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Effect of wind breakers using eucalyptus on cultivation of kinnow mandarin

Sanjeev K. Chauhan*, W.S. Dhillon, N. Gupta[1], Pankaj Panwar[2] and Rajni[3]

Department of Forest and Natural Resources, Punjab Agricultural University, Ludhiana - 141 004, India.

ABSTRACT

Windbreaks are established around farms to reduce the adverse effects of hot and cold winds. However, in Punjab, the objective of raising eucalyptus in the boundary is to get additional income. Boundary plantation of eucalyptus trees negatively affects fruit crops through competition for light, moisture, nutrients, etc. The experiment was conducted to quantify the effect of eucalyptus boundary plantation on mandarin orange. The effect on tree growth, fruit yield and juice quality differed in all four directions and at different distances from the boundary plantation. Mandarin growth was not affected adversely, but the fruit yield was considerably affected in the south and west direction of the boundary. The fruit yield reduction was 45.69, 64.1, 61.2 and 56.86 % in the south, east, north and west direction in the sixth year of plantation, respectively. TSS was more to the eucalyptus boundary plantation and reduced progressively with distance. Eucalyptus trees captured significant carbon, which can be sequestered long-term through its variable end uses.

Keywords: Boundary planting, Citrus, Eucalyptus, Fruit yield and quality, Horti-silvicultural system

INTRODUCTION

Horticulture based agroforestry systems are possible multifunctional solution for global food/ nutritional security, environmental protection and climatic change adaptation Colmenares *et al*., (4).

Temperature goes above 40°C in summer and touches as low as 0 - 1°C for few days in January months in arid and semi arid areas of India. Many fruit crops do not tolerate to such extreme climatic conditions. Strong winds have been reported to cause 70 to 100 % of crop loss, particularly in sugar cane, bananas, vegetables and fruit trees Singh *et al*., (14). In such a situation, it is advocated that wind breaks/trees should be grown surrounding orchards. Such systems have been reported to modify temperature variation in the orchard and gives better fruit yield, Dhillon *et al.,* (5). Wind breaks/ trees around orchard also protect the soil effectively against wind erosion particularly when soil is devoid of vegetation cover. Other benefits include creation of favourable microclimate, reduction of wind pressure. Altieri and Nicholls (1) reported soil loss of 0.38 cm in crop protected by a *Gliricidia sepium* and *Paspalum conjugatum* barrier, as compared to 4.20 cm soil loss for an unprotected crop. On-farm timber trees also benefit farmers from the global environmental facilities like carbon trading and mitigation of changing climate Dogra (9). These boundary plantations of tall trees however, has complex interactions among the components for light, space, water, nutrients, *etc*. which have positive or negative interactions ecologically and economically.

Horti-silvicultural system besides production also plays an active role of protection of the environment through carbon sequestration to mitigate ongoing climate change. The most suitable climate smart tree-tree combination with minimum competition for resources and maximizing synergies is appropriate for adoption. Dhillon *et al*. (7) have reviewed the little resources available on the issue and stressed for assessing location specific long-term ecological and economic interactions in the system. The present study was thus conducted to evaluate see the effect of *Eucalyptus* trees as boundary plantation along Kinnow mandarins plantation in horti-silviculture agroforestry system.

MATERIALS AND METHODS

A field experiment was laid for two years on the farmer's field in village Chauni Kalan in Hoshiarpur District of Punjab, India. The experimental site is situated at 31˚48'N and 75˚ 94'E at 296 m above the mean sea level. The climate is sub-tropical with hot and dry summers during April to June, hot and humid during July to September and cold winter during December to February. The average annual rainfall is 990 mm and majority is received during monsoon season (July - October). The experimental

*Corresponding author: chauhanpau@rediffmail.com

[1]Department of Soil Science, PAU, Ludhiana - 141 004, Punjab, India

[2]ICAR - IISWRC, Chandigarh-160019, Punjab, India.

[3]Department of Botany,PAU,Ludhiana - 141 004, Punjab, India.

soil was loam (0-15 cm), sandy loam (15-30 cm) and loamy sand (30-60 cm) in texture. The soil was slightly alkaline and low in organic carbon (OC) (0.31 %), low in alkaline $KMnO_4$-extractable N, medium in 0.5N $NaHCO_3$-extractable P and medium in NH_4Oac-extractable K.

