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Performance of different multipurpose trees and their effect on physical and chemical properties of loamy sand soil under rainfed condition

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Abstract
The present study was conducted at Agroforestry Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat, India, in a Randomized Block Design with Four replications during the 2014-15. Thirty years old agroforestry tree plantation consisted of four multipurpose tree species (MPTs) *viz., Azadirachta indica*, *Prosopis cineraria*, *Prosopis juliflora* and *Acacia tortolis*. Relative to open field, soils under MPTs noted significantly increased WHC (26.50 per cent) and soil porosity (40.67 per cent) under *Prosopis cineraria* tree and *Azadirachta indica* tree species respectively while the lower values of BD (5.25 per cent) and minimum soil temperature (29.12 ^{o}C) was noted under *Acacia tortolis* and lower values of maximum soil temperature (35.25 ^{o}C) was under *Azadirachta indica* amongst all tree species. The pH and EC value decreased while organic carbon, available nitrogen, available phosphorus and available potash value in soil was increased under all tree species at different soil depth compared to open field. Reduced mean soil pH (3.97 per cent) and EC (75.45 per cent) was noted under the tree species of *Acacia tortolis* and *Prosopis juliflora*, respectively over control whereas mean maximum OC (0.63 per cent) and Available N (167.25 kg/ha) noted under *Acacia tortolis* tree species which was 320 per cent and 88.24 per cent higher over open field. Mean maximum available P_2O_5 (34.20 kg/ha) and available K_2O (419.45 kg/ha) noted under *Prosopis cineraria* and *Azadirachta indica* tree species respectively which was 38.57 per cent and 64.26 per cent higher over control.

Keywords: multipurpose trees (MPTs), physico-chemical property

Introduction
Trees provide food, fuel wood, fodder, fertilizer and timber, reduction in incidence of total crop failure and sustained productivity. Trees also provide the some more efficient recycling of nutrients by deep rooted trees on the site, reduction of surface run-off, nutrient leaching and soil erosion through impeding effect of tree roots and stems on these processes improvement of microclimate, such as lowering of soil surface temperature and reduction of evaporation of soil moisture through a combination of mulching and shading, increment in soil nutrients through addition and decomposition of litter fall and improvement of soil structure through the constant addition of organic matter from decomposed litter.

The multipurpose trees help in the improvement of soil and ecosystem services. Trees with deep rooting system can improve ground water quality by serving as a 'safe net' where by excess nutrients that have been leached below the rooting zone of agronomic crops are taken-up by tree roots. The trees are able to maintain or improve soil health, the process by which trees improve soil fertility are photosynthesis, fixation of carbon and it's transfer to the soil *via* litter and root decay. Nitrogen fixation by leguminous trees, improve nutrient retrieval by tree roots and erosion control by a combination of ground cover and barrier effects, efficient uptake of nutrient from soil, soils under trees have a favorable structure and water holding capacity through organic matter stabilization and root action and exudation of growth promoting substances.

Material and Methods
Site description
The field experiment was carried out at Research Farm, Agroforestry Research Station, Sardarkrushinagar Dantiwada Agricultural University, and Sardarkrushinagar. Geographically, Sardarkrushinagar is situated 28 km West of Palanpur at 72° - 19' East longitude

and 24° - 19' North latitude at an altitude of 154.52 meter above the sea level.

Climate and weather conditions

The climate of the North Gujarat is typically semi-arid type. In general, monsoon is warm and moderately humid, winter is fairly cold and dry, while summer is quite hot and dry. The monsoon commences by middle of June and retreats by the middle of September with an average rainfall of 550 mm in 21 rainy days. The regular winter season starts by the middle of October and it continues till the end of February. The December and January are the coldest months of winter season and the summer season commences with the beginning of March and ends by the middle of June in which April and May are the hottest months of the season. The area receives erratic and less precipitation with high evapotranspiration due to high solar radiation and wind speed.

Experimental details

The experiment was designed in Randomized Block Design with four replications and total plot size 48 x 18 m whereas 3 x 3 m tree spacing in one plot 96 tree is planted before 30 years.

