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Influence of *Alnus subcordata, Populus deltoides* and *Taxodium distichum* on Poor Drainage Soil, Northern Iran

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ABSTRACT This study was conducted to choose the best species for plantation on a poor drainage soil in southern coast of Caspian Sea, Iran. Nutrient concentrations in live and senescent leaves and soil properties were compared among *Alnus subcordata* C.A.Mey (N-fixing tree), *Populus deltoides* Marsh. (Non N-fixing tree) and *Taxodium distichum* (L.) Rich. (Coniferous tree) plantations. In each of these plantations and an adjacent natural forest, six 20×20m plots have been selected according to a 100m × 100m randomly systematic grid. Leaf samples of green trees were collected from the bottom one-third of the tree crown by clipping two small twigs located on opposite sides of the crown (six representative trees were sampled in each plot). Senescence leaves have been collected inside wooden trap-based in each stand. Results revealed different effects of species on soil nutrients. *Alnus subcordata* increased soil N (%) whereas *Populus deltoides* and *Taxodium distichum* reduced it. The results of nutrition, litter quality, retranslocation and soil properties indicated that *Alnus* improve soil quality in comparison with the two others.

Key words: *Nutrient Return, Nutrient Retranslocation, Nutrition, Plantation, Soil Properties*

1 INTRODUCTION

Vast areas of flat lands in northern Iran had been covered with dense forests. They currently are degraded and abandoned; the exact statistics is not available. The areas with poor drainage soil and high ground water level are abundant in this region, that they would be flooded in the seasons with high precipitation (approximately 90 days in winter). Generally, in such sites flooding is one of the most important limiting factors for tree survival (Vann and Megonigal, 2002). Also it is a restriction for planting timber species with the aim of wood production in these sites.

In recent years, large areas of these lands (low drainage site) were planted by *Alnus subcordata*, *Populus deltoides* and *Taxodium distichum* species. Often sustainability and productivity of pure plantations have been failed due to planting of inappropriate species (Hosseini, 1998). On the other hand, tree species could influence on nutrient cycle through accumulation of various nutrients and organic acids production in the leaves and other organs (Dijkstra, 2001), so they could change

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soil physiochemical properties (Fichter *et al*., 1998; Augusto *et al.,* 2002). Thus, the role of forest tree species is important in nutrient return to soil and it depends on differences of their litter quality (Parrotta, 1999), nutrient uptake, interception of atmospheric deposition, canopy interactions and leaching (Hagen-Thoren *et al*., 2004). Therefore more attention should pay to factors such as nutrition uptake patterns, nutrient return and soil properties of habitat for species selection (Cuevas and Lugo, 1998). Hardwood species foliage usually has higher concentrations of N, K, and Mg than coniferous. Thus, litterfall of hardwoods could be richer in nutrients than coniferous species (Augusto *et al*., 2002). On the other hand, application of nitrogen fixation species due to more nitrogen production and high quality litter will increase the site quality and could have continuous production (Parrotta, 1999). Also, to ensure the sustainable management of forests, the resiliency of the ecosystems should be estimated to determine the most appropriate tree species and silviculture management (Augusto *et al.,* 2002).

Although effects of tree species on various soil qualities and/or distribution of nutrients between ecosystem compartments have been demonstrated in many studies (e.g. Challinor, 1968; Binkley, and Valentine, 1991; France *et al.,* 1989; Gower and Son, 1992; Norden, 1992; Augusto *et al*., 2002; Myrold and Huss-Danell, 2003; Hagen-Thoren *et al*., 2004; Inagaki *et al*., 2004; Parfitt *et al*., 2005; Ritter, 2007; Li and Han., 2008; Wang *et al.*, 2008; Yamashita *et al*., 2008; Hansen *et al*., 2009), but such studies are needed all over the world and in the northern forest of Iran (Sayyad *et al*., 2006; Rouhi-Moghadam *et al*., 2008).

The aim of this investigation was to study nutrient concentrations in the live and senescent leaves and soil properties of *Alnus subcordata* (N-fixing tree), *Populus deltoides and Taxodium distichum* (as non N-fixing and coniferous trees, respectively) plantations in north of Iran at Tashbandan in Amol as factors could helping us choosing the best species for plantation on poor drainage soil sites.

