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Performance of poplar (*Populus deltoides* Bartr.) clones after eleven years of plantation in calcareous alluvial soil of Bihar

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ABSTRACT

Poplar (*Populus deltoides* Bartr.) has recently emerged as a popular short-rotation tree for agroforestry in the northern and eastern India. The growth of poplar depends upon various factors such as clone, quality of planting stock, spacing of trees, site quality, climate and management practices. A study was conducted under 11 years old poplar plantation at Rajendra Agricultural University, Pusa (Samastipur), Bihar, to assess the performance of different poplar clones (PP - 5, Uday, L - 52, L - 49, G - 48 and L - 188) based on their timber volume, biomass yield and soil properties. The study revealed that among different poplar clones, L - 52 showed significantly higher plant height (15.2 m), diameter at breast height (23.98 cm), timber volume (187.0 m^3 ha^{-1}) and timber biomass (87.9 Mg ha^{-1}). A considerable build-up of macronutrients (N, P_2O_5, K_2O and S) and micro-nutrients (Zn, Cu, Fe, Mn and B) was also observed in surface soils under L - 52 plantation. Hence, L - 52 emerged as the best among the tested clones for growing and promotion under calciorthent soils of Bihar.

1. INTRODUCTION

Poplar (*Populus deltoides* Bartr.) is an important agro-forestry tree that has been widely planted on a significant scale in India to meet the growing demand for wood. It has emerged as a popular short-rotation tree for agroforestry in northern and eastern India. The growth of poplar depends upon various factors such as clone, quality of planting stock, spacing of trees, intercrops, site quality, climate and management practices (Tewari, 1995). Poplar has a winter-deciduous nature with leaf fall starting at the end of September and continuing till January. Intercropped poplar stands produce a higher quantity of litter with higher N, P and K content than pure stands, and litterfall production increases as trees age (Mohsin *et al.*, 1996). Litterfall has been reported to enhance the soil organic matter content of soil and recycle the nutrients, and thus improve soil fertility. Singh and Sharma (2007) reported macro and micronutrients return through poplar litter fall in the order: Ca > N > K > S > P and Fe > Mn > Zn > Cu, respectively. On account of recycling of organic matter, higher organic carbon (OC) and available N, P and K content were observed in the soil under an inter-cropped poplar plantation than at a site without trees (Singh *et al.*, 1989), and the content varied depending upon the intercrops (Mohsin *et al.*, 1996). Hence, there is tremendous scope for improving the nutrient-deficient north-west alluvial plain of Bihar by afforestation with multipurpose tree species. Keeping these facts in view, an evaluation study for the suitability of different poplar clones after eleven years of plantations was carried out in calciorthent soils of Bihar.

2. MATERIALS AND METHODS

Experimental Site

The field experiment was carried out at Birouli Farm, Rajendra Agricultural University, Pusa (Samastipur), Bihar, under ICAR-All India Coordinated Research Project on Agroforestry since February 2004. The experimental site is situated at $25^0$39N latitudes, $85^0$48E longitudes and 53.12 m above mean sea level. The site experiences a subtropical climate having three distinct seasons, *i.e.* rainy (mid-June to September), winter (October to February) and summer (March to mid-June). During 2015, there was a 23% rainfall deficiency compared to the normal. The total annual rainfall during the study period was 952.2 mm, of which 86% was received during monsoon months. Significant variability was recorded for maximum and minimum temperature, which ranged from 19.4^{0}C (January) to 36.7^{0}C (June) and 9.6^{0}C (January) to 25.6^{0}C (June), respectively.

The soil of the experimental site is calcareous, sandy loam (sand, silt and clay: 53.8, 35.6 and 10.5%, respectively) in texture, alkaline in reaction [pH (1 : 2) 8.7], high in free $CaCO_3$ (38%), low in OC (0.28%), available N (130.20 kg ha^{-1}), P_2O_5 (19.05 kg ha^{-1}) and K_2O (97.82 kg ha^{-1}). The site was an abandoned agricultural land, which was fallow for the last five years. The initial important physico-chemical properties of the experimental site are presented in Table 1.

