

Research Article

Malays. j. med. biol. res.



Effects of *Ziziphus Spina-Christi* (L.) on Selected Soil Properties and Sorghum Yield in Habru District, North Wollo, Ethiopia

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ABSTRACT

Ziziphus spina-christi is a multipurpose tree which grows naturally on the farm lands in Habru district. Since, the effects of this tree on soil and crop have not scientifically quantified; this study has been carried out with the aim of assessing the effect of *Ziziphus spina-christi* on soil physicochemical properties, grain and biomass yield of sorghum. Five isolated and nearly identical *Ziziphus spina-christi* tree growing on farm lands with similar site condition were selected and canopy coverage of each tree was divided into four radial transects. Soil samples from three horizontal distances: 1.2m, 2.9m and 15m with two soil depths (0–15cm and 15–30cm) were taken for analysis of soil physico-chemical properties. Three quadrates 1m x1m at each transect and distances were laid for sorghum grain yield and biomass estimation. The result shows that soil pH, EC, CEC and soil texture were not significantly ($p>0.05$) influenced by *Ziziphus spina-christi* tree, whereas soil bulk density, soil moisture content, total nitrogen, organic carbon, available phosphorus and exchangeable cation (Mg, Ca and K) were significantly ($P<0.05$) influenced mainly due to higher organic matter input through litter fall, root biomass, uptake and return of nutrients from deeper soil profiles under the tree canopies. While the grain yield of sorghum and above ground biomass were not statistically significant ($p>0.05$). Hence, retaining of this tree on crop land improves the soil fertility status.

Key words: *Ziziphus spina-christi*, soil properties, under canopy, edge of canopy, open field

Manuscript Received: 11 April 2019

Revised: 01 July 2019

Accepted: 13 July 2019

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INTRODUCTION

Soil fertility has declined from time to time (Gachengo et al., 1999) due to high rates of soil erosion, removal of crop residues for fuel and animal feed, rapid population growth, deforestation, inappropriate land use systems and continuous cultivation of the land without sufficient management (Girma Tadesse, 2001; Lal, 2001). Rapid population growth has resulted in extensive forest clearing for agricultural crop production, fuel wood and construction material consumptions in Ethiopia. These lead to soil fertility decline, which is a major problem to increase agricultural productivity (EFAP, 1994). Hence, to ensure sustainable agricultural productivity for the wellbeing of the people a tree based land use system i.e, agroforestry is needed. Agroforestry is arguably a more sustainable and optimal way of farming in most resource limiting environments. Hence, with this context traditionally farmers in eastern parts of Amhara region, Habru district they preserve and manage *Ziziphus spina-christi* trees on their farm lands in association with sorghum and other agricultural crops in the form of parkland agroforestry / scatter trees on farmland.

Scatter trees on farmland plays a significant role in soil fertility maintenances (Rachel et al. 2012) mainly through nitrogen fixation, litter fall, root activities, nutrient cycling, and numerous additional external factors such as Cow dung, bird and wildlife droppings, reducing nutrient losses from erosion and leaching (Vetaas, 1992; Nyberg and Hogberg, 1995; Rhoades, 1997). In addition to soil fertility maintenance trees on farmland provides shade for livestock and human being, fuel wood and construction materials, fodder, timber and other products.

Influence of scattered trees on soil properties of the agricultural lands has been reported by different scholars (Kamara and Haque, 1992; Parthiban and Vingaya, 1994; Yeshanew Ashagrie, 1997; Tadesse Hailu et al., 2000). However, quantitative information on effects of *Ziziphus spina-christi* on soil properties and sorghum yield is limited. Hence, this study has been quantifying the effect of *Ziziphus spina-christi* on soil fertility improvement and crop performance around the tree and that is good for managing the system properly, enhance its productivity and raise the benefits of the local community.

MATERIAL AND METHODS

Description of the study area

The study was conducted at Habru district which is located at 11° 27' - 11° 55' N latitude and 39° 33' - 40° 01' E longitude in north Wollo zone, Amhara region. The district is about 495 Km north east of Addis Ababa and it has a total area of 47,210 hectare with an altitude ranging from 1300 to 3800 meter above sea level. Large area of the district covered by vertisols, nitosols and cambisols soil types. The rainfall distribution is bimodal; the main rainy season, occurring between July to September and the small rainy season (erratic and unpredictable) occurring from the end of February to end of April and rainfall ranges from 750-1000 mm. The mean annual temperature also ranges from 16 °C to 21 °C (Shimelse Mekonnen, 2007).

