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Long term effect of root management practices on rooting pattern in *Dalbergia sissoo* and grain yield of mustard under agrisilviculture system

Ram Newaj, S. K. Dhyani, Badre Alam, Ajit, Rajendra Prasad, A. K. Handa, Upendra Kumar and Shikha Neekher
National Research Centre for Agroforestry, Gwalior Road, Jhansi-284003, Uttar Pradesh, India
Corresponding author e-mail: ramnewaj@rediffmail.com
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Abstract

Root management is a potential tool for minimizing competition between tree and crops grown together in agroforestry systems. To investigate the long term effect of deep /shallow ploughing on root density of trees and their impact on crop yield, a field study was carried out at NRCAF Jhansi during 2003-04 to 2008-09 with root management practices *i.e.*, deep ploughing and shallow ploughing. Mustard *(Brassica Juncia L. Czernj. & Coss.)* was taken as intercrop. Deep ploughing significantly had lower root length density (RLD) over shallow ploughing (0.165 cm root length cm^{-3} cm soil volume) at 0-15 cm soil depth but at 15-30 cm soil depth differences were not significant. Root length density was significantly higher at 0.5 m away from tree base as compared to 1.0, 2.0 and 3.0 m away from tree base but difference in RLD between 3.0 m and 4.0 m away from tree base was not significant. Root length density decreased with increasing distances from tree base under deep and shallow ploughing at 0-15 and 15-30 cm soil depth. Deep ploughing had significantly higher mustard yield (102.23 g m^{-2}) than shallow ploughing (84.02 g m^{-2}) and on per hectare basis, the deep ploughing gave 28% higher grain yield of mustard than shallow ploughing. The competition between tree and crop was higher at vicinity of tree and it decreased with increasing distances from tree base. Linear regression equations fitted between grain yield and distances from tree base indicated that average crop yield was 21.46 g m^{-2} at 0.5 m from tree base which would increase by 57.15 gm^2 for each meter increase of distance from tree base up to 4 meters distance under deep ploughing. Similar pattern was also found in shallow ploughing but the yield was 16.0 g m^{-2} at 0.5 m from tree base and increment in yield with per unit distance was 50.40g m^{-2} up to 4 meter.

Key words: Agroforestry, Deep ploughing, Regression equation, Root length density, Shallow ploughing

Abbreviations: dbh: Diameter at breast height, **DP:** Deep ploughing, **RLD:** Root length density, **SP**: Shallow ploughing

Introduction

Agroforestry system can be more productive provided that trees and crops are at least partly complementary in use of growth resources (above and belowground). Tree and shrub are known to use their extensive root system to absorb nutrients from lower soil horizons. It is a general apprehension of the farmers that trees in association with crops in agroforestry system compete strongly with crops for nutrients and moisture (Dhyani *et al.,* 1990). The effective root system of woody perennials tends to be deeper than non-woody perennials. Thus the knowledge of the root distribution of trees is essential to understand the ecological niche of a tree species to design agroforestry system and its management to optimize the productivity of trees and crops in various agroforestry systems (Tufekcioglu *et al.,* 1999; Toky *et al.,* 1989).The tree roots remain active in subsoil and may serve as safety net for nutrient leaching. Deep ploughing up to 20 cm soil layer destroys fine roots which lower the concentration of roots on upper soil surface before sowing of crops thereby protecting the crops for some time from tree root competition.

Dalbergia sissoo (shisham) is one of the most important timber species of India and is widely distributed on riverain beds in sub-Himalayan tract from Indus to Assam and Himalayan valleys. It can be grown successfully on field bunds in combination with a variety of crops. The aim of this study was to find out the effect of ploughing on spatial distribution of roots and their impact on yield of intercrop grown in agrisilviculture system.

Materials and Methods

A field experiment was initiated during 2003-04 to 2008-09 at National Research Centre for Agroforestry, Jhansi (U.P.), India. The soil of experiment site had pH 7.2, organic carbon 0.46 %, available nitrogen 210.80 kg ha^{-1}, available phosphorus 14.6 kg $ha^{-1}$and available potassium 280 kg ha^{-1}at 0-15 cm soil layer. The study consisted of two management practices *viz.* deep ploughing (with disk plough or mould board plough) and shallow ploughing (with cultivator). The present study was conducted in 9-years old plantation of shisham (*Dalbergia sissoo* Roxb.), planted during 1994 at 8x4m spacing with recommended planting technique. Whole field was divided in two blocks and each block had 40 trees. Mustard (*Brassica Juncia* L. *Czernj.* & *Coss.*) was taken as intercrop with recommended cultural practices. The tree was commonly pruned up to 70% height in both the blocks during October every year, before sowing of mustard. The tree height was measured every year during October by Ravi Altimeter (M/S Ravi Vaigyanik Yantra Nirmata, Dehradun, India) and diameter at breast height (dbh) was recorded with measuring tape at 1.37 m height. Grain yield of mustard was recorded by quadrate method on both the side of tree line at 0.5, 1.0, 2.0, 3.0 and 4.0 m from tree base in both the blocks every year. The whole block was harvested to generate grain yield of mustard. The observations were replicated six times in both the blocks. In this way, data was generated from two blocks at five distances from tree base with six replications. The pooled analysis of data was done through SAS V9.2 using proc GLM procedure and the graphs have been prepared using MS Excel-2010.

