Print : ISSN 0970 – 7662
Online : ISSN 2455 – 7129

Journal of Tree Sciences

online available at www.ists.in

Volume 39 No. 2 December, 2020

Physico-chemical properties of soil and productivity of lentil (*Lens culinaris* Medic.) and wheat (*Triticum aestivum* L.) under existing agri-horticulture system in mid hills of Uttarakhand Himalaya

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DOI: 10.5958/2455-7129.2020.00014.X

ABSTRACT

The study quantifies the soil properties and productivity of agriculture crops under peach, plum and apple based agri-horticulture system in Garhwal Himalaya. The results of experiment revealed that the soil pH, available N and P decreased with increasing soil depth while soil bulk density (BD), electrical conductivity (EC), soil organic carbon (SOC) and soil organic matter (SOM) showed optimistic association with soil depth in all studied land used systems. In crop productivity, the highest plant height, plant population (m^2), number of pod per plant, 1000 grain weight, seed yield, stover yield and harvest index of both crops were reported lower under agrihorticulture systems than control, and among tree based land used systems growth and yield of both crops were higher under peach based agri-horticulture system.

Key Words:

Agrihorticulture, crop productivity, lentil, wheat, yield

INTRODUCTION

Agroforestry is a common land use management practice in which agricultural and forestry technologies combined together to create more productive, profitable, protective, diverse, healthy and sustainable land use systems (Misra 2011). Agroforestry land use systems, covers 20 percent of the total geographical area of Indian Himalayan region (Salve et al. 2018). It has the potential to provide food security and various ecosystem services. Agroforestry also helps in poverty alleviation by providing livelihood security through simultaneous production of food, fuelwood and fodder as well as to reduce the impact of climate change (Tiwari et al.

2017). Agri-horticulture system is exclusive and unique agroforestry practices of Himalayan region. Cultivation of agriculture crops with the combination of plantation or existing fruits tree species provides sustainable and better income to the farmers. Apple (*Malus domestica*), peach (*Prunus persica*) and plum (*Prunus domestica*) are core component of agrihorticulture system in the Garhwal Himalaya region (Bijalwan 2012).

Trees in agroforestry system are competent to uptake nutrients from the sub-soil due to their deep root system and return them to the topsoil by nutrient cycling thereby making them available for agricultural crops (Misra 2011, Panwar et al. 2017). However, agroforestry also deplete the soil nutrients due to additional competition between trees and agriculture crops (Sanchez 1995). Tree crop interaction and microclimate in agroforestry systems affects the productivity of agriculture crops (Lakshmanakumar and Guru 2014).

Lentil (*Lens culinaris* Medic.) is a legume crop and is widely cultivated as a rainfed crop in hills of Uttarakhand. Lentil is a very important and valuable crop among legumes because of its digestibility, high content of protein, fibre and carbohydrates and is also a good source of calcium, iron, phosphorus and vitamin-B (Nkhata et al. 2018 and Wang and Daun, 2005). Wheat (*Triticum aestivum* L.) is an important cereal crop, extensively grown under different agroforestry system in central and northern India. It is a main source of minerals and vitamins such as iron, calcium, thiamine, niacin, riboflavin, vitamin-D and fibre (Singh and Supriya, 2017).

The present study was conducted to evaluate the performance of lentil and wheat under apple (*Malus domestica*), peach (*Prunus persica*) and plum (*Prunus domestica*) based agri-horticulture system. Physico-chemical properties of soil were also evaluated to find the sustainability of the system.

MATERIALS AND METHODS

The study was conducted, during the *rabi* season of 2018-19, at Horticulture block of College of Forestry, Ranichauri, Tehri Garhwal, Uttarakhand. The experiment was laid out in Randomized Block Design (RBD) with three replications. Agri-horticulture system comprising of three fruit trees viz., apple (*Malus domestica*), peach (*Prunus persica*) and plum (*Prunus domestica*) was evaluated for evaluating performance of lentil and wheat. After field preparation, seed sowing was carried out by line showing method, on 3-4 November, 2018. Data was recorded for plant height (cm), number of plants/m^2, 1000 grain weight (g), grain yield (kg ha^{-1}), stover yield (kg ha^{-1}) and harvest index (Khandakar 1985). Soil samples were collected after harvesting from each plot at 0-15 cm and 15-30 cm depth to study the physico-chemical properties viz., pH, bulk density, electrical conductivity, soil organic carbon, soil organic matter, available nitrogen, and phosphorus.

