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Impact of Alder (*Alnus subcordata*) in Fertility of Forest Soil

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Abstract: This research was carried out in natural Alder (*Alnus subcordata* C. A. Meyer) stands for evaluation effects of Alder trees on restoration of forest soil in North forest of Iran. The soil samples and different parts of Alder such as leaves, barks, roots and nodules were collected from three altitudes zone in Alder and birch stands. Mineral amount of plant and soil sample were analyzed in laboratory by standard methods. Results of mineral analysis in deferent parts of Alder revealed that the amount of nitrogen and phosphorus in leaves significantly more than bark and root. Generally the fallen leaves of Alder remained in the soil as a source of nitrogen. Amount of nitrogen in nodules was significant higher than roots. Nitrogen analysis of soil profiles in two Alder and birch stands also showed that mean amount of nitrogen in Alder stand was significantly more than birch stand. Overall, the results indicated the positive role of Alder trees in restoration of soil fertility by nitrogen fixation.

Key words: Forest, alder, *Alnus subcordata*, nitrogen fixation, North of Iran

INTRODUCTION

Today by human developments and influences of industries and deforestation caused climate change and global warming. Quantity and quality development of forests and forestation is the most important operation against these problems. Alder is the name of a genus of flowering plants (*Alnus*) belonging to the birch family (Betulaceae). The genus comprises about 30 species of monoecious trees, distributed throughout the North Temperate Zone. The *Alnus subcordata* is a species native to temperate area in North forests of Iran and the some Caucasus regions (Sagheb-Talebi *et al*., 2003).

Alders are sturdy and fast-growing, even in acidic and damaged sites such as burned areas and mining sites. The trees establish symbiosis with the nitrogen-fixing Actinomycete (*Frankiella alni*). These bacteria convert atmospheric nitrogen into soil-soluble nitrates, which can be utilized by alder plants and favorably enhances the soil fertility. The fallen alder leaves make very rich compost, especially through mineralization of nitrogen leached from litter (Stephan *et al*., 2000; Rezaei Taleshi, 2008).

Worldwide experience indicates that Alder contributes significantly to the supply of nitrogen in the ecosystem. This contribution markedly benefits soil fertility. A definite potential exists for employing Alder in forest management in much the same way that legumes are utilized in agriculture (Robert Tarrant and James Trappe, 1971).

Kramer *et al*. (2000) and Gaulke *et al*. (2006) were shown in forestry, an analogous relationship is formed by the Frankiaceae. Frankia are a type of filamentous actinomycete that forms a symbiotic N fixing relationship with actinorhizal plants (e.g., *Alnus*).

The fungi and bacteria release nitrogen as ammonium, NH_4, which may be converted to nitrate, $NO_{2,3}$, by other bacteria. Furthermore, the nitrogen absorbed by mycorrhizal fungi can be passed on to plants. Some experiments have found positive effects of plant diversity on soil microbial processes (Stephan *et al*., 2000).

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Harrington (2002) indicated that Red Alder also has root nodules that fix atmospheric nitrogen. The nodules are a symbiotic association between the tree and an actinomycete (*Frankia* sp.). Nodulation occurs soon after seed germination; root systems of seedlings a few months old commonly have dozens of visible nodules, ranging from the size of a pinhead up to 25 min (1 in) in diameter. Mature trees have nodules on both the large woody roots and the smaller new roots. Nodules found on large trees can be as large as 80 or 90 mm (3.1 or 3.5 in) in diameter. Fixation rates vary diurnally and seasonally and with site and stand age. Maximum annual fixation rates of 320 kg ha^{-1} (290 lb/acre) (based on accretion) in pure stands and 130 kg ha^{-1} (120 lb/acre) (based on acetylene reduction assays) in mixed stands have been reported by Tarrant and Miller (1963) and Trappe *et al*. (1968).

Hurd *et al*. (2001) estimated N_2 fixation by the ^{15}N natural abundance method and indicated that Alders at these sites derive 85-100% of their foliar N from N_2 fixation. At one of the sites, also measured biomass and N content and estimated that the alder foliage contained 43 kg N ha^{-1} of fixed N.

