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Seasonal Variation of Earthworm Abundances and Biomass in Natural Forests and Plantations (North of Iran)

Sh.Mohammadnezhad Kiasari[1]*, Kh. Sagheb-Talebi[2], R. Rahmani[3] and O. Ghasemi Chapi[4]

1-Division of Natural Resources, Mazandaran Research Center of Agriculture and Natural Resources, P.O. Box 3452603, Iran
2- Division of Natural Resources, Research Institute of Forests and Rangelands, Tehran, Iran
3- Dept. of Forestry, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran
4- Division of Soil and Water Research, Mazandaran Research Center of Agriculture and Natural Resources, Iran
** Corresponding author's E-mail: Ms.mohammadnejad@gmail.com*

ABSTRACT
Soil productivity and plant growth are usually affected by biological activities of earthworms. The objective of this study was a comparative evaluation of earthworm abundances in 20-year-old plantations of Alder, Oak, Maple and Cypress with the adjacent natural mixed broad-leaved deciduous forest in the Caspian region of Iran. In this research one sample plot, each 1 ha; was selected in every plantation as well as in the natural stand, more over, in each plot, 10 microsample plots 10×10m were selected random systematically. To determine the seasonal variation of density and biomass with two methods, twenty samples were taken from each microsample plot. In the first method, 10 assigned soil pits of 100×100 cm and 30 cm depth were located among each treatment and adult earthworms were collected by hand counting. In the second method, 10 circular soil samples of 81cm^2 to depth of 30 cm were taken in each treatment. The larves of earthworm extracted by using Berlese funnel and were counted by binocular. Finally in four seasons a total of 400 specimens were taken from 50 microsamples in different treatments. Moreover, some site and treatment parameters were measured in each plot. The abundance and biomass of earthworms in the Cypress plantation with 148.4 (n/m^2) and 4.74 (g/m^2) was significantly lower than other treatments, while the differences between other treatments were not statistically significant. The two important factors were extracted from eight variables in Factore analysis. The analysis of FA showed that some treatment parameters and nutritional values of litter take an important role in seasonal variation of earthworm abundance at all the treatments.

Keywords: Biomass, Earthworm, Natural forest, Abundance, Plantation

INTRODUCTION
Earthworms are subject to physical, chemical and biological changes in soil, so they have a major role in soil structure and performance (Rahmani, 2000). Earthworm activity in soil, transfer minerals to different horizons and also organics to lower horizons of soil (Rahmani & Saleh-Rastin, 2000). Creation of holes in path of earthworms increases water penetration and soil aeration. It has been shown that 60% of earthworm's paths at soil depth of 15 cm and 18% of earthworm's paths at soil depth of 80 cm have been covered by tree roots (Jyrki & Visa, 1997). Results of some studies on castings (worm dung) indicate abundance and diversity of fungal species (Tiwari & Mishra, 1993), Bacterial plate counts, moisture content and concentrations of soluble organic-C are higher than the adjacent soil (Daniel & Anderson, 1992; Tomati *et al.*, 1988). Moreover, most of the physico-chemical characteristics of castings are more than those of the underlying soil in both arable and natural vegetation areas (Reddy *et al.*, 1997). The earthworms have the highest biomass of earthen invertebrates. Also they cause remarkable increase in soil micro-organisms and have an important effect on Soil invertebrates diversity and feed cycle

(Burtelow *et al.*, 1998; Jordan *et al.*, 1999; Rahmani & Saleh-Rastin, 2000; Groffman *et al.*, 2004).

Investigations on forest plantation projects in north of Iran, indicate that about 200,000 ha of degraded forests have been reforested, from which 40,000 ha consist of needle-leaved species (Asad-o-llahi, 2001). Forest plantation activities are one of the methods for rehabilitating of the degraded forests in the Caspian region. Therefore, evaluation of the planted species and comparison with other natural forests is very important. Our qualitative and quantitative studies on forest plantation in this region indicate that Alder (*Alnus subcordata* C. A. Mey.) was the most promising species for rehabilitation of these areas. Maple (*Acer velutinum* Bioss.) and Oak (*Quercus castaneifolia* C. A. Mey.) could also be accepted for further plantation in this region and plantation of Cypress (*Cupressus sempervirens* L. var. *horizontalis*) was not successful in comparison to broad-leaved species (Mohammadnezhad kiasari *et al*., 2009a).

