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ORIGINAL ARTICLE

Effects of Different Fruit-based Multitier Systems On Soil Chemical Properties and Leaf Nutrient Acquisition Under Rainfed Plateau Conditions

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Abstract

The investigation examined a horti-silvi-agricultural system established four years ago, integrating various crops to optimize land use and productivity. This system included short-statured fruit crops such as Aonla and Peach as filler crops, with Mango and Mahogany serving as the main crops, while rice and ragi as intercrops. A split-plot design was employed, designating rice and ragi as main plots, and the following systems as subplots: Mahogany + Mango + Aonla, Mahogany + Mango + Peach, and Mahogany + Mango with no filler crop. The study revealed that the growth and development of filler crops were significantly influenced by the horti-silvi-agricultural system. Notably, in the Mahogany + Mango + Peach system, significant effects were observed on leaf nutrient levels (N, P, K, Ca, Mg) and carbohydrate content. The system also demonstrated greater soil moisture retention compared to a fallow system, with the peach-based combinations resulting in the highest reduction in electrical conductivity (EC). The organic carbon content in the horti-silvi-agricultural system's soil was significantly higher than in a monocropping system, decreasing with soil depth. Additionally, the availability of nitrogen (N), phosphorus (P), and potassium (K) was higher in the surface layer of the Mango + Mahogany + Peach system. Overall, fruit tree-based systems were found to enhance soil organic matter, increase nutrient availability, and improve soil properties.

Keywords Fruit-based multitier systems · Filler crops · Chlorophyll · Leaf nutrient · Organic carbon · Soil properties

Introduction

The multitier cropping system aims to enhance land productivity in resource-limited, low-input conditions prevalent in the rainfed uplands of the Eastern Plateau and Hills Region of India. This system has evolved over time, considering agro-ecological conditions, plant diversity, resources and the needs of local farmers. In these regions, cereal crops are predominantly cultivated to meet food requirements. However, cultivating cereals alone fails to address other essential needs such as fodder for animals, fuelwood, timber, and fruits for additional income. Integrating timber trees and fruit crops, with cereal cultivation is crucial to fulfilling these diverse needs. Thus, developing a multitier cropping system centred around cereals is essential in the current agricultural context.

Multipurpose trees are highly important as they provide timber, fuelwood, fruits, fodder, and fibers, and contribute to soil improvement by adding substantial organic matter through leaves, twigs, stems, and flowers, releasing essential nutrients during decomposition (Rahangdale et al. 2014). Adopting agroforestry systems like the agri-silvi-horticulture system can restore and enhance soil quality and productivity, sustaining agricultural output (Thakur and Kumar 2006). Research by Tewari et al. (2007) shows that integrating trees into agricultural systems boosts productivity and income by mitigating adverse environmental conditions. Litterfall and fine root biomass are crucial for

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nutrient recycling in tree-based ecosystems (Gill and Jackson 2000; Sayer, 2006). The fine root system of trees is integral to acquiring soil resources and contributes detritus carbon to soil organisms, influencing the effectiveness of riparian buffers in processing soil water pollutants and improving soil quality (Stewart and Frank 2008).

In arid regions, the agri-silvi-horticulture system has proven to be economically rewarding (Pareek, 1998). Trees in this system act as natural fertilizers, restoring soil health and increasing crop yields (Rathore et al. 2013). Improved planting stocks of silvicultural and horticultural tree species offer multifaceted benefits, reducing the risk of system productivity failure seen in traditional agricultural systems. This continuous income-generating system ensures steady income under unpredictable weather conditions, protects land from degradation, and enhances soil quality (Devi et al. 2020). This study aims to validate the hypothesis that a cereal-fruit-timber multitier system can enhance soil fertility and improve nutrient acquisition by plants, utilizing resources not fully utilized in monoculture systems. It serves as a valuable case study to demonstrate the potential of such systems to meet the needs of farmers with limited resources in marginal upland areas, assessing the impact of the horti-silvi-agricultural system on soil chemical properties and nutrient availability.

