Earthworm biomass and abundance, soil chemical and physical properties under different poplar plantations in the north of Iran

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ABSTRACT: We evaluated earthworm abundance and biomass in plantations of different poplar species and clones as well as the effect of some soil chemical and physical properties on them. Even-aged poplar species and clones, planted at Safrabasteh Poplar Research Station about 18 years ago in the north of Iran, included: *Populus deltoides* Bartr. cv. 69/55 (*P. d.* 69/55), *Populus deltoides* Bartr. cv. 63/51 (*P. d.* 63/51), *Populus euramericana* Guinier. cv. 45/51 (*P. e.* 45/51), *Populus euramericana* Guinier. *triplo* (*P. e. triplo),* and *Populus caspica* Born M. (*P. caspica),* as endemic and endangered poplar species, were selected in this study. Earthworm abundance and biomass, soil texture, bulk and particle density (BD, PD), pH, organic carbon (OC), total nitrogen (N), available phosphorus (P) and exchangeable potassium (K) were evaluated. The results showed that the earthworm abundance and biomass, OC, P and N in *P. d.* 63/51 were higher than in the other poplar species and clones. The correlation coefficients showed a positive correlation of OC, N and a negative correlation of pH, clay, BD and P with earthworm biomass. Based on the results, compared to the other species and clones *P. d.* 63/51 creates favourable conditions to produce more organic matter and higher abundance and biomass of earthworms, hence it could be beneficial for maintaining the soil quality status for successive plantings.

Keywords: soil properties; *populus* clones; *populus caspica*; organic carbon; poplar

The major part of the north of Iran is covered by the Caspian forest, a deciduous temperate commercial forest, of about 1.8 million ha located on northern slopes of the Alborz Mountains overlooking the Caspian Sea (Salehi, Maleki 2012). Between the mountain region and the Caspian Sea, there are plain areas that have been involved in agriculture, reforestation or deforestation activities in the last decades. Guilan province, as one of the provinces located in the north of Iran, has vast plain areas covered by natural forests, crops and poplar plantations. Because of the population growth, increasing demand for wood and decline of forest harvesting, development of plantations of fast-growing species, especially poplars, has occurred in the plain of Guilan province in recent years (Kiadaliri 2003). Poplar has been planted by the villagers and big companies at various levels in the north of Iran, particularly in Guilan province.

Dickmann and Stuart (1983) concluded that poplars could grow almost everywhere, but they perform up to their full potential only on the best sites. Soil physical properties which play major roles in water holding capacity, aeration and root penetration, have a strong influence on the growth of poplars. As the soil can affect poplar growth, these trees also affect different soil properties. Singh and Sharman (2007), and Augusto and Ranger (2002) stated that tree plantations influence soil physical, chemical and biological properties negatively or positively through litter fall, accretion and decomposition of organic matter. It seems that different poplar plantations of various quality and quantity have been able to change some soil properties in the Guilan plain in successive years.

In soil, earthworms represent the largest component of animal biomass and are commonly termed ecosystem engineers (Blouin et al. 2013). Earthworms are subject to physical, chemical and biological changes in soil. The earthworms have a major role in the soil structure and they transfer mineral and organic materials to different horizons (Rahmani, Salehrastin 2000).The earthworms have the highest biomass of earth invertebrates and they cause a remarkable increase in soil microorganisms and have an important effect on soil invertebrate diversity and feed cycle (Rahmani, Salehrastin 2000).

Earthworm biomass is an appropriate biological indicator of soil fertility, humus quality, degradation, pollution and habitat productivity. Earthworms constitute the highest biomass within the soil macrofauna (Fragoso, Lavelle 1992) and they are known to affect the soil physical, chemical and biological properties. Earthworm biomass is a suitable indicator to determine soil pH, soil moisture and organic layer (Muys, Granval 1997), and it seems that tree species have different effects on earthworm biomass and abundance. In broadleaved forests the presence of earthworms could be dependent on litter and soil characteristics (Irannejad, Rahmani 2009).

