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Evaluation of soil micronutrients under different spacing of *Eucalyptus*-based agroforestry system

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ABSTRACT

A study was carried out during 2016–17 at Research Farm of the Department of Forestry, CCS Haryana Agricultural University, Hisar, Haryana to assess the effect of *Eucalyptus* planting geometry (17 m × 1 m × 1 m, 6 m × 1.5 m, 3 m × 3 m and devoid of trees, i.e. control) on soil micronutrients (zinc, iron, manganese, and copper) at the soil depths of 0–15, 15–30, 30-60 and 60–90 cm. The results showed that the different planting spacing of *Eucalyptus*, soil depths, and their interactions on micronutrients were significantly different and these were decreased with increasing the soil depth. The DTPA extractable micronutrient Zn, Fe, Mn, and Cu were in the range 0.8-1.3, 5.1-6.7, 6.8-8.1, and 2.6-3.1 mg/kg respectively. The soil micronutrient content decreased under a wider spacing agroforestry system but the maximum reduction was found under control treatment when compared with closer spacing (3 m × 3 m). The increase in micronutrient availability in soil due to the influence of *Eucalyptus tereticornis* was more in the surface (0-15 cm) than in subsurface soil (15-30, 30-60, and 60-90 cm) layers.

Keywords: Agroforestry, Depth, *Eucalyptus*, Micronutrients, Spacing

Agroforestry system is a promising technique to achieve sustainable land use and also plays a vital role in maintaining the fertility of the soil (Garitty 2004). These systems have the potential to reduce the severity of erosion and runoff, enhances soil organic matter, improves soil physical and chemical properties, and promote efficient nutrient cycling (Abubakar 2006). The availability of nutrients under agroforestry depends upon various factors. Among these factors, tree spacing is most important. In a soil-plant system, plant nutrients are in a state of continuous, dynamic transfer. Nutrients are absorbed by plants from the soil and thereafter these are used for metabolic activities. In turn, these nutrients are returned to the soil either naturally as litterfall in unmanaged systems, deliberately as pruning in some agroforestry systems, or through root senescence. The leaf litter is decomposed as a result of microbial activities and releases its nutrients into the soil. *Eucalyptus* is one of the important tree species that has been planted successfully under a variety of conditions due to its multifarious uses. In addition to soil fertility and nutrient content, positive impacts was observed on topsoil retention and soil erosion (Palmberg 2002). However, according to Baber *et al.* (2006), *Eucalyptus camaldulensis* plantation is responsible for reduced levels of soil micronutrients because the soil pH was found 8.0-8.5. In contrast to this Oballa *et al.* (2010) reported increased concentrations of Fe and Mn in soil under short-rotation *Eucalyptus* spp. plantations in Kenya. Khanmirzaei *et al.* (2011) found a significant increment in soil available micronutrients from 1.85–3.60 mg/kg and 2.10–11.28 mg/kg, for Fe and Mn, respectively at 0–20 cm soil depth under four *Eucalyptus* spp. plantations.

These studies, however, did not indicate the clear effects of the *Eucalyptus* plantations on the soil micronutrients particularly at different spacing and depths. Therefore, additional information on this aspect is required to be addressed. Therefore, present study was carried out to study the micronutrients in soils and work out the relationship of micronutrients with each other at the different spacing of *Eucalyptus*-based agroforestry system.

MATERIALS AND METHODS

The study site is located at 29º 09' N latitude and 75º 43' E longitudes at an elevation of 215 m amsl. The soil ranges from sandy to sandy loam. Climatic conditions are warm and humid, April and May are the warmest, and December and January are the coolest months in this area. The subtropical monsoon climate prevails in the area with a maximum temperature of 38.6 to 40.8ºC and a minimum temperature of 6.9˚C. The average annual rainfall is 526.4 mm, most of which falls between July-September. The study was carried out at Research Farm of the Department

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of Forestry, CCS Haryana Agricultural University, Hisar in an already established 8 years old *Eucalyptus* plantation at 17 m × 1 m × 1 m, 6 m × 1.5 m, 3 m × 3 m and devoid of trees. The physico-chemical properties of soil of the experimental field are given in Table 1.

