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Effect of Eucalyptus Based Agri-Silvi-Horticultural System on Growth and Yield of Wheat in North-Western Region of Haryana, India

Vishal Johar[*], R.S. Dhillon, K.S. Bangarwa and K.K. Bhardwaj

Department of Forestry, CCS Haryana Agricultural University, Hisar-125 004, Haryana, India
Corresponding author

A B S T R A C T

The study was conducted during 2015-16 at the research farm of CCS Haryana Agricultural University, Hisar, India to assess the effect of three-tier system (Eucalypts-Kinnow-Wheat) on production potential of wheat. The experiment was laid out following split-plot design with three replications. Wheat variety HD-2967 was sown to test its performance under pre-established five years old plantation of Kinnow alone and Kinnow +Eucalypts in comparison to control (devoid of trees). The data revealed that the significantly higher grain and straw yield of wheat (2.79 and 4.15 t/ha respectively,) was observed in case of agri-horti (kinnow + wheat) system as compared to agri-silvi-horti system (1.46 t/ha and 2.26 t/ha respectively) when 20% extra dose of nitrogenous fertilizer was added as compared to the recommended dose. Further, it was also observed that the agroforestry system tremendously affected the soil physical and chemical properties. It was observed that the soil organic carbon and electrical conductivity were significantly affected while there was no effect on soil pH. Similarly, soil nutrient status was also significantly affected show a significant decrease in N and K concentrations after the harvest of the wheat crop.

Introduction

Haryana state with geographical area of 4.42 mha is predominantly an agrarian state having 80 percent of its area under intensive, technical and mechanical agriculture whereas forest occupy only 1586 km^2, which comes out to be about 3.59 percent of total geographical area (Dhyan *et al.,* 2013). In view of the prevailing socioeconomic and agroclimatic conditions favorable for agriculture in the state, it is also not possible to divert the fertile agriculture to forest. The only option to increase area under tree cover is to integrate the tree species with agricultural crop on farm lands. Traditional tree-integrated farming systems are adopted since time immemorial for security of food, fodder and fuel wood in drought-prone arid region (Harsh *et al.,* 1992; Leakey and Simons, 1998; Ndayambaje and Mohren, 2011; FAO, 2013), but are unable to meet the requirement of the ever increasing population. There is a need of intensification of such tree-integrated system too to improve total land productivity as it provides greater carbon offset opportunities than any other climate mitigation practices in agriculture (FAO, 2004; Udawatta and Jose, 2012; Murthy *et al.,* 2013). Agroforestry system is one of the options with multifunctional value among numerous issues involved with livelihood

improvement in dry areas (Gathumbi *et al.,* 2002; Pandey, 2007; Fukushima *et al.,* 2010). The most important benefit of agroforestry systems is the enhancement in total production by improving soil fertility (Stahl *et al.,* 2002; Singh, 2010), mitigation of soil carbon loss by erosion control, replenishment of nutrients removed through biomass harvest (Nair *et al.,* 1999; Ilany *et al.,* 2010), improvement in microbial population (Belsky *et al.,* 1989; Yadav *et al.,* 2008; Vallejo *et al.,* 2012), economic benefits (Gajja *et al.,* 1999; Jianbo, 2006; Fadl and Sheikh, 2010), and nutrient and water-use efficiency (Anderson *et al.,* 2009; Pinho *et al.,* 2011).

Belowground resources are more limiting than the above-ground resources in an arid environment that influences the growth and productivity of tree and crop both (Dalal *et al.,* 2016). Productivity of the arid and semi arid region is about two times less as compared to humid and sub humid region therefore, enhancing income in the low rainfall region can be realized by cultivating different crops with fruit plants and forest trees in agri-silvi-horticultural system (Kumar *et al.,* 2012). However, in most of the regions, people are reluctant to adopt agroforestry because of lesser short term benefits from silvicultural species.

Integrating horticultural species with silvicultural species will ensure income/productivity to the farmers much earlier. Irrigation to the system, where water is available, will provide added income to the farmers. While tree component in agri-silvi-horticultural system maintains higher productivity, enhances economy of the farmers, improves farmers livelihood on sustainable basis and provides carbon sequestration benefits, wheat (*Triticum aestivum*) as staple food grown under irrigation (wherever water is available) could provide additional benefits of improved productivity of all components, i.e. tree, horticultural species and agriculture crop because of irrigation. Keeping in view the vital importance of agroforestry systems in present day context, the present study was planned to find out the effect of shade, multitier interaction and nutritional competition of both annual (Grain crop) and perennial (Kinnow plus Eucalypts) components of agri-silvi-horticultural system on production potential of various wheat varieties.