The researches that investigate a relationship between the activity of earthworms and the soil properties and environmental factors have shown the increasing importance of earthworms. Zou and Gonzalez (1999) concluded that tree plantations may influence earthworm abundance by altering the chemical and/or physical properties of soil such as moisture regime, pH, soil organic matter levels and litter inputs. Also, native tree plantations can benefit from the establishment of populations of native earthworm species (Zou, Gonzalez 2002). According to Tian et al. (2000), tree plantations may influence earthworm abundance by altering the physicochemical properties of soils viz. temperature, moisture regime, pH, soil organic content, litter inputs.

On the basis of the above-mentioned facts it seems that there are complex relationships between soil properties and poplar plantations. This study was carried out to determine the influence of different poplar species and clones on earthworm biomass and abundance, soil chemical and physical properties and then to establish how earthworm activities correlate with soil properties.

MATERIAL AND METHODS

Study area

The study was carried out at the Safrabasteh Poplar Research Station in Guilan province in the north of Iran (37°19'N, 49°57'E). The area is on a flat and uniform terrain in a plain region at the altitude of –10 m a.s.l. Mean annual rainfall and temperature are 1,186 mm and 17.5°C, respectively. The soil of the study area is formed on the alluvial fine-textured sediment with moderate to heavy texture and neutral to low acidic reaction.

The study area, which was dominated by natural forests containing native species such as *Alnus glutinosa, Pterocarya fraxinifolia, Populus caspica, Gleditschia caspica*, was planted with different poplar species and clones about 18 years ago. The area of the poplar plantation is about 4 ha and the poplar trees were planted at a 4 × 4 m spacing.

Experimental design, soil sampling and analyses

The experimental design was a completely randomized block with three replications and five treatments: *Populus deltoides* Bartr cv. 69/55 (*P. d.* 69/55), *Populus deltoides* Bartr cv. 63/51 (*P. d.* 63/51), *Populus euramericana* Guinier. cv. 45/51 (*P. e.* 45/51*), Populus euramericana* Guinier. *triplo (P. e. triplo),* and *Populus Caspica* Born M. (*P. caspica)* as endemic and endangered poplar species. As the highest abundance of earthworms, because of suitable soil aeration conditions and more food and atmosphere, is present in the surface layers of the soil (Rahmani, Salehrastin 2000), three soil samples were randomly taken from a soil depth of 0–20 cm in each clone. In this way, fifteen soil samples were taken from the depth of 0–20 cm and transferred to a soil laboratory for analyses. All soil samples were air-dried and passed through a 2 mm mesh. In the laboratory, these soil characteristics were determined: bulk density (BD) by clod method, particle density (PD) by pycno meter method (Ghazanshahi 1999), soil pH in a water suspension of 1:2.5 (soil to liquid ratio), soil texture by hydrometer method (Bouyoucos 1962), total nitrogen (N) by Kjeldahl method (Bremner 1996), organic carbon (OC) by Walkley and Black method (Walkley, Black 1934) and available phosphorus (Olsen et al. 1954). Available phosphorus (P) was analysed according to the standard methods

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Table 1. Analysis of variance of soil physical and chemical properties among the treatments

Source of variance	df	PD	BD	Clay	Silt	Sand	pH (H_2O)	OC	N	C/N	P	K
		F-value										
Block	2	0.19	0.38	0.17	1.21	0.37	1.19	0.27	0.37	3.41	3.83	2.28
Treatment	4	1.45	0.50	0.28	0.45	0.27	1.86	3.82**	4.56**	4.02**	8.36*	3.56
Error	8	–	–	–	–	–	–	–	–	–	–	–

df – degrees of freedom, PD – particle density, BD – bulk density, OC – organic carbon, *significant at $\alpha = 0.05$, **significant at $\alpha = 0.01$

(Olsen et al. 1954). Exchangeable K is analysed after extraction with 1M ammonium acetate at pH 7.0 by flame photometer (Black et al. 1965).

