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Impact of tree cropping models on exchangeable cations and soluble anions in reclaimation of sodic soil

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Abstract
All the tree cropping models viz. Aonla + Ber, Aonla + Guava, Ber + Guava + Phalsa, Aonla + Karonda and Aonla + Subabool improved the chemical properties of soil as compared to control (barren site). Decrease in exchangeable K^+, soluble Cl^-, SO_4^-, CO_3^{--}, HCO_3^-, boron and increase in exchangeable Ca^{++}, Mg^{++} indicated considerable improvement in chemical properties of sodic soil. Improvement was noticed more in upper depth as compared to lower depth as well as more under inside canopy as compared to open side canopy of plants.

Keywords: Fruit trees, Aonla, ber, guava, phalsa, subabool, canopy, exchangeable cations and soluble anions

Introduction
Land is one of the limited and inelastic resources, which is reached to the state of high degree of degradation and shrinkage due to over exploitation by ever increasing population growth and consequential anthropogenic pressure. Out of the total geographical area of 329 million ha, nearly 175 million ha area is suffering from different levels of degradation. Among degraded wastelands (173.08 million ha.), 7.0 million ha is adversely affected with excessive soluble salts/exchangeable sodium salts, which is unsuitable to profitable crop production. In Uttar Pradesh, out of 135.25 lakh ha degraded lands (46% of total geographical area), 12.0 lakh ha area is under sodic lands, which is difficult to manage for cultivation of agronomical crops with optimal crop harvest (Agrawal & Gupta, 1968). The majority of such lands is lying barren and has become ecologically and economically unproductive due to chronic degradation and denudation. The presence of excessive salt in soil decreases its productivity as the salt inhibits not only the plant growth, but also deteriorates physical and chemical properties of soil. Evidently, the distribution pattern of salt-affected soils in different areas and countries depends upon number of factors viz., geological, climatic hydrological, ecological conditions and natural water resources. Salt affected soils are quite variable in arid and semi-arid climate of India due to presence of predominating sodium salts, which is divided into saline and alkali/sodic soils. The alkali/sodic soil is characterized by high degree of sodium salts (>15%), pH range from 8.50 to 10.0, EC value less than 4 mmhos/cm and low infiltration rate. The absorption of sodium salt in such soil results into compact soil structure, low availability of essential plant nutrients and reduced microbial activities in soils, which inhibits the growth activities of most of the corps/plants.

The research work carried out earlier has shown that the reclamation of salt affected soils for cultivation of agronomical crop is not only expensive but management of such soil further becomes more complicated. Beside this, considerable systematic works have been undertaken at different institutions for growing of various agricultural crops, grasses, forest species, pulses and oil bearing trees in degraded lands (Gangulee, 1924; Rege and Tamhane, 1964; Kausik *et al.*, 1969; Bhumbla, 1977; Mahindra, 1983; Kumar and abrol, 1983; Singh and Randhawa, 1983; Tomar and Gupta, 1985) [7, 23, 11, 2, 13, 31, 33]. The growing of such tolerant fruit species in multi-tire cropping models is one of the new approaches of utilization of sodic lands and waste land. The effect of fruit trees based multiple cropping system in relation to changes in chemical properties like increase or decrease in exchangeable cations and soluble anions towards reclaimation of sodic soil, is not systematically worked out. Thus, keeping in view for efficient management of sodic lands through potential/ tolerant fruit species, the present investigation have been undertaken to find out the most suitable and potential cropping model for reclamation of salt affected soil.

Material and Methods

The present investigation was undertaken at the Wasteland Management Farm, Akma, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.) during the year 2010-11. The 12 year old five selective tolerant fruit species viz. Aonla, Ber, Guava, Phalsa, Karonda and one fodder species subabool planted in different cropping models in an area of 0.5 ha each under wasteland conditions having alkali/sodic soils and poor soil fertility status were taken under study. The plant spacing was kept 8 meter for Aonla, Guava, Ber and Phalsa and 4 meter for Karonda and Subabool. The pit size was 1 m^3 and filling mixtures were applied as per recommendations for sodic land plantation. The cultural practices were followed as per recommendations. The details of treatment are given below:

(1) Treatments

a. The tree cropping systems – 5

- Aonla + Ber (C_1)
- Aonla + Guava (C_2)
- Aonla + Karonda (C_3)
- Ber + Guava + Phalsa (C_4)
- Aonla + Subabool (C_5)

b. Sampling sites – 2

- Inside tree canopy (Basin)
- Outside tree canopy (Centre)

c. Control – 1 (bare site)

(2) Total treatment = 5 x 2 + 1 =11

(3) Design – Randomized Block Design (RBD)

(4) Replication – 4

(5) Plot size – 0.5 ha each.