Materials and Methods

Experimental Details

This study was conducted on 4-year-old horti-silvi-agricultural systems of agro-forestry at the ICAR Research Complex for Eastern Region, FSRCHPR, Ranchi, Jharkhand, India. The experimental site is situated in the hilly region of the Chotanagpur Plateau at coordinates $23^{0}\ 16'\ 46''$ and $23^{0}\ 16'\ 48''$ N latitude and at $85^{0}\ 24'\ 48''$ and $85^{0}\ 24'\ 51''$ E longitude, with an average elevation of 629 m above mean sea level. The region has as a subhumid mega-thermal climate with an average annual rainfall ranges from 1400–1430 mm, and the mean annual maximum and minimum temperatures are 33.10 °C and 20.50 °C, respectively. The experimental site soil was acidic in nature with low in organic carbon and nitrogen status.

Details of Treatments

A split-plot design was employed in the study featuring Mango (*Mangifera indica* L.) variety 'Amrapali' and Mahogany (*Swietenia mahogany*), along with two fruit tree species, Peach (*Prunus persica* (L.) Batsch) variety 'Florda Prince' and Aonla (*Emblica officinalis*) variety 'NA-7'. The main crops (Mango and Mahogany), were planted with a spacing of 20 m × 20 m between rows and 10 m × 10 m between individual plants. The filler crops (peach and Aonla) were planted with a spacing of 5 m × 5 m between rows and 10 m × 10 m between plants. Kharif crops (Rice and Ragi) were also grown in conjunction with perennial woody plants and horticultural plants, forming a silvi-horti-agricultural system. Rice variety 'Anjali' and ragi variety 'BM2' were sown in rows with a spacing of 12 cm. The split-plot design included Rice (A_1) and Ragi (A_2) as the main plots and following combinations as subplots. Mahogany + Mango + Aonla (B_1), Mahogany + Mango + Peach (B_2), and Mahogany + Mango + without filler (B_3) Additionally, a fallow system, where only rice and ragi intercrops were grown, served as subplot for comparing the soil nutrient status with the other subplots. Each subplot was replicated four times.

Leaf Chlorophyll, Carbohydrate and Nutrient Analyses

Fully matured open leaves from Mahogany and Mango were collected from four replications. The estimation of leaf chlorophyll content (chlorophyll a, b, and total chlorophyll) from fresh leaves samples followed the method proposed by Hiscox and Israelstam (1979). Carbohydrate levels were determined using the procedure outlined by Yoshida et al. (1971). The other set of leaves were dried in an oven, ground and analysed for nutrients, including N, P, K, Ca, and Mg. Nitrogen was assessed through the Kjeldahl method (Jackson 1973), phosphorus via the Vando-molybdate phosphoric yellow color method with diacid digestion (Jackson 1973), potassium through diacid plant extract using a Flame photometer (Jackson 1973), and calcium (Ca) and magnesium (Mg) with titration method using EDTA.

Soil Chemical Analysis

The soil samples collected Soil samples were collected from two depths (0–30 cm and 30–60 cm) after the intercrop harvest for soil analysis. Air-dried samples were crushed with a mortar and pestle, sieved through a 2 mm stainless steel sieve and stored in polythene bags. The soil samples were analysed for pH, electrical conductivity, and organic carbon and available nutrients (nitrogen, phosphorus, potassium, calcium, and magnesium). Soil pH and electrical conductivity (EC) were determined in 1:2 soil-water suspensions according to the method of Jackson (1973), while organic carbon was assessed using the chromic acid titration method by Walkley and Black (1934). The available nitrogen was determined using the alkaline potassium permanganate method (Subbiah and Asija 1956), and the available phosphorus was determined using the Bray and Kurtz method. Available potassium was determined through the neutral normal ammonium acetate method (Jackson

Table 1 Effects of different silvi-horti-agricultural systems on the chlorophyll and carbohydrate contents of mahogany and mango leaves under rainfed conditions. (mg gm^{-1} fresh weight)

Parameter	Mahogany				Mango			
	Chlorophyll a	Chlorophyll b	Total chlorophyll	Carbohydrate	Chlorophyll a	Chlorophyll b	Total chlorophyll	Carbohydrate
A_1	1.64	0.61	2.05	1.64	2.68	1.57	4.74	1.69
A_2	1.63	0.60	2.04	1.63	2.67	1.58	4.73	1.68
C.D. (5%)	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
SE(d)±	*0.002*	*0.002*	*0.002*	*0.002*	*0.001*	*0.003*	*0.004*	*0.003*
B_1	1.63	0.60	2.04	1.64	2.67	1.58	4.73	1.68
B_2	1.64	0.61	2.05	1.65	2.68	1.59	4.74	1.70
B_3	1.63	0.60	2.04	1.63	2.67	1.58	4.73	1.65
C.D. (5%)	*NS*	*NS*	*NS*	*0.006*	*NS*	*NS*	*NS*	*0.006*
SE(d)±	*0.003*	*0.002*	*0.002*	*0.002*	*0.002*	*0.003*	*0.003*	*0.002*