RESULTS AND DISCUSSIONS

There was a significant variation in plant height among crops, trees and interaction between tree and crop, except in the interaction between tree and crop at 30 and 60 DAS (Table 1). Wheat reported higher (19.13, 37.73 and 73.94 cm respectively) plant height compared to lentil (11.04, 15.89 and 27.35 cm respectively) at 30 DAS, 60 DAS and harvesting. Among treatments, maximum plant height was recorded under control (17.65, 29.39 and 59.65 cm respectively) at 30 DAS, 60 DAS and harvesting, whereas minimum under plum (13.71 cm) at 30 DAS, and under apple (25.08 and 46.00 cm respectively) at 60 DAS and harvesting. In case of interaction maximum plant height was recorded by wheat under control (21.82, 40.40 and 87.57 cm respectively) at 30 DAS, 60 DAS and harvesting while minimum by lentil under plum (8.57 cm) at 30 DAS and under apple (14.50 and 24.63 cm respectively) at 60 DAS and harvesting.

For both crops greater plant height at control may be attributed to the fact that there was no competition between tree and crop under sole cropping system. However among agri-horticulture system higher plant height of lentil under peach was observed due to the early shedding of leaves by peach that result in absolute supply of sunlight to crop and thus high crop photosynthesis rate while higher plant height of wheat under plum was due to the late germination of wheat seeds.

Table 1: Plant height of lentil and wheat at 30 DAS, 60 DAS and at harvesting time.

Tree	Plant height (at 30 DAS) (cm)			Plant height (at 60 DAS) (cm)			Plant height (at harvest) (cm)		
	Crops		Mean	Crops		Mean	Crops		Mean
	Lentil	Wheat		Lentil	Wheat		Lentil	Wheat	
Apple	10.52	17.76	14.14	14.50	35.66	25.08	24.63	67.36	46.00
Peach	11.60	18.10	14.85	15.98	37.05	26.52	28.26	69.32	48.79
Plum	8.57	18.85	13.71	14.69	37.79	26.24	24.78	71.52	48.15
Control	13.49	21.82	17.65	18.37	40.40	29.39	31.73	87.57	59.65
Mean	11.04	19.13		15.89	37.73		27.35	73.94	
Factors	Crops (A)	Trees (B)	A×B	Crops (A)	Trees (B)	A×B	Crops (A)	Trees (B)	A×B
Sem ±	1.38	1.95	0.90	1.43	2.02	0.93	0.59	0.84	1.19
C.D. (5%)	0.45	0.37	NS	0.47	0.66	NS	1.82	2.57	3.64

Number of plants/m^2 and 1000-grain weight are presented in Table 2. Number of plants/m^2 varied significantly among crops, trees and interaction between tree and crop whereas for 1000-grain weight there was significant variation among trees while non-significant among crops and interaction between trees and crop. Among crops, lentil reported greater number of plants/m^2 (62.86) and 1000-seed weight (33.17 g) compared to wheat (57.53 and 32.62 g respectively). Among treatments, maximum number of plants/m^2 and 1000-seed weight was reported under control (69.76 and 36.15 g respectively) while minimum under apple (55.28 and 30.60 g respectively). In case of interaction, maximum number of plants/m^2 was recorded by wheat under control (71.62) while minimum by wheat under apple (49.39) whereas maximum 1000-seed weight was recorded by lentil under control (36.65 g) and minimum by wheat under apple (29.58 g). Number of plants (m^2) for both crops was higher under control, which might be due to highest light concentration and maximum photosynthesis activity and also due to no competition between tree and crops for different resources. The 1000-seed weight was also higher under control, which might be due to absence of competition for various sources between crops and trees and also due to better nutrient uptake in control condition which resulted in better accumulation of dry matter in plants, thus resulting higher 1000-grain weight. Lower value of 1000-grain weight of both crops under apple based agri-horticulture system may be due to the late leaves shedding as well as wider crown of tree. Satyawali et al. (2018) also found reduction in 1000-grain weight of crop under agroforestry system.

Table 2: Number of plants m^2 and 1000-grain weight of lentil and wheat.