Earthworm sampling

Earthworm populations were sampled by digging and hand sorting two 50 × 50 cm areas into a depth of 20 cm in each treatment. Sampling was done in the autumn 2012. Earthworms were counted in the field and brought to the laboratory. All the earthworms were counted and then they were oven dried at 60°C for 24 h. All the dried earthworms were weighed to the nearest 0.0001 g to determine their biomass (Welke, Parkinson 2003). The abundance of earthworms was calculated as the number of indd per m^2.

Statistical Analyses

Normality of variables was checked by the Kolmogorov-Smirnov test and Levene's test was used to examine the equality of variances. One-way analysis of variance (ANOVA) was used to compare soil properties and earthworm abundance and biomass. Tukey's HSD test was used to separate the means of dependent variables which were significantly affected by treatment. Correlations between earthworm abundance and soil variables were determined by Pearson's correlation coefficient. For all the statistical analyses, SPSS (Version 17.0) was used.

RESULTS

The results did not show any significant differences in soil physical properties among the treatments. OC, N and P contents of soil differed significantly among the treatments (Table 1).

The amounts of N and P as the most important nutrient elements and also OC are higher in *P. d.* 63/51. The soil surface layer of *P. caspica* showed the lowest amounts of OC, N and P compared to the other species and clones (Table 2).

Based on the results of this study, the abundance and biomass of earthworms differed significantly among the treatment (Table 3).

The abundance and biomass of earthworms in *P. d.* 63/51 are higher than in the other clones and *P. caspica* showed the lowest amount (Figs 1 and 2). On the basis of field observations, 53–63% of the total number of earthworms has the clitellum in *P. caspica* and *P. d.* 63/51, respectively.

Table 2. Mean ± standard error of soil chemical properties among the treatments

Treatment	pH (H_2O)	OC (%)	N (%)	C/N	P (mg·kg^{-1})	K (mg·kg^{-1})
P. caspica	7.98 ± 0.13^{a}	1.61 ± 0.14^{b}	0.13 ± 0.01^{b}	12.10 ± 0.14^{a}	130.34 ± 4.62^{b}	170.69 ± 5.63^{a}
P. d. 69/55	7.85 ± 0.12^{a}	2.41 ± 0.20^{ab}	0.21 ± 0.01^{ab}	11.65 ± 0.11^{a}	180.56 ± 32.02^{b}	226.94 ± 22.41^{a}
P. d. 63/51	7.82 ± 0.09^{a}	2.85 ± 0.31^{a}	0.24 ± 0.02^{a}	11.58 ± 0.16^{a}	276.02 ± 31.23^{a}	250.11 ± 21.07^{a}
P. e. triplo	7.92 ± 0.23^{a}	1.78 ± 0.13^{b}	0.15 ± 0.01^{b}	11.79 ± 0.13^{a}	176.97 ± 24.65^{b}	170.69 ± 15.12^{a}
P. e. 45/51	7.94 ± 0.18^{a}	1.70 ± 0.27^{b}	0.14 ± 0.02^{b}	12.02 ± 0.18^{a}	136.70 ± 15.45^{b}	190.54 ± 14.31^{a}

OC – organic carbon, *P. caspica* – *Populus Caspica* Born M., *P. d.* 69/55 – *Populus deltoides* Bartr. cv. 69/55, *P. d.* 63/51 – *Populus deltoides* Bartr. cv. 63/51, *P. e. triplo* – *Populus euramericana* Guinier. *triplo*, *P. e.* 45/51 – *Populus euramericana* Guinier. cv. 45/51; different letters indicate significant differences between the mean values for a particular parameter

