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Changes in soil fertility under multipurpose tree species in Thar Desert of Rajasthan

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Abstract
A study was conducted to investigate the effect of multipurpose tree species namely *Prosopis cineraria*, *Acacia senegal* and *Tecomella undulata* on the physical and chemical properties of soils representing Typic Haplocambids. The plantations of *Prosopis cineraria* and *Acacia senegal* were even aged, while that of *Tecomella undulata* was relatively young. The soils had an overall low status of SOC (<0.50%), low to medium P (8.2-15.7 kg/ha) and medium to high K (276-498 kg/ha).There was improvement in water holding capacity and decrease in surface soils bulk density under these tree species when compared to field without plantation. Slight decrease in pH of the soils under these tree species was noticed, whereas changes in EC were not appreciable. Significant improvement in soil organic carbon (0.12 to 0.27 %), available P (9.70 to 13.36 kg/ha) and K (336 to 393 kg/ha) was observed under these tree species compared to field without plantation. The content of Fe, Mn, Zn and Cu was 15, 31, 101 and 86 percent, respectively higher under these tree species than the field without plantation. The amount of nutrients returned to the soils through litter fall followed the order of Ca>K>Mg>P>Fe>Mn>Zn>Cu under tree species and variation in the amount of nutrient returned to the soils among the different tree species and field without plantation explained by the quantity of litter production and its chemical composition. The present study also indicated that these available nutrients had significant and positive correlation with organic carbon content across the land uses.

Keywords: Arid soils, Available nutrients, Litter nutrient content, Soil properties, Tree species

Trees in general provide a number of environmental benefits and play an important role in ecosystem services. Tree plantation is known to bring changes in edaphic, micro-climate, floral and other components of ecosystem recovery process through bio-recycling of mineral elements, micro-climate modification, changes in vegetation composition etc (Oddeman, 1983). Inclusion of tree species on agricultural systems can also optimize the nutrient recycling and have positive effects on soil physical and chemical properties. Studies have shown that tree plantation improved many soil physico-chemical properties (Belsky *et al.,*1989).Microbial biomass and their activity enhancement and microclimatic improvement under tree canopies compared to open areas especially in arid and semiarid areas have been reported earlier (Tewari *et al.,* 2013). These favourable conditions of soils and microclimate under trees have been called as island of fertility or resource islands (Belsky *et al.,* 1989; Frost and Edinger, 1991).

These patterns can be important indicator of stability or risk of desertification in such areas (Burke *et al.,* 1998; Schlesinger *et al.,* 1996). Trees on agricultural fields can improve soil physico-chemical properties through N fixation, litter fall and its subsequent decomposition, root decay and reduced nutrient loss by wind erosion and leaching under plantation sites (Schroth and Sinclair, 2003; Fisher, 1995). Under trees considerable amount of nutrients are incorporated into soil through litter fall and it's recycling which in turn improve the nutrient reserve of the soils. Moreover the effect of different tree plantation to enrich nutrient status depends on various factors such as leaf litter and its chemistry, behaviour of nutrients, nature of soils, organic matter accumulation, microbial activity and quantity of nutrient bearing minerals (Geeda, 2003). Vegetation restoration through tree plantation is one of the effective ways to combat and control desertification. Tree species like *Prosopis cineraria, Acacia Senegal* and *Tecomella undulata* due to their drought hardiness, resistance to inhospitable climate and assured economic returns are considered excellent for arid land conditions. These tree species can be grown on soils having poor fertility, moisture deficit and high soil temperature. Therefore, the present study was carried out to evaluate effect of these tree species on the physico-chemical properties of soils under arid environment.