[A_1 = *Rice*, A_2 = *Ragi*, B_1 = *Mango + mahogany + aonla*, B_2 = *Mango + mahogany + peach*, B_3 = *Mango + mahogany + no filler*]

1973). The exchangeable calcium and magnesium were determined by extracting with ammonium acetate, followed by versenate titration method with EDTA. Soil moisture content was estimated using the gravimetric method, as described by Reynolds (1970).

Statistical Analysis

The statistical methods were performed according to the methods proposed by Panse and Sukhatme (1989). Analysis of variance (ANOVA) was used to analyse the data to determine the significance the treatments effect, with the 'F' test at the 5% level of significance employed to determine the significant difference among the treatment means. (Fisher 1950).

Results and Discussion

Chlorophyll and Carbohydrate Contents of Leaves

Table 1 illustrates the effect of various silvi-horti-agricultural systems on the chlorophyll and carbohydrate contents in the leaves of mahogany and mango plants. The chlorophyll content in mahogany and mango leaves showed nonsignificant differences between the main crops (rice and ragi) and subplots (filler crops). However, the carbohydrate content in mahogany and mango leaves within the subplots varied significantly. Notably, the mango + mahogany + peach system exhibited the highest carbohydrate content with 1.65 mg g^{-1} fresh weight in mahogany leaves and 1.70 mg g^{-1} fresh weight in mango leaves. The mango + mahogany + no filler system had the lowest carbohydrate content (1.63 and 1.65 mg g^{-1} fresh weight in mahogany and mango leaves, respectively). Among the filler crops, the peach system had a greater chlorophyll concentration compared to aonla system, possibly due to shading effects. These findings align with observations by Goncalves et al. (2001) and Evans and Poorter (2001).

Leaf Nutrients of Mahogany and Mango Under Different Systems

In the different subplots, the highest nitrogen, phosphorous and magnesium contents in mahogany leaves were recorded in the mango + mahogany + peach system (1.64, 0.17 and 0.34%, respectively), while the lowest values were recorded in the mango + mahogany + no filler system (1.62, 0.12 and 0.32%, respectively). Similarly, the highest potassium and calcium contents in mahogany leaves were found in the mango + mahogany + peach system (1.13 and 1.21%, respectively), which were similar to those in the mango + mahogany + aonla system (1.10 and 1.19%, respectively), and the lowest values were observed in the mango + mahogany + no filler system (0.81 and 1.01%, respectively) (Table 2).

For mango leaf N, P, K, Ca and Mg contents were significantly greater in the mango + mahogany + peach system (0.80, 0.12, 0.92, 1.63 and 0.71%, respectively), while the lowest values were recorded in the mango + mahogany + no filler system (0.75, 0.09, 0.61, 1.40 and 0.44%, respectively) (Table 2).

The superiority of the Mango + Mahogany + Peach system is attributed to its relatively higher soil fertility compared to that of the aonla system. Koukoulakis et al. (2013) on leaf analysis of various trees revealed that synergistic elemental interactions in pistachio leaves and soils contributed to substantial quantities of available nutrients, enhancing the nutrient status of pistachio trees and increasing soil fertility levels.

Table 2 Effect of different silvi-horti-agricultural systems on the nutrient content of mahogany and mango leaves under rainfed conditions

Parameter	Mahogany					Mango				
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
A_1	1.63	0.15	1.01	1.16	0.34	0.78	0.11	0.80	1.53	0.60
A_2	1.63	0.14	1.08	1.11	0.33	0.78	0.11	0.80	1.53	0.55
C.D. (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SE(d)±	0.002	0.002	0.08	0.02	0.001	0.001	0.005	0.002	0.01	0.04
B_1	1.63	0.15	1.10	1.19	0.33	0.77	0.11	0.87	1.56	0.58
B_2	1.64	0.17	1.13	1.21	0.34	0.80	0.12	0.92	1.63	0.71
B_3	1.62	0.12	0.81	1.01	0.32	0.75	0.09	0.61	1.40	0.44
C.D. (5%)	0.006	0.006	0.30	0.12	0.003	0.009	0.003	0.09	0.09	0.12
SE(d)±	0.002	0.002	0.10	0.04	0.001	0.003	0.001	0.03	0.03	0.04