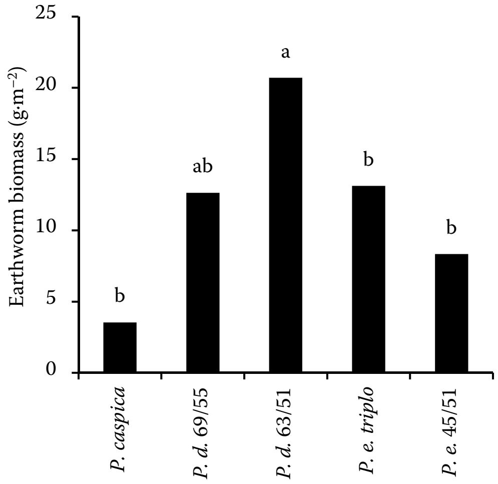

Fig. 1. Average of earthworm biomass in the different treatments

different superscripts indicate significant differences among the treatments ($P < 0.05$)

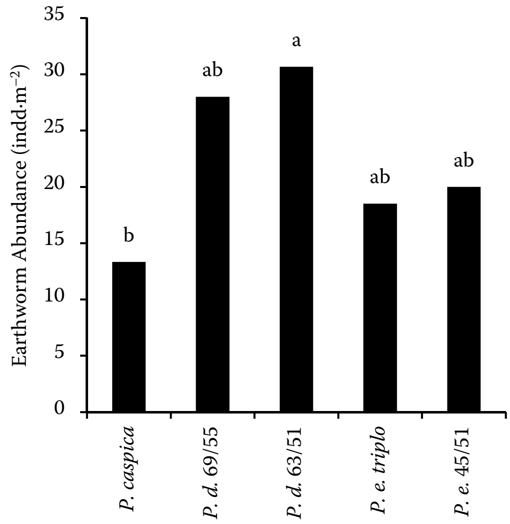

Fig. 2. Mean of earthworm abundance in the different treatments

different superscripts indicate significant differences among the treatments ($P < 0.05$)

Correlation of physical and chemical properties of soil with earthworm abundance

The results of Pearson's correlation coefficient in *P. d.* 63/51 and *P. caspica*, as two important treatments, showed a negative correlation of the soil properties pH, clay content, BD and P with earthworm abundance and a positive correlation of OC and N with earthworm abundance. The other treatments also showed some correlations (Table 4).

DISCUSSION

As the even-aged and adjacent clones and species of poplar were planted and developed under the same site conditions, it seems that the variations of the studied soil chemical and biological properties were caused by poplar species and clones.

The results of this research did not show any significant differences in physical properties of soil among poplar species and clones (the treatments). Augusto and Ranger (2002) and Binkley and Sollins (1995) stated that the soil physical properties such as texture, density, porosity and structure are almost related to variations of site conditions. Fakharirad (2005) also stated that in even-aged alder and loblolly pine stands, the differences in soil physical properties were very small and soil chemical properties often showed significant changes.

After about 18 years, different treatments had different effects on the soil nutrient status and it seems that the surface soil nutrient differences are due to the nutrient function of each treatment. N, P, K and organic carbon showed significant differences in the soil under the treatments and their high and low amounts were observed in *P. d.* 63/51 and *P. caspica*, respectively. OC and N, as the most important soil organic and inorganic elements, can be influenced by different combinations of trees. Salehi (2004) concluded that the effects of trees on soil properties occur mostly due to the increase of organic matter and the release of nutrients from it. Direct effects of plant species on soil and litter biota are caused by plant inputs of organic matter (Neher 1999). Augusto and Ranger (2002), Singh and Sharman (2007) noted the effect of the poor quality and quantity of litter on its inappropriate decomposition and weak nutrient release to the soil.

Several studies (Nicolai 1988; Zou 1993; Tian et al. 2000) suggested that the chemical composition of plants, including N, lignin content and phenol compounds, plays a crucial role in the properties of soil and litter fauna through their effect on decomposability. The results of this study indicated that the abundance and biomass of earthworms were higher and lower in *P. d.* 63/51 and *P. caspica*, respectively. Changes in vegetation can affect the distribution and abundance of earthworms through changes in litter quality and indirectly through changes in soil properties (Muys, Granval 1997). The variations of earthworm biomass are related to soil properties and site conditions (Irannejad, Rahmani 2009).