Details of the cropping systems and plant population

S. No.	Tree cropping systems	Plot size (ha)	Total No of Plants per plot	Plant density /ha.
1	Aonla + Ber (C_1)	0.5	Aonla = 72 Ber = 50	144 100
2	Aonla + Guava (C_2)	0.5	Aonla = 72 Guava = 50	144 100
3	Aonla + Karonda (C_3)	0.5	Aonla = 72 Karonda = 110	144 220
4	Ber + Guava + Phalsa (C_4)	0.5	Ber = 50 Guava = 72 Phalsa = 60	100 144 120
5	Aonla + Subabool (C_5)	0.5	Aonla = 72 Subabool = 110	144 220
6	Control (C_0)	0.5	Nil	Nil

Collection of soil samples

The soil samples were collected from each plot of cropping model and control plot (barren site). The soil samples were taken randomly from the basin (inside canopy) of each tree species and between the centre of rows and plants from 4 selected spots of each model at the depth of 0-15, 15-30, 30-45 and 45-60 with the help of spade, khurpi, and soil serew auger after offset of mansoon i.e. in the month of October – November. The soil samples were collected from the inner rows of tree species by covering 4 trees (2 +2) of Aonla + Ber, Aonla + Guava, 8 trees (2 + 2 + 4) of Ber + Guava + Phalsa, 8 trees (2 + 6) of Aonla + Karonda and Aonla + Subabool.

Preparation of soil samples

The samples collected from the plots of different models were brought to the laboratory and fresh weight was taken. The samples were dried in the shade at room temperature as well as in oven at 105^0C temperature for 24 hours till the constant weight. Thereafter, each sample was grinded and sieved with 20 meshes and used for analysis of chemical properties soil as influenced by different cropping models.

Observations recorded

The exchangeable cations and soluble anions of sodic soil of soil samples were determined to find out the changes in chemical properties of soil as affected by each cropping models The data was analyzed statistically as per method given by Panse and Sukhatme (1985) and results were evaluated at 5 per cent level of significance. The methods employed for estimation of changes in soil properties is mentioned below.

Methods used in analysis of exchangeable cations and soluble anions of sodic soil

Soil properties	Methods adopted
Chemical properties	
Exchangeable cations i.e.	Determined by 1 N ammonium acetate (pH, 7.0) extractable soil water
Exchangeable Calcium (Ca^{++})	U.S.D.A. Hbk. No. 60, Method No. 18
Exchangeable Magnesium (Mg^{++})	U.S.D.A. Hbk. No. 60, Method No. 8
Exchangeable Sodium + Potassium ($Na^+ + K^+$)	U.S.D.A. Hbk. No. 60, Method No. 18
Soluble anions	
Soluble Chloride (Cl^-)	Method No. 13, U.S.D.A. Hbk. No. 60
Soluble Sulphate ($SO_4^=$)	Method developed by (Chauhan & Chaunan, 1979)
Soluble Carbonate and Bicarbonate ($CO_3^= + HCO_3^-$)	Method No. 12, U.S.D.A. Hbk. No. 60
Soluble Boron	Method No. 62 U.S.D.A. Hbk. No. 60

Result and Discussion

Exchangeable cations (Ca^{++}, Mg^{++} and K^{+}) of salt affected soil

Results indicated that exchangeable cations particularly calcium (Ca^{++}) and Magnesium (Mg^{++}) increased appreciably whereas, sodium (Na^{+}) and potassium (K^{+}) decreased considerably in areas planted with tree crops in different combination as compared to bare sites (Control). Boyko and Boyko (1966) [4] stated that some tree species absorb large amount of salts from the soil and thus mitigate the problem of soil salinity to some extent. Desalinization and dealkalinization normally takes place under the tree growth in salt affected soils (Nigunova, 1972). Similarly Srivastava *et al.* (1988) [32] advocated that production of organic acids helps in liberating calcium for replacing harmful sodium in the exchange complex. Kater *et al.* (1992) [10] reported that soil under trees-Karite (*Vittelaria paradoxa*) and Nere (*Parkia biglobosa*) canopy was slightly richer in organic matter content and several cations as compared to adjacent tree less sites.

