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Research Article

Effect of short-rotation trees on nutrient dynamics and rooting pattern in intercropped with aromatic grasses in terai of U.P.

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ABSTRACT
An Experiment was conducted in District Pilibhit.U.P., to study the yields of aromatic grasses in pure fields as well as intercrops under *Populus deltoids* and *Eucalyptus hybrid*. Quantity of litterfall, its chemical composition, nutrient addition, changes in chemical constituents of soil and herb and oil yield of *Cymbopogon spp*. were studied under agroforestry systems involving *Populus deltoids* and *Eucalyptus hybrid* with intercrop of Aromatic grasses (*C.winterianus, C.martinii, C.flexouses*). Trees were intercropped with grasses have significantly more diameter and height in comparison to trees planted without intercrops. High herbage and oil yield was recorded in pure fields of grasses than their crops intercropped with trees. Maximum yield was produced by Palmarosa and minimum by Citronella in poplar plantation intercropped. In *Eucalyptus hybrid* intercropped grasses, maximum oil yield was produced by Lemon grass and minimum by Palmarosa. Higher quantity of litter was produced in Palmarosa and lower was produced in Citronella intercropped trees. The litter produced by the intercropped stands had higher NPK contents than pure stands. The concentration of nutrients in the litter decreased with increasing age of the stands. Similarly, the total addition of nutrients (NPK) through litter fall to the soil increased as the age of trees increased. In the field of trees intercropped with Palmarosa was maximum addition of nutrients, while in Citronella intercropped field it was seen minimum. In comparison to intercropped stands, available NPK content of soil was higher in pure stands of trees. Maximum amount of N and K was found in superficial layer of the soil, which decreased with increasing depth. Most of the phosphorus was accumulated in the soil at the depth of 15-30cm in all the stands. The concentration of roots was more near the base of the trees at juvenile age,but as the age increases the roots tended to proliferates uniformly.. The total root biomass decreased continuously with increasing soil depth at all the radial distances and under all the age groups. It is clear that there is no completion among the root system with roots of intercrops grown along with Poplar and Eucalyptus.
Keywords: *Litterfall, Populus deltoids, Eucalyptus hybrid. Aromatic grasses, Nutrient return, Agroforestry system*

INTRODUCTION
The litter of the forest is an important stage in the cycle of habitat conservation. It provides the return of nutrients and the replenishment of organic matter and supports a wide variety of riches for fauna and micro-organisms. These species are covering the largest area in India among the exotics. crops such as medicinal herbs on farm land without than the slow growing and long rotation trees Prasad, et.al (1985). But at the same time, it is a winter deciduous tree species and produces a considerable quantity of litter fall in the winter season.

In North India, Eucalyptus plantation is again picking up under agrisilvicultural system due to introduction of colonel Eucalyptus having fast rate of growth, small canopy, uniform stem girth and 30 to 40 percent higher wood production Bhardwaj, et.al (2001).The amount and pattern of litter fall varies with the type of species, growth and age, tree density, canopy characteristics, intercrops, season, etc. (Bhardwaj, et. al 2001; Mohsin, et.al.1996 and Singh 1998).

The addition of litter fall and return of nutrients through litter fall, especially N. P. K have been quantified in many studies Mohsin (2005), Mohsin and Singh (2007) and Mohsin and Singh (2008)., but a meager information is available regarding return of nutrients through litterfall at farmers field.

Roots provide anchorage for the tree and serve the vital functions of absorption and translocation of water and nutrients.

They exert a significant influence on soil profile development, and upon dying, roots contribute to soil organic matter content (McClaugherty et.al.1982).

The difficulty in predicting the rooting pattern and root interaction of woody species in agroforestry is further compounded by the fact that the root systems of most tropical trees have been only scantily investigated (Halle et.al., 1978). Some of the reviews that are available on the work (Kerfoot,1963; Jenik,1977) indicate that for many woody species the largest number of roots, are located in the uppermost fertile portion of the soil profile.