Soil properties and Analysis of soil samples

Depth wise (0-30, 30-60 and 60-90 cm) soil samples were taken from four replications with an augur in each plantation as well as from control during 08-02-2015. In each replication soil sample were taken from three points composited and air dried. The samples were powdered using a wooden mortar and pestle and passed through 2 mm plastic sieve to avoid metallic contamination. Soil moisture content was determined gravimetrically (Piper, 1950) [9], bulk density in undisturbed Core method (Cully, 1993). Soil pH was measured by Potentiometric method (Jackson, 1978) [12], OC by Walkley and Black's method (Jackson, 1978) [12], Available Nitrogen (AN) by Alkaline permanganate Method (Subbiah and Asija, 1951), Available Phosphorus (AP) Olsen's method (Jackson, 1978) [12] and Available Potassium (AK) by using Flame photometric Method (Jackson, 1978) [12].

Results and Discussion

Effect of different MPTs on soil physical properties

Data of soil bulk density presented in Table 1 showed significant variation under different MPTs at various soil depths. The lowest soil bulk density at 0-30 cm soil depth (1.57 Mg/m^3) was recorded under *Acacia tortolis* tree species but at 30-60 cm soil depth (1.63 Mg/m3) it was lower under *Prosopis juliflora* and at 60-90 cm soil depth (1.65 Mg/m^3) reported under *Azadirachta indica*. The descending trend on mean value of BD for tree species was as *P. cineraria* > *A. indica* > *P. juliflora* > *A. tortolis*. The lower bulk density under tree species could be attributed to their larger and deeper root system and root biomass resulting from accumulation of higher organic carbon, proliferation of rhizosphere and microbial activities and root exudation below ground which helps to bind soil particles into larger aggregates and thereby loosen the soil and decrease its bulk density (Arunacha lam and Pandey 2003) [8]. While, maximum bulk density at 0-30, 30-60 and 60-90 cm soil depth was recorded under absence of tree species *i.e.*, open field (1.69 Mg/m^3, 1.72 Mg/m^3 and 1.73 Mg/m^3, respectively). Similar results were correlated with the results of Ramesh *et al.* (2013) [2] and Patel *et al.* (2010) [5].

Data of soil Water Holding Capacity (WHC) showed significant variation at various soil depth under different tree species (Table 1). Maximum WHC at 0-30 cm soil depth (27.28 per cent) recorded under *Acacia tortolis* tree while at 30-60 cm soil depth (27.25 per cent) under *Azadirachta indica* tree but at 60-90 cm soil depth (28.11 per cent) it was under *Prosopis cineraria.* Higher WHC under tree covers might be ascribed primarily to the continuous vegetative covers with litter fall of trees and also to their subsequent decomposition and decayed root biomass. Lowest WHC (20.67, 21.81 and 21.69 per cent, respectively) was recorded under open field at 0-30, 30-60 and 60-90 cm soil depth under study. The descending trend on mean value of WHC for tree species was as *P. cineraria* > *A. tortolis* > *A. indica* > *P. juliflora*. Patel *et al.* (2010) [5] and Devevaranavadgi *et al.* (2000) [1] have also noticed improving WHC in soils when different tree species were planted as compared with without tree species. Soil under trees has a favourable structure and WHC through organic matter stabilization and conservation and root action (Subba rao and Saha, 2014) [7].

The data pertaining to soil porosity at varying soil depth are presented in Table 1 and showed significant variation of soil under different tree species at various soil depth. Maximum soil porosity at 0-30 cm soil depth (40.81 per cent) recorded under *Acacia tortolis* but at 30-60 cm soil depth (41.26 Per cent) recorded under *Azadirachta indica* while at 60-90 cm soil depth (42.08 per cent) noted under *Prosopis cineraria* might be attributed to better soil aggregation by the addition of large amount of organic carbon and organic acids through the fall of biomass to the soil after 30 years of plantation. The lowest soil porosity recorded under no tree cover at all the soil depth compared to under tree species data. The descending trend on mean value of soil porosity was as *A. indica* > *P. cineraria* > *A. tortolis* > *P. juliflora*. Hence trees improve the soil physical properties, eco-friendly and enhance the soil health. Patel *et al.* (2010) [5] and Devevaranavadgi *et al.* (2000) [1] have also noticed improved soil porosity in soils when different tree species were planted as compared to without tree species.