2 MATERIAL AND METHOD

2.1 Site Characteristics

The study site is located in southern coast of the Caspian Sea, 10 Km from Amol city, north of Iran (36˚34′N, 52˚19′E). The altitude is 10 m above sea level and with low slope (0-3%). In this site *Alnus subcordata* (Caucasian alder), *Populus deltoides* (Eastern Cottonwood), and *Taxodium distichum* (Swamp Cypress) were planted with spacing of 4m × 4m approximately 17 years ago, adjacent of natural forest after cutting the devastated natural forest containing *Quercus castaneifolia* C.A.Mey *Parrotia persica* (DC.) C.A. Mey and *Carpinus betulus* L.. Rainfall with wetter months occurs between September and March, and a dry season from April to August. The climate is temperate based on Demarton climate classification, with a mean annual temperature of 16.9 ˚C and mean annual precipitation of 883 mm (based on 1990 to 2008 years). The soils of plantations are poor drainage and have a silty-loam texture with pH 7.6-8.1. The soil texture of natural stand is silt-loam and has 7.6 pH, in comparison with plantations has rather better drainage.

2.2 Nutrition, litter quality and retranslocation

In each of the plantations and the adjacent natural forest, six 20m × 20m plots have been sampled according to a 100m × 100m randomly systematic grid. All the samples were taken in these plots. Green leaf samples were collected from the bottom one-third of the tree crown by clipping two small twigs located on opposite sides of the crown (July 2008). The samples were collected from six representative trees (two near the center of plot and one in each corner) in each plot in order to evaluating nutrition (highest nutrient concentration) of plantations and natural stand.

Senescent leaves have been collected in wooden trap-based to evaluate liter quality in each stand. Litter traps (1m×1m×0.3m) placed in the center of each plots (30 cm above ground) from mid-September to November 2008. The samples were dried at 70 °C for 48 hours. Nitrogen using the Kjeldhal, P using Spectrophotometer (by the Olsen method), K, Ca and Mg (by ammonium acetate extraction at pH 9) using Atomic absorption spectrophotometer were determined (Bower *et al.*, 1952).

The percentage of net retranslocation was calculated by Eq. (1) (Parrotta, 1999; Rouhi-Moghadam *et al*., 2008):

$$\%\mathrm{Re} = [1 - \frac{B}{A}] \times 100 \qquad (1)$$

where, Re is the nutrient retranslocation in percent, B is the nutrient concentration in senesced leaves, and A is the nutrient concentration in mature green leaves.

2.3 Soil properties

During February 2008, four soil sub samples were taken at two depth (0-15 and 15-45cm) in each plot using a 7.6 cm diameter core sampler. Four soil sub samples were composited as a soil sample for subsequent analysis. After air drying, soil samples were sieved (aggregates were broken to pass through a 2 mm sieve) to remove roots prior to chemical analyses. Soil texture was determined by the Bouyoucos hydrometer method (Bouyoucos, 1962). Soil pH was measured using an Orion Ionalyzer Model 901 pH meter in a 1:2.5, soil: water solution. EC (electrical conductivity) was determined using an Orion Ionalyzer Model 901 EC meter in a 1:2.5, soil: water solution. Soil organic carbon was determined using the Walkley–Black technique (Allison, 1975). The total nitrogen was measured using a semi Micro-Kjeldhal technique (Bremner and Mulvaney, 1982). The available P was determined with spectrophotometer by using Olsen method (Homer and Pratt, 1961). The available K, Ca, and Mg (by ammonium acetate extraction at pH 9) were determined with Atomic absorption spectrophotometer (Bower *et al*., 1952).

2.4 Statistical Analyses

Normality of the variables was checked by Kolmogorov–Smirnov test. Levene's test also was used to examine the equality of the variances. One-way analyses (ANOVA) of variance with Duncan tests were used to compare nutrition, litter quality and soil properties among the stands. Pearson correlation was used to assess the relation between nutrient of live leaves, senescent leaves and soil. SPSS 11.5 was used for all the analyses.

