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Effects of Coppicing on the Growth and Distribution of Hybrid Poplar Roots[1)]

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맹아유도가 잡종 포플러 뿌리생장 및 분포에 미치는 영향[1)]

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Summary

Coppicing markedly reduced root growth for all clones and densities of hybrid poplar at two locations. Larger total root weight was shown for the Iowa plot than for the Wisconsin plot. The lowest density yielded the larger root weight. Clone NC−5323 produced the largest total root weight before coppicing, whereas clone NC−5377 produced the largest after coppicing. Results obtained by core sampling indicated that most root weight was concentrated in the top soil and near the tree stem. Mixed planting of clones having different rooting habits is suggested for better utilization of soil horizons.

Introduction

The close association of root development with above−ground tree growth has been examined for a number of plants (Foth, 1962 ; Eliasson, 1968 ; Troughton, 1974). Root systems serve as absorbing organs for water and mineral nutrients, as anchoring structures for supporting shoot systems, and as synthesis sites for growth regulators required by both roots and shoots. Shoots are important sources of photosynthate and hormons for roots. The above−ground biomass production from coppice regeneration is even related more to the characteristics of root systems than originally thought to be(Bedeneau and Auclair, 1989; Fownes and Anderson, 1991).

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Therefore, information on root growth responses influenced by coppicing is of practical importance to intensive culture of woody plants under short rotation. This study was done to compare root growth and distribution of four hybrid poplar clones before and after coppicing in three planting densities at two locations.

Materials and Methods

The study was conducted on two *Populus* plantations growing on a silt loam soil in Ames, Iowa, and on a loamy sand soil in Rhinelander, Wisconsin. Each plantation consisted of a split−plot design with two replicates and four clones planted at three densities : 5,000, 10,000, and 15,000 trees per hectare (Rose and Promnitz, 1975). The four *Populus* x *euramericana* hybrids were clone NC − 5377, clone NC − 5321, clone NC−5323, and clone NC−5326. All trees were cut at 10 cm above the soil surface during December at the end of the third year.

Roots were sampled for three trees for each clone and spacing giving a total of 36 sample trees.

The root sampling area was divided into three strata by increasing distance from the sample tree. Because of evidence from a previous study (Lee and Promnitz, 1978) that most root weight was concentrated near the tree stump in large roots including root stock, soil core sampling was not done in the immediate stump area (stratum 1 in Figure 1). Soil core samples were randomly located in strata 2 and 3, and extracted from each stratum at three depths (Figure 1).

Except for sample collections at the Ames plantation, the methods for sampling, processing, and estimation of number and dry weight of roots were the same as those used in previous study (Lee and Promnitz, 1978). At the Ames plantation, soil core sampling was done around three sample trees at the end of the third year just prior to coppicing. After coppicing two trees chosen randomly from the tree selected sample trees were used.

In addition, root systems of all sample trees were excavated to approximately the same distance from the stem and the same depth from the soil surface as defined for core sampling.

Results

Horizontal and vertical distribution of roots. The number of total root, roots greater than 1 cm in diameter, and dry weight decreased with increasing distance from the tree stem both before and after coppicing except for the total root number after coppicing (Table 1). These differences were significant before coppicing for all variables, but only for root dry weight after coppicing. In general, among clones, root numbers showed a small decrease with increasing distance from the stem, but root dry weight decreased greatly (Table 2).

All root growth variables tended to decrease with increasing depth from the soil surface, and differences were highly significant (Table 1). A similar trend was shown in most clones except for the root dry weight variable of clone NC−5323 after coppicing (Table 3).

Root dry weights of clones NC−5377 and NC−5323 decreased with increasing depth before coppicing, but only the root dry weight of clone NC−5323 increased with increasing depth after coppicing.