[A_1 = *Rice*, A_2 = *Ragi*, B_1 = *Mango + mahogany + aonla*, B_2 = *Mango + mahogany + peach*, B_3 = *Mango + mahogany + no filler*]

Soil Nutrient Status Under Different Systems

Available Soil Nitrogen (N)

The different soil depths in agroforestry systems showed significantly greater available nitrogen. The Available nitrogen content was significantly greater for all the B1, B2, B3 and B4 treatments (154.55 kg/ha, 157.51 kg/ha, 152.51 kg/ha and 151.68 kg/ha, respectively) in the surface layer (0–30 cm) than in the sub-surface layer (30–60 cm) (120.48 kg/ha, 121.75 kg/ha, 118.67 kg/ha and 117.48 kg/ha, respectively). A significant increase in available nitrogen (0–30 cm depth) was observed in the mango + mahogany + peach system (157.51 kg/ha) compared with the fallow system (151.68 kg/ha) (Table 3). The increase in nitrogen suggests a higher organic matter accumulation, which serves as a labile pool of nutrients for soil microflora and plants or crops. This is further supported by studies by Devi et al. (2020) Rizvi et al. (2011) and Kaushal et al. (2016), which reported the positive impact of agroforestry systems on soil fertility, particularly increased organic matter content and total nitrogen in the surface soil. Beauty et al. (2020), noted significant growth parameters, under the silvi-horti-agricultural system due to soil nutrient enrichment facilitated by the filler crop. Saha et al. (2014) observed the highest increase in available nitrogen (26.7%) after harvest in a gamhar + mango + pigeon pea agroforestry model. Dalal et al. (2015) reported the highest available nitrogen levels in the topsoil in a guava + khejri + wheat agroforestry model, with the lowest was found in monocropping systems, decreasing with soil depth.

Available Soil Phosphorus (P)

Among the three tree-based systems, the average available P concentration was highest under the mango + mahogany + peach system (24.95 kg/ha), followed by the mango + mahogany + aonla system (21.95 kg/ha), the mango + mahogany + no filler system (19.95 kg/ha), and the control/fallow system (18.88 kg/ha) at the 0–30 cm soil depth (Table 3). The P content was higher in the surface soil than in the subsurface layer for all the treatments (13.0 kg/ha, 14.83 kg/ha, 11.76 kg/ha and 10.57 kg/ha in B1, B2, B3 and B4, respectively). The significant influence of tree-based system and soil depth on soil available phosphorus may be attributed to higher acidic phosphatase activity. The organic anion exudation and acid phosphatase activity of tree roots increase the mobilization of P in the rhizosphere (Cadwell 2005). The decreasing availability of phosphorus (P) with increasing soil depth aligns with findings by Swamy et al. 2008; Majumdar et al. 2004; Ghimire 2010. Kumar et al. (2017) observed an increase in available P from 9.70 to 13.36 kg/ha under tree species compared to a field without tree plantation. Kaushal et al. (2016) reported an increased in available P in various grewia-based agroforestry systems compared to fallow plots. Singh et al. (2018) found significant higher available phosphrous under different agroforestry systems, including agri-silvi-horticulture, agri-horticulture, agri-silviculture, and silvi-pastoral systems, compared to a sole agriculture land use system. Kaushik et al. (2017) observed higher P content in surface soil than in subsurface soil with the highest P value (18.5 kg/ha) under the khejri + guava + cluster bean-barley system compared to a sole cropping system. Dhara and Sharma (2015) reported the highest increase in available P under eucalyptus + mango + pigeon pea and eucalyptus + mango + black gram, with a 35.6% and 27.7% increase, respectively, from their initial values.