The citrus + eucalyptus plantation was raised in approximately 3.5 acre area and assessment was carried out for two years at the farmers field with trees of "Kinnow" mandarin orange in block bordering eucalyptus. The age of Eucalyptus and kinnow were same (5 and 6 years) during study period of two years. Kinnow mandarin was spaced at 6 × 4.5m and eucalyptus seedlings at 2.0 m along border. All other recommended practices of Punjab Agricultural University, Ludhiana, India were followed for the management of trees. Plants were irrigated through flooding in the channels and well managed against weeds and insect/pests. Eucalyptus was occasionally irrigated with no other management practices.

The collar diameters of trees were measured at 15 cm above ground surface on both the years of observation through caliper. The height and crown spread was measured through measuring tape. The "Kinnow" crop was harvested in the month of January for recording data. Randomly five trees per replication in different rows in different directions were completely harvested. Data on tree parameters were recorded in the month of January itself for tree height, diameter, spread, *etc*. Fruit parameters for quantity (size, weight, *etc.*) and quality (juice, rag, peel, rag, TSS) were randomly recorded from harvested fruits during both the years.

Allometric equations were used (that relate the tree's height and diameter to its biomass) for above and below-ground woody stocks estimation without harvesting the trees. *Eucalyptus* tree biomass was estimated as per the standard regression to calculate the biomass and carbon storage. The total carbon storage was arrived at by using the average carbon values and multiplying it with biomass of trees obtained through the standard regression equations.

Soil samples were collected through standard procedure. Soil samples were air dried and passed through a 2-mm sieve. Soil chemical analysis was done following Jackson (11). A combined glass–calomel electrode was used to measure pH of aqueous suspensions (1:2.5 soil/solution ratio). Electrical conductivity (EC; dS m^{-1}) was measured in the supernatant liquid of soil/water suspension (1:2) with 110 conductivity bridge. Soil organic carbon (OC) was arrived at by using wet-digestion method. Available nitrogen (N) was estimated by alkaline permanganate method. Available phosphorus (P) was estimated by Olsen method. Exchangeable cation potassium (K), was extracted with 1 M ammonium acetate (NH4OAc) (pH 7.0) and its content was determined by flame photometer. The soil status of the site is given in table 1.

The replicated data on growth, yield and fruit quality in eucalyptus- citrus based horti-silvicultural model were analyzed following Gomez and Gomez (10). Significant differences between treatment means were tested at $p \leq 0.05$ level of significance using least significant difference test.

RESULTS AND DISCUSSION

The growth performance of kinnow with *Eucalyptus* as boundary plantation is given in table 2. The average collar diameter, height and crown spread were higher in trees facing north direction and lowest in trees facing East direction during both the years. Collar diameter ranged from 9.5 to 11.38 cm. In the 6^{th} year, the collar diameter did not show any statistical differences for orientation of boundary plantation. Height of trees varied from 2.77 to 3.24 m. The height had no statistical difference in 5^{th} year but showed significant variation in 6^{th} year of trees with minimum height of 2.89 m in south direction and maximum height of 3.24 m in west direction. Crown spread had significant variation during both the years of study. The spread varied from 2.97 m to 3.25 m. Competition for water and nutrients and effect of shade may primarily be responsible for reduction in mandarin tree growth at tree crop inter-phase, thus values increased with distance from the boundary of eucalyptus trees.

With increasing distance from Eucalyptus boundary plantation, collar diameter and height showed significant differences during 5^{th} year only but had no significant effect during 6th year. The collar diameter in 6^{th} year varied from 10.67 to 11.71 cm and height varied from 3.02 to 3.17 m. Crown spread had significant difference for distance from boundary plantations during both the year. The crown spread varied from 2.70 to 3.01 m in 5^{th} year and 2.90 to 3.28 in 6^{th} year. In both the years, values were higher in control plants.

Various fruit quality parameters as affected by direction and distance from Eucalyptus boundary plantation (Table 3). Fruit yield varied significantly with direction and distance from the boundary plantations during both the years. On an average, fruit yield was higher in north direction (63.45 kg $tree^{-1}$) and least in south direction (48.79 kg $tree^{-1}$) of boundary. Average quantity of juice varied from 45.39 to 48.22 per cent and was higher in west direction. Average values for other fruit quality parameters varied from 28.63 to 31.93 for fruit peel being higher

Table 1. Soil chemical properties of orchard.

	pH	EC	N	P	K	OC
Soil Depth						
0 - 15	7.82	0.0973	0.0145	24.59	33.6	0.1825
15 - 30	8.03	0.0953	0.0113	17.9	39.2	0.1327
30 - 60	8.21	0.094	0.0088	13.46	56	0.1162
CD	0.042	NS	0.001	0.754	0.0079	0.0026

Table 2. Biomass and Carbon estimation (kg tree^{-1}) of *Eucalyptus* boundary plantation.

