Indian Journal of Ecology (2018) 45(4): 841-849

Manuscript Number: 2770
NAAS Rating: 4.96

Managing Saline Soils of Indo-Gangetic Plains with *Eucalyptus* and *Melia* based Agroforestry Systems

R. Banyal, R.K. Yadav, Parvender Sheoran, A.K. Bhardwaj, Parveen Kumar Rajkumar and Rahul Tolia

ICAR-Central Soil Salinity Research Institute, Kachhwa Road, Karnal-132 001, India
E-mail: drbanyal08@gmail.com

Abstract: Salinity is a common problem in irrigated agriculture and abandoned degraded areas. Agroforestry practices on abandoned lands could be the viable option to use saline lands for productive services with soil amelioration benefits. Therefore, an experiment was conducted in ICAR-Central Soil Salinity Research Institute, Karnal, Haryana for managing the saline soils with *Eucalyptus* and *Melia* based agroforestry systems. Three irrigation regimes viz. (i) I_1- saline and normal water in cyclic mode, (ii) I_2- best available water combined with need based saline irrigation, & (iii) I_3-control (rainfed conditions) and two landuses (LU) of (i) (LU_1) tree (*Eucalyptus tereticornis* and *Melia composita)* + crop (mustard and pearlmillet), and (ii) (LU_2) sole agronomical crops in open conditions. Both the systems studied independently and the results clearly indicate that both the systems adapted well in saline soils with saline irrigation. The best available water with need based saline irrigation (I_2) outperformed than the rest of the irrigation regimes in terms of establishment, growth of trees and companion crops and soil reclamation. Best available water combined with need based saline irrigation+trees+crops (I_2+LU_1) treatment combination observed to be the best in both the developed agroforestry systems. Germination and yield of mustard and peralmillet found to decrease with the increase in the salinity levels. For better mustard germination, the EC value should be at below 6.0 dS/m in field conditions. The EC (electrical conductivity) and pH values of soil found to decrease from its initial levels under the influence of irrigation with good quality water and tree+crop landuse which indicate the reclamation of saline soils. The synergistic effect of trees and intercrops on saline soils will certainly improve the biological productivity of saline soils. Such developed agroforestry systems in saline soils of Indo-Gangetic plains are the best option to manage saline soils on economical and ecological security mode.

***Keywords*:** Agroforestry system, Saline soils, *Eucalyptus*, *Melia*, Reclamation, Mustard, Peralmillet

Salinity is the rising problem in many parts of the world especially arid and semi-arid regions. This can be directly linked with the significant yield losses from the existing landuses. The total area of salt affected soils in the world is 831 m hectares which include 397 and 434 m hectares of saline and sodic soils, respectively. In India, 6.75 million hectares (M ha) land area is salt affected (Mandal et al 2010) and is likely to increase upto 20 m hectares by the end of 21^{st} century (CSSRI 2013). The area statistics showed that 80 per cent of salt affected soils are in arable cropping areas, 18 per cent co-existed with erosion and 2 per cent is located in the forest covered areas. This accounts for 2 per cent of the total geographical area of the country and 4.2 per cent of the total arable land area with major chunk in irrigated cropped area in canal commands. The total area under saline soils is 2.95 m ha (44% of the total salt affected soils) and spread in 12 states including Andaman and Nicobar island. Saline soils spread in 1.75 m ha area with poor quality ground water in inland plains of arid/semi arid regions and 1.2 m ha area in coastal plains intercepted by sea water intrusion with humid climate. Such areas could be put under utilization by using the salt tolerant flora. The methods in practice are the agronomic and/or phytoremediation. Agronomic practices driven by high labour cost and need developmental strategies for its effective delivery. On the other hand, phyto-remediation can be easily executed without any significant problems. Agroforestry system on salt-affected soils is one of the viable alternative land use option to use saline soils with their full potential for production and soil amelioration (Lambert and turner 2000 and Wicke et al 2013). Saline soils offer great potential for tree plantations because such lands are unsuitable for traditional agriculture practices. Plantation on saline soils is economical option to increase the availability of tree products to bridging the gap of demand and supply. Suitable salt tolerant tree species on saline soils not only provide the green coverage but also give good economical returns to the farmers. This could be one of the best practice to double the farmers' income by 2022. Based on earlier studies of categorization of woody species as highly and moderately tolerant, two tree species i.e. *Eucalyptus tereticornis* and *Melia composita* were selected for experimentation. *Eucalyptus tereticornis* is reported to be tolerant to soil salinity, sodicity or both (Marcar and Crawford 2004 and Souza et al 2015). *Eucalyptus* is also well known agroforestry tree species with rice-wheat cropping system on salt affected soils. But, it is not tested with low water intensive crops especially in saline soils. *Melia composita* is moderately tolerant to salinity and not tried yet in saline soils. Mustard is the third most important edible oil source in the world. In India, it is grown mainly for edible oil in about 7.0 m ha of arid and semi-arid regions of the country with poor quality ground water for irrigating the crop. Pearl millet has been reported to have high tolerance to salinity and drought thus, it can serve as an important fodder cum cereal crop in the arid and semi-arid regions of India. Therefore, two potential tree and crop species were selected for developing farm based models in saline soils under the influence of saline water irrigation.

