Indian Journal of Ecology (2023) 50(4): 989-994
DOI: https://doi.org/10.55362/IJE/2023/4001

Manuscript Number: 4001
NAAS Rating: 5.79

Performance of Mustard Crop Under Citrus Based Agroforestry Systems in Vidarbha Region of Maharashtra

Aarti P. Deshmukh, V.M. Ilorkar, P.D. Raut and Lalji Singh

Department of Forestry, Indira Gandhi Krishi Vishwavidyalya Raipur-492 012, India
E-mail: aartideshmukh776@gmail.com

Abstract: Traditional agroforestry is very common in Vidarbha region of Maharashtra with forest tree crops. Now fruit tree crops are also introduced to increase the farmer's income. Hence, the experiment was conducted at AICRP on Agroforestry research farm at College of Agriculture, Nagpur under citrus based agroforestry systems. The citrus fruit trees were planted at 6 x 6 m and forest species including *Tectona grandis, Eucalyptus teretocornis* and *Ailanthus excelsa* at equilateral distance of 3 meter in each treatment between two mandarin trees, where, Mustard crop (*Brassica juncea* var. Pusa bold) was cultivated as traditional agri-horti-silviculture system during 2020-21. The growth performance and yield of Mustard under different set of treatments viz. T_1 (Sole mustard), T_2 (Sole mandarine + mustard), T_3 (Mandarin + *Tectona grandis* + mustard), T_4 (Mandarin + *Eucalyptus teretocornis* + mustard) and T_5 (Mandarin + *Ailanthus excelsa* + mustard) was recorded. The growth parameter and yield of mustard crop was found maximum in open field crop (Sole Mustard) than the treatment under citrus based agroforestry systems and it was 25.57, 56.35, 44.00 and 63.12 per cent higher as compared to treatment T_2, T_3, T_4 and T_5, respectively. The grain and straw yield of mustard was 5.75 and 11.90 q ha^{-1} in crop of open field (Sole mustard). As regard the soil fertility, the most important parameter i.e., the organic carbon was significantly increased in sole cropping (0.57), sole Mandarin (0.53) and Mandarin + *Ailanthus excelsa* (0.48). Whereas, it decreased under Mandarin + *Tectona grandis* (0.48) and Mandarin + *Eucalyptus tereticornis* (0.44) after the harvesting of *rabi* mustard crop.

Keywords: Citrus based agroforestry system, Mustard, Productivity*, Ailanthus*

Agroforestry is a land use system that integrates trees, crops and animals in a way that is scientifically sound, ecologically desirable, practically feasible, and socially acceptable to the farmers (Nair 1993). Agroforestry systems can be advantageous over conventional agricultural and forest production methods through increase productivity, economic benefits, social outcomes and the ecological goods and services provided. Agroforestry is one of the best option to increase the tree cover outside the forest. An efficient agroforestry system not only maximizes the benefit it provides but also ensures the link to climate change mitigation. Trees are important carbon warehouses that filters massive quantities of carbon from the atmosphere, trapping it in their biomass (Montagini and Nair 2004). An average tree can remove about 23kg of carbon dioxide from the atmosphere annually. In agroforestry systems, the amount of carbon sequestration is further increased. The interaction of the different components of agroforestry systems can help absorb and sequester carbon dioxide and other greenhouse gasses from the atmosphere (Pandey 2002). Thus, trees in an agroforestry system make it a potential strategy in mitigating climate change (Patra and Behera 2014). XV finance Commission in its report submitted in July 2020, mentioned that in 2017 total consumption of wood in India was 65 million cum of which 3 million cum was produced from forests, around 47 Million cum was produced from plantations (mainly agro forestry systems), and balance 15 million cum was imported (Anon 2020). This clearly brings out the fact that around 25% of the demand for industrial wood is met from imports. Of the balance met with through domestic production around 94% is from ToF, primarily from agroforestry (Bansal 2021). Keeping this in view, an investigation was carried out to study the performance of mustard crop (*Brassica juncea* var. Pusa bold) under citrus based agroforestry systems in Vidarbha Region of Maharashtra.