Salau *et al.* (1992) [25] reported that exchangeable cations like Ca^{++}, Mg^{++} and K^{+} were more favourable under elephant grass and other organic mulches. The studies of Bhojvaid and Timmer (1998) indicated that in long term, *Prosopis juliflora* tree growth altered the micro-climate, improved the soil moisture status, organic carbon, total nitrogen, extractable phosphorus, exchangeable calcium, magnesium, and potassium, decreased electrical conductivity (ECe) and exchangeable sodium levels that contributed to the reclamation of sodic soils. Similarly, Jain and Singh (1998) [8] also stated that potassium (K^{+}) calcium (Ca^{++}) and magnesium (Mg^{++}) cations increased with plant growth as well as plant density.

Soluble anions (Cl^{-}, $SO_4^{=}$, $CO_3^{=}$ and HCO_3^{-}) of salt affected soil

Present findings revealed that soluble anions like chloride (Cl^{-}), sulphate ($SO_4^{=}$), Carbonate ($CO_3^{=}$) and bicarbonate (HCO_3^{--}) were found to be decreased significantly with all the cropping systems at all the depths of soil as compared to area without plantation. Concentration of these ions declined with increasing depths. The reclamation was faster in area planted with Ber + Guava + Phalsa followed by Aonla + Ber tree crop combination. This may be due to the leaching of these ions into lower layers through vertical drainage with improved porosity, permeability and increased availability of cations like calcium and magnesium in exchange soil complex. Desalinization and dealkalinization normally takes place under the tree growth in salt affected soils (Nigunova, 1972). Srivastava *et al.* (1988) [32] advocated that exudation of tree roots neutralizes the alkalinity of soils. They further stated that tree rots absorbed most of the soil moisture to meet the transpiration loss, leaving very little quantity for upward movement through capillary action to evaporation loss and salt concentration is maintained at safe level under tree growth. Dhankar and Dahia (1980) [6] reported the ability of ber plants to accumulate higher amount of chloride which favours soil reclamation from salinity. Various organic mulching treatments were found able to decrease the cations like potassium (K^{+}) and anions like chloride (Cl^{-}), carbonate ($CO_3^{=}$) and bicarbonate (HCO_3^{-}) in the tree basin as compared to control. It was due to leaching of these anions in lower horizon of soil with irrigation water as advocated by Rao (1995) [22].

Soluble boron of salt affected soil

Soluble boron concentration was found significantly higher in barren land (control) as compared to area planted with different combinations of tree crops at all the depths of soil because of more accumulation of soluble boron with salt concentration. Higher boron concentration in salt affected soil as compared to normal soil is also reported by Kanwar and Singh (1961) [9] and Chauhan & Chauhan (1984) [5]. Studies indicated that cropping models reduced markedly the toxic boron concentrations of soil towards safe level. Boric acid (H_3BO_3) or borate is the predominant form of boron in soil. It is well known fact that availability of boron is associated with soil pH. Higher boron concentration in salt affected soils decreases with lowering of pH. In our findings also, pH of soil was found to be reduced from 10.68 in control (barren site) to 8.48 in the basin of Ber + Guava + Phalsa cropping system.

Table 1: Effect of various tree cropping systems on Exchangeable Ca^{++} [Cmol (P^{+}) kg^{-1}] of soil

S. No.	Treatment / Tree cropping systems		Exchangeable Ca^{++} at different depth (cm)				Mean value (0-60 cm)	Average value of basin and centre
			0-15	15-30	30-45	45-60		
1	Aonla + Ber	Basin	5.79	4.86	3.92	2.86	4.36	3.95
		Centre	4.50	3.75	3.50	2.42	3.54	
2	Aonla + Guava	Basin	5.21	4.72	3.86	2.67	4.12	3.74
		Centre	4.30	3.70	3.29	2.20	3.37	
3	Aonla + Karonda	Basin	4.20	3.95	3.24	2.26	3.41	3.08
		Centre	3.54	3.02	2.60	1.85	2.75	
4	Ber + Guava + Phalsa	Basin	6.20	5.24	4.45	3.02	4.73	4.36
		Centre	5.04	4.16	3.94	2.80	3.99	
5	Aonla + Subabool	Basin	4.52	4.08	3.52	2.38	3.63	3.31
		Centre	3.90	3.16	2.80	2.04	2.98	
6	Control		1.87	1.58	1.17	0.71	1.33	1.33
	CD at 5%		0.13	0.11	0.09	0.07		

Table 2: Effect of various tree cropping systems on Exchangeable Mg^{++} [Cmol (P^+) kg^{-1}] of soil