3 RESULTS

3.1 Nutrition, litter quality and retranslocation

The results showed that N, P, K, Ca and Mg concentrations in live leaves were significantly different among the species (Table 1). Nitrogen concentration in live leaves of *Alnus* was the highest, but the lowest N concentration was found in *Taxodium* (Table 1). Phosphorus concentrations in live leaves of *Populus* and natural stand were the highest and the lowest P concentration was found in *Alnus* and *Taxodium* (Table 1). Potassium concentration in live leaves of the natural stand was the highest and the lowest K concentration was found in *Populus* (Table 1). Calcium concentration in live leaves of *Populus* was significantly higher than other stands (Table 1). Mg concentrations of *Alnus* and *Populus* stands were higher than the natural and *Taxodium* stands (Table 1). The C/N ratio in live leaves of *Alnus* was the lowest.

The results of litter quality showed that N, P, Ca and Mg concentration in senescent leaves were significantly different among stands but the P concentration was not significantly different (Table 1). The highest N concentration in

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senescent leaves was found in *Alnus* (Table 1). Nitrogen, K and Mg return by senescent leaves of *Taxodium* were lower than other species (Table 1). Calcium and Magnesium return by senescent leaves of *Populus* were the highest (Table 1). Senescent leaves of *Alnus* and natural stands returned higher K than other stands (Table 1) while they have lower C/N ratio.

Nitrogen retranslocation was significantly different among stands, while P and K retranslocation did not show any significant differences (Table 1). Nitrogen retranslocation of *Alnus* was the lowest while it was the highest in *Taxodium* and *Populus* stands (Table 1).

3.2 Soil properties

The results of soil properties in the 0-15cm soil depth showed that the plantations had affected soil properties (Table 2). Soil EC and available Mg in 0-15 cm soil depth did not show any significant difference between the plantations (Table 2). Organic matter (%) in 0-15 cm soil depth was lowest under *Alnus* (Table 2). Nitrogen (%) in 0-15 cm soil depth of *Alnus* was higher than other stands (Table 2). The highest available P and C/N ratio and the lowest N and available K in 0-15 cm soil depth were observed under *Taxodium* (Table 2), whereas the highest available Ca in 0-15 cm soil depth were observed under *Populus* plantation (Table 2). Soil EC, available Ca and Mg in 0-15 cm depth in natural stand were significantly lower than plantations (Table 2). The results of soil properties in 15-45cm depth showed that EC, available Ca and Mg under plantations were higher, whereas, their C/N ratio and organic matter (%) were lower than natural stand (Table 2).

The soil texture particles in both soil depth (0-15 and 15-45cm) did not show any significant difference between the stands (Table 2).

Table 1 Nutrients concentration (mean±SE) in live and senescent leaves and retranslocation Percent

	Alnus	*Populus*	*Taxodium*	Natural stand	ANOVA
Live leave					
Nitrogen (%)	2.59±0.06 a	1.95±0.06bc	1.77±0.04 c	2.02±0.08 b	**
C/N ratio	15.71±0.60c	22.59±1.35ab	25.73±1.27 a	21.15±1.30 b	**
Phosphorous (%)	0.14±0.004 b	0.17±0.004a	0.15±0.003 b	0.16±0.005 a	**
Potassium (%)	0.92±0.07 ab	0.68±0.01c	0.75±0.01 b	1.01±0.07 a	*
Calcium (%)	1.29±0.08 b	2.21±0.05a	1.15±0.10b	1.39±0.17 b	**
Magnesium (%)	1.40±0.08 a	1.35±0.07a	0.80±0.03b	0.95±0.06 b	**
Senescent leave					
Nitrogen (%)	2.15±0.06 a	1.01±0.06 c	0.90±0.02 c	1.37±0.03 b	**
C/N ratio	20.97±1.10 c	36.78±3.23 b	44.29±1.90 a	30.65±2.09 b	**
Phosphorous (%)	0.14±0.003	0.15±0.003	0.14±0.004	0.14±0.006	ns
Potassium (%)	0.56±0.06 a	0.39±0.03 b	0.28±0.03 c	0.62±0.06 a	**
Calcium (%)	1.36±0.05 c	1.95±0.09 a	1.73±0.10 ab	1.51±0.05 bc	**
Magnesium (%)	1.04±0.02 ab	1.08±0.09 a	0.67±0.12 c	0.92±0.18 b	**
Retranslocation					
Nitrogen (%)	16.70±3.27 c	47.67±3.59 a	48.62±1.61 a	31.47±3.49 b	**
Phosphorous (%)	4.34±3.94	11.01±3.01	7.04±4.00	10.44±3.35	ns
Potassium (%)	36.97±5.97	41.52±4.60	55.68±9.48	38.61±5.64	ns