Spatial distribution and biomass of roots in *E.camaldulensis* (Prasad et.al.,1984; Zohar,1985), E. grandis (Baldwin and Stewart,1987), *E. hybrid* (Dabral et.al.,1987), *E.tereticornis* (George,1985 and Dhyani et.al.,1990), *E. marginata* (Carbon et.al.,1980) and *E. globules* (Mathur et.al.,1984) plantation were studied.

Therefore, the study was carried out to assess the dynamic pattern and quantity of litter fall and to estimate the amount of nutrients return to soil during different months in plantations .

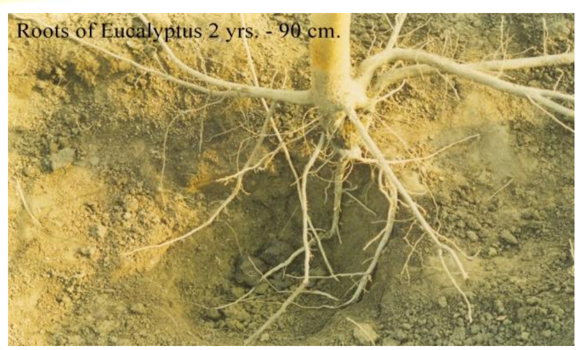
MATERIALS AND METHODS

Field experiment was conducted at farmers field in Distt. Pilibhit, U.P. for 72 - Months. Maximum and minimum temperature ranges from 18 to 47 C and 5.2 to 29.10 C, respectively. The agroforestry systems were *Poplus deltoides*(S7C15) and Eucalyptus hybrid with improved varieties of aromatic grasses viz., *Cymbopogon winterianus* (Bio-13), *Cymbopogon flexouses*(Krishna) and *Cymbopogon martini* (PRC- 1). There were seven treatments, in both the tree component; viz; three were with intercrops, three were of pure crop component of each aromatic grasses and one of pure *Populus deltoids* and *Eucalyptus hybrid.* The soil of experimental fields was typic Hapludoll derived from alluvium. It was silty clay loam having pH of 7.0, organic carbon 1.0%, available N,P and K were 272.5, 12.8 and 245.4 kg/ha, respectively. Trees of Poplar and Eucalyptus were planted at the spacing of 5m x 4m and 2.5m x 2.5m. All the above aromatic grasses were planted both as pure and intercropped with *Populus deltoids* and *Eucalyptus hybrid*, during first week of February at spacing of 60 x 60cm by slips in the first year of the study . A suitable fertilizer dose of 180 kg N, 80 kg Pand 60 kg K per hectare was applied to *Cymbopogon winterianus*. One third dose of N and total P and K was applied at the time of planting and

Rooting Pattern of *Populus deltoids* (Age: 2 Years, Depth : 45cm)

Rooting Pattern of *Populus deltoids* (Age: 5 Years, Depth : 45cm)

Rooting Pattern of *Eucalyptus hybrid*



Rooting Pattern of *Eucalyptus hybrid*

rest amount of N was applied in two equal doses after every harvest in *Cymbopogon winterianus*. In the second year, full dose of P and K was given and three equal doses of N applied after each harvest. In third and fourth year same doses of fertilizer were applied as in the second year. *Cymbopogon winterianus* continued for four years. In *Cymbopogon flexouses* and *Cymbopogon martini* same fertilizer dose was applied except N, i.e., 150 kg/ha.

From second to sixth year same fertilizer application was done as in *Cymbopogon winterianus* , *Cymbopogon flexouses* and *Cymbopogon martini* continued upto end of the study period i.e., 72 – months ,in pure as well as intercropped system. First weeding was done after 45 days of planting and second weeding was done after 90 days of planting. After each harvest of grasses, hoeing was done. Fifteen irrigation were given to these crops per year. First harvest of aromatic grasses were done in June and second harvest was done in October. From second to sixth year of study, three harvests were taken in the month of February, June and October each year, except *Cymbopogon winterianus*, in which only from second to fourth year of study three harvest were taken. Fresh herbage yield of aromatic grasses were recorded in each harvest by quadrate method.

