



## Potential of *Melia dubia* agroforestry system in soil improvement and environmental sustainability

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### Abstract

The current study intended to understand the influence of *Melia dubia* based agroforestry system on soil properties. The research was carried out at Gillan Khera in district Fatehabad, situated in the semi-arid region of Haryana. Analysis of soil samples were done for pH, electrical conductivity (EC), organic carbon, soil moisture and available nitrogen, phosphorus and potassium. The soil pH and EC decreased more under trees than under control (sole wheat crop) i.e, 8.09 to 7.89 and 0.46 to 0.44 dSm<sup>-1</sup> respectively. However, the amount of N, P, K, organic carbon (131.38, 16.00, 301.10 (kg/ha) and 0.46 % respectively) and soil moisture content was found higher in intercropped conditions at both soil depths. Extra moisture in shaded conditions resulting in the breakdown of litter, mineralization and nitrogen gain at a faster rate compared to full sunlight conditions justifies the increased amount of nutrients, organic carbon and other favorable changes in the soil under trees. The current study recommends *Melia dubia* based agroforestry system as an excellent opportunity in order to enhance soil fertility and for environmental sustainability.

Key words: *Agroforestry system, Environment, Melia dubia tree, Organic carbon, Soil parameters*

### Introduction

Agroforestry is a feasible choice to face environmental challenges and accomplish the demands of fast-growing human population in a sustainable mode. Sustainability necessitates fertile soils and that can be well preserved and enhanced through agroforestry interventions. Trees on agricultural lands are capable of solving a number of complications of agricultural systems for example sustainable biological production, indiscriminate deforestation, declining soil fertility, occurring of droughts and increasing use of dangerous chemicals (Arya *et al.*, 2018). Trees in agroforestry systems improve soil organic matter, N-retention, water holding capacity and infiltration rates in the soil. They help in the preservation of soil fertility through nitrogen fixation and return of organic content through leaf fall (Rosenstock *et al.*, 2014). Soil is the biosphere's greatest reservoir of terrestrial organic carbon; it contains more carbon than the atmosphere in combination with the plants (Magar *et al.*, 2020). The presence of agricultural systems optimizes recycling of nutrients which results in tree species having a positive effect on various soil properties. Agro-forestry technologies

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have proved their worth as substitutes (or complements) to fertilizer (Bhardwaj *et al.*, 2020). For decades, studies relating to the interaction between trees, crop and soil have been an interesting subject for researchers. Trees alter soil properties in a variety of ways. Root systems of trees and crops play an important role, since they decide major soil functions via involvement in major below-ground processes (Sto"cker *et al.*, 2020). Proper understanding of interactions of agroforestry and soil processes may aid us in meeting our sustainability goals such as sequestration of soil organic carbon. Soil organic carbon content is often found higher in agroforestry systems compared to treeless croplands, owing to tree litter fall and pruning residues, as well as tree root inputs. Other than inputs of tree canopy by leaf fall there are numbers of ways trees can enhance nutrients through small efforts such as faecal inputs of birds and browsing or grazing animals residing on the tree or near them. Faunal diversity and abundance are habitually found to have a positive effect though, comparing to the forest lands the effects are neutral or negative (Cardinael *et al.*, 2020). The chief benefit of agroforestry is sustainability most researchers focus primarily on the ecological benefits, whereas growers are



concerned only with instantaneous profits and income. As a result, the future must resolve the balance between climate and economy. (Liu *et al.*, 2019). Over the last half-century, a lot of scientific research has shown that a huge number of issues related to sustainability can be tackled through agroforestry that the world is facing (Kmocho *et al.*, 2018, Jemal *et al.*, 2018).