S. No.	Treatment / Tree cropping systems		Exchangeable Mg^{++} at different depth (cm)				Mean value (0-60 cm)	Average value of basin and centre
			0-15	15-30	30-45	45-60		
1	Aonla + Ber	Basin	5.34	4.70	3.85	2.30	4.05	3.62
		Centre	4.25	3.82	2.76	1.98	3.20	
2	Aonla + Guava	Basin	5.06	4.56	3.94	2.16	3.93	3.51
		Centre	4.08	3.64	2.72	1.86	3.08	
3	Aonla + Karonda	Basin	4.02	3.80	2.95	1.90	3.17	2.84
		Centre	3.38	2.76	2.30	1.58	2.51	
4	Ber + Guava + Phalsa	Basin	5.92	4.90	3.98	2.62	4.36	3.84
		Centre	4.54	3.86	2.85	2.04	3.32	
5	Aonla + Subabool	Basin	4.10	3.78	3.06	2.10	3.26	2.93
		Centre	3.65	2.94	2.15	1.65	2.60	
6	Control		1.01	0.70	0.51	0.37	0.65	0.65
	CD at 5%		0.12	0.10	0.07	0.05		

Table 3: Effect of various tree cropping systems on Exchangeable K^+ [Cmol (P^+) kg^{-1}] of soil

S. No.	Treatment / Tree cropping systems		Exchangeable K^+ at different depth (cm)				Mean value (0-60 cm)	Average value of basin and centre
			0-15	15-30	30-45	45-60		
1	Aonla + Ber	Basin	0.51	1.16	1.45	1.51	1.16	1.18
		Centre	0.54	1.22	1.48	1.54	1.20	
2	Aonla + Guava	Basin	0.95	1.24	1.50	1.61	1.33	1.35
		Centre	1.06	1.27	1.52	1.64	1.37	
3	Aonla + Karonda	Basin	1.27	1.30	1.56	1.68	1.45	1.49
		Centre	1.35	1.42	1.58	1.71	1.52	
4	Ber + Guava + Phalsa	Basin	0.27	0.96	1.42	1.46	1.03	1.06
		Centre	0.30	1.03	1.47	1.50	1.08	
5	Aonla + Subabool	Basin	1.15	1.24	1.51	1.68	1.40	1.44
		Centre	1.30	1.32	1.57	1.72	1.48	
6	Control		0.92	1.05	0.85	0.78	0.90	0.90
	CD at 5%		0.04	0.04	0.05	0.05		

Table 4: Effect of various tree cropping systems on Soluble Cl^- (me/l) of soil

S. No.	Treatment / Tree cropping systems		Soluble Cl^- at different depth (cm)				Mean value (0-60 cm)	Average value of basin and centre
			0-15	15-30	30-45	45-60		
1	Aonla + Ber	Basin	12.72	13.38	13.64	14.02	13.44	14.09
		Centre	13.56	14.69	15.02	15.68	14.73	
2	Aonla + Guava	Basin	12.90	13.57	13.80	14.23	13.62	14.30
		Centre	13.95	14.81	15.37	15.80	14.98	
3	Aonla + Karonda	Basin	13.60	14.68	15.12	15.60	14.75	15.27
		Centre	15.20	15.70	15.90	16.32	15.78	
4	Ber + Guava + Phalsa	Basin	12.40	13.18	13.47	13.89	13.24	13.87
		Centre	13.50	14.48	14.81	15.25	14.51	
5	Aonla + Subabool	Basin	13.48	13.83	14.17	16.60	14.02	14.67
		Centre	14.02	15.31	15.72	16.20	15.31	
6	Control		19.42	18.70	18.20	18.03	18.59	18.59
	CD at 5%		0.67	0.70	0.71	0.73		

Table-5: Effect of various tree cropping systems on Soluble SO_4^{--} (me/l) of soil

S. No.	Treatment / Tree cropping systems		Soluble SO_4^{--} at different depth (cm)				Mean value (0-60 cm)	Average value of basin and centre
			0-15	15-30	30-45	45-60		
1	Aonla + Ber	Basin	9.64	10.54	11.26	12.10	10.64	11.22
		Centre	10.82	11.40	12.08	12.90	11.80	
2	Aonla + Guava	Basin	10.20	10.64	11.56	12.20	11.15	11.63
		Centre	11.38	11.75	12.26	13.05	12.11	
3	Aonla + Karonda	Basin	10.65	11.46	11.87	12.60	11.65	13.11
		Centre	11.80	12.20	12.90	13.42	12.58	
4	Ber + Guava + Phalsa	Basin	9.24	10.30	10.70	11.82	10.27	10.97
		Centre	10.72	11.28	11.90	12.75	11.66	
5	Aonla + Subabool	Basin	10.42	11.20	11.82	12.50	11.49	11.95
		Centre	11.78	12.03	12.67	13.20	12.42	
6	Control		16.30	15.80	15.20	14.92	15.56	15.56
	CD at 5%		0.53	0.56	0.58	0.61		