Establishment of *Populus deltoides* Clones

The experiment was established with poplar (*Populus deltoides*) clones in an agroforestry system on 1 ha of land, leaving 15 m buffer to serve as a control (treeless plots) for growing sole crop without any trees. Before the establishment of the experiment, six promising clones of poplar ***viz.*** PP - 5, Uday, L - 52, L - 49, G - 48 and L - 188 were procured from G.B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) and grown in a nursery for one year. The one-year-old entire trans plants (ETP) without any co-leader or branches and with necked root (without any ball of earth) were planted in the month of February at 4 × 5 m spacing in pits of size 50 × 50 × 100 cm as monoclonal blocks in a randomized block design. Each clone was replicated quadruple times with a total number of 16 trees maintained for a clone per replication (plot) and thus in all forming 384 trees in the entire field (6 clones × 4 replications × 16 trees per replication). The size of the plot was 16 × 20 m^2. Each tree was fertilised with 5 kg well-rotten farmyard manure, 50 g of single super phosphate (SSP) and 25 g of muriate of potash. Nitrogen as diammonium phosphate (DAP) was given @ 100 g $plant^{-1}$ in two split doses (last week of June and September). The fertilization was done initially during the first two years. The plantation was irrigated weekly in summer (March - June) and fortnightly in winter seasons (October - February). No irrigations were provided during the rainy season (July - September). The lower one-third portion of the stem was kept clean by removal of emerging buds for good growth of leading shoot up to the third year. Pruning of 50% of the height of the tree from 3^{rd} year was done during winter.

Rice (*Oryza sativa*) - wheat (*Triticum aestivum*) were taken as the intercrops in the plantation of poplar clones during 2^{nd} and 3^{rd} year. During the 4^{th} and 5^{th} year urd (*Phaseolus mungo*) - wheat were taken as the intercrops. From the 6^{th} year to the 8^{th} year of the plantations, only in the *rabi* season wheat was taken. Monospecific crop plots (treeless controls) were established block-wise in the contiguous area for comparative purposes. Local recommendations regarding agronomical practices and fertiliser applications were followed for the various crops.

Table: 1
Initial soil properties of the experimental site before plantation

Soil properties	Soil depth (cm)	
	0-15	15-30
Sand (%)	53.8	-
Silt (%)	35.6	-
Clay (%)	10.5	-
Textural class	Sandy loam	-
pH (1 : 2, Soil : water)	8.70	8.80
EC (dSm^{-1})	0.32	0.20
Organic carbon (%)	0.28	0.21
Available N (kg ha^{-1})	130.2	111.6
Available P_2O_5 (kg ha^{-1})	19.1	13.3
Available K_2O (kg ha^{-1})	97.8	82.3
Available S (mg kg^{-1})	8.20	7.10
Available Zn (mg kg^{-1})	0.56	0.46
Available Cu (mg kg^{-1})	0.65	0.47
Available Fe (mg kg^{-1})	10.5	6.89
Available Mn (mg kg^{-1})	3.90	3.10
Available B (mg kg^{-1})	0.46	0.32
Free $CaCO_3$ (%)	38.0	34.0

Soil Analysis

Representative soil samples were collected from 0-15 and 15-30 cm depths. Collected soil samples were air-dried in shade, ground with the help of pestle and mortar, passed through a 2 mm sieve and stored in polyethene bags for further analysis. Processed soil samples were analysed as per standard procedure *viz.,* Mineralizable N by using alkaline $KMnO_4$ (Subbiah and Asija, 1956), available P_2O_5 by ascorbic acid (Olsen *et al.* 1954), available K_2O by ammonium acetate method (Merwin and Peech, 1951), available sulphur was determined by turbidimetric method (Chesnin and Yein, 1950), available Zn, Cu, Fe and Mn by DTPA extraction method using atomic absorption spectrophotometer (Lindsay and Norvell, 1978) and B using hot water (Berger and Troug, 1939).

Tree Growth and Biomass Production

The growth of poplar clones was determined in terms of height, diameter at breast height (DBH), and crown width after eleven years of plantation. The height of trees (meters) was recorded from the base of the tree to the growing tip with the help of Clinometer (Suunto, PM-5/360 PC). DBH was determined using the formula as DBH = girth/3.14, where girth was measured at breast height (1.37 m) from the tree base. Crown width was measured in two directions at the right angle to each other using the formula: Crown width = $(D_1+D_2)/2$, where D_1 is crown width in north-south direction, and D_2 is crown width in east-west direction (Chaturvedi and Khanna, 1994). Timber volume (V) has been estimated by the formula: $\sqrt{V} = 4.9058 \times (DBH)^{1.45847}$ (Dhanda and Verma, 2001). Timber biomass was determined from timber volume using the formula: Timber biomass (q $tree^{-1}$) = 10 × specific gravity × timber volume, where volume is in m^3.