MATERIAL AND METHODS

Study area: The study was conducted at Experimental Research Farm, Nain, Panipat of ICAR-CSSRI, Karnal, Haryana. Geographically, it extends from $29^0$19'7.09" to $29^0$19'10" N latitude and $76^0$47'30" to $76^0$48'0" E longitude and is located at an elevation of 230 to 231 m above mean sea level. The historical data showed severe salinity and poor quality ground water restricting agricultural activity.

Climate: The climate is semi-arid, sub-tropical and monsoonal receiving an average annual rainfall 678 mm. The maximum rainfall is received between July to October amounting to 548 mm, which accounts for 81 per cent of the total annual rainfall. The average annual evaporation is 1598 mm. The period between July to October remains water surplus, while remaining period is water deficit. The mean maximum and minimum temperatures were 37.9^0C and 6.2^0C, respectively indicating seasonal climate. The mean summer and winter soil temperatures were 38.3^0C and 5.9^0C, respectively. Mean annual soil temperature (MAST) is 26.5^0C that showed hyperthermic soil temperature regime. Soil moisture regime is primarily ustic.

Soil and ground water table: The soil was saline with poor quality ground water and electrical conductivity (EC) ranged from 4 to >30 dS/m. The range of soil pH was from 7.21 to 9.25.

Experimental details: *Eucalyptus tereticornis* (Clone 413) and *Melia composita* saplings were planted in line geometry with 4x3 m and 6x3 m spacing in N-S direction. The saplings were planted after making the pits of 100 cm in depth and 30 cm in width with tractor mounted auger hole to facilitate the roots to penetrate deeper in the soil. The pits were re-filled in ratio of 2:1:1with mixture of original soil+sand+FYM. The saplings of both trees were out-planted in August, 2014 (monsoon planting). After this, the sub-surface planting-cum-furrow irrigation method was adopted to irrigate the plantations. Initially, 3 to 4 irrigations of best available water (ECiw <1.0) was given with spot irrigation method to make the planted saplings survived on saline soils. Once the plants established, then saline irriqation (ECiw ranging from 2.75 to 4.0 dS/m) were given. There were three irrigation regimes viz. (i) I_1- saline and normal water in cyclic mode, (ii) I_2- best available water combined with need based saline irrigation, and (iii) I_3-control (rainfed conditions). There were three landuses (LU) treatments which comprised of (i) (LU_1) tree (*Eucalyptus tereticornis* and *Melia composita)* + crop (Mustard and Pearlmillet), (ii) (LU_2) sole agronomical crops in open conditions, (iii) (LU_3) sole tree. Both the tree species were planted in separate blocks comprised of nine rows with 19 plants in each row of individual tree species. Mustard and Pearlmillet were sown in rabi and Kharif seasons under *Eucalyptus* and *Melia* trees and in open area without trees. The experiment was laid out in Strip Plot Design with three replications.

Response variables: The response variables recorded in trees were survival percent , plant height (cm), diameter at breast height (DBH) (cm), number of branches, length of longest branch (cm) and crown spread (cm^2) in October, 2016 (with the onset of autumn season). The parameters recorded in Pearlmillet were total yield (q/ha) and correlation with salinity. In mustard the parameters like germination %age, average plant height (cm), average number of primary branches, average number of secondary branches, mean shoot length (MSL), average number of pods per plant, average yield per plant (g), total yield per plot (Kg) and total yield per ha (q) were recorded. Correlation was also drawn with the Mustard yield and soil salinity level. In addition to this, soil attributes were also observed to determine the change in the salinity level of the soil in respect of the reclamation measure. For this, electrical conductivity (EC_2) and pH were measured at the start and end of the experiment to estimate the addition or reduction in the salinity level in surface layer of the soil.

RESULTS & DISCUSSION

Eucalyptus based agroforestry system

Plantation survival and growth: The data on planted survival and increment in growth parameters are presented in Table 1. All the plants survived in treatment I_2 (100%) followed by I_1 and I_3. The lowest survival was observed in the trees maintained on rainfed and/or life saving irrigation. The life saving irrigation was given only in summer months i.e. from April to June frequently and occasionally in winter

Table 1. Effect of irrigation regimes on establishment and growth of *Eucalyptus tereticornis* plantations in saline soils

Irrigation	Establishment and % increment in growth attributes					
	Survival (%)	Plant height	DBH	No. of branches	Longest branch	Crown spread
I_1	95.00	38.33	228.3	12.0	30.5	80.5
I_2	100.0	41.00	238.7	15.3	33.1	91.4
I_3 (Control)	80.00	22.00	212.3	9.40	20.1	60.2
Mean	91.67	33.78	226.4	12.2	27.9	77.4
CD (p=0.05)	NS	3.03	4.24	NS	2.36	0.56

months during long dry spells. These results on survival percentage are in line with findings of Akhtar et al 2008. The growth parameters were analyzed on the basis of increments attained by plants in second year of growth during January to October, 2016. The two year old *Eucalyptus* plantations gave higher increments of growth parameters namely plant height, DBH, number of branches, longest branch length and crown spread when irrigated with (I_2) best available water combined with need based saline water than (I_1) saline and normal water in cyclic mode and (I_3) control. DBH parameter gave highest increment (%) among all the recorded parameters in all the applied irrigation treatments. The lowest increment
(%) was in number of branches and gave non-significant effect of irrigation regimes. Highest and lowest increment in DBH and number of branches is due to fast growing nature and the silvicultural behavior of the *Eucalyptus tereticornis*. The order of the growth parameters in terms of percent increment was DBH>crown spread>plant height >longest branch >number of branches. The increment in tree growth parameters is low in saline soils than the normal soils. In these soils, the plants may not absorb optimum water and nutrients from soil solution due to the presence of salts which results in higher concentration of the soil solution. This lead to de-osmosis process in plants and in extreme cases eventual death of plants may occurred.

