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Alnus subcordata C.A.M. Cambium Cells Dynamics Along Transport Corridors in Hyrcanian Forests

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Abstract: Problem statement: In this study, we considered transport corridors and sampling aspects to be the major indicators of ecological effects on Alder (*Alnus subcordata*) cambium cells dynamics. **Approach:** Thus, 240 cores were taken from forest-facing and road-facing trunk of Alder trees along Amre, Neka and Darab Kola transport corridors in hyrcanian Forests of Iran. Results showed that the roads corridor had significant effects on *Alnus subcordata* annual rings ($p = 0.04$) and bark growth ($p<0.0001$). **Results:** In Darab Kola and Neka the bark thickness in road-facing aspect was significantly ($p<0.05$) more than forest-facing aspect because of consistency reaction to natural hazards. Annual rings width in adjacent stand was significantly ($p<0.05$) more than the rings width at both sides of trees trunk along transport corridors. **Conclusion:** Cambium cells dynamic diagram in production of annual rings indicated that the *Alnus subcordata* at commence of growth had been produced wide rings but in continuance the rings width reduced. This reduction was obviously for road-facing cores. Soil compaction, drainage structures, natural hazards and etc caused the thinner rings to be produced by cambium cells in road-facing aspect.

Key words: *Alnus subcordata*, cambium cells, annual rings, bark, transport corridor

INTRODUCTION

Transport corridors are becoming a focus of ecological research because of their distinctive structure, function and impact on surrounding ecosystems[12]. Forman and Alexander[8] defined road corridors as pavement or unpaved plus managed roadsides and parallel vegetated strips along the roadside that extend up to the end of the right-of-way usually terminated by forest, lake, agricultural or other natural boundaries. Transportation corridors alters disturbance regimes in adjacent plant communities, both directly by creating gaps and by changing the plant composition[16], and indirectly by altering environmental conditions such as light, soil moisture and bulk density[6,10,13,18].

Alnus subcordata, Caucasian Alder, is a species in the family Betulaceae, native to temperate areas of Iran and the Caucasus. It is a deciduous tree growing to 15-25 m tall, closely related to the Italian Alder (*A. cordata*), with similar glossy green cordate leaves 5-15 cm long. The flowers are catkins, the male catkins very slender, 8-15 cm long, and the female catkins small, maturing into a woody cone-like fruit 2-3 cm long containing numerous small winged seeds. Alder tree is a stabilizer of nitrogen and often appear in the edge of the hyrcanian forest road after construction[11].

Cambium is the thin growth layer that produces the phloem (outward towards the bark) and the xylem (inward towards the center) (Fig. 1). Damage to the cambium can weaken or kill a tree because new phloem and xylem will not be produced, preventing food and water transport. Common forms of damage are wounds by road construction and compaction. Growth cycles in

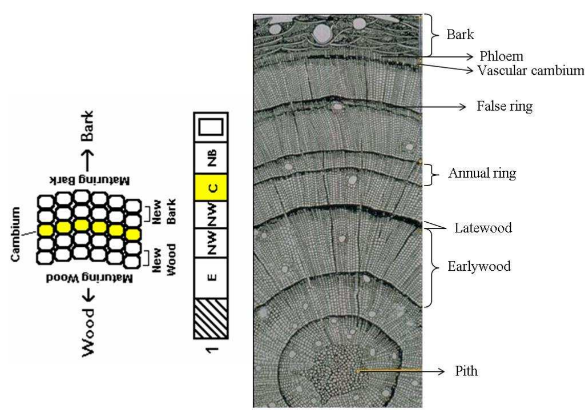

Fig. 1: Cross section of a conifer

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trees are regulated by the seasonality of climate. In the temperate climate zones such as hyrcanian forest of Iran, tree-ring formation is limited to the vegetation period, which roughly lasts from spring to autumn. During the vegetation period, tree-ring formation is driven by a meristem called the vascular cambium. This tissue is located between the secondary xylem (wood) and the secondary phloem (bark) and divides off cells that will be become additional xylem and phloem[5,14].

We carried out a research study to monitor effects of transport corridors on *Alnus subcordata* cambium cells dynamics in three sites of hyrcanian forests of Iran. In this study, we considered transport corridors and sampling aspects to be the major indicators of ecological effects on Alder rings and bark growth. Our aims were to (i) assess alder distribution along transport corridors; (ii) determine effects of forest roads on annual rings growth pattern; (iii) evaluate bark thickness for forest-facing and road-facing cores.