A 100 gm sample of each crop at both harvest was collected and oil content was measured with the help of Clevenger's apparatus. Oil yield was also calculated.

The annual litter production of the trees in intercropping stands was recorded by collecting all the leaves and twigs, falling to the soil surface in litter traps made by demarcating 100 x 100 cm areas at six places. The litter samples collected were pooled together to represent annual fall. A represented sample of each annual litterfall were taken, oven dried at 80 C for 36 hrs. and subjected to further chemical analysis for N, P and K, using the modified microkjeldahl Vanadomolybdo phosphoric acid yellow colour method and flame photometry, respectively Jackson (1967). On the basis of nutrient concentration in the litter, the quantity of nutrient elements released and their periodical addition to the soil was calculated.

The pattern of root distribution of the Eucalyptus and Poplar trees was studied by excavation method as reported by Ghosh and Chattopadhyay (1972) and Chandra et.al.(1979). A circle of 150cm radius was marked around the tree trunk and further sub-divided

The roots were graded into following four classes (Aiyappa and Srivastava,1965), on the basis of their diameter measured with the help of vernier calipers.

1. g1 (Fibrous) = < 0.2cm
2. g2 (Thin) = 0.2- 0.5cm
3. g3 (Medium) = 0.5 – 1.5cm
4. g4 (Thick) = > 1.5 cm.

RESULTS AND DISCUSSION

Herbage and Oil Yield: The data recorded on the fresh herbage and oil yield has been given in Table – 1. It is revealed from the table that higher herbage and oil yield was recorded in all the aromatic grasses, in pure fields and then with intercropped with *Populus deltoides* and *Eucalyptus hybrid*. In *Cymbopogon winterianus*, the fresh herb yield (q/ha) and oil yield (kg/ha) increased upto third year but in fourth year the herb yield decreased. In *Cymbopogon flexouses* and *Cymbopogon martini* remained for 72-months in the field, but *Cymbopogon winterianus* remained only for 48 months. The fresh herbage and oil yield was recorded higher in pure crops than intercropped crops with trees. The herbage and oil yield recorded under trees was less due to increased amount of shade, in comparison to pure fields of aromatic grasses. Upto the age of 48- months of trees the yield of intercrops did not decreased but as the age increased to 60 and 72- months the yield was also decreased. This was due to canopy effect of trees.

In the study, it was recorded that herb yield was recorded highest in rainy season harvest continuing by winters and summers harvest. Similarly oil percentage of all the aromatic grasses was low in rainy and winter season than by summer season harvest.

Spectral composition and intensity of light on cell structures which are known as site of terpene formation can be explained for the oil percentage. light favours the formation of oil and stimulates the bio-chemical and physiological reactions during the bio-synthesis of oil. Thus, shorter period of sunshine due to clouds and more shade under trees, resulted in reduction of oil contents. These findings are in conformity with those of Dutt and Thakur (2004), Dabral, et.al. (1987) and Thakur and Dutt(2007).

Table 1: Total herb (fresh weight) and oil yield of aromatic grasses as affected by age and treatments in *Populus deltoids* and *Eucalyptus hybrid* plantations

Age (Months)	Herb Yield(q/ha)						Oil Yield(kg/ha)					
Treatments	12	24	36	48	60	72	12	24	36	48	60	72
C.winterianus (Pure)	160.4	250.5	265.1	200.0	-	-	128.3	200.4	212.1	160.0	-	-
C.martinii (Pure)	200.5	300.1	310.0	315.6	280.5	280.2	100.3	150.1	155.0	157.8	140.3	140.1
C.flexouses (Pure)	200.2	280.4	300.1	300.5	250.2	210.2	180.2	252.4	270.1	270.5	225.2	189.2
Poplar+C.winterianus	145.1	200.5	185.2	130.0	-	-	116.1	160.4	148.2	104.0	-	-
Poplar+C.martinii	180.4	240.5	217.2	158.2	140.1	140.6	90.2	120.3	108.6	79.1	70.1	70.3
Poplar+C.flexouses	180.5	238.6	240.5	240.0	175.4	147.8	162.5	214.7	216.5	216.0	157.9	133.0
Eucalyptus+C.winterianus	130.5	188.4	159.2	101.0	-	-	104.4	150.7	127.6	80.8	-	-
Eucalyptus+C.martinii	172.5	211.6	211.8	180.9	150.4	149.5	86.2	115.8	105.9	90.5	75.2	74.8
Eucalyptus+C.flexouses	170.7	210.2	186.8	142.5	118.9	114.7	153.5	189.2	168.1	128.3	107.0	103.2

