Soil carbon stock of *Morus-Lepidium* based Agroforestry system on application of different nutrient sources in Western Himalayas

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Abstract

Lepidium sativum is a fast growing annual herb belonging to the Brassicaceae family and possesses the galactogogue effect that promote milk synthesis and production. Study was conducted at the experimental farm of Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) to evaluate the effect of planting condition and different nutrient sources on soil physicochemical properties and carbon stock of Morus based Agroforestry system. The study consisted two structural and functional components *Morus alba* fodder tree as woody perennial and *Lepidium sativum* as intercrop. There were eight treatments *i.e.*T_1: Lepidium + *Morus* +FYM@ 4 tonnes ha^{-1}, T_2: Lepidium + *Morus* +Vermicompost@ 1.12 tonnes ha^{-1}, T_3: Lepidium + *Morus* +Jeevamrut@ 500Litre ha^{-1}, T_4: Lepidium + *Morus* +No Manure, T_5: Lepidium + FYM @ 4tonnes ha^{-1}, T_6: Lepidium + Vermicompost @ 1.12 tonnes ha^{-1}, T_7: Lepidium + Jeevamrut@ 500Litre ha^{-1}, T_8: Control (without *Morus* and no Manure). Jeevamrut liquid organic manure made up of cow dung, cow urine, jaggery, gram flour, soil and water. It acts as an agent to increase the microbial count. The present study revealed that the tree proximity and nutrient sources significantly affected the soil physicochemical properties and carbon stock of the system. The results of the study indicated that the highest soil, bulk density (1.35 g cm^{-3}), available Nitrogen (344.60 kg ha^{-1}), Phosphorus (91.76 kg ha^{-1}) Potassium (539.52kg ha^{-1}), organic carbon (10.50 g kg^{-1}), and soil organic carbon stock (21.31 Mg ha^{-1}) was recorded in treatment T_2*i.e. Lepidium sativum*+ *Morus alba*+ Vermicompost @ 1.12 tonnes ha^{-1} while the lowest was recorded in treatment T_8*i.e.* Control (without *Morus* and no Manure). Maximum seed yield (1613.07 kg ha^{-1}) was observed in treatment T6 while the lowest was recorded in treatment T4. The treatment T_3 (*Morus*+ Lepidium+Jeevamrut) resulted in higher net return (1021.85 USD ha^{-1}) and B:C ratio (2.44) when 500 litres hectare^{-1} Jeevamrut was applied as organic manure.

Introduction

Agroforestry is a sustainable land use a system whereby a deliberate integration is done to manage the agriculture as well as forest resources on the same piece of land in order to harvest the diversified products. It is an intensive farming and forest management shaped by intentional introduction of multiple productive species and management of their complex agroecological interactions to increase marketable yields and provision of ecological services (Gold et al. 2009, Garrett 1997). *Morus alba* (Mulberry) is a multipurpose agroforestry tree species belonging to

family Moraceae. It grows in sub-tropical region and up to higher altitudes in the Himalaya-Hindu Kush region (Imran et al. 2010). Mulberry foliage is an excellent source of crude protein (20-24%) and is Morus leaves are feed as a part of mixed ration used to animals in lean period. *Lepidium sativum* (Chandarshoor) belongs to family Brasicacae and is widely cultivated in tropical and subtropical zones of India. The plant has its origin in Egypt and Southwest Asia but is now cultivated throughout the world for its seeds (Manohar et al. 2012). Considerable attention has been given to the use of chemical fertilizers in conjunction to maintain soil health and quality. Improvement of environmental conditions and public health are important reasons for advocating increased use of organic materials (Seifritz 2011). Apart from using conventional farm based products there is an increasing demand for improved materials like Jeevamrut which is liquid organic manure prepared from cow dung, cow urine, unpurified sugar, chickpea flour and soil from underneath the wild trees and water. It acts as an agent to increase the microbial activity and if used consistently, it minimizes the need of chemical fertilizers (Palekar 2006). Jeevamrut is low cost improvised preparation that enriches the soil with indigenous microorganisms required for mineralization of the soil. Application of vermicompost to crop has also been reported to improve early root initiation, increased root biomass, enhanced plant growth and development. It is considered as one of the important indices of sustainable land management, which contributes to improve soil quality and crop productivity. Himachal Pradesh being a north-western region of Himalayas is generally considered as a good site for soil organic carbon sequestration. Emerging evidence indicated that integrated soil fertility management in which both organic and inorganic resources is a feasible approach to overcome the soil fertility constraints. Therefore, to understand the hypothesis, the objectives of the study were to determine the effect of planting condition and different nutrient sources on soil physicochemical properties and carbon stock of *Morus* based Agroforestry system.