Materials and Methods

Study sites and climate

The present study was conducted during 2015-16 during winter season at CCS Haryana Agricultural University, Hisar (29°09'N latitude and 75°43'E longitude at an elevation of 215 m above sea level), situated in semi-arid region of North-Western India. The climate is subtropical-monsoonic with an average rainfall of 350-400 mm, 70-80 per cent of which occurs during July to September. The summer months are very hot with maximum temperature ranging from 40 to 45°C in May and June whereas, December and January are the coldest months (lowest January temperature as low as 0°C). The texture class of the soil is 'sandy loam' and the soil of the experiment site is medium in organic carbon, available N, P and K.

A pre-established five year old plantation of Kinnow alone and Kinnow plus Eucalypts was used as the basic agroforestry model in the study. The experiment was laid out in split plot design with three replications.

Tree data and soil analysis

The woody perennials at random were measured for their top height, girth at breast height (GBH) and basal area. The top height

was measured from ground to the top of the tree. The girth at breast height (1.37 m above the ground level) was taken. For soil sampling, surface (0-20 cm) soil was sampled from five different spots from both the agroforestry systems and control. Soil samples were taken before the sowing of the wheat varieties in October and after harvesting of wheat varieties from both the agroforestry system and control for the study of various soil properties like pH, EC, organic carbon and available N, P and K. The samples were air dried, ground in wooden pestle with mortar, passed through a 2mm stainless steel sieve and stored for subsequent analysis. The soil pH and electrical conductivity were determined in soil: distilled water suspension (1:2). The available N in soil was determined by alkaline permanganate method (Subbiah and Asija, 1956), organic carbon by Walkely and Black (1934) method, available P by Olsen (1954) method and available K by neutral normal ammonium acetate method (Jackson, 1973).

Wheat crop varieties

Wheat variety HD-2967 representing early sown variety of north-western India was selected to test its performance under agri-silvi-horticultural system in comparison to control (devoid of trees). Four fertilizer levels i.e. recommended dose of fertilizer [RDF: 150 kg N + 60 kg P_2O_5 + 30 kg K_2O + 25 Kg $ZnSO_4$ per hactare), RDF + 10% additional dose of N, RDF + 20% additional dose of N and RDF + 30% additional dose of N were applied. Sowing of all the above varieties was done in the start of the second fortnight of November following all the package and practices. Observations for plant population, yield and yield attributing parameters such as plant height, number of tillers per plant, ear length, number of grains per ear, 1000-grain weight etc were recorded to assess the performance of variety under agri-silvi-

horticultural system in comparison to control. The yield of the produce (grain and straw) was extrapolated to be expressed in t ha^{-1} by bringing the produce at 14 per cent grain moisture content.

Results and Discussion

Soil chemical properties

Soil organic carbon and electrical conductivity were significantly affected by the perennial component, whereas the pH was non-significant. The electrical conductivity was lowered under both the agroforestry models. It was observed that the electrical conductivity of soil under agri-horticultural system reduced significantly after the harvest of the annual component then it was observed before sowing of wheat crop i.e. 0.28 dδ m^{-1} and 0.32 dδ m^{-1} respectively. Similar trend was also observed under agri-silvi-horticultural system i.e. 0.34 dδ m^{-1} and 0.39 dδ m^{-1} respectively. A small amount of reduction was also observed for soil organic matter that may be due to lower decomposition rate of leaf litter during winter season as compared to the utilization by different components in a agroforestry system as compared to the sole cropping while no significant variation was observed for pH uner both the agroforestry system and sole crop as it takes a slightly longer duration to change soil pH. Similar results were also reported by Gupta and Sharma (2009), Das and Chaturvedi (2005) and Yadav *et al.,* (2008). Corroborative results were reported by Aguiar *et al.,* (2010) with six month study on litter production under Poplar.