Soil samples were collected randomly before sowing of barley crop during 2016–17 at different depths (0-15, 15-30, 30-60, and 60-90 cm) in four replicates. Collected soil samples were firstly sieved through a 10 mm mesh sieve to remove gravel, small stones, and coarse roots and then passed through a 2 mm sieve. Then the sieved samples were dried at room temperature. The DTPA extractable Fe, Cu, Zn, and Mn were determined in soils using the method of Lindsay and Norvell (1978). A sieved soil sample of 20 g was taken in a 100 ml plastic bottle and 40 ml of DTPA extracting solution was added and contents are shaken in a temperature-controlled shaker for 2 hr at 25°C. The contents were then filtered and readings were taken on atomic absorption spectrophotometer (AAS) using an appropriate cathode lamp and standard.

All the observations were statistically analyzed by using the statistical methods described by Panse and Sukhatme (1989). To see the significance of the effect of the treatments, the data were subjected to statistical analysis by the "analysis of variance" technique given by Fisher (1950). The significant treatment effect was judged with the help of the 'F' test at a 5% level of significance. To judge the significant difference between the means of two treatment effects, the critical difference (CD) was worked out.

RESULTS AND DISCUSSION

After 8 years of *Eucalyptus* plantation, the chemical properties and available soil nutrients are given in Table 1. Initially, the observed value of soil *p*H and electrical conductivity differed significantly among different spacing and control (devoid of trees). The experimental soil is highly saline in nature. The electrical conductivity increased with the increase in *Eucalyptus* spacing and it was found maximum in the control treatment. The organic carbon was higher under *Eucalyptus* plantation as compared to control under different spacing. The available nutrients (N, P and K) also differed significantly from each other. Among different *Eucalyptus* spacing improvement in soil properties was more under closer spacing (3 m × 3 m) spacing.

High organic matter content and nutrient availability in the intercropping treatment particularly in closer spacing of *Eucalyptus* could be ascribed to the fact that leaf-litter fall before and during crop sowing period on the soil which incorporates into the soil through tillage practices and their partial decomposition adds to the soil organic matter. These results are similar to the results reported by Gupta and Sharma (2009), Das and Chaturvedi (2005), and Yadav *et al.* (2008). The lower organic carbon content under the sole cropping systems may be attributed to scant vegetation and continuous cropping with subsequent removal of plant residues.

DTPA-Zinc in soil: The DTPA extractable zinc content of the soil is presented in Table 2. The results shows that the zinc content in soil at different spacing and depths differed significantly but their effect was found non-significant. The zinc content decreased with an increase in spacing as well as soil depth, however, the maximum zinc (1.8 mg/kg) content was found at 0-15 cm soil depth in the 3×3 m closer spacing. Thereafter the zinc content in soil decreased throughout the soil depths and it was recorded least under control treatment at various soil depths. As indicated in Table 2, the zinc content decreased under a wider spacing agroforestry system but the maximum reduction was found under control treatment when compared with closer spacing (3 m × 3 m) and it decreased to a tune up to 28%. The maximum reduction of zinc was found at the shallow layer as compared with deeper soil horizon.

Planting at different spacing and depth significantly affected the zinc content in soil but their interaction effects were found non-significant. Significantly mean highest zinc content (1.06 mg/kg soil) recorded in 3 m × 3 m followed by 6 m × 1.5 m spacing (0.95 mg/kg) and 17 m × 1 m × 1 m (0.88 mg/kg). In all the plant spacing, zinc content was significantly increased as compared to control (no tree). Depth-wise, the significantly higher zinc content was recorded at 0-15 cm (1.6 mg/kg of soil) and it decreased with increased depth. The lowest zinc content was observed under soil depth 60-90 cm (0.48 mg/kg).