ns: treatment effect not significant. * $P < 0.05$ (ANOVA), ** $P < 0.01$ (ANOVA)

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Table 2 Nutrient concentration (mean±SE) in two soil depth in the plantations and natural stand

	Soil depth (cm)	*Alnus*	*Populus*	*Taxodium*	Natural stand	ANOVA
pH (1:2.5 H2O)	0-15	7.82±0.02 a	7.88±0.01 a	7.55±0.09 b	7.68±0.12 ab	*
	15-45	8.11±0.06	8.08±0.04	7.98±0.06	8.04±0.03	ns
EC (ds/m)	0-15	0.22±0.005a	0.24±0.10 a	0.27±0.02 a	0.18±0.004 b	**
	15-45	0.20±0.10 a	0.17±0.004 ab	0.19±0.01 a	0.16±0.005 b	*
Organic carbon (%)	0-15	3.82±0.25 b	4.57±0.009 a	4.58±0.03 a	4.62±0.01 a	**
	15-45	2.65±0.23 b	2.48±0.11 b	2.56±0.09 b	3.31±0.16 a	**
Total N (%)	0-15	0.40±0.006a	0.35±0.02 b	0.31±0.02 c	0.37±0.005 ab	*
	15-45	0.22±0.01 a	0.19±0.01 ab	0.17±0006 b	0.21±0.01 a	*
C/N ratio	0-15	5.72±0.38 c	6.86±0.01 b	8.13±0.61 a	7.19±0.10 ab	**
	15-45	6.80±0.17 c	7.55±0.27 bc	8.32±0.52ab	9.94±0.20 a	**
P available (mg kg^{-1})	0-15	25.76±1.35b	24.03±2.09 b	36.08±4.03a	25.48±1.50 b	*
	15-45	39.90±9.16	33.31±4.12	24.99±3.11	31.87±2.81	ns
K available (mg kg^{-1})	0-15	48.75±1.96b	45.91±3.59 b	28.47±1.15c	56.91±1.81 a	**
	15-45	32.50±2.88	31.16±2.72	26.50 ±1.05	35.91±2.38	ns
Ca available (mg kg^{-1})	0-15	71.70±4.57b	91.62a±0.89	66.48b±8.25	39.48c±2.42	**
	15-45	74.78±8.34a	67.80±3.51 a	75.77±7.22a	47.52±4.86 b	*
Mg available (mg kg^{-1})	0-15	23.70±1.45a	20.09±2.20 ab	25.75±3.92a	15.78±0.99 b	*
	15-45	22.65±2.26a	18.06±1.61 a	20.16±1.09a	14.79±0.69 b	*
Clay (%)	0-15	18.50±2.09	16.66±0.95	21.33±1.96	20.00±1.65	ns
	15-45	23.33±1.74	22.66±2.65	23.50±1.82	26.00±1.41	ns
Silt (%)	0-15	52.38±3.07	49.16±2.22	51.66±1.38	47.16±2.54	ns
	15-45	54.16±2.10	50.50±3.008	50.66±3.60	44.66±1.68	ns
Sand (%)	0-15	28.66±2.94	34.16±1.79	27.00±2.68	32.83±2.37	ns
	15-45	22.50±2.80	26.83±1.16	24.33±2.80	29.33±0.91	ns

ns: treatment effect not significant. * $P < 0.05$ (ANOVA), ** $P < 0.01$ (ANOVA)

3.3 Correlations

There were positive correlations between N concentration in live leaves and N in soil (0-15 cm) of *Populus* and *Taxodium* stands (Figure 1, A, B). Also, a positive correlation was found between K concentration in senescent leave and soil K (0-15 cm) of *Alnus* stand (Figure 1. C). In *Populus* stand, Ca concentration of senescent leaves was positively correlated with Ca concentration of soil (0-15 cm) (Figure 1, D), whereas in natural forest negative correlations were detected between N and K retranslocation of senescent leaves with soil N and K (0-15 cm) respectively (Figure 1, E, F). The other factors did not have significant correlation together.