The study sites used in present investigation was central research farm of Central Arid Zone Research Institute, Jodhpur (26° 18' N and 73° 01'E) located at a general elevation of 224 m above mean sea level. The central farm receives mean annual rainfall of 370 mm. The soils are reddish brown to brown, sand to loamy sand at surface followed by a reddish brown loamy fine sand to fine sandy loam, weakly blocky, negligible to slightly calcareous sub soil followed by lime coated gravelly material of transported fragments of rhyolites and sand stones at depth mostly below 100 cm. Taxonomically these soils belong to Aridisols soil order sub group Typic Haplocambids. To understand the impact of multipurpose tree species on changes in soil physico-chemical properties in arid regions, plantation stands of *P. cineraria* and *A. senegal* (each 56 years old), and *T. undulata* (31 years old) were selected. Tree density, mean basal cover and total basal cover were calculated as per the methods given by Missra (1968) and that of percent canopy by the methods given in Tewari *et al.* (2003). Silvicultural operations were employed at an interval of five years in *A. Senegal* and *T. undulata.* Vertical lopping of canopy at 25-30% was carried out on both the species. In case of *T. undulata* the side branches are also removed regularly. In case of *P. cineraria* lopping of canopy at the end of growing season at 50% was employed after 8 years of initial plantation date and afterwards followed regularly every year. One stand of open field without plantation was kept as a control. Soil samples from two depths (0-15, 15-30 cm) were collected from 10 locations for each of tree species under study. Soils were analyzed for bulk density (BD), water holding capacity (WHC), pH, electrical conductivity (EC), soil organic carbon (SOC), available P and K, exchangeable cations (Ca, Mg and Na) following standard procedures (Jackson, 1973). The available quantities of micronutrients *i.e.* Fe, Mn, Zn and Cu in the soil were extracted with DTPA reagent (Lindsay and Norvell, 1978) and determined with the help of atomic absorption spectrophotometer. Leaf litter catchers of 1m × 1m size were installed randomly under the tree crown. The leaf fall was quantified every month by collecting leaf litter from each trap in paper bags and brought immediately to the laboratory, where it was dried (80 °C for at least 48 h), weighed and expressed in g/m² on monthly basis. The values obtained throughout the year on monthly intervals were added to work out annual litter fall. One gram of ground sample was digested in perchloric-nitric acid mixture and analyzed for various elements.

The density of all the tree species were 400 trees/ha. The values of mean as well as total basal cover was maximum in case of *P. cineraria* and minimum in *A. Senegal* (Table 1). As total basal cover reflects the biomass accumulation (Tewari and Singh, 1985), from the data it can be said that *P. cineraria* stands had maximum biomass. The short statured *A. senegal* exhibited minimum mean and total basal cover even then it had the same age as that of *P. cineraria*. Younger plantation stands of *T. undulata* had mean and total basal cover values between *P. cineraria* and *A. senegal* plantation stands. It was very interesting that canopy cover of *P. cineraria* and *T. undulata* was about 42.92 and 18.80 %/ha and that of *A. Senegal* was only 9.52%/ha. *P. cineraria* canopy cover is lopped every year at the end of growing season (November-December) every year for leaf fodder and fuel wood, and perhaps due to these operations the canopy cover of the species was not in expected lines because in such dense plantation much higher canopy cover was recorded earlier (Sharma and Tewari, 2005).

Tree plantation had significant and favorable effect on physical properties of soils especially on BD and WHC. All the tree species *i.e. P. cineraria, T. undulata* and *A. senegal* under study contributed to lower mean BD and higher WHC to the soils. In general the mean water holding capacity was18.12, 18.75 and 18.50% in *P. cineraraia, A. senegal* and *T. undulata* respectively, than 16.48% in the field without plantation. BD decreased from 1.55 Mg/m³ in field without plantation to 1.53, 1.53 and 1.54 Mg/m³ under *P. cineraria, A. senegal and T. undulata* plantation, respectively (Table 2). Higher WHC and lower BD under tree plantation fields could be attributed to litter fall and decayed root biomass in well extended and deep root system.

Soil pH ranged from 8.12 to 8.45. Mean soil pH was slightly lower under the tree species than the field without plantation. However, the change in soil pH due to tree plantation was not significant. Among the tree species highest pH was found under *A. senegal* (8.20) followed by *P. cineraria* (8.15) and *T. undulata* (8.12). This decrease in pH may be related to litter fall, decay of root biomass and production of weak acids during its decomposition, increased CO_2 level through root respiration and nitrification under nitrogen fixing trees (Vijay Shankar Babu *et al.,* 2007; Yao *et al.,* 2010). Vertical distribution pattern of pH indicated that reduction in soil pH in subsurface layer was more pronounced due to more abundance of root biomass at lower depth (Tornquist *et al.,* 1999).