Soil nutrient status

Available soil nitrogen (N) and potassium (K), were significantly, whereas available phosphorus (P) was non-significantly influenced by the agroforestry systems as

compared to the soil cropping (devoid of trees). The data in table 1 shows that the status of N under agri-horticultural system, agri-silvi-horticultural system and sole cropping were recorded to be 132 Kg/ha, 110 Kg/ha and 144 Kg/ha respectively, before sowing of the wheat crop which significantly reduced to 120 Kg/ha, 104 Kg/ha and 136 Kg/ha respectively, under all the systems. Similar results were also observed for K which was earlier observed to be 320 Kg/ha, 290 Kg/ha and 325 Kg/ha respectively, significantly reduced to 280 Kg/ha, 256 Kg/ha and 310 Kg/ha after harvest of the wheat 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 liter fall and its decomposition and also due to non-leguminous nature of all the components as a result of which there was no

or a very less amount of atmospheric nitrogen fixation that further affect soil nutrient status. While, there was no significant difference in the concentration of P in soil before sowing and after harvesting of the wheat crop.

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; Hymavathi *et al.,* 2010). The intercropping of trees with crops that are able to biologically fix nitrogen is common in tropical agroforestry systems. Non N-fixing trees can also affects soil physical, chemical and biological properties by adding some amount of organic matter and releasing and recycling of nutrients in agroforestry systems (Paoli *et al.,* 2008; Yadav *et al.,* 2008; Antonio and Gama-Rodrigues, 2011)

Table.1 Soil chemical properties of the experimental field before sowing and after harvest of wheat crop

Treatment	Before Sowing						After Harvest					
	pH (1:2)	EC (dδm⁻¹)	OC (%)	Available Nutrients (Kg ha⁻¹)			pH (1:2)	EC (dδm⁻¹)	OC (%)	Available Nutrients (Kg ha⁻¹)		
				N	P	K				N	P	K
Kinnow + Wheat	7.7	0.32	0.28	132	10	320	7.5	0.28	0.24	120	10	280
Kinnow+Eucalypts+ Wheat	7.7	0.39	0.20	110	8	290	7.7	0.34	0.18	104	8	256
Control	7.6	0.24	0.32	144	10	325	7.6	0.26	0.30	136	10	310
CD (5%)	NS	0.05	0.05	16	NS	24	NS	0.05	0.05	14	NS	20

Table.2 Growth performance of eucalypts and kinnow under silvi -agri-horti system

Treatment	Tree growth of *Eucalyptus tereticornis*						Annual growth increment		
	Initial			At Harvest					
	Height (m)	Basal diameter (cm)	DBH (cm)	Height (m)	Basal diameter (cm)	DBH (cm)	Height (m yr⁻¹)	Basal diameter (cm yr⁻¹)	DBH (cm yr⁻¹)
Eucalyptus (Eucalyps + Kinnow + Wheat)	17.9	21.5	17.1	19.4	27.6	21.6	1.5	6.1	4.5
Kinnow (Eucalyps + Kinnow + Wheat)	2.70	6.94	-	2.81	7.44	-	0.11	0.5	-
Kinnow (Kinnow+ Wheat)	2.80	7.60	-	3.09	8.62	-	0.29	1.02	-
CD (p=0.05)	3.521	6.112	NS	4.341	3.212	NS	0.21	0.45	NS

Table.3 Effect agroforestry models on Plant height (cm) as compared to sole cropping

| Treatment		Plant height (cm)			
		30 DAS	**60 DAS**	**90 DAS**	**120 DAS**
Kinnow+Wheat	RDF	25.0	44.9	84.5	87.2
	RDF +10% additional dose of N	27.4	47.8	88.6	91.2
	RDF +20% additional dose of N	28.1	48.6	90.1	92.2
	RDF +30% additional dose of N	28.6	49.3	90.8	92.6
	Mean	27.3	47.7	88.5	90.8
Kinnow+ Eucalypts+Wheat	RDF	22.4	42.5	81.7	83.1
	RDF +10% additional dose of N	24.2	45.3	84.8	86.2
	RDF +20% additional dose of N	25.0	46.4	85.4	87.0
	RDF +30% additional dose of N	25.3	47.0	86.2	88.1
	Mean	24.2	45.3	84.5	86.1
Control	RDF	29.9	52.2	91.3	93.3
CD at 5%: AFS		1.2	1.5	2.4	2.1
Fertilizer levels		1.4	1.8	2.7	2.8
AFS x FLS		NS	NS	NS	NS

Table.4 Effect agroforestry models on yield attributing parameters of wheat as compared to sole cropping

