub - surface and ridge - trench planting methods. The biomass of *Prosopis juliflora* and *Casuarina glauca* was the highest (98 t/ha and 96 t/ha), followed by *Acacia nilotica* (52 t/ha—67 t/ha) and *A. tortilis* (41 t/ha) when planted with subsurface or furrow techniques, proving that these are the suitable species for saline waterlogged soils (Tomar *et al.*,1998).

2.2 Judicious use of saline water for raising forestry, forages, flowers and plants of industrial importance

Since most of the productive lands having supply of good quality irrigation water are already being used for growing arable crops, in arid and semi-arid areas where growing of agricultural crops is not profitable due to availability of only saline ground water for irrigation, offer one of the possibilities for extending these lands for forestry. In many of these areas the quality of the underground water is extremely poor and poses a serious problem particularly in the regions where no alternative source of good quality water is available, the use of saline water for irrigation is inevitable. Thirty tree species were evaluated for saline irrigation (ECiw 8—10 dS/m) in a highly calcareous soil at Hisar. The results showed that tree species like *Acacia nilotica, A. tortilis, A. farnesiana, Azadirechta indica, Eucalyptus tereticornis, Pithecellobium dulce, Prosopis juliflora, P. cineraria, Tamarix articulata*, and *Feronia limonia* hold promise. Among grass *species Panicum laevifolium, P. antidotale, P. virgatum, P. maximum, Cenchris ciliaris, C. setigerus, and Brachiaria mutica* are promising It could be concluded that irrigation Diw/CPE 0.4 should be considered optimal for saline irrigation (with water of Eci 8—10 dS/m) for raising these grasses.

In another field experiment conducted on calcareous saline soil seven under-explored species of industrial application were raised in furrows and three irrigation treatments (T_1: irrigation with available water of very high salinity, EC_i = 18—20 dS/m; T_2 : irrigation with available water of EC_i = 8—10 dS/m; T_3 : alternate irrigation with above two waters) were imposed. Results after two years showed that all seven species viz. (*Cordia rothii, Azadirachta indica, Salvadora persica, Jatropha curcas, Adhatoda vasica, Ricinus communis* and *Catharanthus roseus* have performed well under all the treatments. Of course the growth performance was reduced with increase in salinity of irrigation water (Table 4). The salinity development in soil was low in the furrows as compared to inter-spaces between the two furrows. The salinity development under *S. persica* was least. Castor (*R. communis*) could yield 400 kg to 900 kg seeds per ha during first year itself. In a separate trial vetiver (*Vetiveria zizanoides*) showed tremendous promise for calcareous saline soils yielding 72.6 t/ha to 78.7 t/ha fresh shoot and 1.19 t/ha to 1.73 t/ha root biomass when irrigated with saline water of EC_i 8—10 dS/m. The medicinal Isabgol *(Plantago ovata*) produced 1.35 t/ha to 1.55 t/ha medicinal material when irrigated with this water. This could also be integrated with *Acacia nilotica* plantations without any significant yield reduction.

Table 4 The performance of different species under three irrigation treatments

Species	Height (m)			Stump diameter (cm)			Fresh biomass (kg/plant)		
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
Cordia rothii	2.55	3.81	4.68	5.41	8.22	9.61	4.24	10.47	16.14
Ricinus communis	1.47	2.52	4.16	4.78	4.91	7.38	1.34	4.23	5.41
Azadirachta indica	2.39	2.68	2.79	3.38	4.21	5.73	2.22	3.38	5.79
Jatropha curcas	1.21	1.65	2.26	4.91	6.32	7.02	1.81	5.23	10.75
Salvadora persica	1.16	1.40	1.59	1.70	2.26	3.74	0.63	1.31	2.68
Adhatoda vasica	0.67	0.83	1.17	1.30	1.71	2.84	0.18	0.81	2.24
Catharanthus roseus	0.37	0.62	0.70	1.01	2.39	2.43	0.48	0.58	0.67

LSD (P=0.05)	Height		Stump diameter		Fresh biomass	
	$P \leqslant 0.01$	$P \leqslant 0.05$	$P \leqslant 0.01$	$P \leqslant 0.05$	$P \leqslant 0.01$	$P \leqslant 0.05$
Between species(A)	0.176	0.124	0.124	0.088	0.227	0.160
Between treatments(B)	0.076	0.057	0.101	0.075	0.108	0.080
Interaction (A × B)	0.235	0.176	0.312	0.232	0.333	0.220
CV (%)	3.08		1.99		2.33	

Some aromatic and medicinal valued plants of arid and semi-arid areas were established in a field study to evaluate their potential with irrigation of underground saline water. These included Lemon grass (*Cymbopogon citratus*), Palmarosa (*Cymbopogon martinii*), 3 varieties of Vetiver (*Vetiveria zizanioides* var. NC 66403, NC 66404 and hybrid 8), Periwinkle (*Catharanthus roseus*), Ocimum (*Ocimum sanctum*), Celery (*Apium graveolens*), Kalmegh (*Andrographis paniculata*), Aloe (*Aloe barbadensis*), Citronella java (*Cymbopogon winterianus*), Mint (*Mentha piperita*), Isabgol (*Plantago ovata*) and Metha (*Trigonella foenum-graecum*). These were irrigated either with saline or canal water alone or with the alteration of canal and saline water. The experimental observations have suggested that there are many aromatic & medicinal valued plant species which have tremendous potential for cultivation with irrigation of underground saline waters having salinity up to 10 dS/m. Amongst the aromatic plants, Vetiver was found most promising which was followed by Palmarosa and Lemon grass. Celery behaved satisfactorily. Similarly in case of medicinal valued plant species, Isabgol was found very promising, as there was no significant reduction in its yield due to irrigation with saline water. *Aloe* was also found equally tolerant to saline environment.