MATERIALS AND METHODS

Study area: The study sites are located in the northern forests of Iran and near the Caspian Sea (Fig. 2). The roads type in Amre and Darab Kola was unpaved and in Neka site was paved or asphalted. The height of forest sites at sea level starts from 260 m and continues to 883 m. The average slope of forest fields is about 40% (Min. 5% and Max. 80%). The mean annual precipitation was ranged from 750-1110 mm. Table 1 shows other characteristics of study areas. The experimental road section situation in all of the sites was from southeastern to northwestern.

Data collection: At each site, a sampling design consisted of two transects. First transect was established along transport corridor and the second transect was placed in the vicinity of the first transect into the forest stand. In each transect 10 circular plots with a size of 500 m^2 were chosen. In each plot healthy and cylindrical Alder trees were numbered. Then, two Alder trees were selected with a simple randomize sampling method. The diameter of these trees was measured by means of the caliper and two cores were taken by means of the increment borer from two opposite sides of all trees (Forest-facing and road-facing cores) at standard breast height (Totally 240 cores were taken from three sites). Each core was dried, mounted and glued to a wooden core mount. Cores were sanded with sandpaper until the cellular structure of the tree rings was distinguishable. Variations in year to year ring widths for each core were recorded and then pooled to create a visual live-tree chronology of *Alnus subcordata* at each site.

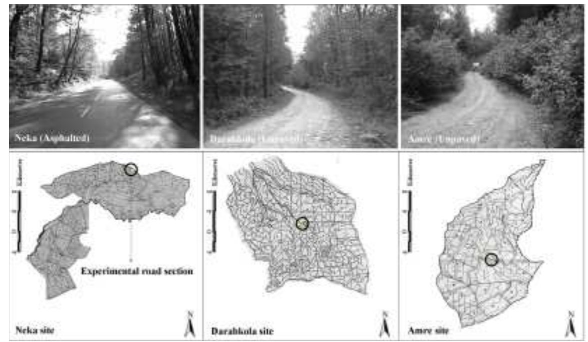

Fig. 2: Location of the study area in the north of Iran

Table 1: Characteristics of study sites

Forest	Geographical position	Temperature range	Soil type
Amre	53°55′-53°85′ E N ′27°-36 ″30′ 25°36	2-27.4°C	Non development randzin to washed randzin soil
Neka	53°30′ -53°44′ E N ″27 ′27°-36″7 ′23°36	0.4-28.4°C	Brown and washed brown forest soil with pseodoglay
Darab Kola	52°14′ to 52°31′ E N ″30 ′33°36-″20 ′33°36	-3-28°C	Non development randzin to washed randzin soil

Statistical analysis: All statistics were calculated with EXCEL and SAS software. Analysis of variance (ANOVA) was used to determine the effects of forest roads on annual rings growth and bark thickness. Wherever treatment effects were significant the Duncan's Multiple Range Test at probability level of 5% was carried out to compare the means.

RESULTS AND DISCUSSION

Alder distribution and density along transport corridor: In this study the *Alnus subcordata* (Alder) distribution and density was clearly related to distance from the transport corridors. At three sites the Alder was most prevalent within 0-10 m of the roadsides. In Amre the density of *Alnus subcordata* in the distance of 0-5 m was more than other distances from road edge. But in Darab Kola and Neka, Alder was most prevalent within the 5-10 m (Fig. 3).

Effects of transport corridor and sampling aspect: Analysis of variance showed that the roads corridor had significant effects on *Alnus subcordata* annual rings ($p = 0.04$) and bark growth ($p<0.0001$). Also, the amount of bark thickness was significantly ($p<0.0083$) influenced by sampling aspects (forest-facing or road-facing cores) (Table 2).