Method of data collection

Sample tree selection and soil sampling design

Five individual *Ziziphus spina-christi* having approximately similar canopy width, height and DBH grown on the sorghum field were selected. The selection criteria were presence of relatively homogenous site conditions (topography and soil type), absence of influence from other trees and history of the farm land were used as selection criteria for this study. The height, DBH and crown radius of the tree were measured by using hypsometer, diameter caliper and meter tape, respectively. Each of the five selected tree were considered as a replica and the area covered by the canopy was divided in to four radial transects (Hailemariam Kassa et al., 2010; Tadesse Hailu et al., 2000). Soil samples were taken in four directions (North, South, East and West) from the tree at three horizontal distances; under the tree canopy (1.2m), edge of the canopy (2.9m), and far away from the tree canopy (15m) and at two soil depths; 0-15cm and 15-30cm using augur. Soil samples from the same radial distances and depths in the four directions were pooled or bulked together to form a composite sample. A total of thirty composite samples (three horizontal distance* two soil depths* five trees) were collected for soil analysis.

Soil laboratory analysis

The soil samples were air-dried, homogenized and passed through 2 mm sieve for analysis of soil chemical properties. Soil samples were analyzed at Sirinka Agricultural Research Centre, soil laboratory. Soil texture was determined by Bouyoucos methods using hydrometer (Bouyoucos, 1962), soil pH was determined by using pH meter in a 1:2.5 (%) soil: water suspension and soil electrical conductivity (EC) was measured using conductivity meter in saturated paste extract. Total nitrogen (TN) was determined by Kjeldahl method (Bremner and Mulvaney, 1982) and soil organic carbon (SOC) was determined by Walkley-Black, 1934. Available soil phosphorus was determined by Olsen method (Olsen et al., 1954). Cation exchange capacity (CEC) and exchangeable cation were determined after extraction of soils with ammonium acetate (1N) at pH 7. Potassium (K) in the extract was determined by flame photometer and calcium (Ca) and magnesium (Mg) were determined by atomic absorption spectrophotometer. Soil bulk density was determined by dividing oven dry (105 °C) mass of soil by the volume of the core (cm³). Soil moisture was determined by gravimetric method.

Growth, biomass and grain yield of sorghum

Three quadrat 1m x 1m were laid on the existing sorghum farm under the canopy of the tree, edge of the canopy and outside the canopy of the tree (Hailemariam Kassa et al., 2010; Kessler, 1992). Grain yield of sorghum and above ground biomass were measured in each quadrat. Plant height was measured from five randomly selected sorghum plants from the net quadrat area at maturity stage using meter tapes. Grain yield of sorghum were measured by harvesting from all plants in the net quadrat of 1m². Threshing of sorghum were done manually, cleaned and weighed the grain yield in grams. Sorghum aboveground biomass was estimated from 400 grams samples draw from the net quadrat and oven dried to constant weight at 65 °C (Osman et al., 1998) for 48 hours.

Data analysis

Analysis of Variance was tested using R software. The grain yield, biomass and plant height of sorghum data were subjected to one way ANOVA while soil properties were tested by two-way ANOVA. Mean comparison of treatment were performed by Tukey's honest significance difference (HSD) at 5% probability level.

RESULT AND DISCUSSION

Soil texture, Bulk density and Soil moisture content

The results of textural analysis indicated that soil particle fractions of clay, silt and sand did not significantly vary ($p > 0.05$) with distance from the tree trunk (Table 1). This, suggesting that soil textures more of inherent parent material related but clay fractions significantly varied in soil depths. Clay fraction content variation in depth-wise found from parkland agroforestry ecosystem of *Acacia nilotica* in India (Pandey et al., 2000).

