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Comparative Study of Soil Properties under Gamhar (*Gmelina arborea*) Based Agrisilvicultural System

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Authors' contributions

This work was carried out in collaboration among all authors. Author AK carried out the study, organized the field experiment and wrote the first draft of the manuscript. Author MSM major advisor, provided guidance in revising the manuscript, and authors PRO, RK and SB help in statistical analysis and made suggestions in the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

A two year experiment was conducted during *kharif* and *rabi* season of 2016-2017 and 2017-2018 at experimental site near Faculty of Forestry in main campus of Birsa Agricultural University, Ranchi, Jharkhand, India. Sole cropping and gamhar based agrisilviculture systems with four different intercrops (arhar, cowpea, greengram and mustard) were under investigation. To study the overall scenario of soil properties under agrisilviculture system, soil samples were analysed at different profile depths (0-15 and 15-30 cm) to measure the changes in soil properties under the influence of gamhar (*Gmelina arborea*) tree and intercrops grown in between. Soil pH, electrical conductivity (dsm^{-1}), organic carbon (%), available nitrogen, phosphorus and potassium (kg ha^{-1}) were found higher at the soil depth 0-15 cm as compared to 15-30 cm due to addition of organic

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residue on the surface soil. Soil OC, available N, P and K in 0-15 cm as well as in 15-30 cm profile was found to be statistically significant. It showed an increase from initial value in all the treatments in 2016-17 and 2017-18. The increase was more in gamhar based agrisilviculture system than in sole tree and sole crops in both the years.

Keywords: Agroforestry; soil properties; intercrops; arhar; cowpea; greengram; mustard.

1. INTRODUCTION

Agroforestry has always been endorsed for its carbon sequestration potential and other allied benefits such as improved nutrient content in soil, soil erosion, runoff control and providing different socioeconomic benefits and ultimately greater agricultural productivity [1,2,3]. Agroforestry provides both climate change mitigation and adaptation benefits to farmers. In addition to income from sale of agroforestry products, trees on farms area critical component of climate smart agriculture in many systems. Trees contribute to soil fertility by adding nutrients in the case of nitrogen fixing species and they contribute to increasing soil organic matter. It can control runoff thereby reducing soil erosion, reducing losses of water, soil material, organic matter and nutrients. It also can increase and maintain soil organic matter and biological activity at levels satisfactory for soil fertility. Agroforestry system also have the potential to serve in the restoration and rehabilitation of degraded ecosystems, food security, land tenure security, enhanced farm incomes, management of terrestrial and soil biodiversity, reduced soil erosion, carbon sinks, hydrological functions, wildlife corridors, biodiversity conservation, microclimate improvement, increased nutrient retention via root capture and cycling, etc. [4,5,6].

Gamhar has a vigorous root system which enables it to effectively act as a nutrient pump for the uptake of leached nutrients from subsoil to the soil surface through leaf litter. The high capacity of gamhar and gliricidia plantations ensure nutrient cycling, restore degraded soil, conserve soil moisture and protect the soil through the soil plant system [7]. In my experiment out of four crops, three pulses which ability to nitrogen fixing (30-251 kg ha^{-1}) enriches the soil quality and fertility and hence leading to enhanced productivity in subsequent crop rotations. Soil bacteria are utilized for nitrogen fixation from air which replaces additional requirement of nitrogen fertilizers in pulse crops. Nitrogen enriches the soil in different forms like fertilizer, manure or crop residue, and then most part of it is converted into a powerful greenhouse gas, nitrous oxide. Soil health is also improved through pulses as they feed soil microbes.

2. MATERIALS AND METHODS

A two year field experiment was conducted during *kharif* and *rabi* season of 2016-17 and 2017-18 at experimental site near Faculty of Forestry in main campus of Birsa Agricultural University, Ranchi, Jharkhand, India. Birsa Agricultural University is located between $23^0 26' 54.6''$ N to $23^0 26' 55.0''$ N Latitude and $85^0 18' 53.0''$ E to $85^0 18' 53.7''$ E longitudes and at an altitude of 625 meters above mean sea level, in the southern part of the Chota Nagpur plateau in India. It is the eastern section of the Deccan plateau and comes under Central and North-Eastern Plateau (Sub Zone-IV), a part of agro-climatic (Zone VII) of the country known as Eastern Plateau and Hill Region. The experimental site is shown in Fig. 1.