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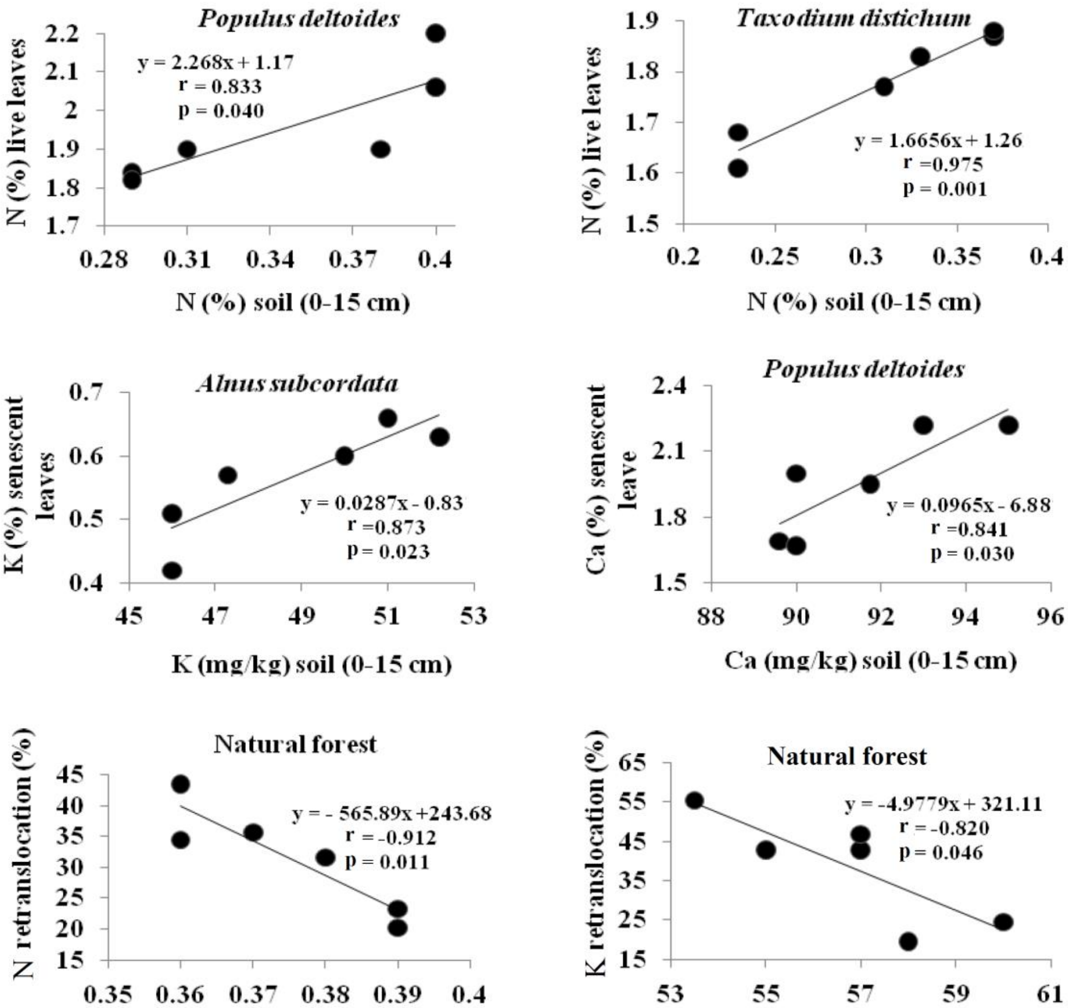