Table 1: Physico-chemical properties (depth-wise) of the soils under different multipurpose tree species.

Soil property	Depth (cm)	*A. indica* (T_1)	*P. cineraria* (T_2)	*P. juliflora* (T_3)	*A. tortolis* (T_4)	Control (T_5)	C.D. (5 %)	C.V. (%)
BD (Mg/m^3)	0-30	1.62	1.62	1.60	1.57	1.69	0.04	1.59
	30-60	1.64	1.65	1.63	1.64	1.72	0.05	1.92
	60-90	1.65	1.67	1.66	1.66	1.73	0.05	1.87
WHC (%)	0-30	24.16	24.15	25.57	27.28	20.67	1.82	4.84
	30-60	27.25	27.23	25.10	24.64	21.81	1.38	3.56
	60-90	25.07	28.11	25.12	25.48	21.69	1.60	4.14
Porosity (%)	0-30	38.78	38.89	40.52	40.81	35.11	1.53	2.56
	30-60	41.26	40.92	38.96	38.97	37.06	1.29	2.15
	60-90	41.97	42.08	40.02	40.02	33.19	2.22	3.66

pH	0-30	7.42	7.50	7.52	7.32	7.63	0.17	1.47
	30-60	7.25	7.45	7.38	7.23	7.55	0.18	1.58
	60-90	7.22	7.42	7.30	7.23	7.50	0.18	1.62
EC (dS/m)	0-30	0.053	0.055	0.038	0.055	0.110	0.0092	9.65
	30-60	0.035	0.045	0.030	0.020	0.110	0.0027	11.41
	60-90	0.020	0.018	0.013	0.020	0.120	0.0047	7.97
OC (%)	0-30	0.81	0.62	0.58	0.83	0.18	0.11	11.49
	30-60	0.35	0.46	0.57	0.59	0.14	0.07	10.70
	60-90	0.32	0.45	0.35	0.47	0.14	0.07	13.12
AN (kg/ha)	0-30	121.20	184.24	203.84	254.80	113.68	15.22	5.63
	30-60	118.75	130.50	137.20	125.44	94.08	16.72	8.95
	60-90	117.49	129.36	130.50	121.52	58.80	21.03	12.24
AP (kg/ha)	0-30	38.81	37.43	35.21	34.10	26.56	4.31	8.13
	30-60	35.77	36.46	33.70	34.00	24.86	3.82	7.52
	60-90	27.95	28.72	31.70	32.75	22.63	4.20	9.48
AK (kg/ha)	0-30	463.68	420.00	416.64	413.28	268.80	58.41	9.56
	30-60	461.08	366.24	416.64	383.04	265.44	65.58	11.25
	60-90	333.58	258.72	310.27	299.93	231.84	43.76	9.90

BD = Bulk Density, WHC = Water Holding Capacity, OC = Organic Carbon, AN = Available Nitrogen, AP = Available Phosphorus, AK = Available Potash.

Effect of different MPTs on physico-chemical properties of soil

Different tree species significantly influenced the soil pH (Table 1). Among the different tree species, the lower values of soil pH (7.32) recorded under *Acacia tortolis* at 0-30 cm soil depth, while *Acacia tortolis* reported lowest soil pH (7.23) at 30-60 cm soil depth. Whereas at 60-90 cm soil depths lower value of pH (7.22) was reported under *Azadirachta indica*. Decrease in soil pH under tree may be attributed to release of organic acids during decomposition due to addition of leaf residues to the soil. Significantly higher pH recorded at different soil depth under control means in the soil of open field. Similar results were also reported by Patel *et al.* (2010) [5] and Ramesh *et al.* (2013) [2].

Significantly higher EC (0.110 dS/m, 0.110 dS/m and 0.120 dS/m respectively) value was noted at 0-30, 30-60 and 60-90 cm soil depth under control (Table 1). Whereas lower soil EC value was noted under tree species at different soil depth compared to open field. Among the tree species, lowest mean EC (0.027 dS/m) was noted under *Prosopis juliflora* tree species. Similar results were also reported by Gupta *et al.* (2005) [6] and Patel *et al.* (2010) [5].