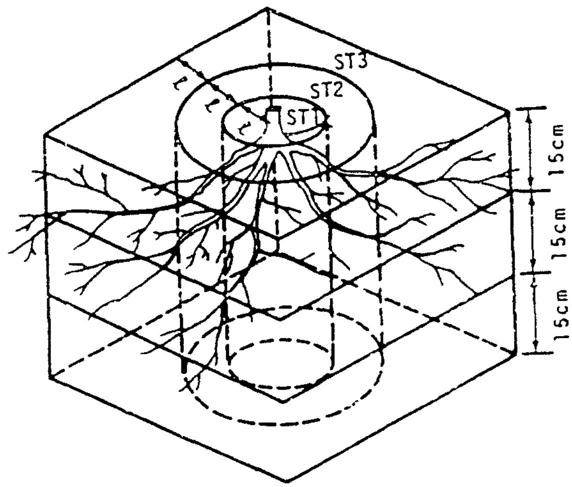

Figure 1. Diagram for soil core sampling. Three strata (ST1, ST2 and ST3) and three depths were defined by increasing distance from the sample tree and from the soil surface, respectively. The distance, *l*, changes with the planting density, 23.6cm for 5,000 trees/ha, 16.7cm for 10,000 trees/ha, and 13.6 cm for 15,000 trees/ha

Table 1. Means of root variables by strata and by depths for the core measurements before and after coppicing

	Total root no.		No. of roots(>1cm in diameter)		Root dry wt. (mg)	
	Before	After	Before	After	Before	After
Strata*						
2	47.3	35.0	8.3	6.4	69.1	47.6
3	41.9	36.6	6.9	6.2	17.4	18.4
	0.003[a]	0.511	0.001	0.578	0.000	0.008
Depths(cm)						
0−15	75.8	58.2	10.8	8.2	76.6	50.3
15−30	41.5	31.4	7.6	5.9	41.5	29.2
30−45	16.5	17.8	4.4	4.7	11.7	19.6
	0.000[b]	0.000	0.000	0.000	0.000	0.000

* Strata 2 and 3 indicate a radical distance from the stem, and the distance changes with the planting density ; distances for strata 2 and 3 are 23.6 to 47.2 cm and 47.2 to 70.7 cm for 5,000 trees/ha, 16.7 to 33.4 cm and 33.4 to 50.0 cm for 10,000 trees/ha, and 13.6 to 27.2 cm and 27.2 to 40.7 cm for 15,000 trees/ha, respectively.

a and b indicate significance level between strata and among depths, respectively.

Table 2. Root means of clones by strata for the core measurements before and after coppicing

Clones	Strata	Total root no.		No. of roots(> 1cm in diameter)		Root dry wt. (mg)	
		Before	After	Before	After	Before	After
5377	2	45.4	39.0	7.9	6.1	84.7	72.6
5377	3	41.3	39.7	7.3	6.0	15.6	33.4
5321	2	50.1	36.7	8.1	6.9	40.5	35.1
5321	3	40.0	33.6	5.9	6.2	14.0	8.9
5323	2	51.2	35.5	10.4	6.8	92.7	36.1
5323	3	42.9	41.2	7.6	7.2	22.6	18.1
5326	2	42.6	28.8	6.9	5.6	58.4	46.6
5326	3	43.3	31.9	6.7	5.2	17.5	13.4

Table 3. Means of root variables for clones by depths before and after coppicing

Clones	Depths (cm)	Total root no.		No. of roots(> 1cm in diameter)		Root dry wt. (mg)	
		Before	After	Before	After	Before	After
5377	0−15	73.7	66.1	11.4	9.0	90.9	89.9
5377	15−30	41.1	33.2	7.4	5.1	50.2	53.4
5377	30−45	15.4	18.8	4.0	4.0	9.4	15.7
5321	0−15	76.9	50.1	9.7	7.3	39.3	37.9
5321	15−30	42.1	34.3	7.4	6.7	33.3	20.5
5321	30−45	16.2	21.1	3.9	5.6	9.1	7.4
5323	0−15	79.7	68.6	12.5	9.2	99.2	21.7
5323	15−30	42.7	29.5	8.9	6.0	51.9	21.9
5323	30−45	18.9	16.9	5.6	5.9	21.8	37.7
5326	0−15	73.1	47.9	9.5	7.4	77.0	51.6
5326	15−30	39.9	28.7	6.8	5.6	30.4	21.0
5326	30−45	15.8	14.4	4.0	3.4	6.4	17.5