Root sampling was carried out with core sampler (11 cm diameter and 15 cm length) in October during every year after rainy season at 0-15 cm and 15-30 cm soil depth. The core samples were taken at both the sides of tree at five distances (0.5, 1.0, 2.0, 3.0 and 4.0m) from tree base. Before coring, four trees were marked from each block on the basis of having a mean tree height, dbh and canopy close to the average of all trees coming under each block. After coring, core sample was placed in a labeled plastic bucket and soaked with water for one night. After soaking, the soil was removed carefully from the core and washed with clean water. After complete washing, the root was filtered with 0.87mm sieve and only fine roots (diameter <2.0 mm) were sorted out from water and placed on soaking paper to minimize water content. The total root length was measured by using root image analysis software (Sky Root SI725, Sky Instrument Ltd. U.K.) and samples were kept in oven for drying at 70^0 C up to one hour. The root weight was recorded and root length density (RLD) was calculated using the method described by Friend (1991).

Results and discussion

***Effect of ploughing on tree growth*:** Tree growth was recorded every year during October and the data at end of experiment (15-years age) revealed that deep ploughing reduced the height and dbh of tree by 5.52% and 2.58 % respectively over shallow ploughing after 15-years of tree plantation (Table 1). It indicated that root pruning through deep ploughing (disk plough) had little effect on tree growth (height and dbh growth). Similar observation was also recorded by Wajja-Musukwe *et al.* (2008) in which they observed that root pruning had only little effect on aboveground tree growth; height growth was unaffected and diameter growth was reduced by 4% in *Casuarina equisetifolia* and *Grevillea robusta*.

Table 1. Effect of ploughing on tree growth at 15-years age

Ploughing	Height (m)	DBH (cm)
Deep ploughing (disk plough)	16.30±3.05	23.20±3.43
Shallow ploughing (cultivator)	15.40±1.24	22.60±2.89

Effect of ploughing on grain yield of crop: Grain yield of mustard was significantly higher in deep ploughing (66.56 to 145.73 g m^{-2}) as compared to shallow ploughing (56.64 to 115.22 g m $^{-2}$) at different distances from tree base. In general, the grain yield was significantly less at adjacent the tree and it increased with increasing distances from tree base. The deep ploughing gave 28% higher grain yield of mustard as compared to shallow ploughing (Table 2). Linear regression equations were fitted taking grain yield as dependent variable and distance from tree as independent variable. For deep ploughing, on an average crop yield was 21.46 g m^{-2} at 0.5 m distances from tree base and it would increase by 57.15 g m^{-2} for each meter increase in distance from tree base up to a distance of 4 meters. Whereas for shallow ploughing the crop yield was 16.00 g m^{-2} at 0.5 m from tree base and it would increase by 50.40 g m^{-2} for each meter increase in distance from tree base up to a distance of 4 meter (Fig. 1, Table 4). Crop yield data provided strong evidence of the reducing competition following root pruning through deep ploughing and competition increasing with shallow pruning. This clearly indicates that deep ploughing is beneficial for increasing the yield of intercrops in agrisilviculture systems. Wajja-Musukwe *et al.* (2008) also reported that root pruning reduced the competition between tree and crop and increased the yield of crop. They also suggested that root pruning on both sides of tree is useful but in some circumstances one-sided root pruning will also be useful. Siriri *et al.* (2010) also suggested that shoot pruning initially sustained crop performance but shoot pruning + root pruning became necessary when tree age exceeded 2-years.

Table 2: Grain yield of mustard (g m^{-2}) under different ploughing at various distances from tree base (pooled mean of 6-years)

Distances from tree base (m)	DP	SP	Mean
0.5	66.56	56.64	61.60
1.0	81.91	68.26	75.09
2.0	99.55	83.93	91.74
3.0	117.40	96.03	106.72
4.0	145.73	115.22	130.48
Mean	102.23(516.38)	84.02(404.07)	93.12
LSD (P=0.05)	Ploughing		4.32
	Distance		9.62
	Ploughing x distance		2.06

Note: Figures in parentheses are grain yield kg ha^{-1} **DP:** Deep Ploughing; **SP:** Shallow ploughing

Table 3: Root length density (cm root length cm^{-3} soil volume) at various distances from tree base (pooled mean of 6-years)