MATERIAL AND METHODS

Nagpur tract fall in sub-tropical zone, at a latitude of 21° 14' N and longitude 79° 08' E at an elevation of 310 meter above mean sea level. The climate of the area is semiarid characterized by three distinct seasons i.e., summer, rainy and winter. The normal mean annual precipitation is 1064.1mm and the major share of precipitation is received during the period of June to September. Winter rains are few and uncertain. The normal mean monthly temperature varies from 27.7°C to 41.7°C during the hottest month (May), while the mean monthly minimum temperature is ranges from

14.5°C to 29.5°C in the coldest month (December). The selected level field of 0.29 ha in which horti-silviculture-system including Mandarin, *Tectona grandis, Eucalyptus tereticornis* and *Ailanthus excelsa* planted during 2015 was selected. The experiment was laid out in Randomized Block Design (RBD) with four replications. There were 20 treatments. The size of unit plot was 6 X 6 m^2. The Mandarin was planted at a distance of 6 x 6 m^2, whereas the forest species were planted at a distance of 3m between two mandarin plantations.

Mustard (*Brassica juncea*) Variety (Pusa bold) was cultivated as per recommended package and practices in rabi season. The treatments includes T_2 - Sole Mandarin + Mustard, T_3 - Mandarin + *Tectona grandis*+Mustard, T_4- Mandarin + *Eucalyptus tereticornis* + Mustard and T_5- Mandarin + *Ailanthus excels* + Mustard were frame, while T_1- sole mustard field area without trees were laid down to accesses the growth and yield performances of mustard crop affected by microclimate condition available to mustard crop at different growth stages, the observation were made for plant population m^{-2}, height of plant (cm), number of branches plant^{-1} number of leaves plant^{-1} number of siliqua plant^{-1}, seed siliqua^{-1}, length of siliqua (cm), grain yield (q ha^{-1}), straw yield (q ha^{-1}), harvest index (%), test weight (gm)1000 seed^{-1}, fresh weight (kg m^{-2}), dry weight (kg m^{-2}), fresh root weight plant^{-1} (gm) and root length (cm). The dry weight of sample was estimated after drying of sample at 75^{0}c for 24 hours. The microclimate observation i.e., solar radiation, atmospheric temperature, humidity where recorded at different growth by wind LICOR-photo meter, digital thermometer & hygrometer at 9.00 to 10.00, 12.00 to 13.00 and 15.00 to 16.00 hours in each replication of the treatments during crop period. The soil of the crop area was analyzed for in organic carbon, pH, electric conductivity (EC), nitrogen, phosphorus and available potassium after harvesting of crop as per standard methods of Jackson (1957), Piper (1967), Olsen et al (1954) and AOAC (2002).