Table 1. Analytical attributes of plantation stands

Tree species	Plantation year	Density (tree/ha)	Mean basal cover (cm^2/tree)	Total basal cover (m^2/ha)	% Can-opy / ha	Average height (m)
Prosopis cineraria	1960	400	237.90	9.52	42.92	5.50
Acacia senegal	1960	400	94.80	3.79	9.52	5.50
Tecomella undulata	1984	400	107.01	4.28	18.80	9.50

Table 2. Soil physico-chemical properties under multipurpose tree species

Soil depth (cm)	pH (1:2)	EC (dS m^{-1})	WHC (%)	BD (Mg /m^3)	OC (%)	P (kg/ha)	K (kg/ha)
Field without plantation							
0-15	8.23	0.10	16.48	1.55	0.12	9.70	336.00
15-30	8.45	0.05	16.22	—	0.10	7.56	218.00
Prosopis cineraria plantation							
0-15	8.15	0.43	18.12	1.53	0.27	13.36	376.00
15-30	8.20	0.07	16.10	—	0.14	9.37	315.00
Acacia senegal plantation							
0-15	8.20	0.15	18.75	1.54	0.26	11.43	357.00
15-30	8.45	0.11	20.71	—	0.14	8.23	286.00
Tecomella undulata plantation							
0-15	8.12	0.09	18.50	1.53	0.22	10.80	393.00
15-30	8.22	0.08	19.32	—	0.14	8.20	281.00

Soil depth (cm)	Ca cmol (p+)/kg	Mg cmol (p+)/kg	Na cmol (p+)/kg	Fe (mg /kg)	Mn (mg /kg)	Zn (mg /kg)	Cu (mg /kg)
Field without plantation							
0-15	4.28	1.20	0.34	4.10	10.80	1.04	0.96
15-30	4.42	1.40	0.40	3.73	9.34	0.62	0.62
Prosopis cineraraia plantation							
0-15	4.84	1.20	0.34	4.68	12.56	2.41	2.25
15-30	5.20	1.60	0.38	4.04	9.04	0.68	0.82
Acacia senegal plantation							
0-15	4.70	1.40	0.32	4.35	14.82	1.96	1.02
15-30	5.00	1.60	0.40	3.64	7.40	0.58	0.54
Tecomella undulata plantation							
0-15	4.56	1.30	0.32	5.10	14.97	1.94	2.10
15-30	4.68	1.50	0.38	4.20	10.20	0.84	0.80

SOC content was found higher (0.22-0.27 %) in soil under selected trees species than the field without plantation (0.12%). Maximum SOC was found under *P. cineraria* (0.27 %) which was at par with *A. senegal* (0.26%) followed by *T. undulata* (0.22 %) tree plantation. The research showed that changes in SOC mainly affected by inputs of organic matter, favorable temperature and moisture conditions, quantity of litter fall and chemical composition of tree roots and litter fall under varying climate and soils (Patron *et al.,* 1987; Saha *et al.,* 2007; Yuefeng *et al.,* 2014). These results are in accordance with the findings of Raina (2003), Singh and Gill (2014) and Singh *et al.* (2012).The SOC was found to decrease with soil depth. The changes in land use from field without plantation to field under tree plantation did not affect SOC content at lower depth, which decreased with increase in soil depth (Yuefeng *et al.,* 2014).

Ca was the most dominant exchangeable cation followed by Mg and Na. Content of Ca (4.28-5.20 cmol (p+)/kg) and Mg (1.20-1.60 cmol (p+)/kg) was low at surface and increased with soil depth. This might be due to presence of carbonate layer at 90-100 cm depth. Na was present in very small quantity (0.32-0.40 cmol (p+)/kg) and distributed uniformly throughout the soil profile. Similar kind of observations was reported by Singh *et al.* (2010) in arid soils of India.