Effects of density on root growth. Tree density did not significantly affect root growth variables (Table 4). This was probably because of similar amounts of roots distributed in strata 2 and 3 for all densities at this stage.

Accuracy of estimated dry weight. Root dry weight estimated by sampling was compared with the actual measured weight for selected trees. Sample estimates were not significantly different from the actual measurements (Table 5). Thus, the accuracy in estimation of root dry weights was increased because core sampling was done without the immediate stump area.

Total root dry weight between locations, among densities, and among clones. Greater total dry weight of roots was shown at the

Ames plot than at the Rhinelander plot (Table 6). The differences were not significant at the 5 percent level in the first and second years before coppicing but were significant in the third year before coppicing and in the first year after coppicing.

Total dry weight of roots for individual trees decreased with increasing planting density both before and after coppicing (Table 6). This relationship was evident when either locations or clones were compared.

Although clonal differences in total root dry weight were highly significant, none of the clones showed a consistently high dry weight. Clone NC−5323 had the greatest dry weight in the first year, clone NC−5326 in the second year, clone NC−5323 in the third year after planting, and clone NC−5377 in the first year after coppicing (Table 6). All clones performed similarly in both locations.

Few interaction effects were significant and generally could be explained by random variation and small sample sizes. The location by density interaction of total root dry weight (Figure 2) may be due to the difference in tree sizes between Ames and Rhinelander. The interaction effects of strata by depths on root dry weight (Figure 3) were not because of decreasing mean response in one stratum and increasing mean response in another stratum as soil depth increased, but rather because more roots were distributed near the tree stem (stratum 2 in Figure 1) where competition was more severe, and thus differences between strata became smaller as soil depth increased.

Table 4. Effect of tree density on root growth before and after coppicing

Densities (Trees/ha)	Total root no.		No. of roots (> 1cm in diameter)		Root dry wt. (mg)	
	Before	After	Before	After	Before	After
5,000	39.9	43.3	7.1	6.5	30.0	34.1
10,000	42.9	28.5	7.7	5.9	58.9	34.6
15,000	51.1	35.6	7.9	6.4	40.8	30.4
	0.46[a]	0.35	0.75	0.23	0.11	0.88

[a] indicates significance level among densities.

Table 5. Root dry weight estimated by sampling technique compared with actual measured weight

Sample tree number	Estimated weight (g)	Actual weight (g)
1	548.3	320.6
2	483.5	499.6
3	209.1	226.7
4	177.4	159.6

Table 6. Means for locations, densities, and clones for total root dry weight of individual trees before and after coppicing

Source	Total root dry weight (g)			
	Before			After
	Year 1	Year 2	Year 3	Year 1
Locations				
Ames	9.3	225.8	625.6	406.0
Rhinelander	4.9	89.7	198.4	273.7
	0.534[a]	0.056	0.007	0.034
Densities				
5,000 trees/ha	8.4	216.1	567.2	519.8
10,000 trees/ha	5.8	141.9	403.2	289.8
15,000 trees/ha	7.2	115.3	265.7	209.8
	0.379[b]	0.017	0.011	0.000
Clones				
5377	5.7	175.6	451.8	410.8
5321	6.0	97.8	281.4	262.2
5323	9.4	157.5	489.4	333.4
5326	7.5	200.1	425.5	353.0
	0.020[c]	0.000	0.002	0.002

a, b, and c indicate significance level between locations, among densities, and among clones, respectively.