Treatment		Yield attributes			
		Tillers/m²	**Ear heads/ m²**	**Grains/ear head**	**Test weight (g)**
Kinnow+Wheat	**RDF**	238.0	235.3	44.2	43.8
	RDF +10% additional dose of N	266.0	261.1	48.0	46.7
	RDF +20% additional dose of N	278.7	272.2	48.6	47.0
	RDF +30% additional dose of N	278.0	271.2	48.8	46.9
	Mean	265.2	259.9	47.4	46.1
Kinnow+ Eucalypts+Wheat	**RDF**	228.0	223.0	40.7	39.8
	RDF +10% additional dose of N	244.0	239.0	43.6	43.0
	RDF +20% additional dose of N	248.0	242.0	43.9	43.3
	RDF +30% additional dose of N	249.0	244.0	43.8	43.2
	Mean	242.3	237.0	43.0	42.3
Control	**RDF**	324.5	319.0	49.8	47.2
CD at 5%: AFS		2.1	10.4	1.9	1.8
Fertilizer levels		2.8	14.7	2.7	2.6
AFS x FLS		NS	NS	NS	NS

Table.5 Effect agroforestry models on yield of wheat as compared to sole cropping

Treatment		Yield (t/ha)	
		Grain	**Straw**
Kinnow+Wheat	**RDF**	2.50	3.88
	RDF +10% additional dose of N	2.80	4.15
	RDF +20% additional dose of N	2.94	4.31
	RDF +30% additional dose of N	2.90	4.25
	Mean	2.79	4.15
Kinnow+ Eucalypts+Wheat	**RDF**	1.31	2.09
	RDF +10% additional dose of N	1.47	2.29
	RDF +20% additional dose of N	1.54	2.33
	RDF +30% additional dose of N	1.53	2.32
	Mean	1.46	2.26
Control	**RDF**	4.70	6.80
CD at 5%: AFS		0.10	0.16
Fertilizer levels		0.15	NS
AFS x FLS		NS	NS

Fig.1 Effect agroforestry models on Plant population (per m^2) as compared to sole cropping
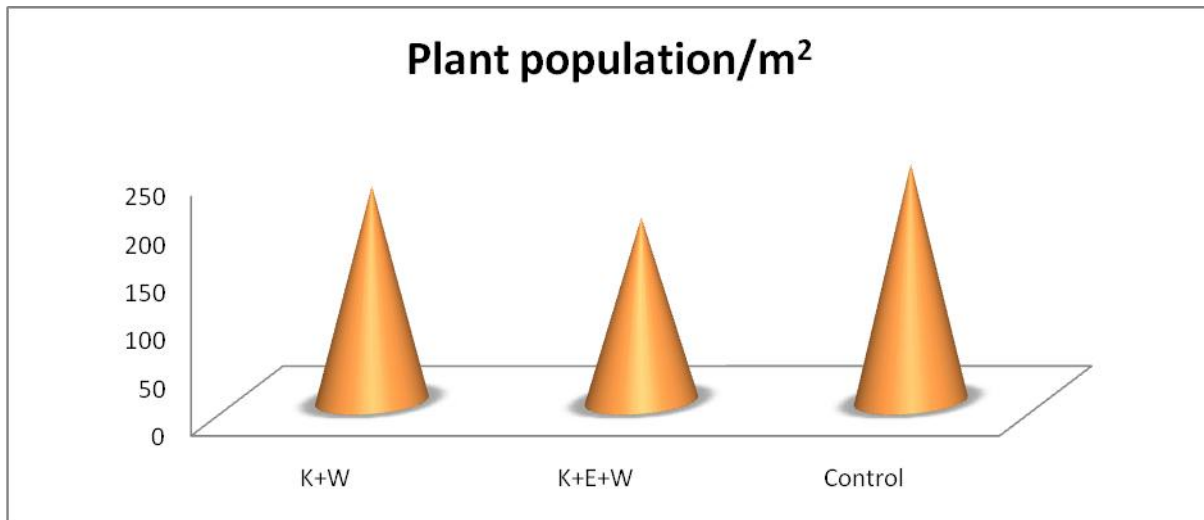
Growth performance of perennials

The overall growth pattern of eucalypts and kinnow under different agroforestry model generally followed increasing trend with the advancement of age. All the growth parameters after completing 5 years of agroforestry plantation are presented in (Table 2). The average initial tree height and basal diameter of *Eucalyptus tereticornis* under agri-silvi-horticultural system was 17.9 m and 17.1 cm respectively, while, the height and basal diameter of Kinnow was 2.70 m and 6.97 cm respectively in combination with Eucalypts whereas it showed 2.80 m height and 7.60 cm basal diameter in absence of trees. The annual increment in tree height and basal diameter was 1.5 m and 6.1 cm respectively. The annual increment in Kinnow was 0.11 m and 0.5 cm respectively with

Eucalypts and while 0.29 m and 1.02 cm in absence of Eucalypts. The results shows a significant variation among the growth patterns of kinnow and Eucalypts which proves that when a crop is grown in association with trees, there is a competition for light, moisture, nutrients and a positive or negative interaction might be expected to develop between them. These results are also in close conformity with the findings of Kumar *et al.,* (2013). Similar trends in growth of various trees under different agroforestry system have also been reported by Banerjee and Dhara (2011).