RESULTS AND DISCUSSION

The highest plant population per square meter of mustard (30 m^{-2}) was recorded under sole cropping followed by sole Mandarin (29.50 m^{-2}) based agroforestry system (Table 1). Whereas, the minimum plant population per square meter (27.25 m^{-2}) was recorded under Mandarin + *Eucalyptus tereticornis* based agroforestry system. No significant differences in plant population were found among different agroforestry systems. The per cent reduction in plant population of mustard was 1.66, 7.5, 5, 9.16 per cent under sole Mandarin, Mandarin + *Tectona grandis*, Mandarin + *Eucalyptus tereticornis* and Mandarin + *Ailanthus excelsa* as compared to sole cropping. Rahangdale et al. (2014) recorded highest reduction in plant population in soyabean (21.61%) and the lowest in paddy (12.35%). They also noticed that the moong and til showed almost the similar trend of reduction (16.06% and 17.63%, respectively) under bamboo based agri-silviculture system over the control that is sole crop. In mustard, significant difference in plant height were observed at 30 and 60 DAS (Table 1). Significantly maximum plant height was recorded in sole mustard i.e. 47.00 and 106.25 cm at 30 and 60 DAS. However, no significant difference in plant height was recorded at 90 DAS. Amongst the different citrus based agroforestry system, maximum plant height was observed in sole Mandarin. Less height under Mandarin + *Ailanthus excelsa* agroforestry systems may be primarily due to reduced light intensity. Rahangdale et al (2014) also recorded reduction in plant height of paddy (3.90 %) and sesame (2.84%) as compared to soybean (8.83 %) and moong (7.57%) under bamboo based agri-silviculture system over the control that is sole crop which may be because bamboo canopy could have even affected the proper penetration of light on the understory annual crop. Significant differences in number of branches plant^{-1} of mustard were observed under citrus based agroforestry systems at 60 and 90 DAS of mustard (Table 1). However, no significant difference was observed in number of branches plant^{-1} at 30 DAS of mustard. Significantly highest number of branches plant^{-1} at 60 DAS (4.17) and 90 DAS (4.91) was recorded under sole cropping followed by sole Mandarin (3.88 and 4.68), Mandarin + *Eucalyptus tereticornis* (3.67 and 4.55), Mandarin + *Tectona grandis* (3.60 and 4.41) and Mandarin + *Ailanthus excelsa* (3.36 and 4.33). Rahangdale et al (2014) noticed that among the *kharif* crop highest reduction in soybean (33.66 %) fro number of branches per plant and the lowest was in paddy (23.75 %) for number of effective tillers per plant. They also observed that the moong and sesame showed the almost similar trend of reduction (31.32 % and 30.41 %, respectively) for number of branches per plant under bamboo based agri-silvicuture system over control that is sole crop. In mustard, no significant difference was observed in number of leaves plant^{-1} at 30 and 90 DAS (Table 2). The significantly maximum number of leaves plant^{-1} was recorded in mustard at 60 DAS (9.08) under sole cropping. Kumar and Nandal (2004) found that the entire test crop sown in the interspaces of *Eucalyptus teretocornis* showed reduced plant vigour in terms of plant height, stem diameter, number of branches, number of leaves and yield attributes as compared to sole cropping. There were no significant differences in number of siliqua plant^{-1} amongst the different treatments. However, maximum number of siliqua plant^{-1} was recorded in sole cropping in mustard (130.00) and lowest was in Mandarin + *Ailanthus excelsa* agroforestry system i.e., 101.20. Kumar et al (2013) found that parameters such as plant running meter row lay, spike length, grains spike^{-1} and test weight was significantly less under *Eucalyptus tereticornis* than sole cropping. In mustard, seeds siliqua^{-1} was less under *Eucalyptus tereticornis* than sole cropping. Yield parameters such as secondary siliqua plant^{-1} and test weight were also significantly higher in sole cropping.

The effect of agroforestry system on seed siliqua^{-1} of mustard as compared to sole cropping indicated that number of seed siliqua^{-1}was significantly maximum in sole cropping in cowpea (16.45) and the lowest seed siliqua^{-1} were in Mandarin + *Ailanthus excelsa* agroforestry system (11.05). The percent reduction in seed siliqua^{-1}was 9.73, 26.26, 16.41 and 32.83 in mustard under sole Mandarin, Mandarin + *Tectona grandis*, Mandarin + *Eucalyptus tereticornis* and Mandarin + *Ailanthus excelsa*, respectively as compared to sole cropping of intercrops. This may be due to competition of light among the annuals and perennials. Kumar *et al.* (2013) observed that parameters such as plant running meter row lay spike length, grains per spike and test weight was significantly less under *Eucalyptus tereticornis* than sole cropping. In mustard, seeds siliqua^{-1} was less under *Eucalyptus tereticornis* than sole cropping. Yield parameters such as secondary siliqua per plant and test weight were also significantly higher in sole cropping.

Highest length of silica (5.23 cm) of mustard was in sole cropping and lowest was in Mandarin + *Ailanthus excelsa* agroforestry systems (4.30 cm). All the treatments were at par with each other. The yield attributing parameter i.e. length of siliqua (cm) of mustard was highest under sole cropping as compared to sole Mandarin, Mandarin + *Tectona grandis*, Mandarin + *Eucalyptus tereticornis* and Mandarin + *Ailanthus excelsa* agroforestry systems, respectively may be due to competition of light among the annuals and perennials. Kumar et al (2013) observed that plant running meter row lay, spike length, grains per spike and test weight of wheat was significantly less under *Eucalyptus tereticornis* than sole cropping. In mustard, seeds siliqua^{-1} was less under

Table 1. Effect of tree crops on plant population m^{-2}, height of plant (cm), number of branches plant^{-1}, number of leaves plant^{-1}, number of siliqua plant^{-1}, seed siliqua^{-1} and length of siliqua (cm)of cowpea under different agroforestry systems