Methods

The experimental farm is located at 30° 51' N latitude and 76° 11' E longitude with an elevation of 1200 m above mean sea level and slope of 7-8 % which falls in subtropical sub-humid temperate agro-climatic zone of Himachal Pradesh. The area receives an annual rainfall varying from 1000 to 1600 mm and 75 % falls during monsoon season (July- September). The climate data of the study area shown in fig 1 (Source: Meteorological observatory, Department of environment science, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, HP 173230).

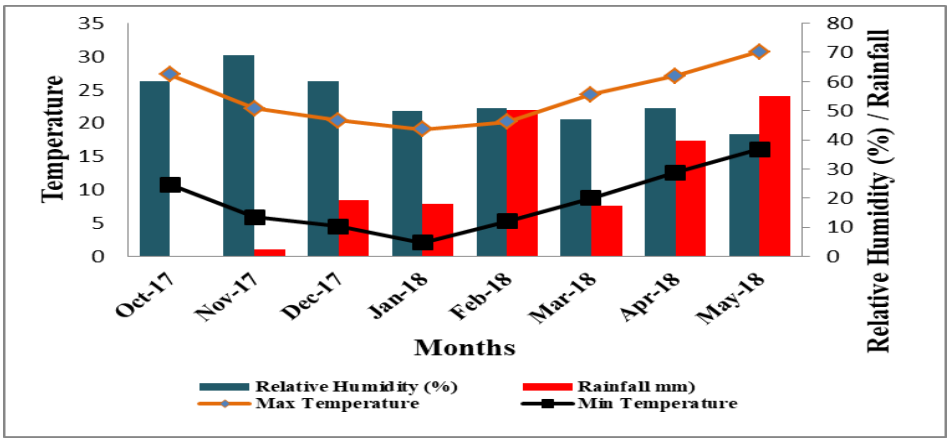

Fig1. Mean monthly temperature (°C), rainfall (mm) and relative humidity (%) during cropping season

Trees rows of *Morus alba* tree consisting of spacing 3×3 m with rows running in East to West direction. The study was conducted in a Randomized Block design factorial with three replications and comprising of four treatments *i.e.* T_1: FYM @ 4 tonnes ha^{-1}, T_2: Vermicopost @ 1.12 tonnes ha^{-1}, T_3: Jeevamrut @ 500Litre ha^{-1} and T_4: No Manure. According to Palekar (2006) Jeevamrut is prepared by mixing cow dung (10.00 kg) with cow urine (10.00 litres), jaggery (1.5 kg), pulse flour (1.5 kg), 1 kg of soil brought from the bunds of the field where cultivation is

to be taken up and add 200 litres of water. Bed sizes of 4 × 2m were made and line sowing was done. Before the sowing of seeds N_{20}: P_{40}: K_{10} Kg hectare^{-1} was applied in the form of FYM and Vermicompost in the individual plots. Jeevamrut is applied as soil drench @ 0.4 litre per plot diluted in 7.6 litre water one time before sowing of seeds and 4 times after sowing at an interval of 15 days. The plants were harvested after five months from the date of sowing of seeds in the main field. Soil samples were taken from surface layer (0–15 cm depth) after harvesting to study the soil physical and chemical properties organic carbon and soil carbon stock.

Five random samples were collected per plot and 500 g of composite sample was taken. Collected soil samples were placed in ziplock bags with proper tags and transported to the laboratory for further analysis. The soil samples were air dried and crushed with mortar and pestle to make them pass through a 2 mm sieve. The crushed samples were then stored properly for use in subsequent analysis. The bulk density of the samples (replicated thrice) was estimated using a core sampler by oven drying the samples at 105° C till constant weight. The dried soil sample were prepared for the estimation of SOC by adopting frequently used method of Walkley and Black (1934), available nitrogen by Alkaline potassium permanganate method (Subbiah and Asija, 1956), available phosphorus by (Olsen's et al. 1954), and available potassium by (Merwin and Peach 1951) method. Soil pH were analysed using soil:distilled water (1:2.5) (Jackson, 1973). The selected parameters were analyzed for understanding their variability through analysis of variance (ANOVA), one way design, as specified by Gomez and Gomez using statistical package R Studio Team (2022) for testing the significance of treatments (Ţ=5%), The packages used were "ggpubr" for line plot using function ~ggline, whereas bar plots were computed using ggplot2 underlying function ~ggbarplot.