Influence on growth parameters of wheat

The significant variation in plant population was recorded among different agroforestry systems and control (Fig. 1). However, variation for plant population/m^2 was non-significant between agri-horti (kinnow+ wheat) and agri-silvi-horti (kinnow+ eucalypts + wheat) systems. The highest numbers of plants per square meter (248) were in control (non-agroforestry) followed by kinnow (225) based agroforestry system while the minimum population (192/m^2) of wheat was observed in Kinnow + eucalypts based agroforestry system. Kiran *et al.,* (2002) also revealed that plant population of wheat crop reduced upto 34 to 54 percent respectively, under *Eucalyptus tereicornis and Dalbergia sissoo* based agroforestry system. Similarly, plant height at 30, 60, 90 and 120 days after sowing (DAS) of wheat showed significant variation with varying levels of fertilizer under different agroforestry systems (Table 3). Significantly higher plant height was in agri-horti (kinnow + wheat) system as compared to agri-silvi-horti (kinnow + eucalypts + wheat) system. In agri-horti (kinnow + wheat) and agri-silvi-horti (kinnow + eucalypts + wheat) system, RDF + additional dose of N (10, 20 and 30%) significantly increased the plant height over

recommended dose of fertilizer at different time intervals of growth in wheat. Prasad *et al.,* (2010) predicted a loss of 45 percent for various yield attributing characters of cowpea under *Eucalyptus tereticornis* based agroforestry system as compared to sole cropping in southern India. However, the differences between RDF + 10% additional dose of N, RDF + 20% additional dose of N and RDF + 30% additional dose of N were non-significant.

Yield and its attributes

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 crop with recommended doses of fertilizer. The number of tillers (m^{-2}) under both the agroforestry system (265.2 m^{-2}, 242.3 m^{-2}) were much less as compared to the sole crop (324.5m^{-2}). Similar results were also obtained for other yield attributing parameters (Table 3).

Recommended dose of fertilizer + additional dose of N (10, 20 and 30%) significantly increased the yield attributing parameters over recommended dose of fertilizer in both agri-horti (kinnow + wheat) and agri-silvi-horti (kinnow + eucalypts + wheat) system.

However, the differences between RDF + 10% additional dose of N, RDF + 20% additional dose of N and RDF + 30% additional dose of N were found to be non-significant. Similarly, Lott *et al.,* (2009) recorded a poor growth maize crop under *Grevillea robusta* based agroforestry system in semi-arid Kenya. A net reduction of 25 percent in different parameters of maize was observed under the agroforestry system as compared to the sole crop due to 30-35% reduction in light intensity under agroforestry system as compared to the sole cropping.

The significantly higher grain and straw yield of wheat (2.79 and 4.15 t/ha respectively,) was observed in case of agri-horti (kinnow + wheat) system as compared to agri-silvi-horti system (1.46 t/ha and 2.26 t/ha respectively) (Table 4). An increase of 83.6 and 91.0 per cent in straw and grain yield, respectively of wheat was recorded under kinnow plus wheat system as compared to kinnow plus eucalypts based agroforestry system. However, the grain yield of wheat under agroforestry was less as compared to sole crop with recommended doses of fertilizer. However, recommended dose of fertilizer + additional dose of N (10, 20 and 30%) significantly increased the grain yield over recommended dose of fertilizer under both the agroforestry systems while varying fertilizer levels did not influence straw yield of wheat under both the agroforestry systems (Table 5). The results revealed that an average grain yield reduction under Kinnow + Eucalypts and Kinnow alone was 68.9 and 40 per cent, respectively as compared to sole crop may due to competition of light among the annuals and perennials. Similarly, Rana *et al.,* (2007) and Verma and Rana (2014) also witnessed a yield reduction in paddy and wheat (14.9 and 29.7 percent respectively) under agroforestry system as compared to the sole cropping.

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