Bark and annual rings growth of *Alnus subcordata*: Table 3 summarizes vegetative characteristics of Alder trees and roads data for the three study areas. On

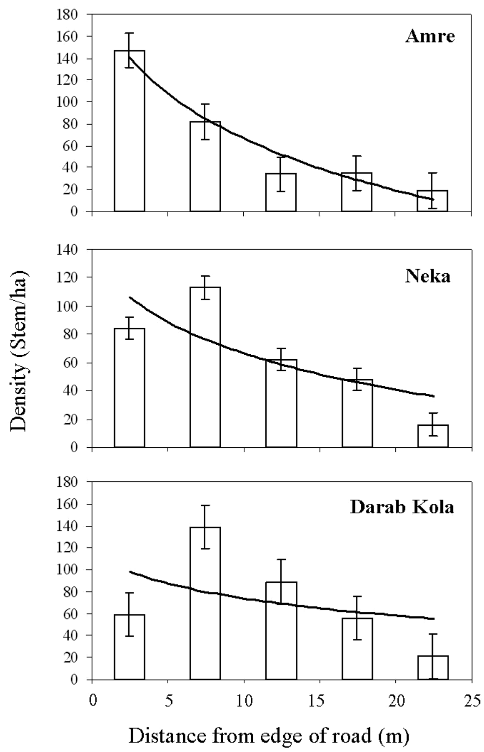

Fig. 3: Alder (*Alnus subcordata*) distribution and density along transport corridors

Table 2: ANOVA for *Alnus subcordata* growth parameters

Parameter	Source	df	SS	MS	F
	Road corridor	2	7.19	3.59	3.31*
Tree rings width	Sampling aspect	1	1.19	1.19	1.10 ^{ns}
	Road. Aspect	2	0.72	0.36	0.33 ^{ns}
	Road corridor	2	103.73	51.87	14.10***
Bark thickness	Sampling aspect	1	26.32	26.32	7.15 **
	Road. Aspect	2	5.85	2.93	0.80 ^{ns}

Table 3: Description of the Alder trees and roads studied

	Alnus subcordata (Alder)			Road	
Site	Dbh (cm)	Height (m)	Age (year)	Construction time	Type
Amre	23.05	14.66	19	1985	Unpaved
Neka	28.93	16.43	35	1970	Asphalted
Darab Kola	27.38	15.21	34	1971	Unpaved

average in each of the sites, bark thickness in road-facing aspect of trees trunk which were located along transport corridors was significantly ($p<0.05$) more than the bark thickness in adjacent stand at both sampling aspects of trees. Also, annual rings width in adjacent stand was significantly ($p<0.05$) more than rings width at both sides of trees along transport corridors (Table 4).

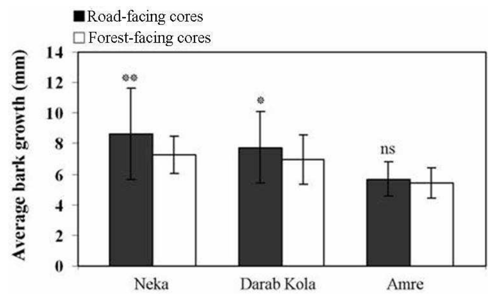

Fig. 4: Comparison of bark thickness for forest-facing and road-facing cores

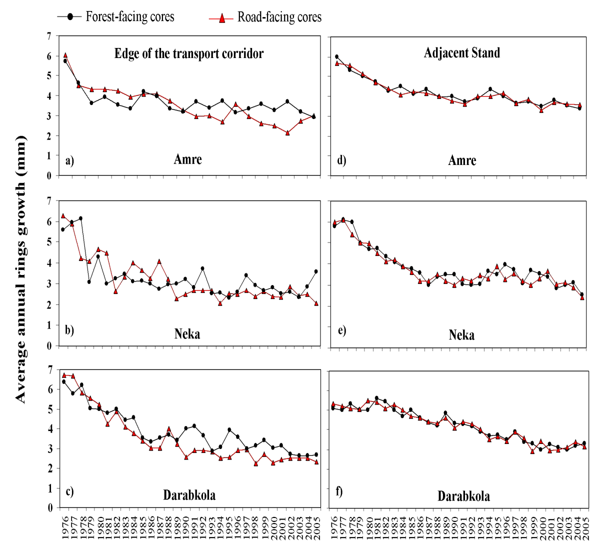

Fig. 5: Comparison of annual rings width for forest-facing and road-facing cores

Cambium cells dynamics along transport corridor: In Amre forest, there was no significant difference ($p>0.05$) in bark thickness between the Forest-facing and road-facing cores, whereas in Darab Kola and Neka the bark thickness for road-facing cores was significantly ($p<0.05$) more than forest-facing cores (Fig. 4). Cambium cells dynamic diagram in production of annual rings indicated that the *Alnus subcordata* at commence of growth had been produced wide rings but in continuance the rings width reduced. This reduction was obviously for road-facing cores (Fig. 5).