Available Soil Potassium (K)

The available potassium content under tree-based system was significantly higher than that under the fallow system (Table 3). The mean available K content was highest in the mango + mahogany + peach system (227.65 kg/ha), followed by the mango + mahogany + aonla

Table 3 Effects of different silvi-horti-agricultural systems on the available soil N, P and K contents under rainfed conditions

Treatments	Available nitrogen (kg N ha^{-1})		Available phosphorous (kg P ha^{-1})		Available potassium (kg K ha–^{1})	
	0–30 cm	30–60 cm	0–30 cm	30–60 cm	0–30 cm	30–60 cm
A_1	154.05	119.58	21.45	12.58	224.49	212.51
A_2	154.08	119.56	21.43	12.52	224.14	212.55
C.D. at 5%	NS	NS	NS	NS	NS	NS
SE(m)±	0.20	0.18	0.12	0.32	0.28	0.30
B_1	154.55	120.40	21.95	13.00	227.65	212.64
B_2	157.51	121.75	24.95	14.83	225.26	213.62
B_3	152.51	118.67	19.95	11.76	222.95	178.92
B_4	151.68	117.48	18.88	10.57	221.37	178.37
C.D. 5%	0.52	0.46	0.47	0.43	0.55	1.94
SE(m)±	0.17	0.15	0.16	0.14	0.18	0.65
CV %	8.81	9.61	8.88	8.64	8.92	8.59

[*A_1 = Rice, A_2 = Ragi, B_1 = Mango + mahogany + aonla, B_2 = Mango + mahogany + peach, B_3 = Mango + mahogany + no filler, B_4 = Fallow*]

system (225.26 kg/ha), and the mango + mahogany + no filler system (222.90 kg/ha), with the lowest in the fallow system (221.37 kg/ha). The decrease in available K content at the 30–60 cm soil depth from 0–30 cm varied by 1.06% (mango + mahogany + peach system), 1.07% (mango + mahogany + aonla system), and 1.24% (mango + mahogany + no filler system and fallow). The increase in available potassium can be attributed to greater litterfall and fine root turnover in the surface layer, as indicated by previous studies (Bhardwaj et al. 2001; Swamy et al. 2008; Kaushal et al. 2016). Observations by Mishra and Swamy (2007) and Kumar et al. (2017) also noted an increase in available potassium (from 336 to 393 kg/ha) under tree species compared to fields without plantations. In a study evaluating soil potassium status after two cropping cycles in West Bengal, Dhara and Sharma (2015) reported a significant increase in potassium of 18.0% and 13.3%, respectively, in the eucalyptus + mango + pigeon pea and eucalyptus + mango + black gram systems. Another investigation by Banerjee and Dhara (2011) examined the available potassium content under various agri-horti-silvicultural models in West Bengal, with the greatest increase in potassium observed in the *A. auriculiformis* + sweet orange + groundnut-based land use system.

Soil Organic Carbon (SOC)

The mango + mahogany + peach system exhibited higher levels of soil organic carbon and available nutrients (N, P, and K) than the fallow system at various depths (Table 4). The availability of N, P, and K reflects the SOC content, as their availability depends upon the organic matter in the soil. The (SOC) content was significantly influenced by the tree-based system, soil depth, and their interaction. Higher SOC content was observed in surface soils (0–30 cm), gradually decreased with depth. At the 0–30 cm soil depth, the mango + mahogany + peach system had the highest soil organic carbon content (0.38%), followed by the mango + mahogany + aonla system (0.37%) and the mango + mahogany + no filler system (0.27%). The lowest organic carbon content was found in the fallow system (0.25%). Between the two soil depths, the average organic carbon concentration was highest in the surface soil (0.38%) at 0–30 cm and lowest (0.15%) at 30–60 cm. No significant changes were observed at the 30–60 cm depth. The enrichment of soil organic carbon under tree-based systems can be attributed to various factors, including the addition of litter, recycling of annual fine root biomass, root exudates, and reduced oxidation of organic matter under tree shades (Gill and Burman 2002). The mineralization of organic matter releases nutrients into the soil (Osman et al. 2001). These findings are consistent with previous studies (Gupta and Sharma 2009; Das and Chaturvedi 2005; Yadav et al. 2008), which showed higher SOC and available N, P, and K contents in the soil of intercropped tree plantations compared to treeless plantations (Singh et al. 1989; Mohsin et al. 1996). Kumar et al. (2017) reported an increase in organic carbon from 0.12 to 0.27% under the tree component compared to a field without tree plantation. Kaushal et al. (2016) also reported an increase in SOC of 13 to 46% in various Grewia-based agroforestry systems compared to that in fallow plots. Palsaniya et al. (2009) reported a significant increase in SOC wherever shisham and subabul were introduced with crops compared to that in treatments involving pure crops and trees alone. The SOC status in the subabul + maize treatment was 0.72%, in the shisham + maize treatment it was 0.61%, and in the crop alone treatment it was only 0.48%. Similarly, Saha et al. (2014) observed the greatest increase in SOC content (by 25%) under the gamhar + mango + pigeon pea agri-silvi-horticultural system (from 0.36 to 0.45%) compared to