The whole field was laid out as per plan to show the four different crops (arhar, cowpea, greengram and mustard) under gamhar based agrisilvicultural system and sole farming systems. The experiment design adopted was randomized block design (RBD) with seven treatments and three replications. They were: T_1: Gamhar+ Arhar, T_2: Gamhar+ Cowpea-Mustard, T_3: Gamhar+ Greengram-Mustard, T_4: Sole Gamhar, T_5: Sole Arhar, T_6: Sole Cowpea-Mustard, T_7: Sole Greengram-Mustard. Plot size was 24m x 7.5m and the spacing of gamhar was 8m X 2.5m. Gamhar seedlings were transplanted in the experimental field on June, 2016 and intercropping conducted during *kharif* and *rabi* season of 2016-2017 and 2017-2018.

The experimental site was medium land with shallow to medium soil depth. On July, 2016 the experimental site was divided into different representative points to collect the soil samples from 0-15 cm and 15-30 profile depths. After air drying of samples from 0-15 cm and 15-30 profile depths, big stones were removed and the soil was passed through 2 mm sieve. A composite sample was then formed and from this composite sample, 500 gm of soil sample and was selected after proper processing as per standard procedure.

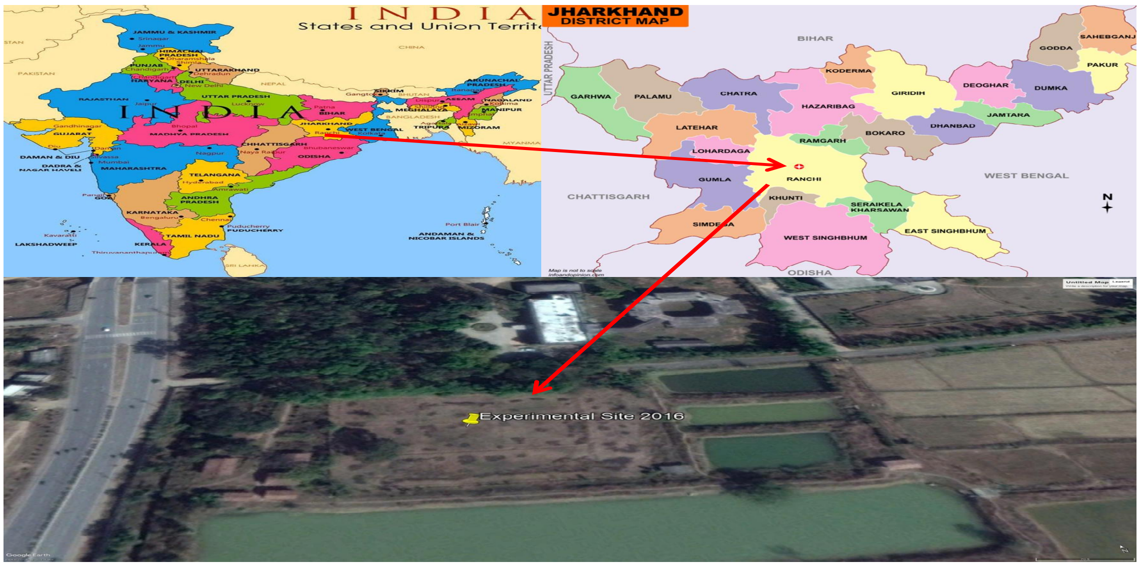

Fig. 1. Location of the experimental site at main campus near faculty of forestry, Birsa Agricultural University, Ranchi, Jharkhand, India

The sample was subjected to mechanical, physical and chemical analysis to assess the initial soil properties of the experimental soil. The soil was loam (sand:silt:clay::42.40:30.80:26.80 in both profile depth), having bulk density 1.55 and 1.61, particle density 2.47 and 2.53, and porosity (%) 37.20 and 36.40 in 0-15 and 15-30 cm soil depth, respectively, acidic in reaction, medium in organic carbon, phosphorus and potassium and low in nitrogen.