## Materials and Methods

Present soil-tree interaction study estimates modifications in soil fertility and moisture content in a four years old plantation of *Melia dubia* having wheat varieties grown in interspaces of trees in semi-arid belt of north-western India. The study was carried out at a farmer field at village Gillan Khara in district Fatehabad, situated in the semi-arid region of Haryana. The coordinates of the study site were 29°50' and 75°30' and altitude 212 m above mean sea level. Regional climate of the location is subtropical-monsoonic. This place receives 360-400 mm of average rainfall annually. Maximum temperature (mean) in May and June during summer months ranges from 40 to 45°C and minimum temperature of 0°C in December and January. The standard package of practices as recommended by CCS Haryana Agricultural University was followed for the cultivation of crops. Collection of soil samples was performed at different depths *i.e.* (0-15 cm, 15-30 cm, 15-45 cm) from the experimental field in three replicates. This was done twice *i.e.* prior to sowing and later after harvesting of wheat crop. Soil samples were analyzed for electrical conductivity, pH and organic carbon and nutrients (nitrogen, phosphorus and potassium). First air-drying of soil samples was done and then ground in a wooden pestle and mortar, the ground soil was passed from a stainless steel sieve of 2 mm. The soil obtained was kept to carry out the analysis. The soil pH and electrical conductivity were determined through distilled water suspension (1:2). Soil samples for soil moisture readings were taken at 0.5m, 1m, and 1.5m distance away from the tree line. Samples were taken three times *i.e.* before irrigation and the 7<sup>th</sup> and 14<sup>th</sup> day after irrigation. The data recorded during the research were analyzed statistically by the Panse and Sukhatme method given in 1985. Soil

parameters were estimated following standard procedures (Table 1).

Table 1: Standard procedure followed for soil estimation

Properties	Method
Electrical conductivity (dS m <sup>-1</sup> )	Conductivity meter (Jackson, 1973)
Soil (pH)	Glass electrode pH meter (Jackson, 1973)
Organic carbon (%)	Partial oxidation method (Walkley and Black, 1934)
Available nitrogen (kg ha <sup>-1</sup> )	Alkaline permanganate distillation method (Subbiah and Asija, 1956)
Available phosphorus (kg ha <sup>-1</sup> )	Sodium bicarbonate method (Olsen <i>et al.</i> , 1954)
Available potassium (kg ha <sup>-1</sup> )	Neutral normal ammonium acetate method (Jackson, 1973).

## Results and Discussion

A significant improvement in the EC, pH, organic carbon content and various soil nutrients such as available nitrogen, phosphorus and potassium were observed in the soil under tree condition over sole crop (control). The decrease in values of soil pH was observed under trees as well as in without tree conditions after harvest at 0-15 cm (Table 2). The results revealed that the maximum decrease in soil pH was observed under trees at 0-15 cm soil depths *i.e.* 8.09 to 7.89, before sowing to after harvest respectively. There is less change in soil pH in condition without tree *i.e.* 7.91 to 7.89 before sowing to after harvest respectively. Compared to the 15-30 cm depth of soil a higher decrease in pH was found at 0-15 cm soil depth. There was a slight decrease in soil pH under *Melia dubia* after harvest of crop however, negligible change was observed in system without trees from November 2018 to April 2019. The decrease in soil pH was more under *Melia* plantation than in control (sole crop). This may be due to microclimate created by crop and tree root system and the acidic nature of litter fall which decreased the soil pH after decomposition. Similar outcomes were witnessed by Tripathi *et al.* (2009). Litter decomposition owing to release of organic matter and weak organic acids into the soil is probably the reason for slightly lesser pH in agri-silviculture systems (Prasadini and Sreemannarayana, 2007).

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**Table 2: Soil pH and organic carbon content at different depth before sowing and after harvesting of wheat varieties in control (field without trees) and under tree condition**

Soil Depth (cm)	Soil pH						Organic carbon (%)					
	Before sowing			After harvest			Before sowing			After harvest		
	Under Tree	Without Tree	Mean	Under Tree	Without Tree	Mean	Under Tree	Without Tree	Mean	Under Tree	Without Tree	Mean
0-15	8.09	7.91	8.00	7.89	7.89	7.89	0.44	0.35	0.40	0.46	0.34	0.40
15-30	8.29	7.89	8.09	8.28	7.89	8.09	0.28	0.23	0.26	0.30	0.21	0.26
Mean	8.19	7.90		8.08	7.89		0.36	0.29		0.38	0.28	
C. D. at 5%												
Depth	NS			0.08			0.005			0.010		
Environment	0.16			0.08			0.005			0.010		
D×E	NS			0.12			0.007			0.014		

**Table 3: Soil EC and nitrogen content at different depth before sowing and after harvesting of wheat varieties in control (field without trees) and under tree condition**