DTPA -Iron in soil: Results showed that spacing, depth, and their interactions had significantly increased the iron content in the soil as compared to without trees (control) (Table 2). Iron content in the soil at 3 m× 3 m spacing (6.7 mg/kg) was significantly higher as compared to 6 m × 1.5 m (6.1 mg/kg) and it was least in 17 m × 1 m × 1 m spacing (5.6 mg/kg). The iron content at different spacing was significantly higher as compared to control (no tree).

Depth-wise, iron content decreased with the increase in depths. Significantly higher iron content was observed at 0–15 cm (8.0 mg/kg of soil) as compared to deeper layers (15–30, 30–60, 60–90 cm). The interaction among different treatments was also found significant.

Manganese in soil: The manganese content in soil was significantly affected by the spacing, depth, and their interaction (Table 2). Among different spacing, the Mn content was highest (8.1 mg/kg) at closer spacing, i.e. 3 m × 3 m as compared with wider spacing, i.e. 6 m × 1.5 m (7.6 mg/kg), 17 m × 1 m × 1 m (6.9 mg/kg), and control (6.8 mg/kg) also. The Mn content differed significantly among different spacing. But this effect was more pronounced in 3 m × 3 m spacing of *Eucalyptus*.

As like different spacing, the Mn content was highest in 3 m × 3 m spacing as far as the different depths are concerned. Depth wise Mn content differed significantly at the surface layer only. In deeper layers, i.e. 15–30, 30–60, 60–90 cm, Mn content decreased but the decrease was found non-significant among the spacings. Whereas Mn content differs significantly as compared to sole crop treatment.

DTPA-Copper in soil: The results of Cu content under different treatments are presented in Table 2. Among the different spacing, the Cu content was highest under closer spacing (3 m × 3 m, 3.2 mg/kg) and it was found minimum under control (2.6 mg/kg). The different spacing of the *Eucalyptus*-based agroforestry system did not differ significantly, however, closer spacing 3×3 and 6×1.5 m was differed significantly as compared to sole crop treatment. Although copper content was higher in wider spacing (17 m × 1 m × 1 m) as compared to control treatment but the effect was found non-significant. Depth-wise, the copper content among different treatment combinations was highest at the upper layer (0–15 cm) and a gradual decrease was observed in the lower depths. The effect was found non-significant among the different spacing but spacing treatment like 3 m ×3 m and 6 m ×1.5 m differed significantly with sole crop treatment at various depths.

Eucalyptus planting at different spacing and depth significantly affected the DTPA extractable micronutrients (Zn, Mn, Cu, and Fe) contents in soil. Significantly highest micronutrient contents were recorded in 3 m × 3 m spacing at surface soil depth (0–15 cm) and these decreased with increasing depth. The higher amount of DTPA extractable micronutrients at the surface layer may be due to the higher accumulation of organic matter on the surface soil. This may be probably due to the extraction of nutrients from deeper soil layers and addition to the topsoil layer through litterfall and fine root biomass. The annual leaf fall which is not removed eventually is incorporated into the soil as plant residue and also the root cutting during the cultivation adds organic matter in the top layer of the soil plant cycling is considered as the leading factor, and anthropogenic disturbance and leaching were the secondary factors that affects the vertical distributions and topsoil accumulation of nutrients under different land uses (Jobbage and Jackson 2001). Campanha *et al.* (2007) reported higher Cu under agroforestry systems than monoculture. Singh and Sharma (2007) reported an increase in Cu under the agroforestry system with an increase in age. The DTPA extractable-Cu in soil was decreased significantly with each successive soil depth, i.e. from 0–15 cm to 60–90 cm and maximum and significantly higher Cu was observed in 0-15 cm soil depth than other soil layers. The higher amount of Cu at the surface layer may due to the higher accumulation of organic matter on the surface soil. Jiang *et al.* (2009) also reported that the DTPA extractable-Mn decreased significantly with each successive increase in soil depth. The impact of agroforestry systems on soil fertility in terms of higher nutrient availability in the topsoil has been reported by Rizvi *et al.* (2011).