Growth and yield of intercrops

Mustard: The effect of salinity on germination of mustard was statistically significant. The correlation was positive with statistical significance showing the value of R^2 0.80. The germination percentage was decreased with the increase in salinity of soil from 0.93 to 9.39 dS/m. Germination ranged from 40 to 90 percent reported in plots having EC_2 upto 4 dS/m and rated as good germination. However, the low germination (<40%) was reported in the plots with salinity more than 4 and upto 9.39 dS/m. This indicates that EC_2 value has direct influence on the germination of the mustard. The results are in line with the existing facts that salt and osmotic stresses are responsible for inhibition in seed germination and seedling establishment (Almansouri et al 2001). Germination failure and low growth in saline soils are often the result of high salt concentration in the seed planting zone caused by upward movement of soil solution and subsequent evaporation at the soil surface. Salt stress on seed germination may be attributed to either osmotic effect and/or to specific ion toxicities to radicle emergence or seedling development. Sharma et al (2013) also reported that the mustard germination and growth characteristics of seedlings were significantly affected by salinity. Salinity affects the growth and development of *Brassica juncea* in various ways. The most common adverse effects of salinity are the reduction in plant height, size and yield as well as deterioration of the product quality (Zamani et al 2011).

Irrigation regimes and landuse pattern gave statistical significant effect on germination, growth and yield parameters of mustard (Tables 2 and 3)**.** The I_2 and LU_1 individually or in combination gave highest values of germination, growth parameters (average plant height, average number of primary branches, average number of secondary branches, mean shoot length and average number of pods per plant) and yield than the rest of tested treatments. The highest germination (46.3%) percentage was in I_2 followed by I_1 and I_3. LU_1 gave better outcome than LU_2. Similar, trend was observed in growth and yield parameters with respect to the landuse and irrigation regimes. The maximum (9.63 q/ha) yield was in I_2 and minimum (2.0 q/ha) in I_1 maintained under rainfed conditions. The yield was more (6.65 q/ha) alongwith the trees (LU_1) than the open situation (5.47 q/ha) (LU_2). The yield was statistically significant with interaction combination of irrigation and landuse pattern. I_2+LU_1 gave better outcome in all the yield parameters. The higher yield in I_2 with LU_1 is directly ascribed to the quality of irrigation water and synergistic effect of trees. The higher values of growth parameters with I_2+LU_1 reflected in the total yield.

Peralmillet: Peralmillet was grown during Kharif 2016 (July to October) under the influence of irrigation regimes (I) and landuse pattern (LU) (Table 4). The Peralmillet yield was significantly higher with I_2 (7.59 q/ha) than I_1 and I_3 irrigation regimes**.** As far as landuse are concerned, the yield was higher (6.97 q/ha) in LU_1 and lower (6.29 q/ha) in LU_2. The interactional combination of I and LU gave statistical significant effect on yield. But, the I_2+LU_1 combination outperformed over the others. The higher yield in I_2 was because of the application of best available water with need based low salinity water. The best available water kept the soil salinity at low level compared to I_1 and control irrigation treatments. The soil salinity ranged in I_1 treated plots varied from 0.94 to 8.68 with average of 4.0 dS/m in the season. In I_2

the EC ranged from 0.93 to 9.39 with average of 3.79 dS/m. The open plots gave 6.29 q/ha yield in which the EC ranged from 3.12 to 5.07 dS/m with average of 4.25 dS/m. The yield was lower in open plots than the plots in alley and/or under trees. The higher yield in plots under the trees may be due to the synergistic effect of the trees on the adjoining crops. The trees are helpful in creating congenial conditions for the intercrops during the initial years up to the time of canopy closure. The trees kept the soil moist and cool in the plots under the trees than the plots without trees. The low rate of upward flux due to partial tree canopy covering may also be responsible in creating low salinity level in rhizosphere resulted in higher yield. Moreover, the results are in congruous with findings of Makrana et al (2017) that the increase in the salt concentrations of irrigation water from good quality to EC 9.0 dS/m caused significant decrease in Peralmillet grain yield. They further observed 37.44 per cent yield reduction at the higher salinity (9 dS/m) of irrigation water compared to good quality water.

A correlation was derived to see the effect of soil salinity on the peralmillet yield (Fig. 3). Although, the correlation was non-significant with R^2 value of 0.34 but, there was reduction in yield with the increase in the soil salinity. The line of correlation is smoothly declined with the increase in EC value from 2 to 10 dS/m. So, it infers from the figure that there is direct effect of salinity on peralmillet yield in saline soils.