The objective of this study was a comparative evaluation of various plantations with the adjacent mixed broad-leaved forests in regards to abundance and biomass of earthworms. It must be mentioned although that earthworm represent only one type of soil macro fauna, they play a critical role in increasing soil nutrients and structure (Johnston *et al*., 2007; Kaneda *et al*., 2008). Moreover, earthworms improve growth conditions of plants by positive effect on soil micro-organisms population (Scheu, 2003; Groffman *et al*., 2004; Jordan *et al*., 2004).

In this study we hypothesized that tree species will have different effects on earthworm abundance and biomass. The basis for this is that the impact of various trees on earthworm abundances is not only through their effects on litter and microclimate (Fragoso *et al*., 1997; Neher, 1999), but also on altering the chemical and physical properties of soil (Zou & Gonzalez, 2002). Our second hypothesis was that different seasons may affect abundance and biomass of earthworms at various stands and there will be relationships between seasonal variation of earthworm abundance with some of the site and species characteristics (Valckx et al., 2006; Nagumanova, 2007). The results of this study would be helpful for forest managers in rehabilitation of degraded broad-leaved natural forests in lowland areas. Moreover, recognition of parameters affecting earthworm population under natural and planted forests, would be usefull at cultural interventions.

MATERIALS AND METHODS

Research site

The research was conducted in four plantations and an adjacent degraded broad-leaved natural forest located in the lowland area of Darabkola city, east of Mazandaran province in the Caspian region, north of Iran (52°14'E, 36°28'N). The study area was located at 240 to 270 m.a.s.l. The slope inclination varied between 3% and 15%. According to data processing of Gharakheill (52°46'E, 36°27'N) Meteorological Station (1980-2005), the mean annual precipitation and temperature were 732.8 mm and 16.8 °C, respectively. The climate is temperate moist and the dry months extends from May to September. The soil type is forest brown and soil texture varies between Sandy Clay Loam to Clay Loam.

The investigated treatments in this research consisted of 20-year-old plantations with species of Alder *(Alnus subcordata* C. A. Mey.*)*, Oak *(Quercus castaneifolia* C. A. Mey.*)*, Maple *(Acer velutinum* Bioss.*)* and Cypress *(Cupressus sempervirens* L. var. *horizontalis)* and the adjacent mixed natural forest. The tree species in the natural forest consisted of Beech, Hornbeam, Maple, Alder and other broad-leaved species (Anon., 1996). In this study one sample plot, of 1 ha; was selected in every plantation as well as in the natural forest. Moreover, in each plot, 10 microsample plots (10×10 m) were selected random systematically. Each plot was the representative of its natural or planted forests. Also all of the microsample plots in the plantation treatments were pure and without bared area and big gaps. The tree species of the plantations were planted at spacing of 2×2 m in 1990. Full callipering of 20-year-old treatments in all of the plots showed that survival rate of trees in the Oak, Maple, Cypress, Alder plantations and natural forest were 1891, 1562, 1423, 489 and 318 stems per hectares, respectively (mohammadnezhad kiasari *et al*., 2009a). It should be noted that no silvicultural interventions have been done in the investigated treatments.

Measurements

To determine earthworm abundance and biomass in every season, twenty samples were taken from microsample plots at each treatment by two methods. Identification of earthworms has been limited at the level of Oligochaeta order (Rahmani, 2000). In the first method, 10 assigned soil pits of 100×100×30 (depth) cm were dug out in order to collect large earthworms by hand counting. In the second method, 10 cylindrical cores, of 10 (diameter) × 30 (depth) cm were taken for determination of small earthworms, soil bulk density and soil moisture content. Soil samples from each microsample plot bulked and the larvae of earthworms at every soil sample extracted by Berlese funnel. The larvae were counted by Binocular. Soil moisture of each sample was determined by standard method and soil bulk density was determined by Core method. The soil moisture content (%) was calculated from sample weight before and after drying. Also the bulk density of the soil was computed by dividing the dry weight by the soil volume (Haghighi, 2003).