Treatment	Plant population m^{-2}	Height of plant (cm)			Number of branches cowpea plant^{-1}			Number of leaves plant^{-1}			No. of siliqua plant^{-1}	Seed siliqua^{-1}	Length of siliqua (cm)
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS			
Sole cropping	30.00	47.00	106.25	138.75	1.28	4.17	4.91	5.46	9.08	9.98	130.00	16.45	5.23
Mandarin	29.50	46.00	102.00	135.25	1.25	3.88	4.68	5.42	8.43	9.31	128.50	14.85	5.03
Mandarin + *Tectona grandis*	27.75	42.00	98.00	126.75	1.13	3.60	4.41	5.15	7.75	8.61	107.55	12.13	4.38
Mandarin + *Eucalyptus tereticornis*	28.50	44.25	99.75	130.50	1.22	3.67	4.55	5.28	7.85	8.82	122.10	13.75	4.67
Mandarin + *Ailanthus excels*	27.25	40.50	94.50	122.75	1.08	3.36	4.33	5.00	7.45	8.11	101.20	11.05	4.30
SE(m) ±	1.65	2.66	3.50	2.44	0.09	0.18	0.19	0.29	0.45	0.58	54.46	1.42	0.38
CD @ 5%	NS	8.21	10.79	NS	NS	0.57	0.59	NS	1.40	NS	NS	4.38	1.19

Table 2. Effect of tree crops on grain yield(q ha^{-1}), straw yield(q ha^{1}), harvest index (%),test weight (gm) 1000 seed^{-1}, fresh weight (kg m^{-2}), dry weight (kg m^{-2}), fresh root weight plant^{-1} (gm) and root length (cm) mustard under citrus based different agroforestry systems

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest Index (%)	Test weight (gm) 1000 seed^{-1}	Fresh weight (kg m^{-2})	Dry weight (kg m^{-2})	Fresh root weight plant^{-1} (gm)	Root length (cm)
Sole cropping	10.31	20.48	33.48	4.50	1.57	0.67	8.80	14.50
Sole Mandarin	8.51	18.05	32.04	4.23	1.46	0.60	8.53	14.25
Mandarin + *Tectona grandis*	7.45	16.24	31.44	3.90	1.11	0.44	8.10	12.95
Mandarin + *Eucalyptus tereticornis*	7.93	17.04	31.75	4.15	1.37	0.57	8.33	13.15
Mandarin + *Ailanthus excels*	6.82	15.00	31.25	3.70	0.79	0.35	7.94	11.65
SE(d) ±	0.87	1.45	1.06	0.47	0.19	0.13	2.92	3.44
CD @ 5%	NS	NS	NS	1.45	0.59	NS	NS	NS

Eucalyptus tereticornis than sole cropping. Yield parameters such as secondary siliqua plant^{-1} and test weight were also significantly higher in sole cropping.

Grain and straw yield (q ha^{-1}) of mustard under different agroforestry systems: It was observed that the due to competition for moisture, light and nutrients among the annual crops, trees and fruit plants, the observed values for different yield attributing parameters were lesser than the sole cropping system. As regards mustard yield, highest grain and straw yield was recorded under sole cropping i.e. 10.31 and 20.48 q ha^{-1}which was 17.46, 27.74, 23.08 and 33.85 per cent higher in grain and 11.87, 21.78, 15.63 and 26.76 per cent higher in straw than the yield recorded under sole Mandarin, Mandarin + *Tectona grandis*, Mandarin + *Eucalyptus tereticornis* and Mandarin + *Ailanthus excelsa* agroforestry systems, respectively (Table 2). Highest harvest index of mustard intercrop was in sole cropping, whereas, lowest harvest index was recorded under Mandarin + *Ailanthus excelsa* agroforestry systems. In mustard, the harvest index under sole cropping was 4.19, 5.08, 5.98 and 6.58 per cent higher as compared to sole Mandarin, Mandarin + *Tectona grandis*, Mandarin + *Eucalyptus tereticornis* and Mandarin + *Ailanthus excelsa* agroforestry systems, respectively and may be due to competition of light among the annuals and perennials. Rahangdale et al. (2014) recorded that the soyabean (67.88%) and moong (61.30%) showed relatively higher reduction in grain and straw yield as compared to sesame (49.25%) and paddy (34.00%) in old bamboo based agri-silviculture system over the sole crops and this reduction in grain yield may be due to less PAR (photosynthesis active radiation) interception and available energy below the canopy of bamboo species in comparison to sole crop (open condition). These results are also in conformity with the findings earlier workers (Kaushik et al 2002, Kiran et al 2002, Swamy et al 2003, Yadav et al 2005 , Bijalwan et al 2009).