Statistical Analysis

The data generated from the present investigation were subjected to statistical analysis using the statistical package SPSS (14.0) and Microsoft Excel. Treatment means were compared for significant difference using the least significant difference (LSD) at the 5% level.

3. RESULTS AND DISCUSSIONS

Tree Growth Parameters

Among the different poplar clones, the maximum growth in terms of height (15.17 m), DBH (23.98 cm) and crown width (3.79 m) was recorded in L-52, followed by L-49, PP-5 and the minimum values were recorded in L-188 (Table 2). Here it is clear from the data that L-52 was significantly superior compared to the other clones in terms of height and DBH. On the other hand, clones L-49 and PP-5 did not show significant differences among themselves in relation to DBH and height. Crown width measured for all the poplar clones were statistically at par, and it varied from 3.39 m in L-188 to 3.79 m in L-52. Height (m) of different poplar clones followed the order: L-52 (15.17) > L-49 (13.70) > uday (13.15) > PP-5 (13.00) > G-48 (11.47) > L-188 (11.38); DBH (cm) followed the order: L-52 (23.98) > L-49 (22.66) > PP-5 (21.47) > uday (20.88) > G-48 (19.73) > L-188 (19.34); and crown width (m) followed the order: L-52 (3.79) > L-49 (3.53) > PP-5 (3.50) > Uday (3.46) > G-48 (3.44) > L-188 (3.39).

Volume and Biomass Production

The data on timber volume for the different poplar clones on the individual tree basis revealed that L-52 had maximum volume (0.374 m^3) followed by L-49 (0.317 m^3), PP-5 (0.271 m^3), uday (0.250 m^3), G-48 (0.212 m^3) and L-188 (0.200 m^3) (Table 3). The same trend was recorded in volume on a unit area basis. The mean annual volume increment varied from 0.018 m^3 $tree^{-1}$ yr^{-1} (L-188) to 0.034 m^3 $tree^{-1}$ yr^{-1} (L-52) (Table 3). It is clear from the data that L-52 clone was significantly superior to all other poplar clones. The volume of clones L-49, PP-5 and uday showed non-significant differences, but was significantly more than G-48 and L-188.

Among different clones, the timber biomass on an individual tree basis varied from 0.94 q $tree^{-1}$ in L-188 to 1.76 q $tree^{-1}$ in L-52 (Table 4). Mean annual biomass increments varied from 0.085 (L-188) to 0.160 (L-52) q $tree^{-1}$ yr^{-1}. Similarly, timber biomass production followed the same trend showing the highest biomass in L-52 and the minimum in L-188. Higher biomass production achieved in clones L-52 and L-49 might be presumably due to the higher photosynthetic efficiency of these clones compared to other clones.

Large and significant differences in growth rate and biomass production among *P. deltoides* clones indicated the presence of substantial genetic variation. These variants can be exploited by selecting the best clones for future plantations. Among the six clones tested, clone L-52 was found outstanding, consistently showing higher growth and biomass. L-49 and PP-5 also exhibited promising growth and relatively higher biomass. The higher DBH and height resulted in higher biomass. High biomass production is an important consideration in all tropical and sub-tropical tree planting programmes. This is particularly significant because of the rising CO_2 level in the atmosphere and the growing need to sequester it. Pingale *et al.* (2014) reported the stem biomass varying from 45.53 to 130.05 Mg ha^{-1} for *P. deltoides* established with different densities of the plantation. The present biomass estimates for different poplar clones are well within the range of these biomass values.

Table: 2
Growth performance of eleven-year-old poplar clones

Poplar clones	Height (m)	DBH (cm)	Crown width (m)
PP - 5	13.0	21.5	3.50
Uday	13.2	20.9	3.46
L - 52	15.2	24.0	3.79
L - 49	13.7	22.7	3.53
G - 48	11.5	19.7	3.44
L - 188	11.4	19.3	3.39
SEm ±	0.43	0.38	0.18
LSD (0.05)	1.30	1.14	0.53
CV (%)	6.64	3.54	9.98