Our study has demonstrated that transport corridor influences Alder tree rings and bark growth. As Hosseini and Jalilvand[11] have suggested, growth of *Alnus subcordata* rings in the forest-facing was greater than those which were in road-facing. They concluded that because of lack of forest road maintaining and repairing operations in suitable periods and tracks

Table 4: Comparison of bark and rings growth in the road edge and adjacent stand

Site	Aspect	Bark growth (mm)		Annual rings growth (mm)	
		Road edge	Adjacent stand	Road edge	Adjacent stand
Amre	Forest-facing	5.44[a]±0.07	5.41[a]±0.05	3.67[a]±0.06	4.20[b]±0.05
	Road-facing	5.69[a]±0.08	5.37[b]±0.06	3.53[a]±0.08	4.16[b]±0.04
Neka	Forest-facing	7.30[a]±0.13	7.38[a]±0.10	3.27[a]±0.06	3.81[b]±0.07
	Road-facing	8.63[a]±0.16	7.54[b]±0.13	3.19[a]±0.04	3.75[b]±0.06
Darab Kola	Forest-facing	6.96[a]±0.10	7.03[a]±0.14	3.87[a]±0.07	4.21[b]±0.05
	Road-facing	7.76[a]±0.15	7.24[b]±0.12	3.51[a]±0.09	4.21[b]±0.09

In a row, means with the same letter(s) are not significantly different at 5% level based on duncan test

traffic, the soil compaction increased and as result the tree growth around the roads decreased.

Bark protects both the living phloem and the vascular cambium of trees. For some tree species the bark has been observed to swell in the radial direction when heated by nearby flames, possibly providing additional protection from thermal injury[19].

The results of this study showed that the amount of bark thickness was influenced by sampling aspects. In Darab Kola and Neka the bark thickness in road-facing was more than forest-facing. Butler *et al*.[4] mentioned that bark swelling occurs in the mature bark of Douglas-fir and to a lesser degree in chestnut oak. Ponderosa pine and red maple did not exhibit statistically significant swelling, but rather a modest decrease in overall bark thickness with heating.

Cambium cells dynamic diagram in production of annual rings indicated that the *Alnus subcordata* at commence of growth had been produced wide rings but in continuance the rings width reduced. This reduction was obviously for road-facing cores. Altering the hydrologic regime of a wetland forest may result in changes in tree growth, as hydrology is a primary factor influencing the growth of wetland trees. Road construction, a common cause of altered hydrologic regimes, modified the hydrology of a permanently flooded southeastern backwater swamp and resulted in significantly higher water levels upstream of the road. Before road construction, annual growth patterns were similar at the two sites. Following construction, annual growth patterns in trees below the road were unchanged; however, growth of trees in the upstream area was accelerated for several years followed by a long-term decline[17,20].

The tree growth effects resulting from soil damage from machine traffic and construction have varied with respect to soil type[1,15], tree species, and severity of damage. Predicting long-term loss of productivity is considerably more complex than predicting growth losses in the compacted area since trees adjacent to the compacted area may grow slower or grow similarly or faster than trees in an undisturbed area[3,7,9].

CONCLUSION

The ability to predict future growth patterns is essential to credible forest management planning [2], and it is especially important in the process of permitting timber harvests where long-term projection is required. In this study the *Alnus subcordata* cambium cells produced thick bark in road-facing cores because of consistency reaction to natural hazards, whereas bark thickness of forest-facing cores was lower than opposite side. This result wasn't observed for trees which were located interior forest stands. For forest-facing cores and adjacent stand the action of *Alnus subcordata* cambium cells in annual rings growth pattern seems that be correlated to climate variables and hydrological condition (accessibility to water), but in the other side (Road-facing cores), rings growth at the beginning of the road construction time was affected by road characteristics such as degree of soil compaction, drainage structures, natural hazards and etc. Therefore these factors caused the thinner rings to be produced by cambium cells in road-facing cores.

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