Table 3. ANOVA for earthworm abundance and biomass among the treatments

Source of variance	df	*F*-value	
		earthworm abundance	earthworm biomass
Block	2	0.42	0.27
Treatment	4	4.20*	5.30**
Error	8	–	–

df – degrees of freedom, *significant at α = 0.05, **significant at α = 0.01

The results of this study showed that the abundance of earthworms had a negative correlation with clay content and BD Ashja (2002) stated that increased soil bulk density caused a reduction of abundance and biomass of earthworms. Jongmans et al. (2003) noted that the soil texture is known as one of the variables affecting the abundance of earthworms. A comparison of two beech forests in Europe also showed that the soil texture can exert an effect on earthworm abundance (Cuendet 1984).

The correlation coefficients in *P. d.* 63/51 and *P. caspica* showed a positive relationship of earthworm abundance with OC (0.58, 0.46), N (0.68, 0.75) and a negative correlation with pH (–0.76, –0.56), P (–0.75, –0.64), respectively. According to the results, earthworm abundance and biomass decreased with increasing soil pH. Although pH did not show any significant differences among the treatments, the amount of it was lower in *P. d.* 63/51, where the abundance and biomass of earthworms were more comparable to the other treatments. Iordache and Borza (2010) found out a negative correlation of pH and phosphorus with earthworm number and biomass. They reported that the phosphorous content of soil exerted the greatest negative influence on earthworm biomass. Bünemann et al. (2011) quoted from Guggenberger et al. (1996) found higher levels of alkali-extractable organic P in earthworm cast than in surrounding oxisol. The amount of P returned into the soil by the earthworm activities and P fluxes through earthworm biomass are unfortunately still poorly known whatever the spatiotemporal scale (Milleret et al. 2009). Bünemann et al. (2011) concluded that earthworm impacts on P dynamics and availability in the soil depend on the particular properties of soil, organic P source, and the specific burrowing behaviour and food preferences of worms.

The positive correlation of the abundance and biomass of earthworms with OC and N indicates the role of OC as energy source for soil organisms. The organic carbon degradation rate improves soil fertility and provides a higher amount of nutrients for the plants and the other soil organisms. Burtelow et al. (1998) and Fonte et al. (2009) found that earthworm biomass was positively correlated with total soil OC

Table 4. Pearson's correlation coefficient and significant area between physical and chemical soil properties and earthworm

	Sand	Silt	Clay	PD	BD	pH (H_2O)	OC	N	P	K	C/N
P. caspica	0.47	0.45	–0.48	0.38	–0.56*	– 0.56*	0.46	0.75*	–0.64*	0.35	0.52
Significant (2-tailed)	0.56	0.23	0.21	– 0.52	0.04	0.02	0.31	0.04	0.02	0.64	0.34
P. d. 69/55	0.31	0.21	–0.53	0.24*	–0.42	– 0.73**	0.89*	0.76*	– 0.58*	0.38	0.42
Significant (2-tailed)	0.64	0.51	0.28	0.48	0.23	0.01	0.02	0.03	0.03	0.61	0.23
P. d. 63/51	0.43	0.23	–0.54*	0.27	–0.78**	– 0.76**	0.58**	0.68**	–0.75**	0.45	0.34
Significant (2-tailed)	0.52	0.42	0.04	0.52	0.02	0.01	0.01	0.02	0.02	0.61	0.28
P. e. triplo	0.32	0.31	–0.74*	0.24	–0.52*	– 0.66*	0.89*	0.49*	0.62	0.32	0.57
Significant (2-tailed)	0.36	0.41	0.04	0.41	0.05	0.03	0.04	0.05	0.32	0.51	0.24
P. e. 45/51	0.33	0.26	–0.64	0.35	0.54	– 0.65*	0.58*	0.62*	–0.54	0.21	0.47
Significant (2-tailed)	0.45	0.36	0.41	0.42	0.24	0.02	0.02	0.04	0.08	0.43	0.53

PD – particle density, BD – bulk density, OC – organic carbon, *P. caspica* – *Populus caspica* Born M., *P. d.* 69/55 – *Populus deltoides* Bartr. cv. 69/55, *P. d.* 63/51 – *Populus deltoides* Bartr. cv. 63/51, *P. e. triplo* – *Populus euramericana* Guinier. *triplo*, *P. e.* 45/51 – *Populus euramericana* Guinier. cv. 45/51, *significant at α = 0.05, **significant at α = 0.01

and N. Ayuke et al. (2009) reported that some earthworm groups were positively correlated with N and were found to be abundant in the forests.