It must be mentioned that at each season a total of 50 soil samples for large earthworms and 50 cylindrical core samples for larvae were taken from 50 microsample plots at different treatments. A total of 400 samples have been investigated during four seasons (from summer 2006 to spring 2007). All of the earthworms and the larvae were dried at $60^{\circ C}$ in Oven for 24 hours and after that were weighed with 0.0001 g. precision balance, separately. Abundance and biomass of earthworm larvae were estimated per m2 area. In addition, contemporary with sampling of the earthworms and the larvae in each season, relative light intensity, some litter properties such as: moisture content, total N, available P, exchangeable K and some tree parameters such as: height, diameter at breast height and crown density were measured at each microsample plots (10×10 m).

To determine seasonal variations of relative light intensity, one hemispherical photograph was taken from center of each microsample plot. Eventually during four seasons, a total of 200 photographs from 50 microsample plots were taken at different treatments. The relative light intensity of every microsample plot was calculated with the aid of the pictures and a special network. The canopy density was estimated also for the various treatments above each microsample plot from 0.05 in open area up to 0.95 in full shade area (Sagheb-Talebi, 1995; Mohammadnezhad kiasari *et al.*, 2009b). In the mean time, during four seasons a total of 200 litter samples were collected, dried at $80^{\circ C}$ in Oven and ground for routine analysis. Total N was determined by micro Kjeldahl method. The Olson method was used for determining available P and the exchangeable K was measured by Flame Photometer method (Haghighi, 2003).

Data analysis

A one-way analysis of variance (ANOVA) was used to compare parameters of earthworm biomass, earthworm abundance and some of the important measured variables in various treatments for each season and also in various seasons for each of the treatments. Normality of data and homogeneity of variances were tested. The means were compared, using the Tukey's test at level 5% and statistical analysis were performed by SPSS 13 (Nasiry, 2006).

To detect relationship between measured parameters with seasonal differences of earthworm abundance at various treatments, factor analysis was made, using the principal components method. The validity of the analysis was assessed by Kaiser-Mayer-Olkin sampling adequacy test (KMO> 0.7) and Bartelett test of Sphericity ($p< 0.001$). This was necessary to avoid strong distortion of the results. Anti-image correlation matrix contains the negative of the partial correlation coefficients. Diagonals of this correlation matrix are used as a measure of sampling adequacy (MSA). In case of KMO being less than 0.7, the variable with the lowest MSA is dropped until the overall KMO rises above 0.7. The analysis was continued with the rest of variables and only factors with eigenvalues higher than one were selected. The loading or variances of extracted principal components were optimized by varimax rotation. The varimax rotation method, maximize the variance within each factor and it was applied for a better interpretation of axes (fig. 1). Also the factor score is a composite measure created for each treatment (observation) on each factor extracted in the factor analysis (fig. 2). Factor weights are used in conjunction with the original variable values to calculate each observation's score (Anon., 1999; Nasiry, 2006).

RESULTS AND DISCUSSION

Analysis of annual differences of earthworm abundances and biomass showed that the Cypress plantation had the lowest value among the treatments, but no significant difference was observed among the other treatments. It should be noted that more than 95% of the earthworm abundances refers to population of the larvae (table 1).

Table1. Comparison of annual means of earthworm abundance and biomass at different treatments.

Studied variables	Plantation areas				Natural forest
	Alder	Maple	Oak	Cypress	
Abundance of large (n/ m^2) earthworms	19.20 ^{a}	18.27 ^{a}	18.92 ^{a}	6.65 ^{b}	16.14 ^{a}
n/) Abundance of larvae and large earthworms (m^2	502.8 ^{a}	374.87 ^{a}	430.99 ^{a}	148.4 ^{b}	386.22 ^{a}
Biomass of earthworms (g/ m^2)	15.24 ^{a}	12.15 ^{a}	13.73 ^{a}	4.74 ^{b}	12.43 ^{a}

Small letters at the right side of the numbers show significant differences among the treatments.

Comparison of the earthworm abundance and biomass in tables 2 and 3 have shown significant differences within the seasons and among the treatments. The only exception was the Cypress plantation, which showed no significant differences within the seasons. The highest average of earthworm abundance and biomass in the natural forest, referred to spring, while in the broad-leaved plantations it referred to summer. Also the lowest average of earthworm abundance at all treatments, was observed in winter.