Table 4 Effects of different silvi-horti-agricultural systems on soil Ca, Mg and OC contents under rainfed conditions

Treatments	Calcium (mg/100gm soil)		Magnesium (mg/100gm soil)		Organic carbon (%)	
	0–30 cm	30–60 cm	0–30 cm	30–60 cm	0–30 cm	30–60 cm
A_1	24.56	20.46	15.42	12.18	0.33	0.18
A_2	22.92	19.42	15.26	12.14	0.32	0.17
C.D. at 5%	NS	NS	NS	NS	NS	NS
SE(m)±	0.03	0.55	0.09	0.10	0.002	0.002
B_1	23.84	21.14	16.12	14.12	0.37	0.19
B_2	26.21	21.55	17.99	14.25	0.38	0.20
B_3	23.25	18.52	14.32	11.10	0.27	0.16
B_4	21.44	18.46	13.06	10.62	0.25	0.15
C.D. 5%	1.95	1.64	3.06	0.49	0.009	0.008
SE(m)±	0.65	0.54	1.02	0.16	0.003	0.002
CV %	8.75	7.94	10.54	9.94	8.95	9.21

[*A_1 = Rice, A_2 = Ragi, B_1 = Mango + mahogany + aonla, B_2 = Mango + mahogany + peach, B_3 = Mango + mahogany + no filler, B_4 = Fallow*]

the sole gamhar agroforestry model, which recorded only a 3.7% increase.

Soil pH, EC, Ca and Mg

Tree-based systems significantly affected soil pH, Ca, Mg and electrical conductivity, although their interaction was not significant (Tables 4 and 5). The average soil pH ranged from 4.72 to 4.80 under the various tree-based systems. The soil pH was a reduced under the mango + mahogany + peach, mango + mahogany + aonla and mango + mahogany + no filler systems compared with the control, with an increase in soil depth. Similarly, the soil electrical conductivity was significantly lower under the tree-based system, mango + mahogany + aonla system, mango + mahogany + peach system and mango + mahogany + no filler system than under the control (Table 5). The soil EC decreased with increasing soil depth. The calcium and magnesium contents in the soil were significantly greater under the mango + mahogany + peach system, followed by the mango + mahogany + aonla system and mango + mahogany + no filler system. A reduction in Ca and Mg content was observed with increasing soil depth (Table 4). The reduction in soil pH and EC under tree cover can be attributed to the accumulation and subsequent decomposition of organic matter, which releases organic acids (Devi et al. 2020). These findings align with those of Gupta and Sharma (2009) and Newaj et al. (2007), who observed little change in soil pH under agroforestry systems. Dalal et al. (2015), reported less EC (0.14–0.18 dS/m) and pH under an agri-silvi-horticulture system than in sole crops (0.22–0.26 dS/m). They also observed a decrease in electrical conductivity and pH with increasing depth.

Table 5 Effects of different silvi-horti-agricultural systems on soil EC and pH under rainfed conditions

Treatments	EC (dSm^{-1})		pH	
	0–30 cm	30–60 cm	0–30 cm	30–60 cm
A_1	0.18	0.15	4.76	4.88
A_2	0.19	0.16	4.75	4.87
C.D. at 5%	NS	NS	NS	NS
SE(m)±	0.002	0.002	0.001	0.003
B_1	0.17	0.15	4.73	4.85
B_2	0.15	0.12	4.72	4.85
B_3	0.20	0.18	4.78	4.92
B_4	0.21	0.18	4.80	4.93
C.D. at 5%	0.007	0.009	0.02	0.03
SE(m)±	0.002	0.003	0.006	0.01
CV %	7.23	8.35	8.00	8.63