Highest test weight of mustard was recorded under sole cropping (4.50 gm 1000 seed^{-1}) (Table 2). All the treatments were at par with each other. The test weight of mustard in sole cropping was 6.0, 13.33, 7.77 and 17.77 per cent higher as compared to sole Mandarin, Mandarin + *Tectona grandis*, Mandarin + *Eucalyptus tereticornis* and Mandarin + *Ailanthus excelsa*. Johar et al (2017) observed the effect of *Eucalyptus tereticornis* based agri-silvi-horticultural system on growth and yield of wheat and test weight of wheat was significantly reduced under Kinnow + wheat (46.1 gm) and Kinnow + Eucalyptus + wheat agroforestry model as compared to sole cropping .

Significantly highest fresh weight of mustard (1.57 kg m^{-2}) was under sole cropping followed by sole Mandarin (1.46 kg m^{-2}) and lowest was in Mandarin + *Ailanthus excelsa* agroforestry systems (0.79 kg m^{-2}). All the agroforestry systems were at par with each other for fresh weight of mustard except sole Mandarin and sole cropping. The dry weight, fresh root weight plant^{-1} and root length of mustard was not significantly affected by different agroforestry systems. However, highest dry weight, fresh root weight plant^{-1} and root length was recorded under sole cropping i.e., 0.67 kg m^{-2}, 8.80 gm and 14.50 cm, respectively. The lowest values of all parameters i.e., dry weight, fresh root weight plant^{-1} and root length were in Mandarin + *Ailanthus excelsa* agroforestry system i.e., 0.35 kg m^{-2}, 7.94 gm and 11.65 cm, respectively.

Available soil nutrient content: The organic carbon, available soil nitrogen (N) and available phosphorus (P) and available potassium (K) was ranged between 0.44-0.53 (%), 173.05-231.10 (kg ha^{-1}), 16.03-17.88 (kg ha^{-1}) and 268.80-314.50 (kg ha^{-1}), respectively (Table 3). The highest soil available nitrogen, phosphorus and potassium were recorded in sole cropping and lowest values of soil available nitrogen (173.05 kg ha^{-1}) and phosphorus (16.03 kg ha^{-1}) were in Mandarin+ *Eucalyptus tereticornis* agroforestry system. Lowest value of soil available potassium (268.80 kg ha^{-1}) was in Mandarin + *Ailanthus excelsa.*

The fertility status of soil after harvest of cowpea crop infers that organic carbon and available soil nitrogen (N) were significantly, whereas, available phosphorus (P) and available potassium (K) was non-significantly affected by the different citrus based agroforestry systems as compared to sole cropping. The organic carbon was significantly increased in sole cropping (0.57), sole Mandarin (0.53) and Mandarin + *Ailanthus excelsa* (0.48) and decreased under Mandarin + *Tectona grandis* (0.48) and Mandarin + *Eucalyptus tereticornis* (0.44) after the harvesting of rabi crop. The initial available nitrogen status under sole cropping, sole Mandarin, Mandarin + *Ailanthus excelsa* was 231.10, 225.15 and 199.95 kg ha^{-1} and increased to 239.00, 230.23 and 207.90 kg ha^{-1}, respectively after harvesting of rabi season mustard crop. In Mandarin + *Tectona grandis* and Mandarin + *Eucalyptus tereticornis*, the nitrogen status before sowing of rabi mustard crop was 195.73 and 173.05 kg ha^{-1} and significantly reduced to 187.08 and 166.63 kg ha^{-1}. Similar results were also observed for potassium (K) which was initially observed as 314.50, 27, 275.85, 282.80, 280.00 and 268.80 kg ha^{-1} under sole cropping, sole Mandarin, Mandarin + *Tectona grandis*, Mandarin + *Eucalyptus teretocornis* and Mandarin + *Ailanthus excelsa*, respectively significantly reduced to 311.75, 273.50, 274.58, 273.10 and 263.75 kg ha^{-1} after harvest of rabi mustard crop. This may be due to over utilization of the nutrients by the different components in the agroforestry system as returned to soil in the form of litter fall and its decomposition. There were no significant differences in the available status of phosphorus in soil before sowing and after harvesting of the rabi mustard crop. Soil moisture was significantly highest during kharif season as compared to rabi season.