Soil available P varied widely among different tree species and decreased with increased soil depth. Available P content was highest in the soils under *P. cineraria* (13.36 kg/ha) followed by soils under *A. senegal* (11.43 kg/ha) and *T. undulata* (10.80 kg/ha). The mean available potassium content was 393, 376, 357 kg/ha in the soils under *T. undulata, P. cineraria* and *A. senegal*, respectively. The greater amount of available P and K in the soils under tree species might be due to root exudates, higher K uptake from lower depth, returned to the surface through litter fall and its decomposition (Tornquist *et al.,* 1999; Singh and Gill, 2014) and increased microbial activity with mycorrhiza in P transformation and distribution within soil profile (Cooper *et al.,* 1996). High nutrient concentration in leaf litter of these tree species might have contributed to high content of nutrients in the soils.

Significant variations in micronutrient contents in soils under tree species and field without plantation was recorded. Average Fe, Mn, Zn and Cu contents in soils under tree species were 15, 31, 101 and 86 percent higher than that of the field without plantation. The high concentration of these micronutrients in the soils related to quantity and quality (chemical composition) of litter fall. Within the tree species, soils under *T. undulata* was high in Fe and Mn content (5.10 and 14.97 mg/kg) followed by *A. senegal* and *P. cineraria* (Table 2), while Zn and Cu was high under *P. cineraria*. Joshi and Dhir (1983) and Kumar *et al.* (2009) also reported more or less similar results in tree based system in arid soils.

The amount of nutrients returned to the soils through litter fall varies and largely depends on the age, growth, quantity of litter addition and concentration of nutrients in litter (Singh *et al.,* 2007). Total litter production was 16120, 2800 and 1000 kg/ha in *P. cineraria*, *A. senegal* and *T. undulata,* respectively. Among the different tree species under study leaf litter of *A. senegal* contained high concentration of P, Ca, Mn and Mg, while *T. undulata* contained high K, Fe and Zn. *P. cineraria* contained 1.38, 2.40, 0.30% K, Ca and Mg, respectively and 335.04, 33.41, 28.70 and 21.71mg/kg of Fe, Mn, Zn and Cu, respectively. Similar findings on the nutrient contents in tree species were also reported by Awasthi and Singh (2010) and Dhir *et al.* (1985). The amount of nutrients returned to the soils through litter fall followed the order of Ca>K>Mg>P>Fe>Mn>Zn>Cu under all the tree species (Table 3). *T. undulata* contributed lower amount of nutrients to the soil which might be due lesser litter production.

Significant positive correlation was found between most of the soil properties. Especially BD had high negative correlation, whereas SOC was highly positively correlated with other soil properties. Available nutrient contents both macro (OC, P, K) and micro (Fe, Mn, Zn, Cu) were

Table 3. Nutrient content in leaf litter and nutrients returned to the soil under multipurpose tree species

Tree Species	Nutrient content							
	P (%)	K (%)	Ca (%)	Mg (%)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Cu (mg/kg)
Prosopis cineraria	0.12	1.38	2.41	0.30	335.04	33.41	28.70	21.71
Acacia senegal	0.16	1.22	2.80	0.62	462.02	52.62	28.70	15.20
Tecomella undulata	0.13	1.48	2.09	0.45	484.00	42.70	36.80	17.40
	Litter nutrient (kg/ha)							
	P	**K**	**Ca**	**Mg**	**Fe**	**Mn**	**Zn**	**Cu**
Prosopis cineraria	19.34	222.40	386.86	48.36	5.40	0.54	0.46	0.35
Acacia senegal	4.48	34.16	78.36	17.36	1.30	0.15	0.08	0.04
Tecomella undulata	1.30	14.80	21.00	4.50	0.48	0.04	0.03	0.01

Table 4. Correlation between important soils properties and available nutrients

Soil properties	BD	OC	P	K	Fe	Mn	Zn	Cu
BD	1							
OC	-0.891*	1						
P	-0.170	0.435*	1					
K	-0.643*	0.680*	0.252	1				
Fe	-0.556*	0.757*	0.613*	0.481*	1			
Mn	-0.520*	0.529*	0.220	0.138	0.483*	1		
Zn	-0.670*	0.816*	0.501*	0.648*	0.822*	0.508*	1	
Cu	-0.679*	0.845*	0.579*	0.628*	0.794*	0.497*	0.857*	1

* (P<0.05); ** (P<0.01)

significantly correlated with SOC content (Table 4), which was mainly due to increase in the available exchange sites for nutrients and increase in the formation of clay-humus complexes. A number of other investigators also suggested significant and positive correlation between soil available nutrients with organic carbon (Kumar *et al.,* 2009; Singh *et al.,* 2012; Sharma and Gupta, 2001).