[*A_1 = Rice, A_2 = Ragi, B_1 = Mango + mahogany + aonla, B_2 = Mango + mahogany + peach, B_3 = Mango + mahogany + no filler, B_4 = Fallow*]

Soil Moisture Dynamics

Figure 1 illustrates the soil moisture content at two depths, 0–30 cm and 30–60 cm, under various silvi-horti-agricultural systems. The highest retention of soil moisture at the 0–30 cm depth for the months of June, July, August, September, October, and November in the subplots (filler crops) was observed in B2 (37.06%, 42.03%, 41.01%, 38.75%, 36.46%, and 20.64%, respectively), comparable to B1 (33.75%, 35.50%, 37.85%, 35.68%, 33.20%, and 16.54%, respectively). Similarly, B3 and B4 had the lowest values. This trend was consistent for the 30–60 cm depth across all six months. The influence of the main crops (rice and ragi) and the interaction effect (A × B) on soil moisture dynamics under different silvi-horti-agricultural systems was found to be nonsignificant (Fig. 1). Compared with the mango + mahogany + aonla system, the mango + mahogany + peach system exhibited greater soil moisture content, potentially attributable to differences in the crown structure of both species. The presence of a peach tree

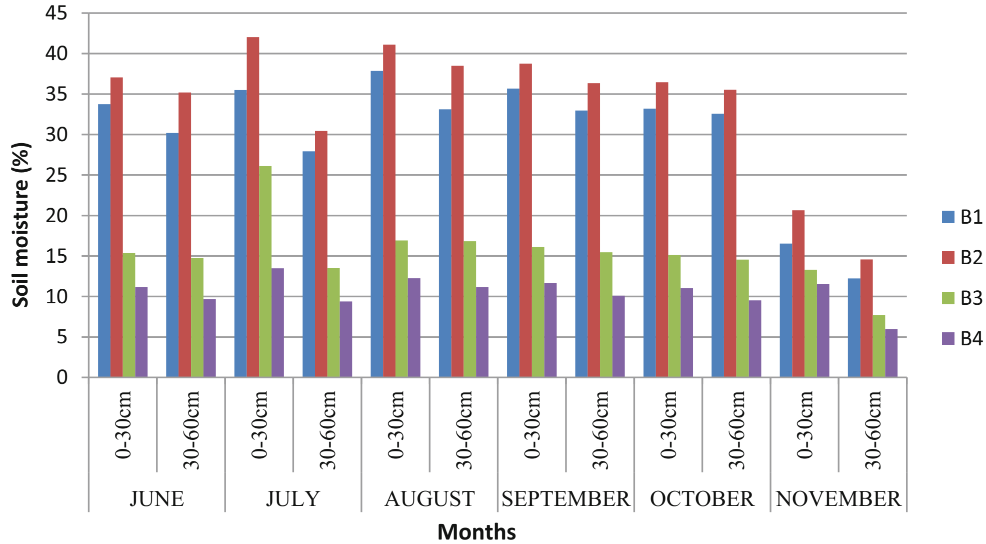

Fig. 1 Effect of different silvi-horti-agricultural systems on soil moisture dynamics under rainfed conditions. (%)

B_1=Mango + mahogany + aonla, B_2= Mango + mahogany + peach, B_3= Mango + mahogany + no filler, B_4= Fallow

reduced the light intensity more than the aonla tree. As observed by Beauty et al. (2020), greater plant density and a greater number of tillers per square meter were noted in the silvi-horti-agricultural system which could be attributed to the availability of moisture in the agri-silvi-horticultural system, a crucial factor for seed germination. The tree canopy in the agri-silvi-horticultural system facilitated moisture retention by reducing evaporation losses from the soil surface.

Conclusion

The findings of the study suggest that the mango + mahogany + peach system has a greater capacity to accumulate organic carbon in the soil than other systems. The combination of a horticultural component (mango, peach or aonla) and a silvicultural component (mahogany) appears to enhance the leaf nutrient status and the chlorophyll and carbohydrate contents more effectively than a tree crop alone, likely due to the increased and faster decomposition of litter. Therefore, the adoption of a mango, mahogany, and peach-based multitier system on a larger scale could prove beneficial for improving soil fertility status.

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Conflict of interest K. Beauty, M.K. Dhakar, B. Das, S.K. Naik, B.C. Oraon, R. Shinde and B.P. Bhatt declare that they have no competing interests.

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