Table 2. Comparison of earthworm abundance means (n/ m^2).

Season	Plantation areas				Natural forest
	Alder	Maple	Oak	Cypress	
Summer	1038 a A	641 a AB	999.7 a A	214.1 a B	237.8 b B
Autumn	242.8 bc AB	284.3 b AB	315.6 b AB	176.1 a C	518.3 ab A
Winter	131.6 c A	146.6 b A	169.2 b A	86.3 a A	128.5 b A
Spring	598.8 b AB	427 ab ABC	239.5 b BC	117.1 a C	660.3 a A

Small letters at the right side of the numbers show significant differences within the seasons and Capital letters under the numbers show significant differences among the treatments.

Table 3. Comparison of earthworm biomass means (g/ m^2).

Season	Plantation areas				Natural forest
	Alder	Maple	Oak	Cypress	
Summer	24.73 a A	16.42 a AB	23.77 a A	4.96 a C	7.08 c BC
Autumn	11.07 b AB	12.52 ab A	12.39 b A	5.71 a B	15.58 ab A
Winter	10.43 b A	9.44 b A	9.62 b A	5.10 a B	8.29 bc AB
Spring	14.73 b A	11.35 ab AB	9.14 b AB	3.21 a B	17.66 a A

Small letters at the right side of the numbers show significant differences within the seasons and Capital letters under the numbers show significant differences among the treatments.

The seasonal measured parameters of the trees in the microsample plots didn't have significant differences at each treatment. Table 4 compares some parameters of the trees at spring and different treatments. Analysis of diameter at breast height (dbh) showed that the natural forest and the Alder plantation were the most promising and the Oak, Maple and Cypress plantations were the less promising, respectively. Analysis of height of trees showed that Alder, natural forest, Maple and Oak were the most promising treatments, respectively and Cypress plantation had the worst result. Also the abundance of trees varied 6.10 to 21.90 ($n/100m^2$) and the greatest value was observed in Cypress plantation.

Table 4. Comparison of tree variables at various treatments and at spring.

Studied variables	Plantation areas				Natural forest
	Alder	Maple	Oak	Cypress	
Diameter at breast height (m)	17.49 ab	12.49 b	12.53 b	11.08 b	23.15 a
Height (m)	17.47 a	15.40 a	14.71 a	9.22 b	17.12 a
Abundance of trees (n/m^2)	9.70 c	16.10 b	18.40 ab	21.90 a	6.10 d

Small letters at the right side of the numbers show significant differences among the treatments.

Table 5 indicates that variables of relative light intensity and crown density were significantly different within the seasons and among the treatments. The relative light intensity varied between 4.6% (Cypress-summer) to 95.86% (Maple-winter). The least relative light intensity reached the ground of Cypress plantation during all of the seasons. Also the highest crown density was observed in spring and summer (growing seasons), while the lowest crown density was measured in autumn and winter.

Table 5. Comparison of two stand characteristics at different treatments.

Variables	Season	Plantation areas				Natural forest
		Alder	Maple	Oak	Cypress	
Relative light intensity (%)	Summer	18.04 d A	11.48 b B	11.51 c B	4.60 b C	7.78 c BC
	Autumn	88.77 b B	95.49 a A	89.38 b B	18.39 a C	90.82 a B
	Winter	93.74 a B	95.86 a A	93.06 a B	19.26 a C	92.41 a B
	Spring	25.18 c B	14.32 b C	13.31 c C	8.38 b D	36.81 b A
Canopy density (%)	Summer	64.5 a C	87 a A	79 a A	81 a A	85.5 a A
	Autumn	36 c C	22 c D	61 b B	74 ab A	30 c CD
	Winter	23 d CD	21 c D	37 c B	64 b A	28.5 c C
	Spring	44 b B	73.5 b A	76 a A	80.5 a A	58.5 b B

Small letters at the right side of the numbers show significant differences within the seasons and Capital letters under the numbers show significant differences among the treatments.