Table: 3
Timber volume of eleven-year-old poplar clones

Poplar clones	Timber volume (m^3 $tree^{-1}$)	Mean annual volume increment (m^3 $tree^{-1}yr^{-1}$)	Timber volume production (m^3 ha^{-1})
PP - 5	0.271	0.025	135.5
Uday	0.250	0.023	125.0
L - 52	0.374	0.034	187.0
L - 49	0.317	0.029	158.5
G - 48	0.212	0.019	106.0
L - 188	0.200	0.018	100.0
LSD (0.05)	0.040	0.004	20.0
SEm±	0.013	0.001	6.50
CV (%)	9.57	9.57	9.57

Table: 4
Timber biomass production of eleven-year-old poplar clones

Poplar clones	Timber biomass (q $tree^{-1}$)	Mean annual biomass increment (q $tree^{-1}yr^{-1}$)	Timber biomass production (mg ha^{-1})
PP - 5	1.27	0.116	63.7
Uday	1.18	0.107	58.8
L - 52	1.76	0.160	87.9
L - 49	1.49	0.135	74.5
G - 48	1.00	0.091	49.8
L - 188	0.94	0.085	47.0
LSD (0.05)	0.19	0.017	9.4
SEm±	0.06	0.006	3.1
CV (%)	9.57	9.57	9.57

Available Macronutrients in Soil

The status of available N was 130.2 kg ha^{-1} in surface soil and 111.6 kg ha^{-1} in sub-surface soil before the start of experiment (Table 1). After eleven years of the plantation, the available nitrogen ranged from 114.5 under L-188) to 170.4 kg ha^{-1} under L-52) and from 110.8 under L-188) to 144.7 kg ha^{-1} under L-52) in surface and sub-surface soils, respectively (Table 5). The available N content of the soil was lower at 15-30 cm soil depth. Among the different poplar clones, L-52, L-49 and PP-5 showed significant improvement in available N in surface and sub-surface soil.

Litterfall from the different forest tree species has been reported to significantly increase available soil nitrogen (Hosur and Dasog, 1995; Chavan *et al.*, 1995; Contractor and Badanur, 1996; Minhas *et al.,* 1997; Rai *et al*., 2003 and Sartori *et al*., 2007). In the present study, higher available N was recorded under L-52 and L-49 clones. The higher available N under these poplar clones can be attributed to higher litter production and decaying of more fine roots. Higher available N in lower soil depths than open (without trees) may be ascribed to leaching of available N to lower soil depths and release of N from root decay.

The soil available P_2O_5 before the start of experiment was 19.0 and 13.3 kg ha^{-1} in surface and sub-surface soils, respectively (Table 1). After 11 years of plantation, available P_2O_5 ranged from 17.9 kg ha^{-1} under L-188 to 34.5 kg ha^{-1} under L-52 in surface soil and from 12.2 kg ha^{-1} under L-188 to 21.2 kg ha^{-1} under L-52 in sub-surface soil (Table 5). Irrespective of poplar clones, surface soils have more available soil P_2O_5 than sub-surface soil. The available soil P_2O_5 varied with the nature of the clones. All the poplar clones had a significant quantity of available P_2O_5 compared to open plots. However, available P_2O_5 under L-188 (17.9 kg ha^{-1}) was at par with open (18.5 kg ha^{-1}). Sub-surface soils (15-30 cm) showed significant build-up in available P_2O_5 only under L-52, L-49 and PP-5 as compared to open.

Laik *et al*. (2009a and 2009b) reported that the organic acids released during the decomposition of residues enhance phosphorous release by reducing metal ions binding phosphate through chelation and competing for exchange sites. The L-52 poplar clones in the present study gave higher available P_2O_5 at both the soil depths (34.45 kg ha^{-1} at 0-15 cm and 21.15 kg ha^{-1} at 15-30 cm). The higher available P under the plantation of these poplar clones might be due to higher litter production and decaying of more fine roots.

The status of available K_2O in surface and sub-surface soil at the beginning of experiment was 97.8 and 82.3 kg ha^{-1}, respectively (Table 1). After 11 years of poplar plantation, the available K_2O ranged from 117.6 kg ha^{-1} under L-188 to 154.0 kg ha^{-1} under L-52, and from 83.1 kg ha^{-1} L-188 to 134.2 kg ha^{-1} under L-52 in surface and sub-surface soils, respectively (Table 6). The available K_2O in the soil decreased with an increase in soil depth. There was a significant increase in available soil K_2O in surface soil of all the plantations of different poplar clones, while in sub-surface soil, it was significant only under the clones of L-52 followed by L-49, PP-5 and uday.