Discussion

All root growth variables decreased with both increasing distance from the tree stem and increasing depth from the soil surface before coppicing. This decreasing trend with increasing distance from the stem was similar to the results in earlier experiments (Lee and Promnitz, 1978). When the root growth change between two years was compared, the average values of root numbers in the third year were smaller than those in the second year, whereas average root dry weight in the third year was larger than that in the second year. This may be attributed to roots becoming thicker and branching less as the tree grows.

For the vertical distribution, root dry weight was mostly concentrated in the top 30 cm of soil. Similar results were reported by Bowen (1964) with monterey pine, and by Safford and Bell (1972) with white spruce. They observed that most of the fine root weights were distributed in the surface 30 to 45 cm. This was probably in part due to better nutrient level and aeration at the surface soil.

After coppicing, the decreasing trends for root variables were similar to those found before coppicing except for the horizontal distribution of total root number. Coppicing caused a large decrease in most root varia bles. This was generally expected because roots could not grow when shoots were removed (Eliasson, 1968; Bedeneau and Auclair, 1989), presumably because of a marked depletion of carbohydrate reserves stored in the root system. Therefore, many growing roots probably died, which resulted in a large decrease in root mass. This result was similar to that reported by Visser (1969) who found that root weights were reduced by removal of shoots on tea plants. Living nodule biomass decreased and dead nodule biomass increased significantly after coppicing in both *Sesbania* and *Leucaena* species(Fownes and Anderson, 1991). In contrast to this, root weight, after coppicing, in the farthest stratum (3) from the tree and all root variables at the lowest soil depth exhibited greater values than those in the year just prior to coppicing. This implies that the growth of deeply penetrating roots may be less influenced by removal of shoots than growth of roots distributed shallowly. Also, root dry weight at Rhinelander showed an increase after coppicing and was shallowly distributed. This increase and the shallow distribution of roots at the Rhinelander plot may be due to frequent irrigation.

Clone NC−5377 showed increased growth in both horizontal and vertical distribution of root weights after coppicing, whereas clones NC−5323 and NC−5326 exhibited increased growth in the vertical distribution. Since clone NC−5323 showed severe incidence of canker and high mortality (Lee, 1988), mixed planting of clone NC−5377 with clone NC−5326 might be recommended for better utilization of soil spaces for root growth.

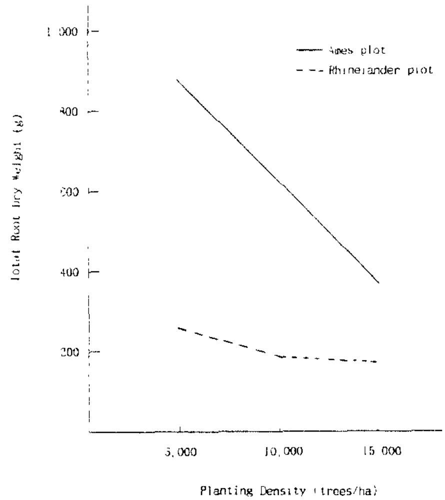

Figure 2. Comparison of total root dry weight per tree for the two locations at each density in the third year after planting

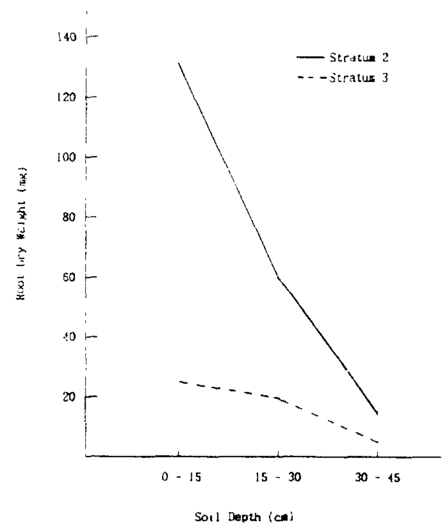

Figure 3. Comparison of root dry weight measured from soil cores for the two strata (distances from the stem) at three soil depths in the third year after planting

Conclusion

Larger total root weight was produced at the Ames plot than at the Rhinelander plot both before and after coppicing. Root weights decreased after coppicing at the Ames plot, but increased at the Rhinelander plot. This increase at the Rhinelander plot is possibly due to frequent irrigation. The lowest density (5,000 trees/ha) yielded the greatest root weight per tree except for the first year. Clone NC−5323 produced the largest root weight before coppicing, and clone NC − 5377 produced the largest after coppicing.