Trees	Plant population (m^{-2})			1000 grain weight (g)		
	Crops		Mean	Crops		Mean
	Lentil	Wheat		Lentil	Wheat	
Apple	61.17	49.39	55.28	31.61	29.58	30.60
Peach	59.39	57.40	58.39	34.32	33.75	34.03
Plum	63.00	51.73	57.37	30.12	31.51	30.81
Control	67.89	71.62	69.76	36.65	35.64	36.15
Mean	62.86	57.53		33.17	32.62	
Factors	Crops (A)	Trees (B)	A×B	Crops (A)	Trees(B)	A×B
Sem ±	0.75	1.06	1.50	0.65	0.92	1.31
C.D. (5%)	2.30	3.26	4.61	NS	2.83	NS

Seed yield, stover yield and harvest Index are presented in Table 3. There was significant variation among trees while non-significant among crops and interaction between trees and crops for seed yield. Among crops, lentil (9.47 q/ha) reported greater seed yield compared to wheat (9.36 q/ha). Among treatments, maximum seed yield was recorded under control (11.87 q/ha) and minimum under apple (8.25 q/ha). In case of interaction, maximum seed yield was recorded by wheat under control (12.05 q/ha) while minimum by wheat under apple (7.85 q/ha). Stover yield reported significant variation among crops and trees while non-significant among interaction between tree and crop. Among crops, wheat (19.03 q/ha) reported higher stover yield as compared to lentil (17.23 q/ha). Among treatments, maximum stover yield was recorded under control (20.61 q/ha) while minimum under apple (16.55 q/ha). In case of interaction, maximum stover yield was recorded by wheat under control (21.66 q/ha) while minimum by lentil under apple (15.77 q/ha). Higher seed yield and straw yield under control may be attributed to the fact that there was no competition between tree and crops under sole cropping system. Lower grain yield under agri-horticulture system was due to the reduction in intensity of sunlight with decrease in the crop distance from the tree base and also due to competition for available nutrients. Among agri-horticulture systems, maximum seed and stover yield of lentil are observed under peach due to the early leaf shedding by tree as well as early growth of lentil crop compared to wheat, while in case of wheat maximum seed yield was observed under peach and stover yield under plum because of the late germination of wheat seeds. Harvest Index reported significant variation among crops and trees while non-significant among interaction between tree and crop. Among crops, lentil (35.33%) reported greater harvest index as compared to wheat (32.80%). Among treatments, maximum harvest index was recorded under control (36.60%) and minimum under plum (32.18%). In case of interaction, maximum harvest index was recorded by lentil under control (37.44%) while minimum by wheat under plum (30.99%). The value of harvest index depends upon grain yield and straw yield, therefore harvest index shows a significant correlation among yields of both crops (Fan et al. 2017). Similar reduction under agroforestry systems were reported by Bijalwan and Dobriyal (2014), Sarvade et al. (2014), Johar et al. (2017), Kaur et al. (2017) and Satyawali et al. (2018).

Table 3: Yield attributes of lentil and wheat under sole cropping and agri-horticulture systems.

Trees (B)	Seed Yield (q/ha)			Stover Yield (q/ha)			Harvest Index		
	Crops (A)		Mean	Crops (A)		Mean	Crops (A)		Mean
	Lentil	Wheat		Lentil	Wheat		Lentil	Wheat	
Apple	8.65	7.85	8.25	15.77	17.34	16.55	35.41	31.18	33.29
Peach	9.36	8.92	9.14	17.28	17.88	17.58	35.11	33.30	34.21
Plum	8.17	8.63	8.40	16.33	19.22	17.78	33.37	30.99	32.18
Control	11.69	12.05	11.87	19.55	21.66	20.61	37.44	35.75	36.60
Mean	9.47	9.36		17.23	19.03		35.33	32.80	
Factors	Crops (A)	Trees (B)	A×B	Crops (A)	Trees (B)	A×B	Crops (A)	Trees (B)	A×B
Sem ±	0.16	0.23	0.32	0.27	0.39	0.55	0.52	0.73	1.03
C.D. (5%)	NS	0.70	NS	0.84	1.19	NS	1.58	2.23	NS