Bulk density varied significantly among distance from the tree trunk ($p < 0.05$) and was higher in the open field than under the canopy. This might be due to soil organic matter accumulation under canopy of the tree through litter fall and root turnover which improves aggregate stability and both have the effect of loosening the soil (Brady and Weil, 2002) whereas the soils outside the canopy of the tree being exposed to direct solar radiation that dries out more and this leads quick organic matter decomposition thus making the soil more compact and higher soil bulk density in the open (Aweto and Dikinya, 2003). The result was in line with reports for *Miltia ferruginea*, *Combretum apiculatum* and *Peltophorum africanum*, *Prosopis juliflora* and *Acacia tortilis* (Tadesse Hailu et al., 2000; Aweto and Dikinya, 2003; Kahi et al., 2009). The variation also observed between the surface and subsurface soil could be due to influence of cultivation practice, tree root and organic matter inputs. The result was supported by the work of (Tadesse Hailu et al, 2000) under *Meltia ferruginea* tree. In contrast with this study, (Endeg Dires, 2008) found no change in soil bulk density under the tree canopy of *Ficus thonningii* as compared to open field.

Soil moisture content was highly significantly different ($P < 0.0001$) among distances from the tree trunk (Table 1). Higher soil moisture content maintained under the canopy of the trees might be the ability of the tree for maintains the soil moisture content by providing shade and reducing rain fall speed through its canopy that increases infiltration rate within the system (Young, 1997; Kessler and Breman, 1991; Rhoades, 1995). This study is in line with (Breman and Kessler, 1995; Tadesse Hailu et al., 2000) higher soil moisture content under the tree canopy than that of open areas.

Table 1: Mean (\pm SE) values of bulk density (g/cm^3), soil moisture content (%) and soil particles (%) at different distances as influenced by *Ziziphus spina-christi* at Menentela, Habru district

Parameter	Depth (cm)	Distance (m) from the tree trunk			Overall mean
		1.2	2.9	15	
BD (g/cm^3)	0-15	1.25 (± 0.03)	1.30 (± 0.05)	1.35 (± 0.04)	1.30 (± 0.026)b
	15-30	1.28 (± 0.04)	1.32 (± 0.04)	1.41 (± 0.03)	1.34 (± 0.025)a
	Over all mean	1.27 (± 0.02) ^b	1.31 (± 0.03) ^a	1.38 (± 0.02) ^a	
SMC (%)	0-15	12.66 (± 0.62)	11.21 (± 0.53)	10.21 (± 0.49)	11.36 (± 0.39)b
	15-30	21.93 (± 0.49)	20.45 (± 0.65)	18.79 (± 0.94)	20.39 (± 0.51)a
	Over all mean	17.30 (± 1.58) ^a	15.83 (± 1.59) ^b	14.50 (± 1.51) ^c	
Clay (%)	0-15	20.7 (± 2.40)	19.5 (± 1.14)	18.8 (± 1.68)	19.7 (± 0.99)a
	15-30	18.9 (± 2.44)	17.6 (± 1.58)	17.4 (± 1.43)	17.9 (± 1.01)b
	Over all mean	19.8 (± 1.63) ^a	18.50 (± 0.98) ^a	18.10 (± 1.06) ^a	
Silt (%)	0-15	21.8 (± 2.30)	20.8 (± 2.43)	21.9 (± 1.63)	21.5 (± 1.15)b
	15-30	25.1 (± 1.42)	25.4 (± 2.45)	23.9 (± 1.60)	24.8 (± 1.02)a
	Over all mean	23.45 (± 1.39) ^a	23.10 (± 1.80) ^a	22.90 (± 1.12) ^a	
Sand (%)	0-15	57.5 (± 1.03)	59.7 (± 2.18)	59.3 (± 2.13)	58.8 (± 1.02)a
	15-30	56.0 (± 1.50)	57.0 (± 2.15)	58.7 (± 0.56)	57.3 (± 0.88)a
	Over all mean	56.75 (± 0.89) ^a	58.4 (± 1.51) ^a	59.00 (± 1.04) ^a	
Texture		Sandy loam	Sandy loam	Sandy loam	

Where: BD = bulk density, SMC= soil moisture content and rows with the same letter superscript are not significantly different at $p < 0.05$

Soil pH, Electrical conductivity, Organic carbon, Total nitrogen and Available Phosphorus

Soil pH and soil electrical conductivity (EC) did not significantly vary ($p > 0.05$) with distances from the tree trunk. Soil organic Carbon (%), total nitrogen (%) and available phosphorus (mg/kg) significantly varied ($p < 0.0001$) with distance from the tree trunk. Soil organic carbon, total nitrogen and available phosphorus decreased as the distances increased from the tree trunks. Soil organic carbon, total nitrogen, available phosphorus and soil electrical conductivity decreased with increasing soil depth (Table 2). Soil pH did not significantly vary with soil depth.