Soil Depth (cm)	Soil EC						Available nitrogen (kg/ha)					
	Before sowing			After harvest			Before sowing			After harvest		
	Under Tree	Without Tree	Mean	Under Tree	Without Tree	Mean	Under Tree	Without Tree	Mean	Under Tree	Without Tree	Mean
<b>0-15</b>	0.46	0.51	0.49	0.44	0.50	0.47	130.43	109.80	120.11	131.38	108.93	120.15
<b>15-30</b>	0.38	0.45	0.42	0.36	0.43	0.40	126.88	107.98	117.43	127.25	107.00	117.13
<b>Mean</b>	0.42	0.48		0.40	0.47		128.65	108.89		129.31	107.96	
C. D. at 5%												
<b>Depth</b>	0.007			0.005			1.27			1.31		
<b>Environment</b>	0.007			0.005			1.27			1.31		
<b>D×E</b>	0.009			0.007			NS			NS		



Soil organic carbon under *Melia dubia* and in without tree conditions showed significant variation in both 0-15 and 15-30 cm soil depth (Table 2). Going deeper in the soil depth it was observed that organic carbon decreased under tree and without tree conditions in both the observations taken before sowing and after harvest. Plots integrated with tree were significantly higher in organic carbon content (0.46%) at 0-15 cm compared to (0.30%) 15-30 cm after harvesting wheat varieties. A decrease in open conditions from 0.35 to 0.34% and 0.23 to 0.21% after harvest among both depths (0-15 cm and 15-30) was found respectively. Soil organic carbon under *Melia* plantation increased significantly at both depths compared to the initial status of organic carbon. Lack of lignified cells in agricultural residues might be the reason for lower organic carbon in the study plots lacking trees. Another reason that has attributed is soil being exposed to the sun at its fullest.

Organic carbon content in the soil is a robust factor of soil quality, specifically in semiarid areas for the determination of agronomic production (Sharma *et al.*, 2014). Gill and Burman (2002) stated that the addition of litter, annual fine root biomass and root exudates, as well as decreased oxidation of organic matter under tree shade, could all contribute to amelioration of soil. Arya and Toky (2017) in their study on poplar based agri-silviculture system found them extremely useful as tree-based cropping system add a large amount of litter hence, ultimately increase amount of organic matter content in the soil. Tropical agroforests have been found to play a significant part in storing organic carbon content in the soil. The total amount of organic carbon in the soil was discovered to be 24.91 tonnes per hectare (Magar *et al.*, 2020). Agroforestry provides an approach through which in very little time organic content could be added by selection of proper nitrogen-fixing tree species and if they are fast-growing too (Tsufac *et al.*, 2021). The value of EC varied significantly under different environment and soil depth before and after harvesting wheat varieties (Table 3). A decrease in EC was recorded at both the soil depths under *Melia dubia* plantation as compared to without tree. The electrical conductivity of soil decreased from 0.46 to 0.44 dSm<sup>-1</sup> at 0-15 cm soil depth and 0.38 to 0.36 dSm<sup>-1</sup> at 15-30 cm under tree during the data collection after harvesting. The

decrease in value of EC was higher under plots with trees than in without trees at both the soil depths *i.e.* 0.51 to 0.50 dSm<sup>-1</sup> (0-15 cm) and 0.45 to 0.43 dSm<sup>-1</sup> (15-30 cm). Maximum decrease (0.03 dSm<sup>-1</sup>) in EC was found under trees at soil depth of 0-15 cm. The electrical conductivity at both soil depths decreased under *Melia dubia* based agroforestry system. The rate of decrease in electrical conductivity was comparatively low in without tree. Similar observations regarding pattern of electrical conductivity were reported by Patel *et al.* (2010). Agroforestry is capable of ameliorating the soils affected by salt and low fertility. It reduces the burden of productive soils for the fulfillment of food requirements of a growing population and various conservational issues (Sharma *et al.*, 2014). The absence of proper quantitative knowledge about the performance of various field crops and resource competition with tree is a chief hindrance in the adoption of agroforestry system for farmers (Artru *et al.*, 2017).

The data presented in table 3 depicts that soil nitrogen under *Melia* plantation soil nitrogen increased significantly. The increase in soil nitrogen was more in the upper layer of soil under tree plantation *i.e.* from 130.43 to 131.38 (kg/ha) at 0-15 cm and 126.88 to 127.25 (kg/ha) at 15-30 cm. The soil available nitrogen was observed to have less quantity in without tree conditions as compared to under tree conditions in both soil depths. Table 2 and 3 depicts data for available macronutrients in the soil advocates for their increased values under *Melia dubia* plantation from their initial values. There was an improvement in the available nitrogen content at harvesting time probably because of the rise of humus in soil after decomposition of litter fall of *Melia* tree. Githae *et al.* (2011) in an *Acacia*-based agri-silviculture system witnessed similar results in their study. They reported that the nitrogen content of soil under agri-silviculture system increased because of litter fall accumulation by *Acacia*. Various researchers such as Tiwari and Baghel (2014) and Bhardwaj *et al.* (2017) noted the positive behavior of agroforestry in increasing the nutrient status and enhancing the fertility of soil in their research. The rise in available nitrogen under agri-silviculture system is because of extra moisture in the shade, combined with a more moderate temperature, resulting in breakdown of litter, mineralization and nitrogen gain at a faster rate