Under the plantations of different poplar clones, available S ranged from 5.58 mg kg^{-1} under L-188 to 9.79 mg kg^{-1} under L-52 in the surface layer, and 5.37 mg kg^{-1} under L-188 to 9.63 mg kg^{-1} under L-52 in sub-surface soils (Table 6). A significant decrease in available sulphur was recorded under uday, G-48 and L-188, whereas L-52, L-49 and PP-5 poplar clones showed a significant increase in available S at both the soil depth over the open condition. It might be due to higher litterfall by these poplar clones, which ultimately enhanced the soil organic matter content. The available S decreased with the soil depth.

The build-up of soil organic matter is an essential strategy for rehabilitating degraded wasteland. Hence, soil organic matter is an essential but transient component that controls several physical, chemical and biological properties of soil (Jha *et al.,* 2010). Litterfall and decaying of roots

Table: 5
Effect of eleven-year-old poplar clones on available N and P_2O_5 content in soil

Poplar clones	Available N (kg ha^{-1})			Available P_2O_5 (kg ha^{-1})		
	0-15	15-30	Mean	0-15	15-30	Mean
PP - 5	150.0	129.5	129.5	28.2	17.1	17.1
Uday	143.0	120.7	120.7	27.2	15.0	15.0
L - 52	170.4	144.8	144.8	34.5	21.2	21.2
L - 49	157.0	138.6	138.6	30.3	19.1	19.1
G - 48	139.1	114.2	114.3	22.7	14.2	14.2
L - 188	114.5	110.8	110.8	17.9	12.2	12.2
Open	131.6	111.8	121.7	18.5	14.8	16.7
SEm±	4.6	2.0		0.96	0.73	
LSD (0.05)	13.9	6.1		2.9	2.2	
CV (%)	6.35	3.18		7.16	8.69	

Table: 6
Effect of eleven-year-old poplar clones on available K_2O and S content in soil

Poplar clones	Available K_2O (kg ha^{-1})			Available S (mg ha^{-1})		
	0-15	15-30	Mean	0-15	15-30	Mean
PP - 5	151.0	118.2	134.6	8.59	6.29	7.44
Uday	137.2	109.2	123.2	7.34	6.21	6.77
L - 52	154.0	134.2	144.1	9.79	9.63	9.71
L - 49	153.4	122.2	137.8	8.77	7.62	8.19
G - 48	133.5	101.0	117.2	7.18	5.48	6.33
L - 188	117.6	83.13	100.4	5.58	5.37	5.47
Open	96.6	87.50	92.1	7.60	6.80	7.20
SEm±	3.18	4.74		0.176	0.156	
LSD (0.05)	9.60	14.3		0.530	0.470	
CV (%)	4.51	8.52		4.47	4.62	

might have improved soil organic matter status in the present study, under all the plantations of different poplar clones. The increase in available nutrients may be ascribed to mineralization of nutrients from litterfall, fine roots and release of nutrients from the residual soil reserves.

Available nutrient contents were high in 0-15 cm horizon and decreased with increasing depth of the soil, which might be due to nutrient cycling and surface enrichment by the biomass. The shade of the tree canopy also improve the mineralisation rate of soil nitrogen. In Queensland, Australia, Wilson *et al.* (1990) artificially shaded pastures with a cloth that gave 50% light transmission and recorded 40-100% higher herbage yield, leaf nitrogen content and soil nitrate-nitrogen under shade.

Soil organic matter does not influence the available soil potassium much, as it is not the direct supplier of potassium. The gain in the amount of available potassium in soils can be attributed to improved physical and chemical soil conditions under the influence of tree cover (Gupta and Sharma, 2009). Reduced loss of nutrients under agroforestry is also attributed to reduced leaching. Thakur *et al.* (2005) reported increased available N, P, and K under agroforestry systems, and argued that the mechanism involved in higher soil nutrients status under agroforestry systems than sole cropping is canopy capture of precipitation inputs and minimum loss of nutrients by leaching.

Available Micronutrients in soil

Under the plantations of different poplar clones, available Fe ranged from13.2 to 18.2 mg kg^{-1} in surface and 6.21 to 11.34 mg kg^{-1} in sub-surface soil; available Mn varied from 6.67 to 10.85 mg kg^{-1} in surface and 3.11 to 3.62 mg kg^{-1} in sub-surface soil; available Cu varied from 0.55 to 0.91 mg kg^{-1} in surface and 0.51 to 0.68 mg kg^{-1} in sub-surface soil (Table 7); available Zn varied from 0.34 to 0.74 mg kg^{-1} in surface and 0.12 to 0.33 mg kg^{-1} in sub-surface soil and available B ranged from 0.40 to 0.72 mg kg^{-1} in surface and 0.35 to 0. mg kg^{-1} in sub-surface soil (Table 8).