Soil status: There was reduction in the EC and pH values from the initial soil status among all the applied treatments (Tables 5 and 6). However, the reduction in the values depends on specific applied treatment. I_2 irrigation regime applied in LU_1 and LU_2 gave the higher (-1.86 and -1.83 dS/m in mustard and -1.84 and -1.63 dS/m in pearlmillet) reduction from the initial value of EC than the other treatments. The minimum (-0.73 dS/m) reduction of EC was observed in control in both the crops. It is further observed that the reduction was more in plots under the trees than open condition irrespective of irrigation regimes. Trees and crops have synergistic positive effect on soil to keep the salinity level in check as compared to open areas. Similar trend was observed in case of pH. The effect of irrigation regimes and landuse pattern on pH with pearlmillet crop was non-significant. The change was minor in the pH value from its initial status. The decrease in soil pH might be due to the release of acidic root exudates. The reduction in EC is possible because of trees larger and deeper root system which provides channels for leaching of soluble salts away

Table 2. Germination and growth of mustard in varying irrigation regimes and landuse patterns in *Eucalyptus* based agroforestry system

Irrigation regimes (ECiw)	Germination %			Plant height (cm)			No. of primary branches			No. of secondary branches			Mean shoot length (cm)			No. of pods/plant		
	LU_1	LU_2	Mean	LU_1	LU_2	Mean	LU_1	LU_2	Mean	LU_1	LU_2	Mean	LU_1	LU_2	Mean	LU_1	LU_2	Mean
Landuses																		
I_1	25.0	22.5	23.8	100.0	75.0	87.50	4.8	4.50	4.65	12.8	10.6	11.7	35.6	26.5	31.1	128.0	100.0	114.0
I_2	60.4	32.1	46.3	125.7	82.2	104.0	6.3	5.83	6.07	18.7	14.0	16.3	44.5	31.8	38.1	195.2	148.2	171.7
I_3 (Control)	18.5	18.5	18.5	65.00	65.0	65.00	3.7	3.75	3.75	7.50	7.50	7.50	20.3	20.3	20.3	85.50	85.50	85.50
Mean	34.6	24.4		96.90	74.1		4.9	4.69		13.0	10.7		33.5	26.2		136.2	111.2	132.7
CD(p=0.05)	I: 1.75 LU:2.47 IxLU: 1.75			I: 2.92 LU:4.13 IxLU: 2.92			I: 0.22 LU:0.32 IxLU: NS			I: 0.52 LU:0.74 IxLU: 0.52			I: 0.54 LU: 0.76 IxLU: 0.54			I: 1.72 LU:2.43 IxLU: 1.72		

Table 3. Effect of varying irrigation regimes and landuse patterns on mustard yield in *Eucalyptus* based agroforestry system

Irrigation regimes (ECiw)	Yield/plant (g)			Yield/plot (kg)			Yield/ha (q)		
	LU_1	LU_2	Mean	LU_1	LU_2	Mean	LU_1	LU_2	Mean
Landuse									
I_1	4.60	3.95	4.28	5.15	3.95	4.55	6.59	6.52	6.56
I_2	7.64	5.50	6.57	8.87	4.79	6.83	11.4	7.90	9.63
I_3 (Control)	2.50	2.50	2.50	2.00	2.00	2.00	2.00	2.00	2.00
Mean	4.91	3.98		5.34	3.58		6.65	5.47	
CD (p=0.05)	I: 0.64 LU:0.90 IxLU: 0.64			I: 0.52 LU:0.73 IxLU: 0.52			I: 0.22 LU:0.31 IxLU: 0.22		

from rhizosphere. Variation in EC and pH was observed only for one year (November 2015 to October 2016). Therefore, the changes are very less as far as soil reclamation is concerned. The values of pH in I_3 were little bit low while compared with I_1 and I_3. This may be directly ascribed to the quality of irrigation water in addition to the landuse patterns.

Melia based agroforestry system

Plantation survival and growth: The effect of applied treatments on survival and growth increments in two year old *Melia composita* plantations was statistically significant except plant height and crown spread **(**Table 7**)** being highest (91%) in I_2 followed by I_1 (87%) and I_3 (70%). The I_2 irrigation treatment maintained its superiority over the rest of the two treatments in terms of all the studied growth parameters namely plant height, DBH, number of branches, length of longest branch and crown spread. The highest (249.2 %) percent increment was reported in DBH and minimum (15.8%) in longest branch parameter. The ascending order of the percent increment of all the growth parameters were DBH>crown spread>plant height>length of longest branch>number of branches. The trend of observed parameters can be linked with the silvicultural characteristics of *Melia composita*.

Growth and yield of intercrops

Mustard: The EC value of plots ranged from 1.05 to 7.44 dS/m irrespective of irrigation regimes. The correlation of

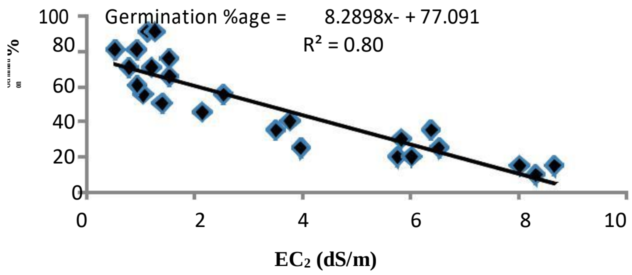

Fig. 2. Effect of salinity levels on Mustard germination (%) under *Eucalyptus* plantations

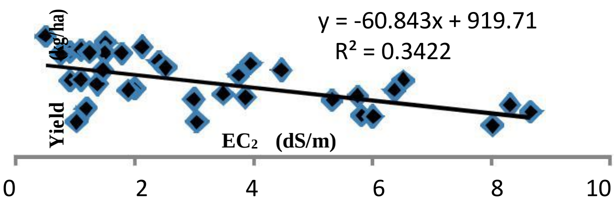

Fig. 3. Correlation of soil salinity (EC_2) with peralmillet yield in *Eucalyptus* based agroforestry system