The observed values of each soil parameters are presented in the Table 4. Among all the observed soil parameters, soil pH has shown a significant difference at both soil depths, while remaining parameters depicted the significant and non-significant variation at both soil depths. Soil pH ranged from 4.83 to 6.02 and 5.12 to 6.07 and soil bulk density from 0.97 to 1.27 g cc^{-1} and 1.07 to 1.22 g cc^{-1} at 0-15 cm and 15-30 cm soil depths respectively. Among crops, lentil reported greater soil pH and bulk density as compared to wheat at both depths. Among treatments, maximum soil pH was reported under peach and bulk density under plum while minimum soil pH under control and bulk density under peach at both depths. Soil pH is positively correlated with soil depth under all studied land used systems due to the leaching of soluble bases and continuous addition of crop residues and their decomposition resulted in releasing organic acid on surface soil (Salve et al. 2018). The highest value of soil pH observed under peach based agri-horticulture system and minimum under sole cropping systems which might be due to absence of vegetations that affect soil microorganisms, nutrients availability and leaching (Gentili et al. 2018). Khattak and Hussain (2007) also reported that the peach, plum and apple prefer slightly acidic to neutral soil. Soil bulk density increased with increasing soil depth under all land use systems owing to the compact nature of subsurface soil (Nanganoa et al. 2019), less organic matter, less root penetration, and less aggregation, therefore less pore space compared to surface layers. At both soil depths, bulk density was higher under plum based agri-horticulture system which might be due to the compact nature of soil, low litter input and less root penetration on upper layers of soil while minimum under peach based agri-horticulture system due to heavy and early leaves shedding by peach. Soil electrical conductivity (EC) ranged from 0.07 to 0.15 at surface soil and from 0.07 to 0.14 at subsurface soil. Among crops, wheat reported greater soil EC at 0-15 cm soil depth while lower at 15-30 cm soil depth as compared to lentil. Among treatments maximum soil EC was reported under peach and minimum under apple at 0-15 cm soil depth while at 15-30 cm soil depth maximum soil EC was reported under plum and control and minimum under apple and peach. Soil EC was also positively correlated with soil depth because of decrease in pore space of subsurface soil due to actions of tree roots and also by the action of leaching and mineralization. Carmo et al. (2016) reported that the rich nutrient content and decomposition of plant and animal wastes are increased soil EC due to the addition of salts and iron in soil.

Soil organic carbon (SOC %) ranged from 1.55 to 2.11% and 1.73 to 2.13% and soil organic matter (SOM %) ranged from 2.68 to 3.64% and 2.90 to 3.67% at 0-15 and 15-30 cm soil depth respectively. Among crops, wheat reported greater SOC % and SOM % at 0-15 cm soil depth as compared to lentil while at 15-30 cm soil depth SOC % remained same under lentil and wheat and SOM % was greater under wheat as compared to lentil. Among treatments, maximum SOC % and SOM % were reported under peach and minimum under control at both depths. Soil organic carbon (SOC) and soil organic matter (SOM) are also positively correlated with soil depth because of limited oxygen and water, less availability of humus and lower mineralization rate in subsurface soil (Hobley and Wilson 2016). The agri-horticulture systems reported higher amount of SOC and SOM at both depth as compared to sole cropping systems, this might be due to heavy decomposition of litter fall and plant roots as also reported by Nanganoa et al. (2019, Koul and Panwar 2012) and coarse deadwood. The value of soil organic carbon decreased with increasing soil depth, that correlates with the finding of Mishra et al. (2018) and Dimri et al. (1997) which suggest increment in litter composition and weathering of parent materials was higher on the soil surface.

Available N ranged from 147.65 to 179.65 kg/ha and 137.40 to 160.46 kg/ha and available P ranged from 40.08 to 73.56 kg/ha and 39.85 to 64.57 kg/ha at 0-15 and 15-30 cm soil depth respectively. Among crops, wheat reported higher available N and P as compared to lentil at both depths. Among treatments, maximum available N was reported under peach and minimum under plum at both depths while maximum available P was reported under peach at both depths while minimum under apple at 0-15 cm soil depth and under control at 15-30 cm soil depth. The value of Available N and P decreased with increasing soil depth because of lower organic matter content in subsurface soil that release the mineral nitrogen and phosphorus and also nutrients uptake around root surface area by tree species (Devi et al. 2013, Digvijay et al. 2020). Available N and P were higher under agri-horticulture system as compared to sole cropping system, due to heavy decomposition of litter fall and plant roots as reported by Nanganoa et al. (2019). Similar decreasing trend of nitrogen and phosphorus with increasing soil depth was also reported earlier by Salve et al. (2018). Similar observation of above mentioned soil properties was also reported by Salve et al. (2018), Mishra et al. (2018), Pandey et al. (2018), Joshi and Negi (2015) and Gairola et al. (2012).

Table 4. Soil parameters under sole and different agri-horticulture systems.