Pure stands of red Alder can sustain high rates of N fixation, up to 200 kg of N ha^{-1} $year^{-1}$ (Scott *et al*., 2008).

Two methods of N transfer between plants-by litter decomposition and root-to-root exchange-were examined in mixed plantations of N-fixing and non-fixing trees. N availability in the different litters was strongly correlated with the amount of water-soluble N, which was highest in leaves of *E. angustifolia*. In the association between fixing and non-fixing plants, 7.5% of the *A. subcordata* N and 25% of *E. angustifolia* N was transferred to *P. avium* by root exchange. These results showed that the magnitude of N transfers by root exchange depended on the associated N_2-fixing species. (Roggy *et al*., 2004).

The objective of this study is evaluation of positive effects of Alder on restoration of forest soil for using pioneer forestation in North forest of Iran.

MATERIALS AND METHODS

Location

This research carried out in even aged pure Alder and birch stands in Sari forest region (North forest of Iran) in summer 2007. Geographical positions is latitude from 36°16′ 32″ N and longitude 53°09′ 05″ E with altitude about 950 m from free sea level.

Average precipitations of region also is 900 mm. Mean temperature of entire area is about 14.6°C and absolute minimum and maximum temperature ranged -6.5 to 40°C. Mean humidity in survey areas is 60 to 85%. In geology point of view, sediments of survey area is including to calcareous, siltstone, argillite with lomashals and some conglomerate stones. This area belongs to the first stage of Cretaceous of second geological period as Eocene of Paleogene. Usually soil is neutral with pH 6.8 to 8.09, in some part acidic and mostly mature soil with profile A (B) C until ABC as type of brown forest. The soil texture in the most part of Sari forest region emphasized influence of parent materials (e.g., existence of marl, calcareous, siltstone and argilice) on soil formation to semi heavy texture (clay loam) to heavy (clay) with 30 to 60% clay. Overall soil of survey area is poor or moderate drainage and the topsoil has gravel.

Dominant plant community is Ruscofagetum and important tree species in survey area are *Fagus orientalis*, *Carpinus betulus*, *Alnus subcordata*, *Diospyrus lotus*, *Parrotia persica* and *Acer insigne*.

Methods

For comparing substances in deferent part of Alder such as leaves, barks, roots and nodules we collected plant samples in three areas randomly with considering equal environmental situation (such as type of soil, aspect and slop similarity) in July 2007.

In next stage mineral materials of leaves, barks, roots and nodules have been extracted under special treatment and amount of mineral. As total nitrogen (N %) by micro Kjeldahl method, total sodium (Na %) and total potassium (K_2O %) by flame photo meter, total phosphorus (P_2O_5 %), total magnesium (Mg %), total calcium (Ca %), total manganese (Mn ppm), total copper (Cu ppm) and total iron (Fe ppm) substances were analyzed by Atomic Absorption Spectrophotometer.

Investigation of mineral amounts was analyzed by Randomly Complete Block Design (RCBD) method and SPSS package (2000, Ver. 11.5). Compare mean also was done by Duncan method with confidence level 0.95%.

For study of Alder stand influence on soil also three profiles dig in two Alder and neighborhood Birch stands (*Fagus orientalis*) with considering similar situation such as type of soil, aspect and slop. Samples of soil collected from the horizons of profiles and mineral substance analyzed by Atomic Absorption Spectrophotometer.

RESULTS AND DISCUSSION

Alders establish symbioses with the nitrogen-fixing Actinobacteria *Frankiella alni*. These bacteria convert atmospheric nitrogen into soil-soluble nitrates which can be utilized by the Alder and favorably enhances the soil fertility generally. Alders benefit other plants growing near them by taking mineral and nitrogen out of the air and depositing it in the soil in usable form.

Results of mineral analysis in deferent part of alder in survey area indicated the amount of nitrogen in leaves is 2.3 (%) and significantly more than bark and root equal 1.05 and 1.26 (%), respectively.

In genus of Alder (*Alnus*), with attention to be a stabilizer of nitrogen, amount of nitrogen in leaves is high, that is resulted to accelerate litter decomposition (Canhoto and Graca, 1996).

Generally fallen Alder leaves remained the N in the soil. Also, the amount of nitrogen in root nodules (1.33%) was greater than roots and bark but it is less than leaves (Table 1).