Comparison of soil moisture and soil bulk density showed that there were significant difference within the seasons and among the treatments. There were only two exceptions. In the summer, soil moisture variables were not significantly different among the treatments and soil bulk density variables in Oak plantation were not significantly different among the seasons. It should be mentioned that the highest soil bulk density (1.14 gr/cm^3) was measured at Maple plantation in spring and the lowest amount of bulk density (1.14 gr/cm^3) was measured at Cypress plantation in summer (table 6).

Some variables of litter characteristics have also been studied. As illustrated in table 6, the highest litter moisture (72.16%) was at Maple plantation in autumn, while the lowest litter moisture (7.52%) was at Alder plantation in summer. The phosphorus content of litter varied between 0.08 ppm (Oak in spring) to 0.32 ppm (Maple in summer). Also the highest potassium content of litter (1.71 ppm) was measured at Maple plantation in spring and the lowest amount of this variable (0.14 ppm) was measured at natural forest in autumn. In addition, the seasonal nitrogen content of litter showed significant difference only among Oak and Maple plantations. This variable varied between 1.55 ppm (Maple in spring) and 2.77 ppm (Maple in summer).

Table 6. Comparison of two soil characteristics at different treatments.

Variables	Season	Plantation areas				Natural forest
		Alder	Maple	Oak	Cypress	
Soil moisture (%)	Summer	17.60 b A	19.75 b A	15.45 b A	17.99 b A	16.85 c A
	Autumn	24.49 a A	19.58 b B	17.52 b B	17.89 b B	19.98 bc B
	Winter	22.30 ab B	27.56 a A	26.52 a A	27.98 a A	27.28 a A
	Spring	19.49 b B	22.25 b B	24.36 a A	13.96 c C	22.88 b B
Bulk density (gr. cm-3)	Summer	1.17 c B	1.17 b B	1.31 a A	1.14 b B	1.23 ab AB
	Autumn	1.25 bc BC	1.33 a AB	1.39 a A	1.28 a BC	1.19 b C
	Winter	1.29 b B	1.16 b B	1.31 a A	1.14 b B	1.24 ab AB
	Spring	1.40 a A	1.38 a A	1.35 a A	1.38 a A	1.32 a A

Small letters at the right side of the numbers show significant differences within the seasons and Capital letters under the numbers show significant differences among the treatments.

Some variables of litter characteristics have been also studied. As illustrated in table 7, the highest litter moisture (72.16%) was at Maple plantation in autumn, while the lowest litter moisture (7.52%) was at Alder plantation in summer. The phosphorus content of litter varied between 0.08 ppm (Oak in spring) to 0.32 ppm (Maple in summer). Also the highest potassium content of litter (1.71 ppm) was measured at Maple plantation in spring and the lowest amount of this variable (0.14 ppm) was measured at natural forest in autumn. In addition, the seasonal nitrogen content of litter showed significant difference only among Oak and Maple plantations. This variable varied between 1.55 ppm (Maple in spring) and 2.77 ppm (Maple in summer).

In factore analysis, to increase KMO to a level higher than 0.7 and the Bartelett test of Sphericity ($p< 0.001$), the seventeen variables were reduced to eight variables. The results of this study showed that, two factors were extracted from the eight variables. As illustrated in figure 1, the results of factors coefficient matrix after Varimax rotation indicates that mean variables of crown density, environment temperature, litter phosphorous with positive coefficient and mean variables of relative light intensity, litter and soil moisture with strong negative coefficients have great values to the first axis (49.56 % of variance), while the mean variables of litter nitrogen and earthworm abundance with strong positive coefficients have great values to the second axis (27.20% of variance). The two factors explained 76.76% of the total variance. Also the variables of crown density and litter nitrogen have the most values to the first and second axes, respectively (table 8).

Table 7. Comparisons of four litter characteristics at different treatments.