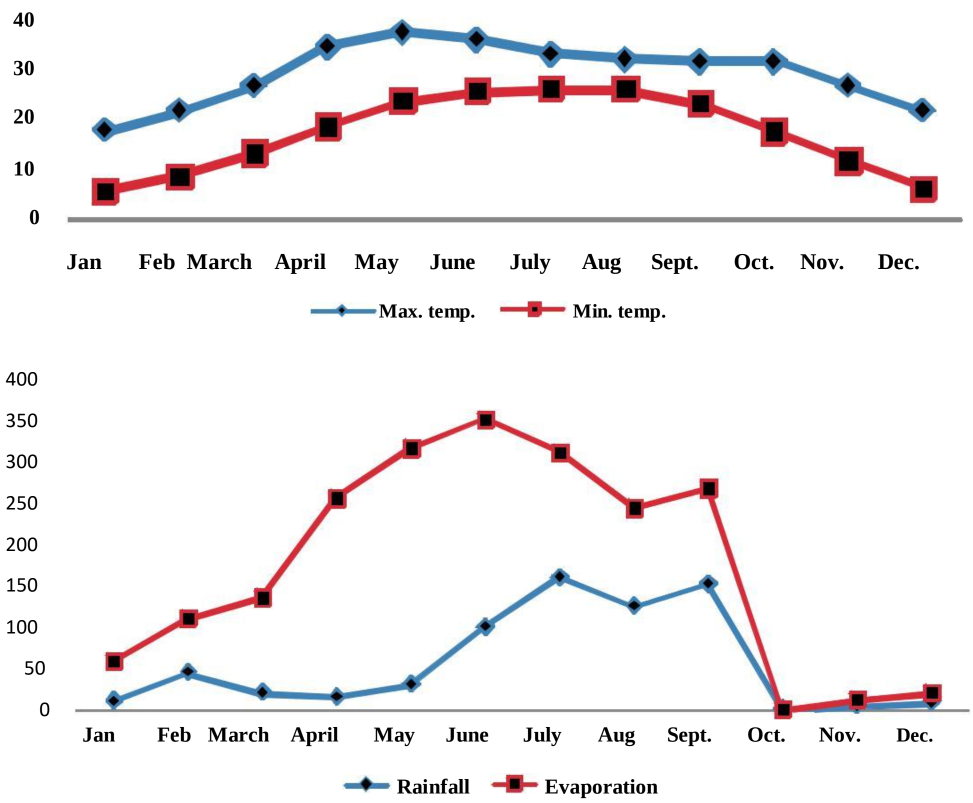

Fig. 1. Average climatic pattern variables

germination and salinity was significant with R^2 value of 0.75. There was consistent decline in germination percent from low to higher salinity levels (Fig. 4). So, it discerns from the correlation equation that EC value has direct effect on the germination. It is further observed that the mustard seeds germinated in the EC ranged from 1.05 to 6.0 dS/m. However, sporadic germination was observed beyond 6 dS/m. The results are in line with the outcome of the Singh and Sharma (2016) that mustard can be germinated upto EC 9.0 dS/m in soils and 12 dS/m with saline irrigation. It can be concluded from the experiment that for better germination, the EC value should be at low i.e. below 6.0 dS/m in field conditions.

The effect of irrigation regimes (I) and landuse patterns (LU) on germination percent, growth and yield parameters was statistically significant (Table 8 and 9). I_2 gave better outcomes in terms of intercrop than I_1 and I_3. The plots in alley gave the highest germination, growth and yield attributes than the plots in the open conditions. Similarly, LU_1 gave the higher values of all the tested parameters namely germination (53.03%), average plant height (115 cm), average number of branches (7.28), average number of secondary branches (16.9), mean shoot length (41.2 cm), average number of pods per plant (170), yield per plant (25.6 g), yield per plot (7.95 kg) and total yield (11.8 q/ha) than LU_2. The order of interactional effect of applied treatments in terms of gains were as $I_2+LU_1>I_1+LU_1>I_2+LU_2>I_1+LU_2>I_3$ which clearly indicate the effect of irrigation regimes and landuse patterns. The higher yield under the *Melia* trees because of its sparse crown and deciduous nature which didn't interfere in the sun light availability (PAR).

Pearlmillet: Peralmillet yield was statistically significant with irrigation regimes and landuse patterns (Table 10). The highest peralmillet yield (6.42 q/ha) was recorded in the plots irrigated with best available water with low saline need based irrigation (I_2) followed by I_1 (5.90 q/ha) and I_3 (4.0 q/ha). The

Table 4. Effect of irrigation regimes and landuse pattern on peralmillet yield in *Eucalyptus* based agroforestry system

Irrigation regimes (ECiw)	Yield/plot (kg)			Yield/ha (q)		
	LU_1	LU_2	Mean	LU_1	LU_2	Mean
	Landuse					
I_1	7.00	6.31	6.66	7.04	6.35	6.70
I_2	8.25	6.48	7.37	8.28	6.90	7.59
I_3 (Control)	5.65	5.65	5.65	5.60	5.60	5.60
Mean	6.96	6.15		6.97	6.28	
CD (p=0.05)	I: 0.10 LU: 0.15 IxLU:0.10			I: 0.13 LU: 0.0.18 IxLU: 0.13		

Table 5. Effect of irrigation regimes and landuse patterns on soil reclamation status in *Eucalyptus* based agroforestry system with mustard as intercrop