The multipurpose tree species studied under the present investigation improved the physico-chemical properties of the soils with time in arid environment. The higher amount of SOC, P and K in soils under these tree species compared to field without plantation might be related to nutrient return through litter fall. The content of Fe, Mn, Zn and Cu was also improved from 15 to 101 percent under these tree species than the field without plantation. Among the tree species, *Prosopis cineraria* contributed more in enhancement of soil fertility. The results from the study indicated that increase in soil organic carbon content and other available nutrients might be helpful in improving productivity potential of arid regions.

References

Awasthi, O. P. and I. S. Singh. 2010. Effect of ber and pomegranate plantation on soil nutrient status on Typic Torripssaments. *Indian Journal of Horticulture* 67:138-142.

Belsky, A. J., R. G. Amundson, J. M. Duxbiry, S. J. Riha, A. R. Ali and S. M. Mwonga. 1989. The effect of trees on their physical, chemical and biological environment in a semi- arid savanna in Kenya. *Journal of Applied Ecology* 26:1005-1024.

Burke, I. C., W. K. Lauenroth and M. A. Vinton. 1998. Plant soil interaction in temperate grasslands. *Biochemistry* 42:121-143.

Cooper, P. J. M., R. R. B. Leakey, M. R. Rao and L. Reynolds. 1996. Agroforestry and the mitigation of land degradation in the humid and sub-humid tropics of Africa. *Experimental Agriculture* 32: 235-290.

Dhir, R. P., B. K. Sharma, B. K. Dutta and S. K. Saxena. 1985. Concentration of mineral elements in some arid zone species from common habitat: Tree and shrub species. *Indian Journal of Ecology* 12: 20-24.

Fisher, R. F. 1995. Amelioration of degraded rain forest soils by plantation of native trees. *Soil Science Society of America Journal* 59: 544-549.

Frost, W. E. and S. B. Edinger.1991. Effect of tree canopies on soil characteristics of annual range land. *Journal of Range Management* 44: 286-288.

Geeda, A. E. 2003. Rangeland evaluation in relation to pastrolist perception in Middle Awash Valley of Ethiopia. University of Free State, Bloemfontein, South Africa. Ph. D. Thesis. pp. 1-297.

Jackson, M. L. 1973.*Soil Chemical Analysis.* Prentice Hall of India Pvt. Ltd., New Delhi.

Joshi, D. C. and R. P. Dhir. 1983. Available forms of manganese and iron in some arid soils and their relation with soil properties. *Annals of Arid Zone* 22: 7-14.

Kumar, Mahesh, P. Kumar and P. C. Bohra. 2009. Effect of land use systems on soil properties and relationship between soil organic carbon and available nutrients in typical arid soils of Rajasthan. *Annals of Arid Zone* 48: 122-127.

Lindsay, W. L. and W. A. Norvell. 1978. Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal* 42: 421-428.

Missra, R. 1968. *Ecology Work Book.* Oxford and IBH Publication Co., Calcutta.

Oddeman, R. A. A.1983. The design of ecological based agroforests. In: P.A. Huxley (ed). *Plant Research and Agroforestry*, ICRAF, Nairobi, Kenya. pp. 172-207.

Patron, W. J., D. S. Schimel, C. V. Cole and D. S. Ojima. 1987. Analysis of factors controlling organic matter levels in Great Plain grasslands. *Soil Science Society of America Journal* 51: 1173-1179.

Raina, Pramila. 2003. Effect of tree plantation on soil fertility in arid regions of Rajasthan. In: Pratap Narain, S. Katju, Amal Kar, M. P. Singh and Praveen Kumar (eds). *Human Impacts on Desert Environment*. Arid Zone Research Association of India and Scientific Publishers, Jodhpur. pp. 189-194.