Direction	Total biomass		Timber biomass		Carbon sequestered in timber		Carbon used by timber	
	5th year	6th Year	5th year	6th Year	5th year	6th Year	5th year	6th Year
West	166.69	219.33	110.59	152.40	51.85	71.45	190.29	262.22
East	147.01	183.51	97.67	128.41	45.79	60.20	168.05	220.93
North	188.18	254.70	120.09	172.97	56.30	81.09	206.62	297.60
South	137.78	187.86	91.43	131.65	42.86	61.72	157.29	226.51
Average	159.91	211.35	104.94	146.36	49.20	68.61	180.56	251.81

in north, 23.35 to 24.38 for fruit rag being higher in south direction and 8.55 to 9.05 for TSS being higher in South direction (Table 4).

Effect of direction on fruit yield and quality varied significantly. It was found that average fruit yield, fruit peel, fruit rag and TSS were higher in fruits obtained from control and these parameters were lowest at a distance of 6-7 m distance from the eucalyptus boundary plantation. Fruit yield was 2.9 times higher in control as compared to yield obtained at 6-7 m distance from eucalyptus trees. Fruit juice showed the reverse trend as compared to other quality parameter of kinnow. The average juice content was higher 23.65 at 6-7 m distance from eucalyptus boundary plantation and it decreased as the distance increased. In control, the juice content was least (40.97). Under silimar conditions, Saroj *et al*. (13) reported that yield of intercrops was reduced more under the tree canopy than away from the tree canopy. At Hissar, India, crop yields reduced by 41% up to 10 m away when 3.5 year old *Eucalyptus tereticornis* was raised on field boundaries (Malik and Sharma, 12). Bangarwa and Wuehlich (2) have concluded that short rotation timber trees like poplar and eucalyptus on boundary substantially makeup for the crop loss, this encourages farmers to adopt this low risk asset during the orchard establishment stage. Colmenares *et al.* (4) have also recommended horti silviculture systems involving poplar, eucalyptus and other timber species with fruit crops like mango, citrus, *etc*. The situation of sustainability in agricultural under changing climate also warrants diversification in traditional crops for better adaptability (Dhillon *et al*., 8).

Growth parameters of Eucalyptus trees planted on boundary of kinnow orchard is given in fig. 1. The diameter at breast height (DBH) varied from 19.34 to 23.07 cm. DBH did not showed statistical difference for directions in which they were planted during both the years. The height of the trees varied from 15.35 to 20.38 m at 5th year and 16.18 to 21.24 m at 6th year of age showing statistical variation during both the

Table 3. Effect of boundary plantation of Eucalyptus on growth of Kinnow plants.

	Collar diameter (cm)		Height (m)		Crown spread (m)	
	5th year	6th year	5th year	6th year	5th year	6th year
			Direction			
South	9.68	11.38	2.85	2.89	3.04	2.97
East	9.50	11.17	2.77	3.09	2.74	2.99
North	10.18	11.24	2.91	3.21	3.06	3.25
West	9.58	11.12	2.87	3.24	2.86	3.12
Control	9.76	11.71	2.85	3.02	3.00	3.28
CD	0.37	NS	NS	0.163	0.15	0.145
			Distance			
6-7 m	9.16	10.67	2.70	3.11	2.70	2.90
11 -12 m	9.91	11.26	2.91	3.13	2.98	3.00
16 -17 m	10.11	11.27	2.95	3.17	3.01	3.16
Control	9.76	11.71	2.85	3.02	3.00	3.28
CD (5%)	0.37	NS	0.16	NS	0.15	0.145

Table 4. Effect of direction and distance from boundary plantation on fruit yield and quality of kinnow.

	Fruit yield (kg $tree^{-1}$)		Juice %		Fruit peel		Fruit rag		TSS	
	5th year	6th year	5th year	6th year	5th year	6th year	5th year	6th year	5th year	6th year
					Direction					
South	48.29	49.3	47.16	46.73	28.32	29	24.51	24.26	9.02	9.09
East	65.66	69.17	45.39	45.4	31.49	29.89	23.11	24.73	9.36	7.75
North	60.82	66.09	48.24	42.92	32.18	31.68	19.57	25.41	8.63	7.53
West	46.46	61.36	49.71	46.74	28.59	28.68	21.68	25.02	9.07	8.03
Control	84.05	107.9	43.21	38.73	34.07	32.78	22.71	28.51	9.3	9.37
CD (5%)	8.51	1.165	NS	2.03	1.68	NS	2.92	NS	0.49	1.165
					Distance					
6-7 m	38.36	39.91	51.35	49.97	27.2	27.44	21.44	22.66	9.05	7.24
11-12 m	48.31	43.29	48.48	46.88	28.69	29.02	21.9	24	8.78	7.71
16-17 m	50.50	55.81	47.46	46.22	30.63	30.01	22.82	24.24	8.94	8.08
Control	84.05	107.9	43.21	38.73	34.07	32.78	22.71	28.51	9.3	9.37
CD (5%)	8.51	1.165	3.1	2.03	1.68	2.589	NS	2.298	NS	1.165