3. RESULTS

Soil properties *viz.* Soil pH, electrical conductivity (EC), organic carbon (OC), available nitrogen (N), phosphorus (P) and potassium (K) are the important soil fertility parameters which affect the growth and yield of intercrops and overall production. The soils were evaluated for these parameters and result and discussion are presented.

The data presented in Table 1 on soil pH showed variation under sole farming and gamhar based agrisilviculture system in which four intercrops were grown.

The variation of soil pH in 0-15 cm as well as in 15-30 cm profile was found to be non significant. Soil pH increased compared to the initial value (6.15 and 6.30 in 0-15 cm and 15-30 cm depth, respectively) in all the treatments in 2016-17 and 2017-18. This increase was in general more in agrisilviculture system than in sole tree and crops in both the years.

The data presented in Table 1 on soil electrical conductivity (dsm^{-1}) showed variation under sole farming and gamhar based agrisilviculture system in which four intercrops were grown.

Soil EC increased compared to the initial value (0.22 dsm^{-1} in 0-15 cm and 0.20 dsm^{-1} in 15-30 cm depth, respectively) in all the treatments in 2016-17 and 2017-18. The increase was more in agrisilviculture system than in sole tree and crops in both the years.

The data presented in Table 2 on soil organic carbon (%) showed variation under sole farming and gamhar based agrisilviculture system in which four intercrops were grown.

The data on soil OC in 0-15 cm as well as in 15-30 cm profile was found to be statistically significant. Soil OC increased compared to the initial value (0.62 % in 0-15 cm and 0.52 %in 15-30 cm depth, respectively) in all the treatments in 2016-17 and 2017-18. The increase was more in agrisilviculture system than in sole tree and intercrops in both the years.

The data presented in Table 2 on soil available nitrogen (kg ha^{-1}) showed variation under sole farming and gamhar based agrisilviculture system in which four intercrops were grown.

Table 1. Soil pH and electrical conductivity (EC) of soil at different profile depths 0-15 cm and 15-30 cm under sole farming and gamhar based agrisilviculture system

Treatments	pH				EC (dS m^{-1})			
	0-15 cm		15-30 cm		0-15 cm		15-30 cm	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Gamhar+ Arhar	6.22	6.24	6.36	6.41	0.24	0.26	0.23	0.24
Gamhar+ Cowpea-Mustard	6.21	6.24	6.36	6.39	0.24	0.26	0.21	0.23
Gamhar+ Greengram-Mustard	6.21	6.23	6.35	6.40	0.23	0.25	0.22	0.24
Sole Gamhar	6.17	6.22	6.33	6.37	0.23	0.24	0.21	0.22
Sole Arhar	6.19	6.23	6.35	6.39	0.23	0.25	0.21	0.23
Sole Cowpea-Mustard	6.21	6.23	6.34	6.39	0.24	0.26	0.22	0.24
Sole Greengram-Mustard	6.20	6.22	6.34	6.38	0.24	0.25	0.22	0.22
SEm±	0.08	0.11	0.08	0.13	0.01	0.01	0.01	0.01
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	4.19	6.12	7.20	8.51	3.88	5.67	5.02	7.23
Initial	6.15		6.30		0.22		0.20	

Table 2. Organic carbon (OC) and available nitrogen of soil at different profile depths 0-15 cm and 15-30 cm under sole farming and gamhar based agrisilviculture system