Distance from	0-15 cm soil depth			15-30 cm soil depth		
tree base (m)	DP	SP	Mean	DP	SP	Mean
0.5	0.193	0.218	0.206	0.242	0.251	0.247
1.0	0.161	0.197	0.179	0.212	0.231	0.222
2.0	0.140	0.157	0.149	0.185	0.193	0.189
3.0	0.118	0.141	0.130	0.156	0.171	0.164
4.0	0.092	0.114	0.103	0.125	0.143	0.134
Mean	0.141	0.165		0.184	0.198	
LSD (P=0.05)		Ploughing	0.012		NS	
		Distance	0.028		0.031	
		Ploughing x distance	NS		NS	

DP: Deep Ploughing; **SP:** Shallow ploughing

Figure 1: Relationship between grain yield and distances from tree base under deep and shallow ploughing

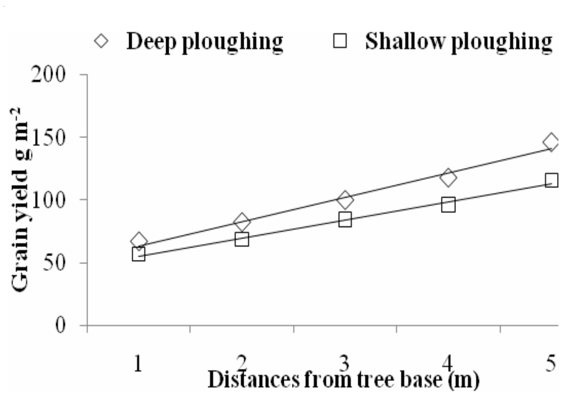

Fig 2. Relationship between RLD and distances from tree base under deep and shallow ploughing at 0-15cm (A) and at 15-30 cm (B) soil depth

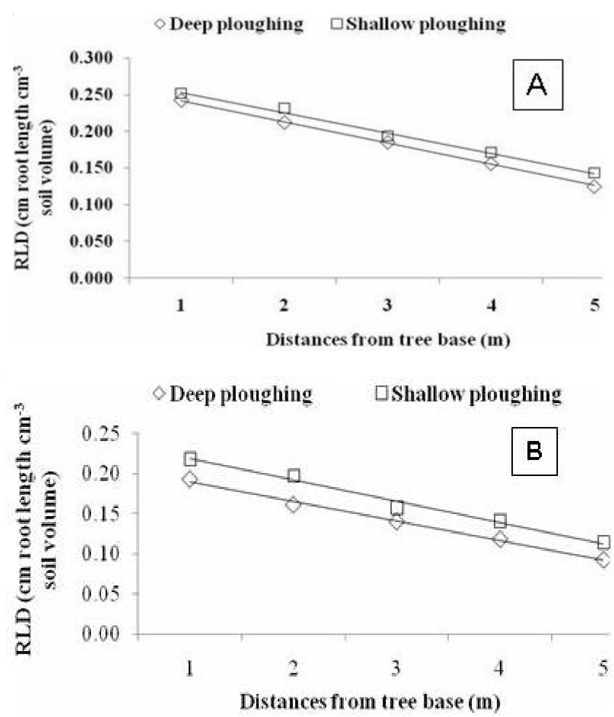

Table 4: Assessing the effect of management practices by fitting linear regression of variable of interest (grain yield or root length density) on distance from tree base

Root management practices	Dependent variable Y	Independent variable X (0.5- 4 m)	Linear regression Y=a+x		
			a	b	R^2
DP	RLD (0-15 cm soil depth)	Distance	-0.026	0.196	0.97
	RLD (15-30 cm soil depth)	Distance	-0.031	0.250	0.98
SP	RLD (0-15 cm soil depth	Distance	-0.029	0.226	0.97
	RLD (15-30 cm soil depth)	Distance	0.030	0.261	0.98
DP	Grain yield (g m^{-2})	Distance	21.46	57.15	0.99
SP		Distance	16.00	50.40	0.99

DP: Deep Ploughing, **RLD:** Root length density, **SP:** Shallow ploughing

***Effect of ploughing on root length density (RLD)*: **Deep ploughing significantly had lower (0.141 cm root length cm^{-3} cm soil volume) RLD over shallow ploughing (0.165 cm root length cm^{-3} cm soil volume) at 0-15 cm soil depth but at 15-30 cm soil depth, differences were not significant. Root length density was significantly higher at 0.5 m away from tree base compared to 1.0, 2.0 and 3.0 m away from tree base but difference in RLD between 3.0 m and 4.0 m away from tree base was not significant (Table 3). Root length density decreased linearly with increasing distances from tree base under deep and shallow ploughing at 0-15 and 15-30 cm soil depth (Table 4 and Fig. 2).

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