Irrigation regimes (ECiw)	EC			pH		
	LU_1	LU_2	Mean	LU_1	LU_2	Mean
	Landuse					
I_1	-1.66	-1.63	-1.64	-0.120	-0.08	-0.10
I_2	-1.86	-1.83	-1.84	-0.170	-0.20	-0.19
I_3 (Control)	-0.73	-1.73	-0.73	-0.050	0.05	-0.05
Mean	-1.42	-1.39		-0.113	-0.11	
CD (p=0.05)	I: 0.05 LU: 0.06 IxLU:0.05			I: 0.03 LU: 0.05 IxLU: 0.03		

Table 6. Effect of irrigation regimes and landuse patterns on soil reclamation status in *Eucalyptus* based agroforestry system with peralmillet as intercrop

Irrigation regimes (ECiw)	EC			pH		
	LU_1	LU_2	Mean	LU_1	LU_2	Mean
	Landuse					
I_1	-1.08	-1.06	-1.07	-0.39	-0.30	-0.35
I_2	-1.84	-1.63	-1.74	-0.42	-0.35	-0.39
I_3 (Control)	-0.73	-0.73	-0.73	-0.10	0.10	-0.10
Mean	-1.222	-1.39		-0.30	-0.25	
CD (p=0.05)	I: 0.06 LU: NS IxLU:NS			I: 0.04 LU: NS IxLU: NS		

Table 7. Effect of irrigation regimes on establishment and growth of *Melia composita* plantations in saline soils

Irrigation regimes (ECiw)	Establishment and % increment in growth attributes					
	Survival %	Plant height	DBH	No. of branches	Longest branch	Crown spread
I_1	87.0	30.5	250.7	20.5	16.3	75.0
I_2	91.0	33.5	267.0	24.1	18.8	81.0
I_3 (Control)	70.0	22.6	230.0	15.0	12.3	67.0
Mean	82.7	28.9	249.2	19.9	15.8	74.3
SEd.	1.41	1.73	3.39	0.88	0.21	2.45
CD (p=0.05)	2.74	NS	6.58	1.64	0.41	NS

Irrigation regimes (EC_{iw})	Germination% LU1	LU2	Mean	Plant height(cm) LU1	LU2	Mean	No.of primary branches LU1	LU2	Mean	No.of secondary branches LU1	LU2	Mean	shoot length(cm) LU1	LU2	Mean
I1	66.0	44.7		138.75.106.206			8.4.6.20.7.80.604			10.15.48.021			26.37.53		
I2	773.	449.		89141.100120.			38801099.4.7.22			78212.17.55.			6435.45.		
I3 (Control)	518.	518.		000065.65.65.			7575750033.3.7.			509337.7.20.			3320.20.		
Mean	63.22.030			11580.0			7.4.16.28399			10.41.12			27.5		
SEd	I:0.54 LU:0.76 IxLU:0.54			I:3.03 LU:4.28 IxLU:3.03			I:0.25 LU:0.35 IxLU:0.25			I:0.50; LU:0.71 IxLU:0.50			I:0.25 LU:0.35 IxLU:0.25		
CD(p=0.05)	I:0.96 LU:1.36 IxLU:0.96			I:5.39 LU:7.62 IxLU:5.39			I:0.45 LU:0.63 IxLU:0..45			I:0.89 LU:1.26 IxLU:0.89			I:0.45 3 IxLU:0.45		

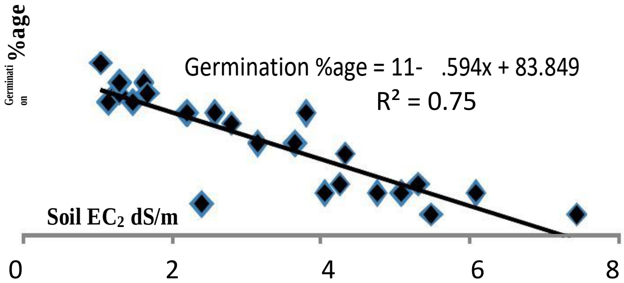

Fig. 4. Effect of salinity levels on mustard germination (%) under *Melia* plantations

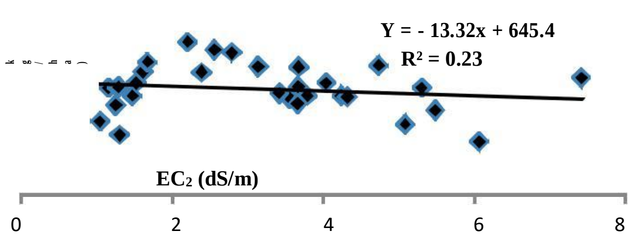

Fig. 5. Correlation of EC_2 with Pearlmillet yield in *Melia* based agroforestry system

yield was higher (5.54 q/ha) in LU_1 and lower (5.35 q/ha) in LU_2. The interactional effect of applied treatments were statistically significant and the ascending order of yield was like $I_2+LU_1 > I_2+LU_2 > I_1+LU_1 > I_1+LU_2 > I_3$. The yield was higher under the *Melia* trees than the in open plots in both the irrigation regimes. The reason for better yield under *Melia* trees may be due to synergistic effect on the intercrop. The results are in line with the earlier findings of the work carried out by Banyal et al (2016) to develop *Melia composita* based agroforestry systems for saline ecologies.