Figure 1 Correlations between nutrition, nutrient return and retranslocation of the plantations and natural forest with soil properties

4 DISCUSSION

Positive correlation was found between N in live leaves and soil N (0-15 cm) of *Populus* and *Taxodium* stands. Similarly, Merino *et al.*, (2004) concluded that foliar N level has been correlated with soil aerobic and anaerobic mineralizable N in *Pinus radiata* plantations in northern Spain. This results might be indicator of high requirement of *Populus* and *Taxodium* species to soil N. In contrast, we did not find any relationship between live leaves N and soil N of *Alnus* and natural stands. The latter results are in line with Tanner *et al.* (1990), Parfitt (2005) and Ritter (2007) that did not find any relationship between foliar N and soil N. It seems that *Alnus* and natural stands have other sources of N supply other than soil such as N fixation. The exact knowledge on the reason of this result needs more research on N sources that trees are using in these stands.

Phosphorus of *Populus* live leaves was higher than the other stands, whereas it was not greater in its soil. We also did not find any significant relationship between P concentrations in live leaves and soil P of other stands. In contrast with our results Merino *et al.* (2004) reported that foliar P levels have been slightly correlated with soil available P and pH.

Mankovska *et al.* (2004) implied that K, Ca and Mg concentration in foliage of the forest trees depends on its soil nutrient content. In line with these results we found that Ca and K concentration were the highest in live leaves and soils of *Populus* and natural stand, respectively. But similar trend was not observed for Mg and its reason is known for us.

Hansen *et al.* (2009) found out the N rates and cycling of senescent leaves of *Alnus* species was higher than conifers species. We similarly observed that senescent leaves of *Alnus* have the highest N concentration. Hansen *et al.* (2009) also reported that there was a correlation between P, K, Ca and Mg return with soil nutrient statues, and implied that low nutrient return is caused by low cation saturation of sands soil. We found similar results about *Taxodium* where N, K and Mg in its senescent leaves were lower than other stands. The higher K of senescent leaves of natural forest is similar to the results that reported by Wang *et al.* (2008), who observed that N, P and K return in mixed natural stand were higher than pure plantation.

N retranslocation in *Alnus* was lower than other stands that could result in soil N increase. The low N retranslocation in N-fixing trees could be the reason of two fold N concentration in their senescent leaves in comparison to non N-fixing trees (Killingbeck, 1996). The results of senescent leaves in our study also showed more than two fold N concentration in N-fixing trees in comparison to non N-fixing trees.

It is widely accepted that soil of N-fixing species have higher N concentration. Myrold and Huss-Danell (2003) reported that mineral N in *Alnus* soil was greater than non N-fixing species. Our results also showed that *Alnus* soil had higher N in comparison to other species. We could relate it to lower N retranslocation of *Alnus* and higher litter N return to the soil. Yamashita *et al.* (2008) also found similar results and related the increase of mineral N in *Alnus* soil to N rich leaves. Nutrition, litter quality and retranslocation could be the reason of the differences in soil N between plantations. Soil N of *Taxodium* was the lowest. This result is in consistent with Pezeshki *et al.* (1999), which reported that flooding had little effect on nutrient uptake by *Taxodium distichum*. Inagaki *et al.* (2004) also reported that consuming of soil N by conifer species (*Pinus* and *Cedrous*) was higher than broad leaves.

Alnus stand had the lowest Organic matter (%) in 0-15 cm soil depth. In contrary Li and Han (2008) observed higher soil organic carbon in broad-leaved species in comparison with conifers. Whereas Parrotta (1999) related the decrease of organic carbon under nitrogen fixing tree to higher biological activity due to soil N increasing of them.

Taxodium Soil (0-15cm) had the highest available P. Similarly, Cole *et al.* (1990) observed that coniferous trees are powerful in storing P in soil in comparison with N-fixing broad leave species. Koele (2005) also reported that the high need of alder for P may limit the P availability in soil. The result of P retranslocation seems to be consistent with result of Francisco and Chapin (1993), which did not show any significant differences in rich and poor soils.