For Fresh herb yield			For Oil yield	
	Poplar	Eucalyptus	Poplar	Eucalyptus
CD at 5% for stand age(a)	0.089	0.082	0.078	0.074
CD at 5% for species mixture(b)	NS	NS	NS	NS
CD at 5% for interaction (axb)	0.0281	0.245	0.362	0.391

Litter Production

The total annual litter production (t/ha/yr) was lower in the juveline stands but it increased significantly ($P<0.05$) over time. The higher litter productivity in the intercropped stands of trees in the present study was expected due to cultural operations given to aromatic grasses, which have ultimately helped the trees in producing more number of twigs and leaves and thus increased litter production. The maximum litter production in intercropped trees than their pure stands was also found by Mohsin, F. and Baburam (2002) and Mohsin (2005). Highest litter production by trees with *Cymbopogon martini* and lowest with *Cymbopogon winterianus*, among the intercropped trees (Table-2).

Table 2: Total litter production (t/ha/yr) in *Populus deltoids* and *Eucalyptus hybrid* as affected by age and treatments

Treatments/ Age (Months)	*Total litter production (t/ha/yr)* 12	*24*	*36*	*48*	*60*	*72*
Poplar+ C.winterianus	*1.52*	*2.32*	*3.24*	*4.92*	*5.14*	*5.66*
Poplar+ C.martinii	*1.85*	*2.91*	*3.97*	*6.18*	*7.41*	*8.22*
Poplar+ C.flexouses	*1.63*	*2.64*	*3.45*	*5.21*	*7.26*	*7.71*
Poplar (pure)	*1.36*	*2.16*	*3.14*	*4.61*	*5.12*	*5.55*
Eucalyptus+ C.winterianus	*0.52*	*0.69*	*2.38*	*4.21*	*6.11*	*7.68*
Eucalyptus+ C.martinii	*0.66*	*0.77*	*2.76*	*4.46*	*6.81*	*7.89*
Eucalyptus+ C.flexouses	*0.61*	*0.74*	*2.49*	*4.35*	*6.32*	*7.75*
Eucalyptus (pure)	*0.43*	*0.58*	*2.14*	*4.09*	*5.92*	*7.49*

	Poplar	*Eucalyptus*
CD at 5% for stand age(a)	*0.091*	*0.075*
CD at 5% for species mixture(b)	*NS*	*NS*
CD at 5% for interaction (axb)	*0.282*	*0.261*

But it is also revealed that Poplar and Eucalyptus intercropped with *Cymbopogon winterianus* did not produce much litter, due to no intercrop in the age of 60 and 72- months of trees. It indicates that trees with *Cymbopogon martini* have big and fully developed canopy. Similar studies were also reported by Issac, et.al, (2004).

Nutrient Concentration in Litter

The concentration(mg/g) of NPK in the litter was found to be higher in the intercropped than that of pure stands at all the ages. The values remained higher in the stands intercropped with *Cymbopogon*, being maximum in the *Cymbopogon martini* and minimum in *Cymbopogon winterianus*, intercropped stands of all the ages in comparison to pure plantation of Poplar and Eucalyptus(Table-3). The concentration of nutrients in the litter decreased significantly($P<0.01$) with increasing age of the stands. Concentration of N,P and K in leaf litter is related to stand age and decline with successive growth of the tree ,Mohsin,et. al. (1996). and Mohsin and Singh (2007). The proportion of mature leaves in plant increases with the advancement of its age and the litter produced by the older trees therefore contain comparatively lower nutrient concentration on N and K in the intercropped stands at various ages was found.