Table 1 Physicochemical properties of soil

Spacing (m)	*p*H (1:2)	EC (dS/m)	Organic carbon (%)	Available nutrients (kg/ha)		
				N	P	K
3×3	7.62	3.4	0.52	148.5	16.0	340.6
6×1.5	7.71	3.7	0.45	140.3	15.3	313.4
17×1×1	7.90	4.0	0.42	136.1	12.6	302.2
Control	8.01	4.3	0.38	128.3	11.7	280.2
CD (P=0.05)	NS	0.2	0.02	6.3	1.4	8.4

Table 2 Effect of different spacing of *Eucalyptus*-based agroforestry system on micronutrient contents (Zn, Fe, Cu, Mn) at different depths

Spacing (m)	DTPA extractable Zn (mg/kg) in soil				Mean	DTPA extractable Fe (mg/kg) in soil				Mean
	Depth (cm)					Depth (cm)				
	0-15	15-30	30-60	60-90		0-15	15-30	30-60	60-90	
3 × 3	1.8	1.1	0.78	0.55	1.06	9	7.8	5.9	4.2	6.7
6 × 1.5	1.6	0.98	0.7	0.49	0.94	8.3	6.9	5.4	3.9	6.1
17 × 1 × 1	1.5	0.92	0.65	0.46	0.88	7.6	6.6	4.9	3.4	5.6
Control	1.3	0.79	0.57	0.4	0.76	7	6.1	4.2	2.9	5.1
Mean	1.55	0.95	0.68	0.48		8	6.9	5.1	3.6	
CD (P=0.05)	Spacing: 0.1	Depth:0.1	Spacing × Depth: 0.2			Spacing: 0.4	Depth: 0.4	Spacing × Depth: 0.8		
Spacing (m)	*DTPA extractable Mn (mg/kg) in soil*				*Mean*	*DTPA extractable Cu (mg/kg) in soil*				*Mean*
	Depth (cm)					*Depth (cm)*				
	0-15	*15-30*	*30-60*	*60-90*		*0-15*	*15-30*	*30-60*	*60-90*	
3×3	12.2	8.8	6.3	5.3	8.1	4.6	3.7	2.5	2.1	3.2
6×1.5	11.5	7.8	5.9	5.2	7.6	4	3.4	2.8	1.9	3
17×1×1	10.9	6.2	5.7	4.8	6.9	3.9	3.2	2.2	1.6	2.7
Control	10.8	6.1	5.6	4.7	6.8	3.8	2.9	2.3	1.3	2.6
Mean	11.4	7.2	5.9	5		4.1	3.3	2.5	1.7	
CD (P=0.05)	Spacing: 0.5	Depth:0.5	Spacing × Depth: 1.0			Spacing: 0.25	Depth:0.25	Spacing × Depth: 0.6		

The DTPA extractable micronutrients (Zn, Mn, Cu, and Fe) contents in soil were decreased with an increase in the spacing between *Eucalyptus* plantations, and these contents were found least in sole cropping treatment (control). The lower micronutrient content under the sole cropping systems may be attributed to scant vegetation and continuous cropping with subsequent removal of plant residues. The higher micronutrient status under closer spacing might be due to the addition of a large quantity of leaf litter. The higher decomposition of leaf litter favours the higher nutrient status of the soil (Singh and Sharma 2007) and also due to the litter-fall addition from *Eucalyptus* trees as well as the addition of root residues of crops and trees. These findings were supported by Das and Chaturvedi (2005), Yadav *et al.* (2008) and Gupta and Sharma (2009).

Soil micronutrients in the study area significantly varied with depth and different spacing of *Eucalyptus*-based agroforestry system. After 8 years of a *Eucalyptus* plantation, soil DTPA-micronutrients status (Zn, Fe, Cu, and Mn) were improved under different spacing of *Eucalyptus* based agroforestry system. The effect was more pronounced under 3 m × 3 m spacing of *Eucalyptus* at surface depth and hence closer spacing was found more suitable for improving the soil fertility.

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