The lowest available K in *Taxodium* (0-15cm depth) soil might be related to K retranslocation, nutrition and nutrient return. On the other hand in the natural stand there was negative correlation between K retranslocation in senescent leaves and soil (0-15 cm). The High K cycle in natural stand might be the reason of higher K in its soil. It was also reported that the K in litter of natural stand was higher than plantations (Wang *et al.*, 2008).

Higher litter Ca in *Populus* plantation compared with other stands might be the reason

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of soil Ca increasing in its stand. Already the same result reported by Washburn and Arthur (2003) for *Acer* species that replanted on *Quercus* stand. Alder forests have generally lower exchangeable Ca due to more rapid absorption of Ca or through leaching of Ca after its replacement of H^+ ions (from H^+ released after nitrification) (Bollen and Lu, 1967). This was the reason that soil pH of the *Alnus* stand is lower than the others.

EC, Ca and Mg available in both soil depth (0-15 and 15-45 cm) in natural stand were significantly lower than plantation. This result might be due to leaching of Ca and Mg from the soil (Zarinkafsh, 1994). These results could be due to denser canopy crown in plantation than natural stand that could result in lower leeching in the plantation. For finding the exact reason more research are recommended. In line with our results several authors have reported a higher C/N ratio, lower pH and lower nutrient content in coniferous stands in comparison with hardwoods stands (Hicks 1980: Emmer *et al*., 1998; Legare *et al*., 2001; Augusto *et al*., 2002).

The result of soil properties at 15-45cm soil depth did not show any significant difference among the plantations, although in comparison with natural stand, had higher EC and available Mg and Ca and lower C/N ratio and Organic matter (%). As we could not clearly relate these results to a particular factor so more researches are required. The physicals soil properties in both soil depth (0-15 and 15-45 cm) did not show any significant differences between the stands. Regarding to the age of plantation, these results could be predictable (Majd Taheri and Jalili, 1997) because it takes long time to change soil physical properties.

The results revealed different effects of species on site nutrient cycle. *Alnus subcordata* increased soil N (%) whereas *Populus deltoides* and *Taxodium distichum* reduced it. The results of nutrition, litter quality, retranslocation and soil properties indicated that *Alnus* improve soil quality in comparison with other species.

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تأثیر *Alnus subcordata*، *Populus deltoids* و *Taxodium distichum* بر خاک‌های با زهکشی ضعیف، در شمال ایران

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چکیده این پژوهش به منظور انتخاب مناسب‌ترین گونه برای جنگل‌کاری روی خاک‌های با زهکشی ضعیف در جنوب دریای خزر، ایران صورت گرفته است. تمرکز عناصر غذایی در برگ‌های زنده و تازه خزان کرده و ویژگی‌های خاک بین جنگل‌کاری گونه‌های *Alnus subcordata* (یک گونه تثبیت کننده ازت)، *Populus deltoids* (یک گونه غیر تثبیت کننده ازت) و *Taxodium distichum* (درخت سوزنی برگ) مقایسه شدند. در هر کدام از این جنگل‌کاری‌ها و یک جنگل طبیعی در نزدیکی آنها ۶ پلات ۲۰ متر در ۲۰ متر بر اساس یک شبکه ۱۰۰ متر در ۱۰۰ متری برداشت شد. نمونه‌برداری از برگ‌های سبز از یک سوم پایین تاج درختان با برش دو شاخه کوچک در دو جهت مقابل در تاج از شش درخت در هر پلات جمع‌آوری شد. برگ‌های تازه خزان شده با قرار دادن تله لاشبرگ جمع‌آوری شدند. نتایج اثرات متفاوت گونه‌ها بر خاک را نشان داد. توسکا درصد ازت خاک را افزایش داد درحالی که صنوبر و دارتالاب آن را کاهش دادند. نتایج تغذیه و کیفیت لاشریزه و بازجذب عناصر غذایی و ویژگی‌های خاک نشان دادند که توسکا در مقایسه با دو گونه دیگر کیفیت خاک را بهبود بخشیده است.

کلمات کلیدی: بازجذب عناصر غذایی، بازگشت عناصر غذایی، تغذیه، جنگل‌کاری، ویژگی‌های خاک