years. The height was more in trees oriented in north direction. Clear bole also showed significant statistical differences for both the years. At 5th year of plantation clear bole varied from 2.56 to 3.76 m and at 6th year it varied from 2.61 to 3.90 m. Maximum clear bole was also more in trees oriented in north direction. Such directional variation in tree height was also recorded by Chauhan *et al.* (3) in poplar but differences in DBH and crown spread was negligible.

Above ground biomass and carbon stored in boundary plantation of eucalyptus presented in table 1, reflects average biomass of trees at 5th and 6th year of age *i.e.*, 159.91 and 211.35 kg $tree^{-1}$, respectively. Utilizable timber biomass from the boundary plantation was 104.94 and 146.36 kg $tree^{-1}$. Carbon sequestration by timber biomass was 49.20

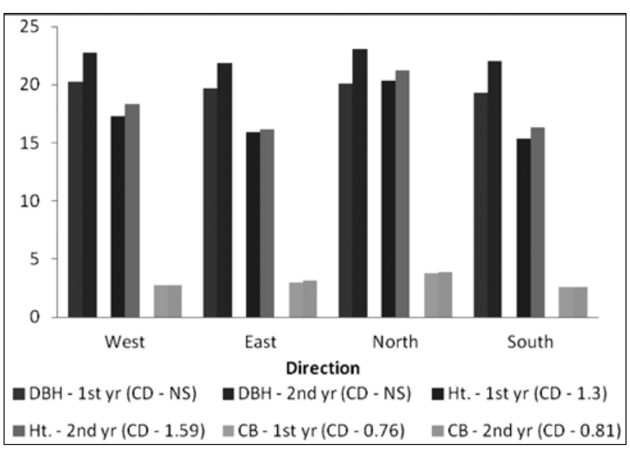

Fig. 1. Growth of Eucalyptus tree planted on boundary.

and 68.61 kg $tree^{-1}$ in 5th and 6th year of plantation. The increase in carbon sequestration through timber biomass in 6th year was 39.45 per cent higher over 5th year, which reflects the un-noticeable additional ecological benefit of the system, which otherwise is not accounted. Loss incurred due to yield reduction of fruit through the boundary plantation is compensated by the eucalyptus tree timber. Since the farmers are mainly concerned with fruit yield therefore, eucalyptus trees can be harvested as soon the orchard stars commercial bearing (5th or 6th year).

Usually farmers are discouraged to plant eucalyptus because of its presumed negative environmental impact due to its' aggressive extraction of water resource/nutrients and allelopathic property. Rather Eucalyptus boundary plantation creates optimum conditions for the farmers in economic terms when crop is at its establishment phase to compensate for high initial input costs. Eucalyptus has been reported to be best in terms of its water use efficiency than other agricultural crops and forest trees and creating favourable microclimate. Realizing negative impact on the crop than control, farmers can take only one rotation of eucalyptus for additional economic advantage. Dhillon *et al.* (6) also reported significant differences how growers can be benefitted by using boundary plantations along the fruit orchard. Otherwise also in the changing climatic conditions, adaptation strategies in terms of diversification in traditional systems of cultivation are required for ecological security and economic sustainability. Fruit based agroforestry systems accord such alternative for adaptation.

It is concluded that a Eucalyptus trees of five to six year of age with a height of about 23 m planted on boundary significantly affect the fruit production of "Kinnow" citrus mandarin up to a distance of 16–17 m as the production is about 50 per cent less than the control. Citrus trees near north orientated eucalyptus had higher fruit yield. The quality of fruits, however did not had much impact. TSS in fruits decreased with increasing distance. But the economic and ecological benefits of boundary plantations are enormous, which would compensate for the little loss in fruit yield.

AUTHORS' CONTRIBUTION

Conceptualization of research (SKC, WSD, NG); Designing of the experiments (SKC, WSD, NG); Contribution of experimental materials (SKC, WSD, NG); Execution of field/lab experiments and data collection (SKC, WSD, NG); Analysis of data and interpretation (SKC, WSD, PP, RS); Preparation of the manuscript (SKC, PP, RS).

DECLARATION

Authors do not have any conflict of interest.

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