Saha, R., J. M. S. Tomar and P. K Ghosh. 2007. Evaluation and selection of multipurpose tree for improving soil hydro-physical behavior under hilly ecosystem of north-east India. *Agroforestry Systems* 69: 239-248.

Schlesinger, W. H., J. A. Raikks, A. E. Hartley and A. F. Cross. 1996. On the spatial pattern of soil nutrients in desert ecosystems. *Ecology* 77: 364-374.

Schroth, G., and F. L. Sinclair. 2003. Trees, crops and soil fertility concepts and research methods, CABI Publishing Wallingford.

Sharma, A. K. and J. C. Tewari. 2005. Arid zone forestry with special reference to Indian hot arid zone. In: *Forests and Forest Plants– Vol. II Encyclopaedia of Life Support Systems*, Developed under the Auspices of the UNESCO. EOLSS Publishers, Oxford, UK.

Sharma, B. M. and J. P. Gupta. 2001. Indigenous knowledge of nutrient management in western Rajasthan. In: C. L. Acharya, P.K. Gosh and A. Subba Rao (eds). *Indigenous Nutrient Management Practices –Wisdom Alive in India.* Indian Institute of Soil Science, Nabibagh, Bhopal. pp. 1-12.

Singh, B. and R. I. S. Gill. 2014. Carbon sequestration and nutrient removal by some tree species in agrisilviculture systems in Punjab, India. *Range Management and Agroforestry* 35: 107-114.

Singh, B., R. I. S. Gill and N. Kaur. 2007. Litter fall and nutrient return in poplar plantation varying in row direction and spacing. *Indian Journal of Agroforestry* 9: 33-37.

Singh, I. S., O. P. Awasthi, B. D. Sharma, T. A. More and S. R. Meena. 2010. *Soil fertility changes under fruit trees in Thar Desert Ecosystem*. Central Institute of Arid Horticulture, Bikaner, Technical Bulletin 37: 2.

Singh, I. S., O. P. Awasthi, R. S. Singh, T. A. More and S. R. Meena. 2012. Changes in soil properties under tree species. *Indian Journal of Agricultural Sciences* 82: 146-151.

Tewari, J. C., D. Tripathi, P. Narain and S. P. Singh. 2003. A study of the structure, energy fluxes and emerging trends in traditional central Himalayan agroforestry systems, forests. *Trees and Livelihoods* 13:17-37.

Tewari, J. C., M. Ram, M. M. Roy and J. C. Dagar. 2013. Livelihood improvements and climate change adaptations through agroforestry in hot arid environments. In: J. C. Dagar, A. K. Singh and J. Arunanchalam (eds). *Agroforestry Systems in India: Livelihood Security and Ecosystem Services.* Springer. pp. 155-183.

Tewari, J. C. and S. P. Singh. 1985. Analysis of woody vegetation in a mixed oak forest of Kumaun Himalaya. *Proceedings of Indian National Sciences Academy* 851: 332-347.

Tornquist, C.G., F. M. Hons, S. E. Feagley and J. Haggar. 1999. Agroforestry system effects on soil characteristics of the Sarapiqui region of Costa Rica. *Agriculture, Ecosystem & Environment* 73: 19-28.

Vijay Shankar Babu, M., C. Mastan Reddy, A. Subramanyam and D. Balaguravaiah. 2007. Effect of integrated use of organic and inorganic fertilizers on soil properties and yield of sugarcane. *Journal of The Indian Society of Soil Science* 55:161-168.

Yao, M. K., P. K.T. Anguni, S. Konate, J. E. Tondoh, Y. Tano, L. Abbadie and D. Benset. 2010. Effect of land use types on soil organic carbon and nitrogen dynamics in mid-west cote d' Ivoire. *European Journal of Science Research* 402: 211-222.

Yuefeng, Guo, Fucang, Qin, Yuefeng Yao and Wei, Qi. 2014. Effect of land use changes on soil organic carbon and soil microbial biomass carbon in low hills of North Yanshan Mountains. *Range Management and Agroforestry* 35: 15-21.