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Table 4: Soil phosphorus and potassium content at different depth before sowing and after harvesting of wheat varieties in control (field without trees) and under tree conditions

Soil Depth (cm)	Available phosphorus (kg/ha)						Available potassium (kg/ha)					
	Before sowing			After harvest			Before sowing			After harvest		
	Under Tree	Without Tree	Mean	Under Tree	Without Tree	Mean	Under Tree	Without Tree	Mean	Under Tree	Without Tree	Mean
0-15	15.33	13.63	14.48	16.00	13.51	14.75	297.38	248.63	273.00	301.10	251.38	276.24
15-30	8.43	7.53	7.98	8.60	7.43	8.01	288.93	244.20	266.56	295.05	247.95	271.50
Mean	11.88	10.58		12.30	10.47		293.15	246.41		298.08	249.66	
<b>C. D. at 5%</b>												
Depth	0.119			0.055			2.777			2.962		
Environment	0.119			0.055			2.777			2.962		
D×E	0.168			0.078			NS			NS		

Table 5: Soil moisture status at different soil depth and distance form tree row for first and second irrigation in sole and under tree condition.

First irrigation																		
Soil Depth (cm)	Before irrigation						After 7 days of irrigation						After 14 days of irrigation					
	0.5 m		1 m		1.5 m		0.5 m		1 m		1.5 m		0.5 m		1 m		1.5 m	
	UT	WT	UT	WT	UT	WT	UT	WT	UT	WT	UT	WT	UT	WT	UT	WT	UT	WT
0-15	11.90	8.91	11.71	8.61	11.62	8.58	16.00	10.60	15.73	10.20	15.69	10.11	14.30	9.80	14.10	9.30	14.06	9.21
15-30	12.07	9.90	11.76	9.10	11.72	9.06	18.40	16.20	18.00	15.70	17.92	15.59	15.20	12.10	14.95	11.83	14.90	11.76
CD at 5%	Distance= 0.22; Depth= 1.8; Distance × Depth = NS						Distance= 0.31; Depth= 0.26; Distance × Depth = NS						Distance= NS; Depth=0.27; Distance × Depth =NS					
Second irrigation																		
Soil Depth (cm)	Before irrigation						After 7 days of irrigation						After 14 days of irrigation					
	0.5 m		1 m		1.5 m		0.5 m		1 m		1.5 m		0.5 m		1 m		1.5 m	
	UT	WT	UT	WT	UT	WT	UT	WT	UT	WT	UT	WT	UT	WT	UT	WT	UT	WT
0-15	11.60	9.27	11.20	8.80	11.11	8.77	18.10	17.30	17.80	17.20	17.68	17.02	10.70	9.20	10.43	8.92	10.37	8.81
15-30	11.91	10.83	11.04	10.60	11.30	10.38	19.40	18.20	19.10	17.90	19.02	17.67	11.10	9.80	10.97	9.45	10.93	10.37
CD at 5%	Distance= 0.21; Depth= 0.17; Distance × Depth = NS;						Distance=NS; Depth= 0.30; Distance × Depth = NS;						Distance=NS; Depth=0.28; Distance × Depth = NS;					



compared to full sunlight conditions (Antonio and Gama-Rodrigues, 2011). The cycling of nutrients in agroforestry system is one of the major developments that support organic matter production (Toky *et al.*, 2018).