Soil organic carbon, total nitrogen and available phosphorus were significantly varied at distance from the tree trunk and soil depths. This might be due to higher organic matter input through litter fall and fine root subsequent decomposition. Soil organic matter was increased by about 13% under the canopy of *Cordia africana* (Abebe Yadessa et

al., 2009). Similarly (Pandey and Sharma, 2005) found higher organic carbon under the canopy of *Acacia nilotica* tree than that of open area. Higher organic carbon recorded under *Cordia africana* and *Millettia ferruginea* trees canopy than that of open area (Zebene Asfaw, 2003). The variation in organic carbon with depth in the present study was similar to other scholars for example, (Tadesse Hailu et al., 2000) observed higher organic carbon in the surface and subsurface soil under the canopy of *Millettia ferruginea* as compared to the open field. In contrast to the finding of the present study (Jiregna Gindaba et al., 2005) found that organic carbon was not enriched under both *Cordia africana* and *Crotonmacrostachyus* trees on farm lands compared with areas away from canopies in Badessa area, Ethiopia.

Total soil nitrogen was influenced by the presence of *Ziziphus spina-christi* on farm lands. Soil nitrogen decreased with increasing distance from the tree trunk and soil depths. This probably due to accumulation of higher organic matter through leaf litter fall and deep rooted nature of a tree can take up nutrients from deepest soil profile and the residential animals and birds could also be responsible for the higher total nitrogen observed under the tree canopies (Pandey and Sharma, 2005; Kahi et al., 2009). The present study is in line with (Tadesse Hailu et al., 2000) found higher total soil nitrogen under the canopy of *Millettia ferruginea* as compared to open area. Similarly, (Jiregna Gindaba et al., 2005) found higher total soil nitrogen under the canopy of *Cordia africana* and *Croton macrostachyus* than that of open area. Higher total nitrogen observed under *Acacia tortilis* canopy than soils in the adjacent open areas (Kahi et al., 2009). In contrast to this study, (Fentahun Mengistu, 2008) has observed no change in total nitrogen under canopy of *Ziziphus spina-christi* trees as compared to away from the tree canopy area in western Amhara region, Ethiopia.

Available soil phosphorus was influenced by the presence of *Ziziphus spina-christi* on farmlands. Available phosphorus decreased as distance increased from tree base and with increasing soil depth from 0-15cm to 15-30cm. Higher soil phosphorus level found under the canopies of *Ziziphus spina-christi* might be due to high litter accumulation from above and belowground tree biomass that increases the soil organic carbon. As SOC increased, correspondingly the organic phosphorus increased. This study agrees with substantial amount of available phosphorus found under the tree canopy by different scholars (Tadesse Hailu et al., 2000) who observed higher available soil phosphorus status in the surface soils than in the subsurface and under the canopy of *Millettia ferruginea* trees than in the open field. Similar trends were also reported under *Faidherbia albida* and *Cordia africana* on farm lands in Ethiopia (Kamara and Haque, 1992; Abebe Yadessa et al., 2009). In contrast to the present investigation, (Enideg Diress, 2008) reported no change in available phosphorus status between soils under canopy of *Ficus thonningii* and open area in Gonder zuria, Ethiopia.