Addition of nutrients into the soil

Though the concentration of nutrients decreased with increasing age of the stands but their addition to the the soil through litterfall was increased significantly with increasing age (Table-4). This was due to significant increase in the total litter production and advancement of the age of the trees in the stands Mohsin and Baburam (2002),Halle et.al.,(1978) and Jennik(1977). Agroforestry practices increase the soil organic matter through litter production which is responsible to enhance the population of ben eficial microorganisms. The soil biological attributes are also responsible for determination and maintenance of physical properties of soil.

Rooting Pattern of Poplar and Eucalyptus

The age of trees had a significant effect on its total root system. The total root biomass of 2 and 3 years old Poplar trees was about 2.11 Kg and 6.30 Kg, respectively; which increased to 21.98 Kg in 4 years and 28.36 Kg in 5 years old trees (Table-5).

The increase in root biomass may be attributed to variation of the growth rate of trees with age. Generally, the growth rate remained higher during early stages, it became constant or decreased with the advancement in tree age. Similar results have been reported by McMinu(1963) for Douglas Fir, Ruark and Bockheim(1987 Mohsin et.al. (2020)) for *Populus tremuloides* and *Populus deltoids* . In 2 and 3 years old trees the total root biomass decreased continuously with increasing radial distance from the base at all the soil biomass increased in 50-100 cm than 0-50 cm distance and decreased further in 100-150 cm distance (Table-10).

The results further indicated that in early stages, the roots of the trees were mostly concentrated near the base of the trees while in the later stages (4 and 5 years), the root system tended to distribute uniformly around the tree. Similar results on radial root distribution have been reported in Citrus (Aiyappa and Srivastava, 1965; Aiyappa et.al.,1968 and Chandra et.al.,1979); mango (Bojappa and Singh, 1975) and Guava trees (Hedge,1980). It was also noticed that the total root biomass decreased continuously with increasing soil depth at all the age groups. Similar results on root distribution with vertical depths have been reported in Slash Pine (Schultz,1972), *Pinus sylvestris* (Robert,1976) and *Populus tremuloides* (Ruark and Bockheim,1987).

Table 3: Nutrient Concentration (mg/g) in litter fall of *Populus deltoids* and *Eucalyptus hybrid* as affected by age and treatments

Age (Months)	12			24			36			48			60			72		
Treatments	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
Poplar+ C.winterianus	1.08	0.11	0.76	0.93	0.09	0.68	0.66	0.08	0.54	0.53	0.07	0.49	0.42	0.07	0.41	0.37	0.06	0.34
Poplar+ C.martinii	1.17	0.11	0.82	1.07	0.10	0.77	0.78	0.09	0.68	0.69	0.09	0.61	0.54	0.08	0.56	0.51	0.07	0.47
Poplar+ C.flexouses	1.10	0.11	0.79	0.96	0.09	0.73	0.69	0.09	0.62	0.57	0.08	0.55	0.47	0.07	0.47	0.43	0.07	0.39
Poplar (pure)	0.96	0.10	0.71	0.84	0.08	0.63	0.51	0.08	0.49	0.42	0.07	0.42	0.36	0.06	0.35	0.29	0.05	0.36
Eucalyptus+ C.winterianus	8.9	0.53	7.1	7.4	0.46	6.2	6.7	0.42	5.6	6.1	0.38	5.2	5.5	0.36	4.8	4.5	.45	4.3
Eucalyptus+ C.martinii	9.3	0.55	7.3	7.7	0.48	6.4	7.1	0.46	6.1	6.4	0.43	5.8	5.8	0.41	5.2	4.8	.48	4.5
Eucalyptus+ C.flexouses	9.2	0.54	7.2	7.6	0.47	6.3	6.8	0.44	5.9	6.2	0.41	5.5	5.7	0.39	4.9	4.6	0.46	4.4
Eucalyptus (pure)	8.4	0.48	6.8	7.0	0.41	5.9	6.4	0.38	5.4	5.8	0.35	4.9	5.1	0.34	4.5	4.3	0.43	3.9