Results

The present study revealed that the tree proximity and nutrient sources, significantly affected the soil physicochemical properties and carbon stock of the system (Fig 2). The results of the study indicated that the highest soil, bulk density (1.35 g cm^{-3}) available Nitrogen (344.60 kg ha^{-1}), Phosphorus (91.76 kg ha^{-1}) Potassium (539.52kg ha^{-1}), organic carbon (10.50 g kg^{-1}), and soil organic carbon stock (21.31 Mg ha^{-1}) was recorded in treatment T_2 *i.e.Lepidium sativum*+ *Morus alba*+ Vermicompost @ 1.12 tonnes ha^{-1} followed by T_1: FYM @ 4 tonnes ha^{-1} with the corresponding values (1.33 g cm^{-3}), (330.02 kg ha^{-1}), (85.39 kg ha^{-1}), (529.393 kg ha^{-1}), (9.03 g kg^{-1}) and (18.00 Mg ha^{-1}) while the lowest was recorded in treatment T_8*i.e.* Lepidium+No Manure with the corresponding values (1.22 g cm^{-3}), (305.87 kg ha^{-1}), (60.24 kg ha^{-1}), (504.507 kg ha^{-1}), (5.61 g kg^{-1}) and (10.33 Mg ha^{-1}).

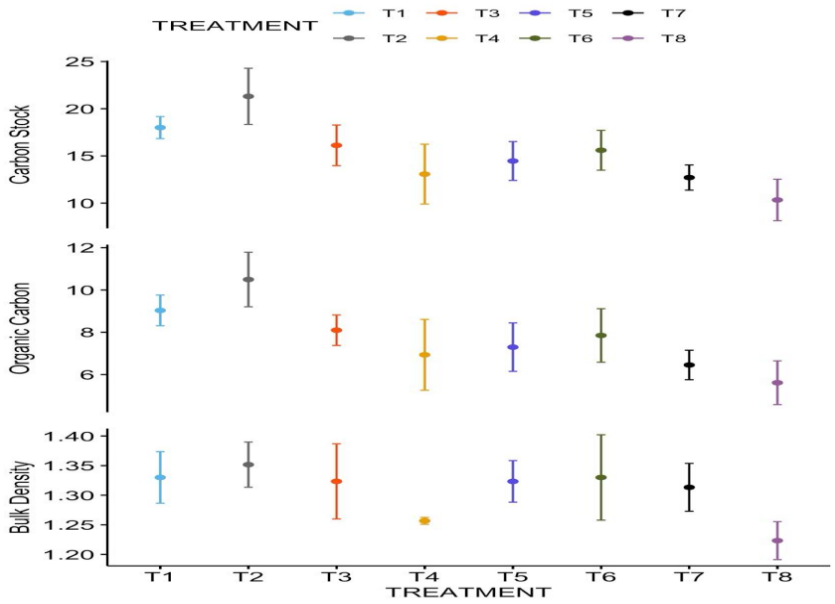

Fig: 2 Effect of planting condition, intercropping patterns and nutrient sources on soil bulk density (g cm^{-3}), organic carbon (g kg^{-1}) and carbon stock (Mg ha^{-1}) under Morus based Agroforestry System.