All the poplar clones studied were effective in bringing about improvement in available Fe, Mn, Cu, and B except Zn. Irrespective of the soil depth, availability of the different soil micronutrients under different plantations of the poplar clones followed the following decreasing order:

Available Fe: L-49 > G-48 > L-188 > Uday > PP-5 > L-52

Available Mn: L-52 > PP-5 > L-188 > Uday > G-48 > L-49

Available Cu: G-48 > PP-5 > L-188 > L-49 > L-52 > uday

Available Zn: L-52 > L-49 > PP-5 > Uday > G-48 > L-188

Available B: L-52 > L-49 > PP-5 > Uday > G-48 > L-188

As in case of macronutrients, the availability of micronutrients was more in the upper 15 cm soil layer than the lower layer. This could be ascribed to litterfall and thus higher higher amount of organic matter present in the upper layer of the soil. Singh and Sharma (2007) reported that the release of nutrients through decomposition of litterfall increased available micronutrients in the soil. Besides, the formation of chelates of micronutrient cations by the organic molecules produced due to the decomposition of organic matter might have enhanced the availability of micronutrients in the soil (Lindsay, 1979).

Table: 8
Effect of eleven-year-old poplar clones on available Zn and B content in soil

Poplar clones	Available Zn (mg kg^{-1})			Available B (mg kg^{-1})		
	0-15	15-30	Mean	0-15	15-30	Mean
PP - 5	0.40	0.18	0.29	0.54	0.46	0.50
Uday	0.37	0.15	0.26	0.52	0.43	0.47
L - 52	0.74	0.33	0.54	0.72	0.51	0.61
L - 49	0.47	0.18	0.33	0.62	0.47	0.55
G - 48	0.35	0.14	0.25	0.48	0.41	0.44
L - 188	0.34	0.12	0.23	0.40	0.35	0.37
Open	0.50	0.40	0.45	0.31	0.28	0.30
SEm±	0.02	0.01		0.010	0.011	
LSD (0.05)	0.05	0.02		0.030	0.033	
CV (%)	6.86	6.98		3.67	4.98	

Table: 7
Effect of eleven-year- old poplar clones on available Fe, Mn and Cu content in soil

Poplar clones	Available Fe (mg kg^{-1})			Available Mn (mg kg^{-1})			Available Cu (mg kg^{-1})		
	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean
PP - 5	14.7	7.37	11.1	9.32	3.62	6.47	0.74	0.63	0.69
Uday	16.3	6.93	11.6	8.45	2.89	5.67	0.55	0.51	0.53
L - 52	13.2	6.21	9.72	10.88	3.55	7.22	0.58	0.56	0.57
L - 49	17.3	11.3	14.3	6.67	3.11	4.89	0.64	0.68	0.66
G - 48	18.2	7.71	13.0	7.30	3.47	5.39	0.91	0.55	0.73
L - 188	15.6	7.91	11.8	8.07	3.56	5.82	0.82	0.54	0.68
Control	10.2	6.42	8.31	3.50	2.80	3.15	0.60	0.44	0.52
SEm±	0.31	0.19		0.37	0.12		0.02	0.02	
LSD (0.05)	0.94	0.57		1.12	0.37		0.06	0.06	
CV (%)	3.94	4.77		8.82	7.21		5.69	6.42	

Available Zn declined under all the plantations at both the soil depths except the soil under the clone L-52, which showed a significant increase in the surface soil compared to open (without trees). The Zn requirement of poplar clones and intercrops grown during 2nd to 8th year might have decreased the Zn concentration in the soil. Poplar growth starts in March after dormancy during winter, and poplar foliage and wood growth are very fast during summer and the rainy season from March to September. The release of Zn from decomposing organic matter may not be sufficient to raise the Zn level considerably. The decline in Zn concentration with the continuous raising of wheat-based cropping systems has been reported by Singh *et al.*, 1995.

4. CONCLUSIONS

Among the six clones evaluated in the study, L-52 showed higher growth and biomass, and emerged as the best clone for cultivation and promotion under calciorthent soils of Bihar, followed by L-49 and PP-5, which also exhibited promising growth and relatively higher biomass than other clones.

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