Table 2: Mean (\pm SE) values of soil pH, EC, OC, TN and AP at different radial distances as influenced by *Ziziphus spina-christi* trees at Menentela, Habru district

Parameter	Depth (cm)	Distance (m) from the tree trunk			Overall mean
		1.2	2.9	15	
pH (H ₂ O)	0-15	7.16 (\pm 0.02)	7.18 (\pm 0.03)	7.20 (\pm 0.02)	7.18(\pm 0.014) ^a
	15-30	7.16 (\pm 0.03)	7.20 (\pm 0.03)	7.18 (\pm 0.03)	7.18(\pm 0.018) ^a
	Over all mean	7.16(\pm 0.01) ^a	7.19(\pm 0.02) ^a	7.19(\pm 0.02) ^a	
EC (ds/m)	0-15	0.48 (\pm 0.03)	0.44 (\pm 0.02)	0.42 (\pm 0.005)	0.45(\pm 0.014) ^a
	15-30	0.41 (0.02)	0.41 (\pm 0.02)	0.39(\pm 0.01)	0.40(\pm 0.011) ^b
	Over all mean	0.45(\pm 0.02) ^a	0.42(\pm 0.01) ^a	0.40(\pm 0.007) ^a	
OC (%)	0-15	1.15 (\pm 0.01)	0.87 (\pm 0.06)	0.62 (\pm 0.08)	0.88(\pm 0.066) ^a
	15-30	0.89 (\pm 0.02)	0.73 (\pm 0.09)	0.49 (\pm 0.11)	0.70(\pm 0.062) ^b
	Over all mean	1.02(\pm 0.04) ^a	0.80(\pm 0.05) ^b	0.56(\pm 0.07) ^c	
Total N (%)	0-15	0.07 (\pm 0.006)	0.05 (\pm 0.001)	0.04 (\pm 0.001)	0.05(\pm 0.003) ^a
	15-30	0.06 (\pm 0.005)	0.05 (\pm 0.001)	0.04 (\pm 0.001)	0.04(\pm 0.002) ^b
	Over all mean	0.06(\pm 0.004) ^a	0.05(\pm 0.001) ^b	0.04(\pm 0.001) ^c	
Av.P (mg/k)	0-15	4.06(\pm 0.59)	3.51(\pm 0.65)	2.51(\pm 0.20)	3.36(\pm 0.32) ^a
	15-30	1.99(\pm 0.44)	1.80 (\pm 0.10)	1.54(\pm 0.20)	1.78(\pm 0.16) ^b
	Over all mean	3.02(\pm 0.49) ^a	2.66(\pm 0.42) ^{ab}	2.02(\pm 0.21) ^b	

Rows with the same letter superscript are not significantly different at $p < 0.05$. Where: EC= electrical conductivity, OC= organic carbon, TN= total nitrogen, AP= available phosphorus and C.V= coefficient of variance.

Cation exchange capacity and exchangeable cations (K, Mg and Ca)

CEC did not significantly differ ($p > 0.05$) with distances from the tree trunk while the mean values of exchangeable base cations (magnesium, calcium and potassium) showed significant variation ($p < 0.05$) with distance from tree trunk (Table 3). Generally exchangeable base cation show a decreasing trend with increasing distances from tree trunk. Exchangeable calcium, magnesium and CEC were similar at 0-15cm and 15-30cm soil depths, but exchangeable potassium decreased significantly ($p < 0.05$) at 15-30cm soil depth. This may be due to high organic matter input through leaf litter and fine root turnover deposition under the canopy of *Ziziphus spina-christi* and subsequent

mineralization. Exchangeable K^+ , Mg^{2+} and Ca^{2+} were higher under the canopy of *Combretum apiculatum* and *Peltophorum africanum* than in the open fields in semi-arid south eastern Botswana (Aweto and Dikinya 2003). Similarly, (Kho et al., 2001) found that higher levels of exchangeable potassium, calcium and magnesium in the top soils under the canopies of *Faidherbia albida* than that of in the open in a semi-arid savanna of Niger. (Kindu Mekonen et al., 2009) also found higher content of exchangeable cations in the surrounding area of *Hagenia abyssinica*. In contrast to the present finding, (Miftha Beshir, 2012) reported that exchangeable cations did not improve under the canopy of *Acacia etbaica* as compared with that of the open field.