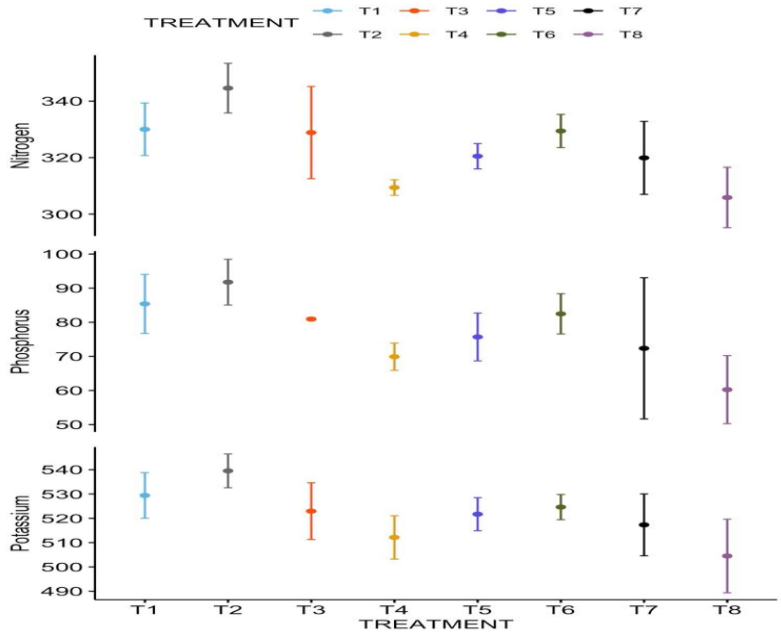

Fig: 3 Effect of planting condition, intercropping patterns and nutrient sources on soil available nitrogen (kg ha^{-1}), phosphorus (kg ha^{-1}) and potassium (kg ha^{-1}) under Morus based Agroforestry System.

Maximum seed yield (1613.07 kg $hectare^{-1}$) was observed in treatment T6 while the lowest was recorded in treatment T4. Under open condition the maximum seed yield kg per hectare (1613.07 kg $hectare^{-1}$) was recorded in treatment T_6 (Lepidium+Vermicompost) which was statistically at par with the T2 (Morus+ Lepidium+

vermicompost). Whereas, minimum seed yield kg per hectare (752.23 kg hectare^{-1}) were observed in treatment T_4 (Morus+Lepidium+No manure). The mean seed yield kg per hectare of *Lepidium sativum* was significantly influenced by different types of organic manures. The maximum seed yield (1460.57 kg hectare^{-1}) was observed in application of vermicompost which was statistically at par with the application of Jeevamrut (1395.26 kg hectare^{-1}) and farm yard manure (1291.66 kg hectare^{-1}) whereas; minimum (834.74 kg hectare^{-1}) was recorded in control where no manure was applied.

Discussion

There have been other reports of increase of N in soil after application of vermicompost (Nethra et al., 1999). Favourable soil conditions as viz. porosity, organic carbon content, biological activities and water holding capacity might have helped in mineralization process of soil nitrogen thereby leading to build-up higher available nitrogen (Kushwala *et al*., 2017). Findings of the present study are in line with the studies of Nkechi *et al*. (2013) and Singh *et al*. (2017). The continuous inputs of P to the soil were probably from slow release from vermicompost and release of P was due largely to the activity of soil microorganisms (Arancon et al., 2006). Marinari et al. (2000) showed similar increases in soil P after application of organic amendments. The selective feeding of earthworm on organically rich substances which breakdown during passage through the gun, biological grinding, together with enzymatic influence on finer soil particles, were likely responsible for increasing the different forms of K (Rao et al., 1996). The results in the present study are in agreement with the previous studies of (Kumar and Singh, 2017) who observed that the higher seed yield per plant in mustard (*Brassica juncea*) was recorded in combined application of RDF+vermicompost. Theunissen et al. (2010) reported that the vermicompost contains most nutrients in plant available form such as phosphates, exchangeable calcium, soluble potassium and other macronutrients with huge quantity of beneficial microorganisms, vitamins and hormones which influence the growth and yield of plants. This may be due to the fact that application of vermicompost results in improving the physical, chemical, and biological properties of soil and also provide N, P, and K to plants (Baziramakenga and Simard 2001). Based on both analytical data and field observations, it can be concluded that application of Vermicompost @ 1.12 tonnes ha^{-1} under *Morus alba* based agroforestry system had a synergistic effect on improving soil physical as well as chemical properties over control (without any manure under open condition). Application of organic manures in the form of vermicompost resulted into better yield parameters of *Lepidium sativum* as compared to other organic manures. Organic farming and agroforestry can be enhanced to drive greater environmental sustainability, increase crop productivity, and strengthen soil health, thereby creating more resilient agricultural systems capable of addressing global challenges like climate change and soil degradation.

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