Treatments	Organic carbon (%)				Available nitrogen (kg ha^{-1})			
	0-15 cm		15-30 cm		0-15 cm		15-30 cm	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Gamhar+ Arhar	0.66	0.74	0.55	0.65	167.00	177.00	158.00	165.67
Gamhar+ Cowpea-Mustard	0.65	0.68	0.54	0.57	164.67	174.70	157.33	161.00
Gamhar+ Greengram-Mustard	0.64	0.68	0.55	0.57	164.33	172.00	155.33	157.00
Sole Gamhar	0.63	0.64	0.53	0.55	155.33	166.70	150.67	154.00
Sole Arhar	0.64	0.71	0.54	0.57	165.33	175.00	155.33	157.33
Sole Cowpea-Mustard	0.63	0.67	0.54	0.56	164.33	172.30	156.00	159.00
Sole Greengram-Mustard	0.64	0.66	0.53	0.56	163.33	168.70	153.33	156.67
SEm±	0.01	0.02	0.01	0.02	2.04	2.06	1.31	2.17
CD (p=0.05)	0.03	0.06	0.02	0.06	6.25	6.33	4.02	6.7
CV (%)	3.36	4.73	5.57	5.80	4.16	7.07	6.46	8.4
Initial	0.62		0.52		150.53		147.62	

The data on soil available nitrogen in 0-15 cm as well as in 15-30 cm profile was found to be statistically significant. Soil available nitrogen also showed an increase than initial value (150.53 kg ha^{-1} in 0-15 cm and 147.62 kg ha^{-1} in 15-30 cm depth, respectively) in all the treatments in 2016-17 and 2017-18. The increase was more in agrisilviculture system than in sole tree and intercrops in both the years.

The data presented in Table 3 on soil available phosphorus (kg ha^{-1}) showed variation under sole farming and gamhar based agrisilviculture system in which four intercrops were grown.

The data on soil available phosphorus in 0-15 cm as well as in 15-30 cm profile was found to be statistically significant. Soil available phosphorus showed an increase than initial value (13.66 kg ha^{-1} in 0-15 cm and 11.87 kg ha^{-1} in 15-30 cm depth, respectively) in all the treatments in 2016-17 and 2017-18. The increase was more in agrisilviculture system than in sole tree and intercrops in both the years.

The data presented in Table 3 on soil available potassium (kg ha^{-1}) showed variation under sole farming and gamhar based agrisilviculture system in which four intercrops were grown.

Table 3. Available phosphorus and potassium of soil at different profile depths 0-15 cm and 15-30 cm under sole farming and gamhar based agrisilviculture system

Treatments	Available phosphorus (kg ha^{-1})				Available potassium (kg ha^{-1})			
	0-15 cm		15-30 cm		0-15 cm		15-30 cm	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Gamhar+ Arhar	13.74	16.17	12.43	14.12	242.36	256.33	182.11	197.74
Gamhar+ Cowpea-Mustard	13.72	15.48	12.38	13.27	240.34	252.38	181.33	191.00
Gamhar+ Greengram-Mustard	13.74	15.07	12.42	13.14	240.65	245.68	180.46	186.78
Sole Gamhar	13.67	14.42	11.92	12.74	237.13	241.96	177.66	180.04
Sole Arhar	13.70	15.18	12.35	13.21	239.56	254.15	179.84	193.68
Sole Cowpea-Mustard	13.72	15.11	12.35	13.61	239.32	249.82	180.42	187.68
Sole Greengram-Mustard	13.69	15.07	12.32	13.01	238.93	243.17	178.77	182.80
SEm±	0.15	0.30	0.24	0.23	3.62	3.20	2.97	3.55
CD (p=0.05)	0.47	0.90	0.75	0.70	11.13	9.84	9.13	10.89
CV (%)	6.26	5.40	7.02	5.00	5.06	4.23	7.34	5.26
Initial	13.66		11.87		231.84		171.36	

The data on soil available potassium in 0-15 cm as well as in 15-30 cm profile was found to be statistically significant. Soil available potassium showed an increase than initial value (0.62 kg ha^{-1} in 0-15 cm and 0.52 kg ha^{-1}in 15-30 cm depth, respectively) in all the treatments in 2016-17 and 2017-18. The increase was more in agrisilviculture system than in sole tree and intercrops in both the years.