	Poplar			Eucalyptus		
	N	P	K	N	P	K
CD at 5% for stand age(a)	0.351	NS	NS	0.481	0.522	0.589
CD at 5% for species mixture(b)	0.582	NS	0.575	0.612	NS	0.591
CD at 5% for interaction (axb)	NS	NS	NS	NS	0.489	NS

Table – 4. Total addition of nutrients through litterfall (kg/ha/yr) of Populus deltoids and Eucalyptus hybrid as affected by age and treatments

Age (Months)	12			24			36			48			60			72		
Treatments	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
Poplar+ C.winterianus	16.09	1.54	11.40	21.41	2.16	17.32	27.96	2.52	22.41	32.14	2.93	28.64	37.42	3.84	32.46	34.42	4.22	36.71
Poplar+ C.martinii	20.08	2.04	15.22	24.92	2.71	23.22	31.42	3.15	25.91	37.11	4.17	31.11	41.25	5.12	36.94	39.64	6.52	39.11
Poplar+ C.flexouses	17.61	1.81	12.49	23.12	2.32	19.12	29.16	2.86	23.89	34.63	3.42	30.21	39.71	4.26	34.16	37.53	5.27	37.13
Poplar (pure)	14.25	1.22	11.23	18.66	2.07	16.86	24.25	2.41	21.32	29.78	2.69	27.92	35.89	3.69	31.55	30.91	4.11	35.21
Eucalyptus+ C.winterianus	6.14	0.36	4.89	17.61	1.09	14.75	24.52	1.26	20.55	29.61	1.96	26.35	33.77	2.33	29.47	34.60	2.69	33.06
Eucalyptus+ C.martinii	6.78	0.40	5.32	21.17	1.32	17.60	28.69	1.89	25.92	33.24	2.34	27.96	35.72	2.46	30.80	37.82	2.91	35.46
Eucalyptus+ C.flexouses	6.53	0.38	5.11	18.46	1.14	15.30	25.72	1.46	24.11	31.46	2.21	28.87	35.05	2.39	30.12	35.55	2.78	34.01
Eucalyptus (pure)	5.71	0.32	4.60	16.17	0.94	13.62	22.42	1.16	19.47	27.56	1.85	22.31	31.21	2.08	27.54	32.89	2.37	29.83

	Poplar			Eucalyptus		
	N	P	K	N	P	K
CD at 5% for stand age(a)	0.812	0.816	0.831	0.749	0.942	0.712
CD at 5% for species mixture(b)	1.012	1.012	1.118	1.031	1.071	1.214
CD at 5% for interaction(axb)	2.234	2.149	2.349	2.142	2.246	2.546

Considering all the factors of root system together, the Poplar trees may be classified as shallow rooted because more than 75 percent of the total root biomass was located in 75 cm soil depth within 100 cm radial distance.

Table 5: Root Biomass (gm) of *Populus deltoids* trees under different age groups, radial distances, soil depths and root grades