Trees	pH			Bulk density (g cc^{-1})			EC			SOC %			SOM %			AVAILABLE N (kg ha^{-1})			AVAILABLE P (kg ha^{-1})		
	Crops		Mean	Crops		Mean	Crops		Mean	Crops		Mean	Crops (A)		Mean	Crops (A)		Mean	Crops		Mean
	Lentil	Wheat		Lentil	Wheat		Lentil	Wheat		Lentil	Wheat		Lentil	Wheat		Lentil	Wheat		Lentil	Wheat	
0-15 cm soil depth																					
Apple	5.83	4.94	5.39	1.09	0.97	1.03	0.09	0.08	0.09	1.67	1.78	1.73	2.88	3.07	2.98	171.69	168.45	170.07	40.08	54.23	47.15
Peach	6.02	5.48	5.75	0.97	1.03	1.00	0.11	0.15	0.13	1.93	2.11	2.02	3.33	3.64	3.48	169.88	179.65	174.76	57.91	73.56	65.74
Plum	5.73	5.36	5.54	1.27	0.98	1.13	0.10	0.10	0.10	1.58	1.81	1.70	2.73	3.12	2.93	153.39	147.65	150.52	66.92	52.88	59.90
Control	4.83	5.12	4.98	1.05	1.16	1.11	0.07	0.12	0.10	1.60	1.55	1.58	2.76	2.68	2.72	156.78	165.94	161.36	43.23	54.42	48.82
Mean	5.60	5.22		1.10	1.04		0.09	0.11		1.70	1.81		2.93	3.13		162.93	165.42		52.03	58.77	
Factors	Crop (A)	Tree (B)	A×B	Crop (A)	Tree (B)	A×B	Crop (A)	Tree (B)	A×B	Crop (A)	Tree (B)	A×B	Crop (A)	Tree (B)	A×B	Crop (A)	Tree (B)	A×B	Crop (A)	Tree (B)	A×B
Sem ±	0.07	0.09	1.33	0.02	0.03	0.04	0.01	0.01	0.01	0.06	0.09	0.12	0.11	0.15	0.21	1.48	2.09	2.96	2.16	3.06	4.32
C.D. (5%)	0.20	0.29	0.47	NS	0.09	0.13	NS	0.03	NS	NS	0.27	NS	NS	0.46	NS	NS	6.41	9.07	6.62	9.36	13.24
15-30 cm soil depth																					
Apple	6.07	5.37	5.72	1.16	1.10	1.13	0.13	0.07	0.10	1.87	1.87	1.87	3.22	3.67	3.45	143.78	161.33	152.55	48.87	40.57	44.72
Peach	5.98	5.69	5.84	1.07	1.08	1.08	0.08	0.12	0.10	2.13	2.13	2.13	3.67	3.67	3.67	160.46	148.60	154.53	50.67	64.57	57.62
Plum	5.90	5.55	5.73	1.19	1.22	1.21	0.14	0.09	0.12	1.84	1.84	1.84	3.17	3.33	3.25	137.40	139.52	138.46	46.51	51.63	49.07
Control	5.12	5.19	5.16	1.11	1.08	1.10	0.10	0.13	0.12	1.73	1.73	1.73	2.99	2.90	2.94	140.33	137.87	139.10	41.97	39.85	40.91
Mean	5.77	5.45		1.13	1.12		0.11	0.10		1.89	1.89		3.26	3.39		145.49	146.83		47.01	49.15	
Factors	Crop (A)	Tree (B)	A×B	Crop (A)	Tree (B)	A×B	Crop (A)	Tree (B)	A×B	Crop (A)	Tree (B)	A×B	Crop (A)	Tree (B)	A×B	Crop (A)	Tree (B)	A×B	Crop (A)	Tree (B)	A×B
Sem ±	0.05	0.07	0.09	0.03	0.04	0.06	0.01	0.01	0.02	0.05	0.07	0.09	0.08	0.11	0.16	1.25	1.77	2.50	1.42	2.00	2.83
C.D. (5%)	0.15	0.21	0.29	NS	NS	NS	NS	NS	0.05	NS	0.20	NS	NS	0.34	NS	NS	5.41	7.65	NS	6.13	8.67

CONCLUSIONS

On the basis of field and analytical findings, it is concluded that the agri-horticultural practices improved the physical and chemical properties of soil through deep rooting system and litter fall with minor reduction in yield of lentil and wheat crops, also provide fruits and maintains environmental services.

ACKNOWLEDGEMENT

The authors are extremely thankful to the Dr. V. P. Khanduri, Dean, College of Forestry (VCSG Uttarakhand University of Horticulture and Forestry), Ranichauri for providing his invaluable support and genuine cooperation.

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Received: 3rd December, 2020 *Accepted: 26th December, 2020*