Root number and root dry weight in a given core generally decreased with both increasing distance from the tree stem and increasing depth from the soil surface. Most root weight was concentrated in the top soil, probably because of better nutrient, aeration, and available moisture at the surface soil.

A mixed planting of clone NC−5377, with seems to have a horizontally oriented root system, with clone NC−5326 which seems to have a vertical root system, is recommended to reduce competition between the trees and also to allow a better utilization of soil water and nutrients.

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요 약

맹아유도(coppicing)는 두 지역의 잡종 포플러 식재지에서 모든 클론과 모든 식재밀도에서 뿌리 생장을 현저히 감소시켰다. 총뿌리 무게를 비교해 볼 때 Iowa 식재지가 Wisconsin 식재지보다 훨씬 컸다. 가장 낮은 식재 밀도(ha당 5000그루)에서 뿌리의 무게가 가장 컸다. 클론 5323호가 맹아유도하기 전에는 뿌리의 무게 생장이 가장 우수했으나 맹아유도 후에는 클론 5377호가 가장 우수했다. 표본을 추출(core sampling)하여 얻은 결과로 볼 때, 뿌리의 무게는 지표층(상층) 토양과 나무 줄기 주위에 가장 많이 집중되어 있었다.

이 연구에서 토양층을 보다 효과적으로 이용할 수 있다는 점에서 뿌리 뻗음이 다른 특성을 가진 클론을 같이 혼식하는 것을 추천한다.

Literature Cited

1. Bedeneau, M. and D. Auclair. 1989. Effect of coppicing on hybrid poplar fine root dynamics. Pages 294 − 296 *in* Forest Tree Physiology. Proc. Int. Symp., 25 − 30 September, 1988, Nancy, France.

2. Bowen, G. D. 1964. Root distribution of *Pinus radiata*. Commonwealth of Australia, CSIRO Division of Soil, Divisional Report 1/64, 14pp.
3. Eliasson, L. 1968. Dependence of root growth on photosynthesis in *Populus tremula*. Physiologia Plantarum 21(4): 806−810.
4. Fownes, J. H. and D. G. Anderson.

1991. Changes in nodule and root biomass of *Sesbania sesban* and *Leucaena leucocephala* following coppicing. Plant and Soil 138(1) : 9 – 16.

5. Lee, D. K. 1988. Leaf biomass yield and coppice growth of Poplar hybrids. Swedish University of Agricultural Sciences, Department of Ecology and Environmental Research, Energy Forestry Project, Report 44. Uppsala, Sweden. 21pp.
6. Lee, D. K., and L. C. Promnitz. 1978. Sampling and estimation of hybrid poplar root systems. Iowa State Journal of Research 53(1) : 1 – 12.
7. Rose, D. W., and L. C. Promnitz. 1975. Verification of a forest stand simulation model. Angewandte Botanik 49 : 1–10.
8. Safford, L. D., and S. Bell. 1972. Biomass of fine roots in a white spruce plantation. Canadian Journal of Forest Research 2(3) : 169–172.
9. Troughton, A. 1974. The growth and function of the root in relation to the shoot. Pages 153–164 *in* Structure and Function of Primary Root Tissues. J. Kolek, ed. Vida, Publishing House of the Slovak Academy of Science, Bratislava.
10. Visser, T. 1969. The effect of root and shoot damage on the growth of tea plants. Netherlands Journal of Agricultural Science 17(3):234–240.