A correlation was drawn between soil EC and peralmillet yield and the value of R^2 was non-significant (0.23) but, it is clear from the equation line that the yield was higher in low salinity plots and decreased with the increase in the salinity level . The EC of plots ranged from 1.05 to 7.44 dS/m at the time of harvesting of the crop irrespective of irrigation regimes and landuse patterns. The equation line clearly infers that the soil salinity has direct effect on the peralmillet yield. Makrana et al (2016) has reported that successive increase in salinity levels decreased the peralmillet green fodder yield in saline soils.

Soil status: The effect irrigation regimes and landuse patterns was statistically significant for EC and pH values (Table 12 & 14). The highest reclamation observed in the plots irrigated with (I_2) best available water and need based low saline irrigation which gave low values of EC and pH. LU_1 outperformed over the LU_2 in reference of soil reclamation. The minimum decrease in EC and pH was observed in

Table 9. Effect of varying irrigation regimes and landuse patterns on mustard yield in *Melia* based agroforestry system

Irrigation regimes (ECiw)	Yield/plant (g)			Yield/plot (kg)			Yield/ha (q)		
	LU_1	LU_2	Mean	LU_1	LU_2	Mean	LU_1	LU_2	Mean
					Landuse				
I_1	34.1	8.95	21.5	7.07	3.92	5.50	15.4	6.52	11.0
I_2	40.2	4.60	22.4	8.62	5.15	6.89	17.9	6.72	12.3
I_3 (Control)	2.50	2.50	15.5	8.15	8.15	8.15	2.00	2.00	2.00
Mean	25.6	5.35		7.95	5.74		11.8	5.08	
SEd.		I: 9.37 LU: 13.26 IxLU: 9.38			I: 5.85 LU: 8.27 IxLU: 5.85			I: 0.15 LU: 0.22 IxLU: 0.15	
$CD_{0.05}$		I: 16.7 LU: 23.6 IxLU:16.7			I: 10.41 LU: 14.72 IxLU:10.41			I: 0.27 LU: 0.38 IxLU:0.27	

Table 10. Effect of irrigation regimes and landuse pattern on pearlmillet yield in *Melia* based agroforestry system

Irrigation regimes (ECiw)	Yield/plot (kg)			Yield/ha (q)		
	LU_1	LU_2	Mean	LU_1	LU_2	Mean
			Landuse			
I_1	10.8	10.0	10.4	6.12	5.69	5.90
I_2	12.6	10.8	11.7	6.50	6.35	6.42
I_3 (Control)	4.00	4.00	4.00	4.00	4.00	4.00
Mean	9.13	8.28		5.54	5.35	
SEd.		I: 0.46 LU: 0.65 IxLU: 0.46			I: 0.18 LU: 0.25 IxLU: 0.18	
CD (p=0.05)		I: 0.82 LU: 1.16 IxLU:0.82			I: 0.32 LU: 0.45 IxLU: NS	

Table 11. Effect of irrigation regimes and landuse patterns on soil reclamation status in *Melia* based agroforestry system with mustard as intercrop

Irrigation regimes (ECiw)	EC			pH		
	LU_1	LU_2	Mean	LU_1	LU_2	Mean
			Landuse			
I_1	-1.63	-1.56	-1.59	-0.12	-0.08	-0.10
I_2	-1.83	-1.76	-1.79	-0.17	-0.20	-0.18
I_3 (Control)	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30
Mean	-1.25	-1.21		-0.20	-0.19	
SEd.		I: 1.41 LU: 0.03 IxLU: 0.02			I: 0.02 LU: 0.03 IxLU: 0.02	
$CD_{0.05}$		I: 2.51 LU: 0.06 IxLU:0.04			I: 0.04 LU: NS IxLU: NS	

Table 12. Effect of irrigation regimes and landuse patterns on soil reclamation status in *Melia* based agroforestry system with peralmillet as intercrop

Irrigation regimes (ECiw)	EC			pH		
	LU_1	LU_2	Mean	LU_1	LU_2	Mean
			Landuse			
I_1	-0.53	-0.38	-0.45	-0.42	-0.35	-0.38
I_2	-0.66	-0.48	-0.57	-0.47	-0.40	-0.44
I_3 (Control)	-0.13	-0.13	-0.13	-0.10	-0.10	-0.10
Mean	-0.44	-0.33		-0.33	-0.28	
SEd.		I: 0.03 LU: 0.04 IxLU: 0.03			I: 0.02 LU: 0.03 IxLU: 0.02	
$CD_{0.05}$		I: 0.05 LU: NS IxLU:0.05			I: 0.04 LU: 0.06 IxLU: 0.04	

control plots which were maintained as rainfed conditions. The individual effect of landuse as well as combined effect of irrigation regimes and landuse were statistically non significant in case of soil pH. The order of reclamation was $I_2+LU_1>I_2+LU_1>I_1+LU_1>I_1+LU_2>I_3$. The combined effects of trees and crops are responsible for reduction in the EC and pH values. The planted trees and inter crops caused discernible changes in electrical conductivity (EC) and pH values of soil with respect to the irrigation (ECiw) and landuse (LU) pattern. The changes of EC and pH were less but showed the positive effect of treatments in reclamation process of soil. The irrigation treatment I_2 was reported to be better than the I_1 and control (rainfed condition) in both the seasons in *Melia* based farming system. Best available water with need based saline irrigation (I_2) with LU_1 and LU_2 gave higher (-1.83 and -1.76 dS/m in mustard and -0.73 and -0.66 dS/m in pearlmillet) and minimum (-0.3 in mustard and -0.13

dS/m in pearlmillet) reduction under rainfed conditions with the mustard as intercrop. The trend of soil reclamation was similar in mustard as well as peralmillet as intercrops with *Melia* trees. The trend of reduction in EC value is directly linked to the quality of irrigation water. This means that saline soils can be managed in effective and better way with the good quality water along with the trees.