Table 6: Effect of various tree cropping systems on Soluble CO_3^{--} (me/l) of soil

S. No.	Treatment / Tree cropping systems		Soluble CO_3^{--} at different depth (cm)				Mean value (0-60 cm)	Average value of basin and centre
			0-15	15-30	30-45	45-60		
1	Aonla + Ber	Basin	3.95	4.40	4.54	5.18	4.52	4.85
		Centre	4.72	5.17	5.32	5.45	5.17	
2	Aonla + Guava	Basin	4.06	4.57	4.66	5.35	4.66	5.10
		Centre	4.80	5.51	5.84	6.03	5.54	
3	Aonla + Karonda	Basin	5.08	5.47	5.61	5.87	5.51	5.87
		Centre	5.75	6.23	6.38	6.53	6.22	
4	Ber + Guava + Phalsa	Basin	3.70	4.36	4.62	4.81	4.37	4.72
		Centre	4.63	5.07	5.21	5.38	5.07	
5	Aonla + Subabool	Basin	4.90	5.30	5.43	5.81	5.36	5.75
		Centre	5.52	6.17	6.35	6.50	6.14	
6	Control		7.61	7.47	7.13	6.92	7.28	7.28
	CD at 5%		0.58	0.60	0.61	0.61		

Table 7: Effect of various tree cropping systems on Soluble HCO_3^{-} (me/l) of soil

S. No.	Treatment / Tree cropping systems		Soluble HCO_3^{--} at different depth (cm)				Mean value (0-60 cm)	Average value of basin and centre
			0-15	15-30	30-45	45-60		
1	Aonla + Ber	Basin	7.90	8.41	8.70	9.32	8.58	9.05
		Centre	8.65	9.10	10.05	10.29	9.52	
2	Aonla + Guava	Basin	8.03	8.47	8.71	9.80	8.78	9.30
		Centre	8.90	9.91	10.08	10.39	9.82	
3	Aonla + Karonda	Basin	8.84	9.56	9.79	10.20	9.60	9.99
		Centre	9.96	10.23	10.42	10.90	10.38	
4	Ber + Guava + Phalsa	Basin	7.82	8.47	8.72	9.20	8.55	9.00
		Centre	8.60	9.21	9.90	10.07	9.45	
5	Aonla + Subabool	Basin	8.65	9.48	9.82	10.05	9.50	9.87
		Centre	9.78	10.09	10.34	10.73	10.24	
6	Control		14.26	13.63	12.79	12.03	13.18	13.18
	CD at 5%		0.98	1.00	1.03	1.04		

Table 8: Effect of various tree cropping system on Soluble Boron (ppm) of soil

S. No.	Treatment / Tree cropping systems		Soluble Boron (ppm) at different depth (cm)				Mean value (0-60 cm)	Average value of basin and centre
			0-15	15-30	30-45	45-60		
1	Aonla + Ber	Basin	1.65	1.84	1.97	2.04	1.88	1.95
		Centre	1.90	1.98	2.06	2.15	2.02	
2	Aonla + Guava	Basin	1.73	1.89	2.01	2.09	1.93	2.00
		Centre	1.92	2.02	2.08	2.20	2.06	
3	Aonla + Karonda	Basin	1.90	2.05	2.14	2.24	2.08	2.15
		Centre	2.08	2.21	2.25	2.32	2.22	
4	Ber + Guava + Phalsa	Basin	1.50	1.80	1.95	2.02	1.82	1.90
		Centre	1.84	1.97	2.03	2.10	1.98	
5	Aonla + Subabool	Basin	1.82	2.01	2.12	2.20	2.04	2.09
		Centre	2.00	2.13	2.18	2.26	2.14	
6	Control		3.50	2.90	2.70	2.45	2.89	2.89
	CD at 5%		0.09	0.09	0.10	0.10		

Conclusion

Based on the results obtained from the present investigation, it is concluded that all the cropping systems improved the soil as compared to control (barren site). The improvement in basin of plants at all the depths was more as compared to the centre. Decrease in exchangeable K^+, soluble Cl^-, $SO_4^{=}$, $CO_3^{=}$, HCO_3^- boron and increase in exchangeable Ca^{++} and Mg^{++}indicated considerable improvement in chemical properties and fertility status of soil.

Among various tree cropping systems, Ber +Guava + Phalsa emerged most superior in improving the soil characteristics and availability of nutrients. Aonla + Ber tree cropping system was found the next best combination in this respect.

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