Variables	Seasons	Plantation areas				Natural forest
		Alder	Maple	Oak	Cypress	
Litter moisture (%)	Summer	7.52 d C	10.60 d AB	9.13 c BC	11.04 c A	8.65 d C
	Autumn	61.44 a BC	72.16 a A	63.75 a B	57.36 a C	60.33 a BC
	Winter	25.96 c A	61.88 b A	60.58 a AB	55.57 a BC	51.87 b C
	Spring	41.21 b A	18.78 c C	42.90 b A	29.54 b B	42.96 c A
Nitrogen (ppm)	Summer	2.63 a A	2.7 a A	2.12 a B	1.73 a C	2.00 a B
	Autumn	2.48 a A	1.92 b B	1.66 b B	1.75 a C	1.92 a B
	Winter	2.45 a A	1.73 c C	1.46 c C	1.83 a B	1.79 a B
	Spring	2.56 a A	1.55 d C	1.49 c C	1.81 a B	1.82 a B
Phosphorus (ppm)	Summer	0.26 a B	0.32 a A	0.23 a B	0.26 a B	0.26 a B
	Autumn	0.09 d C	0.13 b A	0.10 b B	0.11 b B	0.10 b BC
	Winter	0.14 b A	0.13 b A	0.11 b B	0.12 b AB	0.11 b B
	Spring	0.13 bc BC	0.14 b A	0.08 c B	0.12 b A	0.11 b A
Potassium (ppm)	Summer	0.50 c A	0.49 c B	0.51 c A	0.50 b A	0.50 c A
	Autumn	0.20 c B	0.27 d A	0.20 d B	0.16 b C	0.14 d C
	Winter	1.23 b AB	1.39 b A	1.11 b AB	0.85 a B	0.99 b B
	Spring	1.67 a A	1.71 a A	1.58 a A	1.01 a B	1.72 a A

Table 8. Extracted sums of variance explained with varimax rotation.

Axes	Initial eigenvalues		Rotation sums of loadings		
	Variance (Percent)	Cumulative (percent)	total	Variance (Percent)	Cumulative (percent)
	58.64	58.64	3.96	49.56	49.56
	18.12	76.76	2.18	27.19	76.76

The location of factor scores for each treatment (observation), have been shown in figure 2. Situation of various variables in fig. 1 and treatments (observations) in first axis of the fig. 2 indicate that in summer the variables of crown density, temperature and litter phosphorous have a high importance in treatments of natural forest, Oak, Maple and Cypress plantations (coefficient higher than 1 in fig. 2). Also variables of relative light intensity, litter and soil moisture, have a high importance in natural forest and Oak plantation in winter as well as Maple and Alder plantations during autumn and winter (negative coefficient less than 1 in fig. 2). Moreover the second axis in fig. 2 shows that variables of litter nitrogen and earthworm abundance have an important effect on Oak and Maple plantations in summer as well as Alder plantation during spring and summer (coefficient higher than 1 in fig. 2). Moreover, in autumn, winter and spring the variables of litter nitrogen and earthworm abundances have the least significant effect at Cypress plantation while in winter and spring seasons, the above variables have the least Small letters at the right side of the numbers show significant differences within the seasons and Capital letters under the numbers show significant differences among the treatments.

Discussion

This research has confirmed the significant effect of different treatments on earthworm abundance and biomass. Cypress plantation in this research has devoted minimum annual means of earthworm abundance and biomass compared with broad-leaved planted and natural forests (table 1). Other studies have shown the earthworm biomass is significantly influenced by type of tree species (Neirynck *et al.*, 2000; Sarlo, 2006). Also in another research conversion of pure Scots pine treatments to mixed treatments with broad-leaved species, caused an increase in abundance and biomass of earthworms (Ammer *et al.*, 2006).

significant effect in Oak plantation (negative coefficient less than 1 in fig. 2).

The analysis of Factor analysis in this research showed that the variables of temperature, crown density, relative light intensity, soil and litter moisture and litter phosphorous and nitrogen have an important role in seasonal alteration of earthworm abundances (table 8). Our study on seasonal changes of earthworm abundance (table2) showed that the highest abundance in the natural forest is observed in spring and autumn but they decrease in summer and winter. The position of variables in fig. 1 and the treatments of natural forest in fig. 2 indicates that mean variables of crown density, temperature and litter phosphorous (table 6) have an important influence in