CONCLUSION

Saline soils reclamation under the influence of trees and intercrops could be the viable option to increase the production function of these soils. The establishment of both the tree species especially *Melia* on such ecologies is the uniqueness of the developed agroforestry systems from others. The findings are only based on the initial trends and may differ with the passing time as trees get older. But, it is definite that the synergistic effect of trees and intercrops certainly make such soils of service use and results in the economical and ecological security of the farming communities facing the problem of salinity.

REFERENCES

Akhtar J, Saqib ZA, Qureshi MA, Haq MS, Iqbal MS and Marcar NE 2008. The effect of spacing on the growth of *Eucalyptus camaldulensis* on salt-affected soil in the Punjab, Pakistan. *Canadian Journal of Forest Research* **38**: 2434-2444.

Almansouri M, Kiner JM and Lutta S 2001. Effect of salt and osmotic stresses on germination in durum wheat (*Triticum durum*). *Plant and Soil* **31:** 243–254.

Banyal R**,** Yadav RK, Sheoran Parvender, Meena MD, Narjary Bhaskar and Sharma DK 2016. Agroforestry systems for saline ecologies of trans-gangetic plains. In national symposium on "*Agroforestry for environmental challenges, sustainable land use, biodiversity conservation and rural livelihood options*" December 3-5, 2016, ICAR-CAFRI, Jhansi, UP (India): 34.

Central Soil Salinity Research Institute (CSSRI) 2013. *Annual Report ICAR-Central Soil Salinity Research Institute*, Karnal, Haryana-132 001, India.

Lambert M and Turner J 2000. *Commercial Forest Plantations on Saline Land*. CSIRO Publishing, Collingwood.

Makarana Govind, Yadav RK, Kumar Rakesh, Gajendra, Soni Gupta Pooja, Yadav Taramani, Sheoran P and Kumar Ashwani 2016. Effect of irrigation water salinity on growth and yield of fodder Pearlmillet varieties. In 4th *International Agronomy Congress*, Nov. 22–26, 2016, New Delhi, India:552-553.

Makarana Govind, Yadav RK, Kumar Rakesh, Kumar Ashwani, Sheoran P, Yadav Gajendra, Soni Gupta Pooja, Yadav Taramani, Yadav Ram Malu, Kushwaha Manish and Gautam PB 2017. Growth, Yield and Grain Quality of Pearl Millet (*Pennisetum glaucum* L.) Genotypes as Influenced by Salinity of Irrigation Water in North Western Regions of I n d i a . *International Journal of Current Microbiology and Applied Sciences* **6**(6): 2858-2874.

Mandal AK, Sharma RC, Singh G and Dagar JC 2010. Computerized database on salt affected soils in India. *Technical Bulletin:* ICAR-CSSRI/Karnal/2010 Karnal:28.

Marcar NE and Crawford DF 2004. Trees for Saline Landscapes. *Rural Industries Research and Development Cooperation* (RIRDC), Kingston.

Sharma DK, Thimmppa K, Chinchmalatpure Anil R, Mandal AK, Yadav RK, Chaudhari SK, Kumar Satyendra and Sikka AK 2015. Assessment of production and monetary losses from salt affected soils in India, *Technical Bulletin*: ICAR-CSSRI/Karnal/2015/05.

Sharma Pushp, Sardana Virender and Banga SS 2013. Salt tolerance of Indian mustard (*Brassica juncea*) at germination and early seedling growth. *Environmental and Experimental Biology* **11**: 39-46.

Singh B 1998. Contribution of forest fine roots in reclamation of semi-arid sodic soil. *Arid Soil Research and Rehabilitation* **12:** 207-222.

Singh G, Singh NT, Dagar JC, Singh H and Sharma VP 1995. An evaluation of agriculture, forestry and agroforestry practices in moderately alkali soil in north-western India. *Agrofor. Syst.* **37**: 279–295.

Singh Jogendera and Sharma PC 2016. Comparative effects of soil and water salinity on oil quality parameters of *Brassica juncea*. *Journal of Oilseed Brassica* 7(1): 29-37.

Souza de Rodrigues Brenda, Freitas Silvestre Alberto Igor, Lopes Araujo de Vinicius, Rosa Rosario do Vanessa and Matos Santos Fabio 2015. *African Journal of Agricultural Research* **10**(10): 1091-1096.

Wicke Birka, Smeets Edward MW, Akanda Razzaque, Stille Leon, Singh K Ranjay, Awan Rasul Abdul, Mahmood Khalid and Andre PC Faaij 2013. Biomass production in agroforestry and forestry systems on salt affected soils in South Asia: Exploration of t h e GHG balance and economic performance of three case studies. *Journal of Environmental Management* **127**: 324-334.

Zamani Z, Nezami MT, Habibi D and Khorshidi MB 2011. Effect of quantitative and qualitative performance of four canola cultivars (*Brassica napus* L.) to salinity conditions. *Advances in Environmental Biology* **4**: 422-427.

Received 08 September, 2018; Accepted 20 October, 2018