Floriculture is a well-recognized field of business these days of modernization, though we are far behind in the international market. There is a huge demand of flowers in the America, Europe and other developed countries. These days it has become an industry and many Indian progressive farmers are cultivating flowers at large scale and earning good amount of money. The income from the flower industry on per unit area is generally many folds more than other industries. One experiment was conducted on calcareous soils at Bir Reserved Forest, Hisar. The soil was sandy loam in texture and highly calcareous in nature. The experiment consisted 10 promising seasonal flower species viz. Stock (*Matthiola incana*.), Antirrhinum (*Antirrhinum majus*), Sweetwilliam, Candituft (*Iberis amara*), Calendula (*Calendula officinalis*), Marigold (*Tagetes erecta),* Dahalia (*Dahalia rosea*), Ornamental mustard (*Brassica oleracea v*ar. ornamental), Chrysanthemum (*Chrysanthemum indicum*) and Matricaria (*Matricaria chamomilla*) which were evaluated with irrigation treatments of Canal water containing EC 0.4 dS/m, saline water containing EC in the range of 4 dS/m—5 dS/m, established with canal water and rest irrigation with canal water, alternate irrigation with canal and saline water, and one irrigation with canal water followed by two irrigations with saline water. In all 5 and 6 irritations were applied during first and second year of experimentation. The flower yield was markedly affected by saline irrigation in species like stock, antirrhinum, sweetwilliam, candiduft, marigold and dahalia. Maximum flower yield was recorded in case of chrysanthemum (1.08 kg • m $^{-2}$) followed by calendula (0.63 kg • m $^{-2}$) and matricaria (0.28 kg • m $^{-2}$). These species along with ornamental mustard were rated to be promising for saline irrigated conditions. In fact the weight of ornamental mustard was improved from 0.85 kg • m $^{-2}$ with canal water to 1.8 kg • m $^{-2}$ with saline water. Other flowering species produced viable yields only when established with canal water and saline water was introduced during later stages of their growth (Table 5).

Table 5 Weight of flowers (kg/plot of size 4 sq.m) of some selected flower species with different modes of canal and saline irrigation waters

Flower species	Irrigation treatments CW		SW		Est. CW & SW		Alt. 1：1		CW/SW 1：2	
	97	98	97	98	97	98	97	98	97	98
Anterinum	0.91	0.54	0.33	0.44	0.80	0.62	0.68	0.43	0.84	0.50
Calendula	1.80	1.93	1.89	2.28	1.99	2.29	1.47	2.23	1.18	2.35
Candiduft	1.05	1.23	0.27	1.01	0.65	1.40	0.40	1.21	0.98	0.97
Chrysanthemum	8.21	3.69	5.29	3.88	8.00	3.73	6.01	4.06	5.15	3.63
Dahalia	0.09	0.21	0.19	0.13	0.00	0.57	0.01	0.59	0.03	0.25
Marigold	0.56	0.49	0.26	0.23	0.32	0.67	0.38	0.73	0.52	0.43
Matricaria	1.67	1.05	1.39	1.03	1.32	1.06	1.21	1.10	1.50	0.96
Orn. mustard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sweetwilliam	0.95	0.34	0.06	0.11	0.35	0.20	0.32	0.35	0.24	0.18
Stock	0.99	0.72	0.65	0.69	0.85	1.01	0.54	0.82	0.88	0.64

LSD (*P*=0.05)	Irrigation	Species	Irrigation × Species
1997	0.24	0.34	0.75
1998	NS	0.21	NS

These results show that the salt affected soils and poor quality saline waters can judiciously be utilized for growing low water requiring salt-tolerant non-conventional under-explored salt tolerant crops of industrial application on marginal lands. Success in this endeavor requires development of appropriate management systems for their economic explorations and a net work involving other agencies having stake in biosaline agriculture.

References

Dagar J.C., H.B. Sharma , Y.K. Shukla . 2001. Raised and sunken bed technique for agroforestry on alkali soils of Northwest India. *Land Degradation & Development* **12:** 107-118.

Dagar J.C., G. Singh, N. T. Singh. 2001. Evaluation of forest and fruit trees used for rehabilitation of semiarid alkali/sodic soils in India. Arid Soil Research & Rehabilitation **15:** 115-133.

Singh G., N.T. Singh , O.S.Tomar. 1993. Agroforestry in salt affected soils. *Research Bulletin*. CSSRI, Karnal.p.65.

Singh G, N.T.Singh, J.C. Dagar, H.Singh, V.P. Sharma. 1997. An evaluation of agriculture, forestry, and agroforestry practices in a moderately alkali soil in northwestern India. *Agroforestry Systems* **37**: 279-295.

Tomar O.S., R.K.Gupta, J.C.Dagar. 1998. Afforestation techniques and evaluation of different tree species for waterlogged saline soils in semiarid tropics. *Arid Soil Research & Rehabilitation* **12**: 301-316.