Nutrients are made available to plants in agroforestry mainly by atmospheric nitrogen fixation and mineralization of nutrients from organic forms (Muthuri et al 2005, Fang et al 2008, Jose 2009). The intercropping of trees with crops that are above to biologically fix nitrogen is common in tropical agroforestry systems. Non N-fixing trees

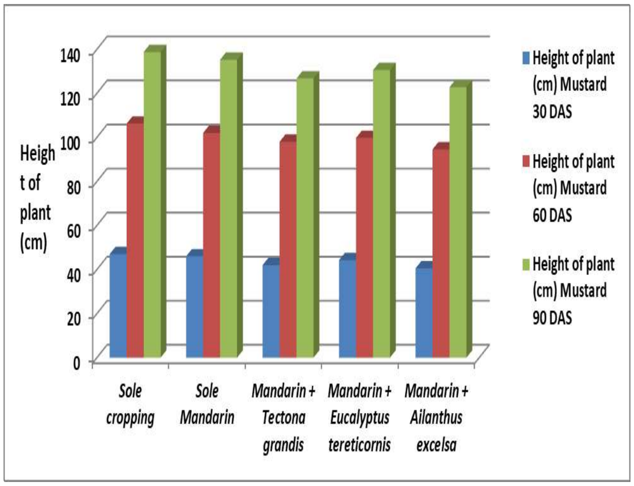

Fig. 1. Effect of tree crops on height of plant (cm) of mustard under different citrus based agroforestry systems

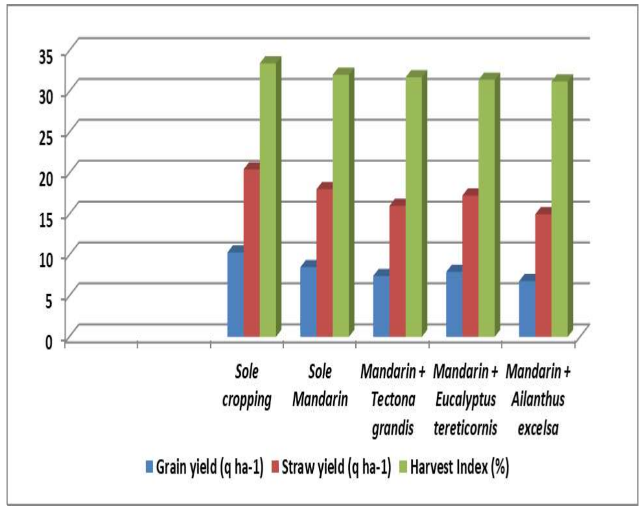

Fig. 2. Effect of tree crops on grain and straw yield (q ha^{-1}) of mustard under different Citrus based agroforestry systems

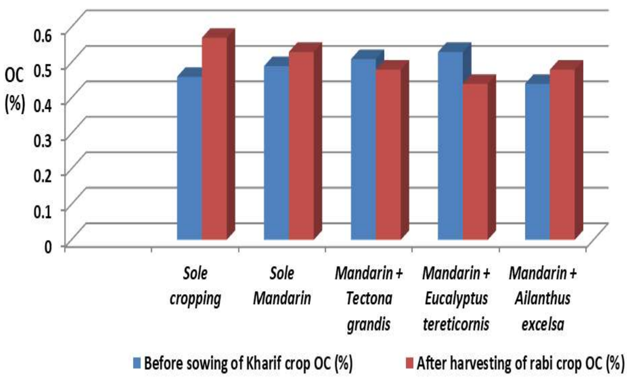

Fig. 3. Effect of tree crops on soil organic carbon content before sowing and after harvest of rabi crop