Alder has generally beneficial effects on associated plants. Part of the nitrogen fixed by alders soon becomes available to other species in mixed stands, especially through mineralization of nitrogen leached from litter. Norway spruce (*Picea abies*) grown in pots with European alder obtained nitrogen fixed in the root nodules of alder although leaves falling in autumn were always carefully removed (Virtanen, 1957).

Comparing amount of mineral separately in roots and nodules shown that mean amount of nitrogen was significant different in two parts equal 0.84 and 1.04 (%), respectively.

RodriGuez *et al*. (1984) revealed the nitrogen fixed in the root-nodules of actinomycete-nodulated plants is in part translocated eventually to the rest of the plant. The nitrogen thus fixed goes back to the soil through annual decomposition of the plant material and through root exudates, both important for growth of associated plant communities.

Must of resources for interpret role of Alder in soil restoration focused only to nitrogen fixation. Result of mineral analysis in current study also revealed that phosphorus (P_2O_5 %) was significantly different in parts of Alder. The most amount of phosphorus recorded in root (0.1%) and this is more than leaves, nodules and bark of Alder equal 0.07, 0.06 and 0.03%, respectively.

Total potassium (K_2O %) in leaves of Alder was 0.86% and that is more than nodules, root and bark with 0.53, 0.4 and 0.36 amount, respectively.

Table 1: Results of mineral analysis (N, P and K) in different parts of Alder which collected in summer 2007

Part of plant	N	Total nitrogen (%)	Total phosphorus (P_2O_5) (%)	Total potassium (K_2O) (%)
Leaf	3	2.31 ± 0.28^{a}***	0.07 ± 0.03^{b}	0.86 ± 0.18^{a}
Bark	3	1.05 ± 0.06^{d}	0.03 ± 0.02^{c}	0.36 ± 0.03^{c}
Root	3	1.26 ± 0.29^{b}	0.10 ± 0.06^{a}	0.40 ± 0.07^{c}
Nodule	3	1.33 ± 0.28^{b}	0.06 ± 0.01^{b}	0.53 ± 0.11^{b}

*Values are expressed as Mean±SD; **Comparing of mean based on Duncan method

Table 2: Mineral status (N, P and K) of soil in Alder and Birch stands

Stand	Soil horizon	Depth of soil (cm)	Texture	pH	Total nitrogen (%)	Total phosphorus (ppm)	Total potash (ppm)
Alder	A	0-16	C-L	7.1	0.468	24.0	310
	B	17-41	C	7.3	0.332	12.0	230
	C	42 >	C	7.5	0.124	8.0	214
Birch	A	0-15	C-L	6.1	0.231	6.8	170
	B	16-45	C	6.7	0.071	8.0	200
	C	46>	C	7.4	0.034	8.0	180

Mineral analysis of soil profiles in two Alder and birch stands also were shown that mean amount of nitrogen in alder stand was 1.7 significantly different to birch stand with 0.84%. Nitrogen analysis of soil profiles in two Alder and birch stands also showed that mean amount of nitrogen in alder stand (0.47%) was significantly higher than birch stand (0.23%). Compare mean amount of total phosphorus (P_2O_5 %) in soil samples also showed that Alder stand was more than birch stand with 24 and 6.8 ppm, respectively.

Mineralization of leaf and fine branch litter and root turnover of actinorhizal species has been shown to increase soil nitrogen and phosphorus status of sites where they have been planted (Arnebrant *et al*., 1993; Dawson, 1990; Malcolm *et al*., 1985).

Total potassium (K_2O %) wasn't significantly different between Alder and Birch stands with amount equal 310 and 300 ppm, respectively (Table 2). This also demonstrated that Alder stands didn't affective in total potassium restoration as nitrogen fixation and phosphorus restoration.

Results revealed that leaves have the most amount of minerals (N, P and K) and fallen alder leaves make very rich compost especially through mineralization of nitrogen leached from litter. Compare mineral amount in soil also indicated that mineral in soil of Alder stand was more than another stand. These results expressed the positive role of alder trees in nitrogen fixation and another mineral restoration of soil fertility.

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