4. DISCUSSION

The results presented in above section on pH, EC, OC, available soil N, P and K revealed that gamhar based agrisilviculture system. Tree added higher amount of litter fall in the forms of litter, bark; small branches and roots to the soil during two year experiment, thereafter the decomposition process started depending upon the intensity of climatic variable (solar radiation, temperature, relative humidity, precipitation and wind velocity). Consequently, variable quantity of pH, EC, OC, available soil N, P and K was produced in the soil as compared to sole farming system. The maximum pH, OC (%), available N, P, K (kg ha^{-1}) were found at the soil depth 0-15 cm due to addition of organic residue on the surface soil. Whereas, the lowest pH, OC, available N, P and K were found at the soil depth of 15-30 cm depth due to physical, chemical and biological processes prevailing in the system which reflect in the soil profile temperature. Arevalo-Gardini [8] reported maximum organic carbon, available N, P and K content in 0-20 cm, followed by 20-40 and 40-60 cm soil depth. Kumar et al. [9] studied that the among soil chemical properties, electrical conductivity, organic carbon, available N, P and K were higher, whereas pH was lower under poplar based agroforestry system compared to open farming. Available nutrients (N, P and K) were higher in the upper 0-15 cm soil layer compared to 15-30 cm soil profile depth.

Rizwan et al. [10] showed that for Gmelina stands, only EC parameters have decreased. Value of soil chemical properties under Mindi and Jabon stands is more varied where pH, OC, N, P and K increase in concentration. Kumar et al. [11] reported that the initial soil organic carbon at the time of tree planting was recorded to be 0.96% in 0-15 cm and 0.80% in 15-30 cm of soil layer. After two years of experimentation, soil organic carbon in all the treatments increased in both the layers. Soil organic carbon under poplar based agroforestry system and open farming was 1.12% and 1.04% in 0-15 cm layer and 0.86% and 0.81% in 15-30 cm layer, respectively. Sharga et al. [12] reported that the nutrient contents viz., N, P and K in decomposed leaf litter of *G. arborea* based agroforestry system. The N, P and K content in decomposed leaf litter was found maximum in treatment (*G. arborea*+cowpea-mustard) followed by treatment (*G. arborea*+greengram-mustard), (*G. arborea*+pigeon pea) and minimum in treatment (sole *G. arborea*). Devi et al. [13] studied that the increment in N, P and K concentrations through leaf litter fall of tree species, and their decomposition and release of nutrients in the soil are major reason of improvement in N, P and K content in the soil. Prasad et al. [14] showed that organic carbon, available N, P and K, and Zn content were relatively higher in surface soil layer (0-15 cm), while soil pH, EC, Fe, Mn and Cu contents were higher in sub-surface soil layer (15-30 cm). Similar findings were reported that, the least increase of pH, OC, available N, P and K content in the soil was obtained under agroforestry system. Nanda et al. [15] studied that the change in soil chemical properties was observed under *Melia dubia* based agri-silvicultural system over control (field without trees). The soil pH and EC decreased more under *Melia dubia* trees than under control (field without trees). The soil organic carbon and available soil N, P and K increased significantly under *Melia dubia* plantation compared to control (field without trees) in both 0- 15 cm and 15-30 cm soil depths. Mevada et al. [16] also studied that the soil chemical properties viz., pH, electrical conductivity (EC), organic carbon (OC), available nitrogen (N), phosphorous (P_2O_5) and potassium (K_2O) assessed at the time of okra sowing and at final harvest varied significantly among different nitrogen management treatments under agroforestry system and in open condition. The interaction effect of years over treatments was found non-significant in pooled analysis for soil properties under teak based agroforestry system. Similar results also found that intercropping with legumes improved the fertility status of the soil by [17,18].

5. CONCLUSION

All the soil parameters, viz. pH, EC, soil organic carbon, available N, P and K were found better in gamhar based agrisilvicultural system than sole farming systems in both the soil profile. Intercropping with legume crops (arhar, cowpea and greengram) improved the fertility status of the soil due to decomposition of leaf litter. Among all the treatments maximum increment in pH, EC, soil organic carbon, available N, P and K was recorded in Gamhar+Arhar which was 1.46, 18.18, 19.35, 17.58, 18.37, 10.56 percent respectively, compared to initial in 0-15 cm soil depth and 1.74, 20, 25, 12.22, 18.37, 18.95, 15.39 percent respectively, compared to initial in 15-30 cm soil depth after two years of experimentation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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