Based on the results OC, N, P and K in the soil differed among the treatments in the order: *P. caspica* < *P. e.* 45/51 < *P. e. triplo* < *P. d.* 69/55 < *P. d.* 63/51. It could be concluded that *P. d.* 63/51 clone showed favourable conditions to produce more organic matter. It could be beneficial for the abundance and biomass of earthworms and for maintaining the soil nutrient status for successive plantings in the north of Iran and other sites parallel to the study area.

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References

Ashja B. (2002): Earth Worm Ecological Group's Relation to with Soil Fertility and Forest Vegetation. Tehran, Tehran University Press: 106. (in Persian)

Augusto L., Ranger J. (2002): Impact of several common tree species of temperate forest on soil fertility. Annals of Forest Science, ***59***: 233–254.

Ayuke F.O., Karanja N.K., Muya E.M., Musombi B.K., Mungatu J., Nyamasyo G.H.N. (2009): Macrofauna diversity and abundance across different land use systems in Embu, Kenya. Tropical and Subtropical Agroecosystems, ***11***: 371–384.

Binkley D., Sollins P. (1995): Factors determining in soil pH in adjacent conifer and alder-conifer stands. Soil Science Society of American Journal, ***54***: 1427–1433.

Black C.A., Evans D.D., White J.L., Ensmiger L.E., Clark F.E. (1965): Methods of Soil Analysis. Madison, American Society of Agronomy-Soil Science Society of America: 231.

Blouin M., Hodson M.E., Delgado E.A., Baker G., Brussaard L., Butt K.R., Dai J., Dendooven L., Peres G., Tondoh J.E., Brun J.J. (2013): A review of earthworm impact on soil function and ecosystem services. European Journal of Soil Science, ***64***: 161–182.

Bouyoucos C.J. (1962): Hydrometer method improved for making particle-size analysis of soil. Agronomy Journal, ***54***: 464–465.

Bremner J.M. (1996): Nitrogen-Total. In: Sparks D. (ed.): Methods of Soil Analysis. Madison, American Society of Agronomy-Soil Science Society of America: 1085–1122.

Bünemann E.K., Oberson A., Frossard E. (eds) (2011): Phosphorus in Action. Berlin Heidelberg, Springer-Verlag: 483.

Burtelow A.E., Bohlen J.P., Groffman P.M. (1998): Influence of exotic earthworm invasion on soil organic matter, microbial biomass and denitrification potential in forest soils of the northeastern United States. Applied Soil Ecology, ***9***: 197–202.

Cuendet G. (1984): A comparative study of the earthworm population of four different woodland types in Wytham woods. Pedobiologia, ***26***: 421–439.

Dickmann D.I., Stuart K.W. (1983): The Culture of Poplars in Eastern North America. East Lansing, Michigan State University: 168.

Fakharirad M. (2005): Afforest Effect *Pinustaeda* on Some Physical and Chemical Properties of Soils in West Guilan Province. Guilan, University of Guilan Press: 101. (in Persian)

Fonte S.J., Thaiis W., Six J. (2009): Earthworm populations in relation to soil organic matter dynamics and management in California tomato cropping systems. European Journal of Soil Biology, ***4***: 206–214.

Fragoso C., Lavelle P. (1992): Earthworm communities in tropical rain forests. Soil Biology and Biochemistry, ***24***: 1397–1409.