Table 3: Mean (\pm SE) values of soil CEC (cmol (+)/kg) and exchangeable cations at different radial distances as influenced by *Ziziphus spina-christi* trees at Menentela, Habru district

Parameter	Depth(cm)	Distance (m) from the tree trunk			Overall mean
		1.2	2.9	15	
CEC	0-15	34.02(\pm 1.96)	33.38 (\pm 1.87)	34.10 (\pm 1.18)	33.83 (\pm 0.91) ^a
	15-30	33.78 (\pm 1.37)	34.64(\pm 2.85)	36.29 (\pm 1.29)	34.90 (\pm 1.09) ^a
	Over all mean	33.90(\pm 1.13) ^a	34.01(\pm 1.62) ^a	35.20(\pm 0.90) ^a	
Ca	0-15	10.85 (\pm 1.09)	10.95 (\pm 0.76)	8.83 (\pm 0.93)	10.21(\pm 0.56) ^a
	15-30	10.98 (\pm 0.75)	10.26 (\pm 0.84)	8.68 (\pm 1.24)	9.97 (\pm 0.58) ^a
	Over all mean	10.91(\pm 0.62) ^a	10.60(\pm 0.54) ^a	8.75(\pm 0.73) ^b	
Mg	0-15	7.84 (\pm 0.79)	6.50 (\pm 0.20)	5.95 (\pm 0.87)	6.76 (\pm 0.42) ^a
	15-30	7.18 (\pm 0.55)	6.14 (\pm 0.58)	6.37 (\pm 0.50)	6.56 (\pm 0.31) ^a
	Over all mean	7.51(\pm 0.47) ^a	6.32(\pm 0.30) ^{ab}	6.16(\pm 0.47) ^b	
K	0-15	0.42 (\pm 0.05)	0.37 (\pm 0.03)	0.34 (\pm 0.03)	0.37 (\pm 0.024) ^a
	15-30	0.37 (0.05)	0.35 (\pm 0.04)	0.31 (\pm 0.02)	0.34 (\pm 0.023) ^b
	Over all mean	0.39(\pm 0.03) ^a	0.36(\pm 0.02) ^{ab}	0.32(\pm 0.02) ^b	

NB: Rows with the same letter superscript are not significantly different at $p < 0.05$. Where: CEC= cation exchange capacity, Ca =Calcium, Mg= magnesium, K= Potassium,(cmol(+)/kg) =centimols of cations/kg of soils.

Effects of *Ziziphus spina-christi* on sorghum plant height, grain and biomass yields

Ziziphus spina-christi had no effect on sorghum yield, plant height and above ground biomass and statistically did not vary significantly ($p > 0.05$) at distances from the tree trunk.

Table 4: Effect of *Ziziphus spina-christi* on sorghum plant height (cm), grain and biomass yield (Kg ha^{-1}) on farm field at Menentela Kebele, Habru district

Parameter	Distance from the tree trunk		
	1.2m	2.9m	15m
Plant height(cm)	196.95	191.71	189.07
Grain yield (kg ha^{-1})	1430.00	1400.00	1386.00
Biomass yield (kg ha^{-1})	12208.6	11266.4	10237.3

NB: Values in rows with the same letter are not significantly different at $p < 0.05$.

CONCLUSION AND RECOMMENDATION

Bulk density and soil moisture influenced by presence of *Ziziphus spina-christi* trees. Soil moisture content was significantly increase with increasing soil depths and decreased with increasing distance. Bulk density increased with increasing distance from the tree trunk and soil depths while soil texture (sand, silt and clay) fraction was not influenced by presence of scatter *Ziziphus spina-christi* tree. Soil OC, TN, available P, K, Ca and Mg were improved by *Ziziphus spina-christi* while soil pH, EC and CEC were not influenced by its presence. *Ziziphus spina-christi* has no influence on plant height, grain and biomass yield of sorghum. In general, *Ziziphus spina-christi* trees in the study area had improves both physical and chemical soil properties. Hence, further research required on contribution of its leave for soil improvements and fine root distribution. The result of sorghum yield reported in this study was from under farmer's management which may not be applied the same management practice. So, further study is needed under controlled experiment in association with this tree. Information also required on the number of trees retaining per hectare for increasing associated crop productivity.

ACKNOWLEDGEMENTS

The authors would like to greatly indebted to Amhara Regional Agricultural Research Institute (ARARI) and Debre Birhan Agricultural Research Center for sponsoring this work, Sirinka Agricultural Research Center, especially soil and water conservation research directorate for their permission to carried out soil analysis on their soil laboratory.

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