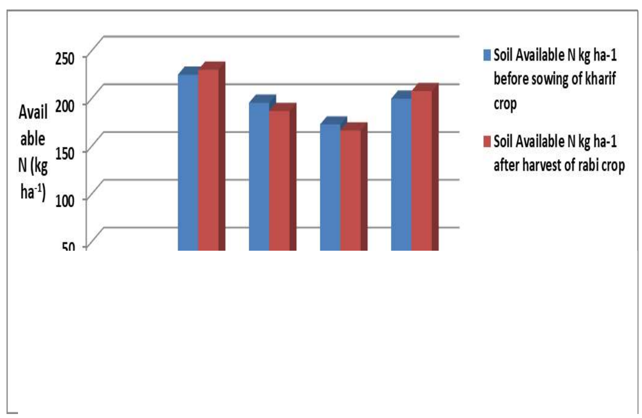

Fig. 4. Effect of tree crop on soil available nitrogen status under different citrus based agroforestry system

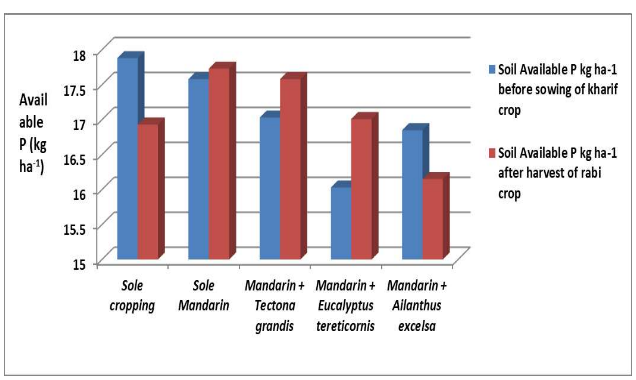

Fig. 5. Effect of tree crop on soil available phosphorus status under different citrus based agroforestry system

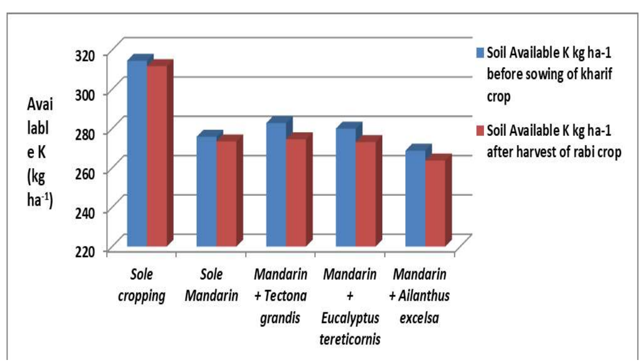

Fig. 6. Effect of tree crop on soil available potassium status under different citrus based agroforestry system

Table 3. Initial and final soil fertility status of soil under different agroforestry systems

Treatment	Before sowing of *kharif* crop						After harvest of *kharif* crop					
	pH (1:2)	EC (dSm^{-1})	OC (%)	Available Nutrients ($kg\ ha^{-1}$)			pH (1:2)	EC (dSm^{-1})	OC (%)	Available Nutrients ($kg\ ha^{-1}$)		
				N	P	K				N	P	K
Sole cropping	7.14	0.38	0.46	231.10	17.88	314.50	7.17	0.36	0.57	239.00	16.93	311.75
Sole Mandarin	7.16	0.32	0.49	225.15	17.58	275.85	7.10	0.31	0.53	230.23	17.73	273.50
Mandarin + *Tectona grandis*	7.21	0.29	0.51	195.73	17.03	282.80	7.24	0.32	0.48	187.08	17.58	274.58
Mandarin + *Eucalyptus tereticornis*	7.25	0.30	0.53	173.05	16.03	280.00	7.22	0.31	0.44	166.63	17.01	273.10
Mandarin + *Ailanthus excelsa*	7.15	0.29	0.44	199.95	16.85	268.80	7.17	0.30	0.48	207.90	16.15	263.75
SE(d) ±	-	-	-	-	-	-	0.06	0.03	0.08	16.82	1.41	20.13
CD (0.05)	-	-	-	-	-	-	NS	NS	0.26	51.85	NS	NS

can also affect soil physical, chemical and biological properties by adding some amount of organic matter and releasing and recycling of nutrients in agroforestry system (Paoli et al 2008, Yadav et al 2008).

CONCLUSION

The growth parameters and yield of mustard crop was maximum in sole cropping as compare to other citrus based agroforestry systems. The grain yield and straw yield of mustard was higher in sole cropping (sole mustard). The organic carbon significantly increase in sole cropping, mandarin +mustard (and mandarin + *Ailanthus excelsa* +mustard whereas it was decrease under mandarin + *Tectona grandis* + Mustard 0.48% and mandarin + *Eucalyptus tereticornis* + mustard. Similar trend also observed with regards to other nutrients.