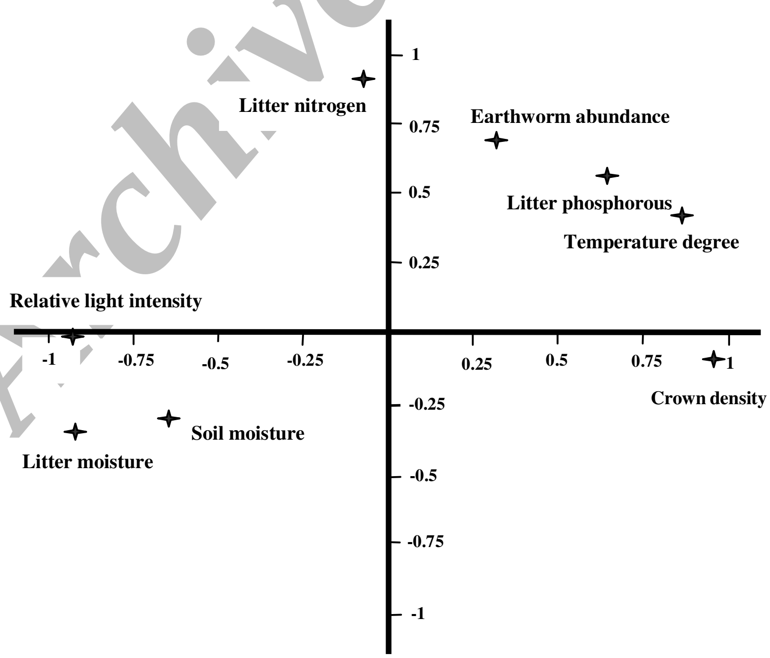

Fig 1. Situation of variables to first and second axes according to rotated factor plot.

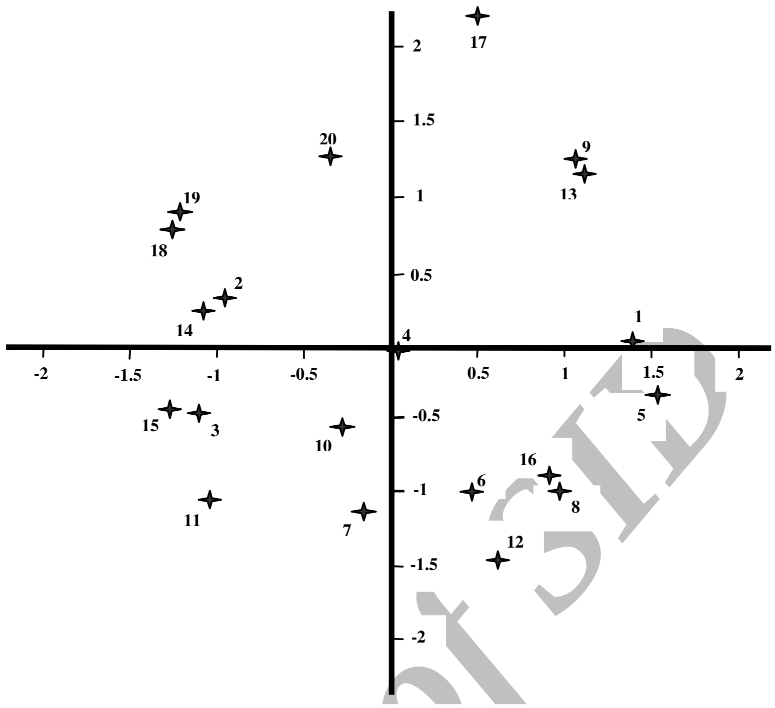

Fig 2. Situation of treatments to first and second axes according to factor scores.

1- Natural forest in summer	**2- Natural forest in autumn**	**3- Natural forest in winter**	**4- Natural forest in spring**
5- Cypress refores. in summer	**6- Cypress refores. in autumn**	**7- Cypress refores. in winter**	**8- Cypress refores. in spring**
9- Oak refores. in summer	**10- Oak refores. in autumn**	**11- Oak refores. in winter**	**12- Oak refores. in spring**
13- Maple refores. in summer	**14- Maple refores. in autumn**	**15- Maple refores. in winter**	**16- Maple refores. in spring**
17- Alder refores. in summer	**18- Alder refores. in autumn**	**19- Alder refores. in winter**	**20- Alder refores. in spring**

summer, while relative light intensity, litter and soil moisture (table 5) are important in winter. On the other hand, unfavourable environmental factors such as high temperature, closed crown density in summer and also high intensity of relative light and high soil and litter moisture in winter decreased earthworm abundance (table 2). Another research in natural forest of hornbeam, Oak-hornbeam and beech treatments in the Caspian region showed that the maximum abundance and biomass of earthworms are in spring and autumn and they decrease in winter and summer (Rahmani & Saleh-Rastin, 2000).