Variables	Age of Populus deltoids (months)			
	24	36	48	60
Radial Distance(cm)				
0-50	950.0 (45.09)	2884.6 (45.52)	8685.6 (39.50)	11056.0 (38.98)
50-100	685.5 (32.51)	2039.4 (32.18)	9042.1 (41.12)	11302.7 (39.85)
100-150	472.5 (22.41)	1413.7 (22.31)	4259.5 (19.37)	6001.5 (21.16)
Soil Depth(cm)				
0-15 d1	1100.8 (52.20)	3303.8 (52.13)	14715.7 (66.93)	15447.2 (54.47)
15-45 d2	656.5 (31.13)	1960.9 (30.94)	5525.4 (25.13)	7781.9 (27.44)
45-75 d3	260.7 (12.36	795.8 (12.56)	1112.7 (5.08)	3086.4 (10.88)
75-105 d4	90.8 (4.31)	277.2 (4.37)	633.4 (2.88)	2044.7 (7.21)
Root Grades				
Fibrous g1	57.4 (2.72)	173.4 (2.74)	728.1 (3.31)	1079.6 (3.81)
Thin g2	195.5 (9.27)	567.1 (8.95)	2291.1 (10.42)	3030.2 (10.69)
Medium g3	416.0 (19.73)	1282.6 (20.24)	2466.1 (11.22)	3831.2 (13.51)
Thick g4	1439.9 (66.28)	4314.6 (66.08)	16501.9 (75.05)	20418.8 (71.99)
Total (gm/tree)	2108.8 (100)	6337.7 (100)	21987.2 (100)	28360.2 (100)

Poplar have well developed tap roots and is capable of surviving on deep and relatively dry sites. However, this tree species, besides its well developed tap roots,also have extensive lateral and sinker roots,that permit them to flourish on shallow soils and soil with fluctuating water tables. As evident from the results on root biomass the age of the trees had significant effect on the total root system of *Eucalyptus* trees. The total root biomass is also given in Table-6 , at various age groups in gm/tree.

Regarding the radial distribution of the roots, the results indicated that in all the age group of trees the total root biomass decreased continuously with increasing radial distance from the tree base at all the soil depths. The results indicated that as the age of trees increased, the radial span of roots also increases. Regarding, the vertical distribution of the roots of the *Eucalyptus*, the results indicated that the total root biomass decreased continuously with increasing soil depth at all the radial distances and under all the ages. According to Zohar (1985), concentration of most roots were reported at a depth of 40-80 cm in *Eucalyptus*.

Table – 6. Root Biomass (gm) of Eucalyptus trees under different age groups, radial distances, soil depths and root grades

Variables	Age of Eucalyptus (months)			
	24	36	48	60
Radial Distance(cm)				
0-50	881.2 (62.13)	3232.7 (62.74)	8635.8 (44.26)	10571.9 (43.13)
50-100	361.8 (25.51)	1245.5 (24.17)	6060.6 (31.06)	7649.7 (31.20)
100-150	175.3 (12.36)	674.6 (13.09)	4812.5 (24.67)	6289.0 (25.65)
Soil Depth(cm)				
0-15 d1	921.8 (64.99)	3171.7 (61.55)	8622.9 (44.20)	10946.4 (44.66)
15-45 d2	397.1 (28.00)	1396.5 (27.10)	5159.2 (26.45)	6362.0 (25.96)
45-75 d3	91.7 (6.47)	420.8 (8.17)	3483.5 (17.86)	4383.2 (17.88)
75-105 d4	7.7 (0.54)	163.8 (3.18)	2243.3 (11.49)	2819.0 (11.50)
Root Grades				
Fibrous g1	45.4 (3.20)	169.6 (3.29)	301.1 (1.54)	368.7 (1.50)
Thin g2	101.4 (7.15)	372.8 (7.29)	638.0 (3.27)	769.6 (3.13)
Medium g3	688.9 (48.57)	2556.7 (49.62)	3259.1 (16.70)	3887.7 (15.86)
Thick g4	582.6 (41.08)	2053.7 (39.86)	15310.7 (78.48)	19484.6 (79.49)
Total (gm/tree)	1418.3 (100)	5152.8 (100)	19508.9 (100)	24510.6 (100)
Values in paranthesis indicate the percentage of total root biomass				

CONCLUSION

This indicated that *Eucalyptus* has superficial root system. The results further indicated that the major part of the root system of juvenile age groups was made up of medium roots (0.5-1.5); while in old age groups the major part of the root system was made up of thick roots (>1.5cm). It is well known that the trees which develop strong tap roots are capable of penetrating the soil to greater depths for anchorage and moisture; so *Eucalyptus* survives well on relatively dry sites.

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