The available phosphorous in soil increased significantly under trees at both the soil depths (Table 4). The available phosphorus content also increased significantly over its initial values under trees. After harvesting wheat varieties the maximum available phosphorous (16.0 kg/ha) was observed in 0-15 cm soil depth under trees however, available phosphorous (7.43 kg/ha) obtained was less at 15-30 cm depth in open conditions. A similar trend was exhibited by phosphorus as of nitrogen depicted in (Table 4). Compared to the initial values phosphorus content of soil was observed to be increased after harvest. The increase in phosphorus content of soil was recorded more at 0-15 cm depth under tree conditions compared to the deeper depth of soil. Sarkar *et al.* (2020) stated that agroforestry recycle plant nutrients in a better way through deep root system and more litter-fall, over conventional agriculture system. Hence, agroforestry system development could be taken over crop production as stable and revival option for enhancing the sustainability of soil. Agroforestry is very promising in decontaminating the polluted soil. There are some potential agroforestry suitable tree species, which are found to be promising candidates for the phytoremediation of pollution (Sade, 2020). Available potassium in soil showed similar results as of nitrogen and phosphorus (Table 4). Highest value for available soil potassium was noted under *Melia dubia* trees (301.10 kg ha<sup>-1</sup>) at a depth of 0-15 cm while the lowest (247.95 kg ha<sup>-1</sup>) at a depth of 15-30 cm in without tree condition. An increase in potassium was observed after harvest when compared to initial values in both environments. Bisht *et al.* (2017) in their study suggested poplar and wheat intercropping suitable for soil physical and chemical properties. In intercropping of poplar and wheat, variety DBW-711 was recorded with the highest available potassium *i.e.*, 219.63 kg/ha under trees. Investigators strongly recommended amalgamation of agroforestry tree species and annual crops instead of sole crop in order to enrich soil nutrients. Investigators studying various soil properties in

Terai region of North India revealed that poplar and *Leucaena* trees grown at 3.0×1.0 m<sup>2</sup> spacing showed results of amelioration (Sarvade *et al.*, 2014). Agroforestry has immense possibilities for greater agricultural production, sequestration of carbon, checking soil erosion, runoff control, proper cycling of water and boosted nutrient content in the soil. As agroforestry research started developing, investigators see this approach of tackling environmental issues as a sustainable and profitable way. (Brown *et al.*, 2018).

In open and under tree (both) conditions the moisture content in the soil increased while going deeper in the soil profile but it decreased with the increasing distance from tree line (Table 5). The maximum loss in moisture content was observed in open condition because of evapo-transpiration. The results showed that the soil depth, aspect, and distance all had a major impact on moisture content. According to the data depicted (Table 5) maximum moisture content in the soil was obtained at a depth of 15-30 cm of soil depth *i.e.*, (12.1%) under tree conditions at 0.5 m distance from the tree row prior to any irrigation. After irrigation also same pattern of increasing moisture content with an increase in soil depth was observed. An increasing trend of moisture content was observed while going deeper into soil profile in both the conditions of crop environment. While a decreasing pattern was recorded while moving away from tree row (0.5, 1.0 and 1.5 m). There is more change in moisture per cent from 0.5 to 1.0 m than from 1.0 m to 1.5 m. The minimum soil moisture per cent is found at 1.5 m away from tree. This might be due to maximum interaction of trees spaced at 3m×3m. In under tree, more moisture per cent is recorded because the phenological behavior of *Melia dubia* being deciduous in nature helps in conservation of moisture in soil probably due to presence of litter as mulch restricting loss of moisture through evaporation and also in Rabi season *Melia* growth is restricted because it enters into dormancy and intake less amount of water for transpiration. Carvalho *et al.* (2020) concluded that shaded agroforestry coffee systems improve microclimate conditions compared with un-shaded coffee systems. Sto"cker *et al.* (2020) found that agri-silviculture system encouraged positive alterations in soil physical traits and resulted in consistent enhancement of soil quality. Researchers suggested



diversified root systems of tree and accumulation of crop residues for the speedy enhancement of quality of soil. Agroforestry improves soil productivity apart from providing an assurance to the farmers against any uncertainty Arya and Toky (2017).

### Conclusion

The present study indicates that *Melia dubia* trees grown in semi-arid environment of Haryana in an agroforestry system have positive effects on soil health. EC and pH were found to be decreased under *Melia dubia* when noted after the harvesting of the wheat varieties. The nutrients and organic carbon content increased in the intercropped system. Moisture content was higher under trees compared to open conditions and this factor contributed to overall changes showing improvement of soil fertility. Overall this very intercropping system could be suggested for its

number of benefits such as recycling through litter-fall, improvement in soil fertility and environmental benefits. The study revealed the potential of *Melia dubia* based agroforestry system to improve the fertility of soil. Hence, it is commended that cultivators must initiate agroforestry practices integrating *Melia dubia* trees on their farms so as to boost the fertility of the soil and for a sustainable environment.

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