Considering the Alder plantation, the variables of crown density, temperature, litter phosphorous have not high importance in spring and summer (the first axis in fig. 1), but litter nitrogen and earthworm population have high importance in spring and summer (the second axis in fig. 2). Also relative light intensity with litter and soil moisture have a big influence in autumn and winter (the first axis in fig. 1). Decrease in tree density of the even aged plantation of Alder (498 stems in ha), reduced its crown density high importance in summer. Favourable nutritional conditions of litter nitrogen have influenced increases earthworm abundance in summer and spring (table 2). Also resembling to the natural forest, high intensity of relative light, high soil moisture (table 5) and high litter moisture (table 6) decrease earthworm abundance in autumn and winter (table 2). Other studies have confirmed the effect of unfavourable environmental and nutritional conditions on earthworm abundance (Qiwei & Thomson, 1994; Saetre, 1998; Timmerman *et al*., 2006).

This research showed that the highest earthworm abundance in the plantaions is observed in summer and the least earthworm abundance in winter (table 2). In the Cypress plantation, variables of temperature, crown density and litter phosphorous (the first axis in fig.1) attain high importance during summer, while the variables of litter nitrogen and earthworm abundance have low importance in autumn, winter and spring (the second axis in fig. 2). Oak and Maple plantation variables including temperature, crown density, litter phosphorous (the first axis in fig.1), litter nitrogen and erthworm population (the second axis in fig.1) attain high importance during summer, while the variables of relative light intensity, litter and soil moisture have high importance in winter (the first axis in fig.2). In addition for Oak plantation, litter nitrogen and earthworm population have low importance in winter and spring (the second axis in fig. 2). This study shows that favourable environmental and nutritional conditions for Oak, Maple and Cypress plantations in summer such as high temperature, closed crown density (table 5) and high litter phosphorous (table 6) increased earthworm population. Also unfavourable environmental and nutritional conditions in Oak plantation with unfavourable environmental conditions in Maple plantation and Unsuitable nutritional conditions in Cypress plantation has influenced the decrease of earthworm abundance in winter (table 2). Moreover, other researches have corroborated the effect of crown density (Sarlo, 2006), soil properties (Cotton & Curry, 1982; Mele & Carter, 1999; Bernard *et al*., 2007), Litter nutrients (Zou, 1993; Gonzalez & Zou, 1999), winter coldness (Timmerman *et al*., 2006), moisture (Madge, 1969), climatic conditions (Lavelle, 1983) and different seasons (Rahmani, 2000) on earthworm abundance.

It must be mentioned that closed crown density of the natural forest in summer has influenced the decrease of earthworm abundance, while in even aged Oak and Maple they increase earthworm abundance. In alder plantation high litter nitrogen has a significant positive effect on earthworm abundance in summer and in Cypress plantation; diminution of litter nitrogen related to decrease of earthworm abundance. Therefore, during silvicultural interventions that occur in the decreasing of abundance we must conserve natural seedlings and suitable root suckers. In this situation, we not only improve growing stock and uneven-ageness of stands but also increase canopy density and litter nutrient cycling that will be also suitable for earthworm abundance.

Introduction of suitable species is the most important factor for successful forest plantation. According to our quantitative studies in microsample plots (table 4) and the previous quantitative and qualitative studies (Mohammadnezhad kiasari *et al*., 2009a), planting of Cypress (*Cupressus sempervirens* L. var. *horizontalis*) is not successful compared with broad-leaved plantations and natural forest. In the mean time, from qualitative point of view, the treatment of natural forest is unsuitable and plantation of Cypress achieved the worst results. This research verifies that the native broad-leaved species has a significant effect in comparison to needle-leaved species on increase of earthworms biomass and abundance. Also there is not a significant difference between broad-leaved plantations and natural forest in terms of earthworm biomass and abundance (table 1). Therefore, in rehabilitation of degraded natural forests in lowland areas in north of Iran, plantation with suitable native broad-leaved species is recommended.

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