Organic carbon content of soil planted with different tree species increased as compared to without tree species (Table 1). Significantly maximum organic carbon (0.83, 0.59 and 0.47 per cent, respectively) at 0-30, 30-60 and 60-90 cm soil depth was recorded under *Acacia tortolis* (T4). The lowest organic carbon (0.18, 0.14 and 0.14 per cent, respectively) at 0-30 cm, 30-60 cm and 60-90 cm soil depth was under control. Hence at lower soil depth (30-60 cm and 60-90 cm) improvement in organic carbon was relatively less as compared to upper soil depth (0-30 cm depth). Litter fall under tree on decomposition improved organic carbon status of under neath soil. The general order of tree species was as *A. tortolis* > *P. cineraria* > *P. juliflora* > *A. indica*. The findings are in agreement with those of Giri Rao *et al.* (2000) and Singh and Sharma (2012) [3, 4].

Available nitrogen (254.80 kg/ha) significantly improved under upper layer of soil (0-30 cm soil depth) in soil under *Acacia tortolis* tree species while it was higher under *Prosopis juliflora* (137.20 and 130.50 kg/ha, respectively) at lower depth of soil *i.e.*, at 30-60 and 60-90 cm soil depth (Table 1). Available N content in soil under tree species was higher than that of without trees (control) in all the soil depth. The decreasing trend of tree species on mean value of soil available N was as *A. tortolis* > *P. juliflora* > *P. cineraria* > *A. indica*. The improvement in available N under trees was higher in upper soil depth than lower depth of soil. The improvement of available N in soil could be credited to the regular addition of litter fall, root decay in situ, higher microbial activity, more favorable soil condition *etc.* (Singh and Sharma, 2012 and Ramesh *et al.* 2013) [2, 4].

Significantly higher available P_2O_5 (38.21 kg/ha) recorded at 0-30 cm soil depth under *Azadirachta indica* (T_1), whereas higher available P (36.46 kg/ha) recorded under *Prosopis cineraria* (T_2) at 30-60 cm soil depth and at 60-90 cm soil depth available P_2O_5 (32.75 kg/ha) was recorded under *Acacia tortolis* (Table 1). The decreasing trend of tree species on mean value of soil available P_2O_5 was as *P. cineraria* > *A. indica* > *A. tortolis* > *P. juliflora*. Available P_2O_5 content of soil under different tree species was higher over open field. These can be attributed to solubilising behaviour of organic acids that are released into soil during organic matter decomposition under tree species. It was also further observed that the available P status of soil decreased with increase in soil depth under all the tree species. (Giri Rao *et al.* 2000 and Singh and Sharma, 2012) [3, 4].

Like available N and P_2O_5, the available K_2O of soil under different tree species decreased with increase in soil depth (Table 4.13). Significantly higher values of available K_2O (463.68, 461.08 and 333.58 kg/ha, respectively) recorded under *Azadirachta indica* at 0-30, 30-60 and 60-90 cm soil depth. Whereas the lowest available K_2O (268.80, 265.44 and 231.84 kg/ha, respectively) recorded at 0-30, 30-60 and 60-90 cm soil depth under control (Open field). The decreasing trend of tree species of mean value of soil available K_2O was as *A. indica* > *P. juliflora* > *A. tortolis* > *P. cineraria*. This showed that under tree plantation, the closed canopy structure at 30 years might have prevented available K_2O in soil from leaching down the profile during rainy season thereby showing higher values at the surface of the soil (0-30 cm soil depth) than lower depth (30-60 and 60-90 cm soil depth) (Giri Rao *et al.* 2000 and Singh and Sharma, 2012) [3, 4].

Conclusions

Multipurpose tree species under study significantly improved the physical (BD, WHC and Porosity) properties of soil. Multipurpose tree species significantly increased available N, P_2O_5 and K_2O in soil over control. Available N, P_2O_5 and K_2O status of soil decreased with increase in soil depth under all

MPTs under study. *Acacia tortolis* tree species stored 320 per cent higher organic carbon in soils over control.

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