REFERENCES

Bijlawan A, Swamy SL, Sharma CM, Shah VK and Singh RK 2009. Phytosociological analysis of overstory and understory woody perennials along with aspects in Balmdi watershed of mixed dry tropical forest I Chattisgarh plain. *Indian Journal of Tropical Biodiversity* **17**(1): 47-57.

Current D, Lutz E and Scherr S 1995. *Costs, benefits and farmers adoption of agroforestry.* Project experience in Central America and the Carribbean. Environmental Paper No. 14. Washington, DC, The World Bank.

Fang S, Huayong l and Baodong X 2008. Decomposition and nutrient release of four potential mulching materials for poplar plantations on upland sites. *Agroforestry Systems* **74**: 27-35.

Jackson ML 1967. *Soil Chemical Analysis*. Asia Publishing House, New Delhi, India.

Jose S 2009. Agroforestry for ecosystem services and environmental benefits: An overview. *Agroforestry Systems* **76**: 1-10.

Johar V, Dhilion RS, Bangarwa KS and Bhardwaj KK 2017. Effect of eucalyptus based agri-silvi-horticultural system on growth and yield of wheat in North-Western region of Haryana, India. *Department of Forestry, CCS Haryana Agricultural University, Hisar*-125-128, Haryana, India.

Kiran R, Agnihotri AK and Saini BC 2002, Wheat yield as influenced by net radiation availability below *Eucalyptus tereticornis* and *Dalbergia sissoo* canopies. *Indian Journal of Agricultural Research* **36**(1): 68-70.

Kumar A, Kumar M, Nandal DPS and Kaushik N 2013. Performance of wheat and mustard under *Eucalyptus tereticornis* based agri-silviculture system. *Range Management and Agroforestry* **34**(2): 192-195.

Kumar A and Nandal DPS 2004. Performance of winter crops under Eucalyptus based agrisilviculture system. *Indian Journal of Agroforestry* **6**(2): 97-98.

Muthuri CW, Ong CK, Black CR, Ngumi VW and Mati BM 2005. Tree and crop productivity in Greville Alnus and Paulownia-based agroforestry system in semi-arid Kenya. *Forest Ecology and Management* **212**: 23-39.

Nair PKR 1993. *An introduction to agroforestry*. Kluwera Academic Publishers, Dordrecht, the Netherlands. Vol. 1 pp. 499.

Paoli GD, Curran LM and Silk JWF 2008. Soil nutrients affects spatial pattern of aboveground biomass and emergent tree density in southwestern Borneo. *Oecologia* **155**: 287-299.

Piper CS 1966. *Soil and plant analysis*. Inter. Science pub. Inc. New York, 4th edn: 135-200.

Rahangdale CP, Pathak NN and Koshta LD 2014. *Impact of bamboo species on growth and yield attributes of Kharif crops under agroforestry system in wasteland condition of the central India.* Department of Forestry, Jawaharlal Nehru Agriculture University Jabalpur, Madhya Pradesh, India.

Chauhan SK, Sharma R and Dhillon WS 2012. *Status of Intercropping in Poplar Based Agroforestry in India.* Department of Forestry and Natural Resources, Department of Fruit Sciences Punjab Agricultural University, Ludhiana-141 004.

Sharma MK 2012. *Final project report on development, evaluation and dissemination of technologies for improving productivity and production of bamboo and bamboo based cropping system.* Assam Agriculture University. 20p.

Swamy SL, Mishra A and Puri S 2003. Biomass production and root distribution of *Gmelina arborea* under an agrisilviculture system in sub humid tropics of central India. *New Forests* **26**: 167-186.

Yadav RS, Yadav BL Chippa BR Keshwar GL 2005. Nubrant removal and yield wheat (*Triticum aestivum linn*) as influenced by different tree species in agroforestry under semi-arid condition of Rajasthan. *Indian Journal of Agroforestry* **7**: 21-24.

Yadav RS, Yadav BL and Chhippa BR 2008. Litter dynamics and soil properties under different tree species in a semi-arid region of Rajasthan, India. *Agroforestry Systems* **73**: 1-12.

Received 17 March, 2023; Accepted 30 July, 2023