Ghazanshahi M. (1999): Soil and Plant Analysis. Tehran, Motarjem Press: 311. (in Persian)

Guggenberger G., Haumaier L., Thomas R.J., Zech W. (1996): Assessing the organic phosphorous status of an Oxisol under tropical pastures following native savanna using spectroscopy. Biology and Fertility of Soils, ***23***: 332–339.

Iordache M., Borza I. (2010): Relation between chemical indices of soil and earthworm abundance under chemical fertilization in Romania. Plant, Soil and Environment, **56:** 401–407.

Irannejad E., Rahmani R. (2009): Evaluation of earthworm abundance and vertical distribution pattern in some forest types of Shast-Kolateh. Journal of Forest and Wood Products, ***62***: 145–157.

Jongmans A.G., Pulleman M.M., Balabane M., van Oort F., Marinissen J.C.Y. (2003): Soil structure and characteristics of organic matter in two orchards differing in earthworm activity. Applied Soil Ecology, ***24***: 219–232.

Kiadaliri S.H. (2003): Study of Populus Plantations on Different Soils in Western Parts of Mazandaran. Tarbiat Modarres, Tarbiat Modarres University Press: 105. (in Persian)

Milleret R., Le Bayon R.C., Gobat J.M. (2009): Root, mycorrhiza and earthworm interactions: their effects on soil structuring processes, plant and soil nutrient concentration and plant biomass. Journal of Plant and Soil, ***316***: 1–12.

Muys B., Granval P. (1997): Earthworms as bio-indicators of forest site quality. Journal of Soil Biology and Biochemistry, ***29***: 323–328.

Neher D.A. (1999): Soil community composition and ecosystem process: Comparing agricultural ecosystems with natural ecosystems. Agroforestry Systems, ***45***: 159–185.

Nicolai V. (1988): Phenolic and mineral contents of leaves influences decomposition in European forests ecosystems. Oecologia, ***75***: 575–579.

Olsen S.R., Cole C.V., Watenabe F.S., Dean L.A. (1954): Estimation of Available Phosphorus in Soil by Extraction with Sodium Bicarbonate. Washington, DC, United States Department of Agriculture: 19.

Rahmani R., Salehrastin N. (2000): Abundance, vertical distribution and seasonal changes in earthworm abundance of oak-hornbeam, hornbeam and beech forests in Neka, Caspian forests, Iran. Iranian Journal of Natural Resource, ***53***: 37–52.

Salehi A. (2004): Investigate Changes in Soil Physical and Chemical Properties in Connection with the Composition of Tree Cover and Topographic Factors in Namkhaneh section Kheyroodkenar forest. Tehran, Tehran University Press: 187. (in Persian)

Salehi A., Maleki M. (2012): Evaluation of soil physical and chemical properties in poplar plantations in north of Iran. Ecologia Balkanica, ***4***: 69–76.

Singh B., Sharman K.N. (2007): Tree growth and nutrient status of soil in poplar (*Populus deltoides* Bartr.) – based agroforestry system in Punjab, India. Agroforestry Systems, ***70***: 125–134.

Tian G., Olimah J.A., Adeoye G.O., Kang B.T. (2000): Regeneration of earthworm population in a degraded soil by natural and planted fallows under humid tropical conditions. Soil Science Society of America Journal, ***64***: 222–228.

Walkley A.J., Black C.A. (1934): Estimation of organic carbon by chromic acid titration method. Journal of Soil Science, ***37***: 29–38.

Welke S.E., Parkinson D. (2003): Effect of *Aporrectodea trapezoides* activity on seedling, growth of *Pseudotsugamenziesii* nutrient dynamics and microbial activity in different forest soils. Journal of Forest Ecology and Management, ***173***: 169–186.

Zou X. (1993): Species effect on earthworm density in tropical tree plantations in Hawaii. Biology and Fertility of Soils, ***15***: 35–38.

Zou X., Gonzalez G. (1999): Plant and litter influences on earthworm abundance and community structure in a tropical wet forest. Biotropica, ***31***: 486–493.

Zou X., Gonzalez G. (2002): Earthworms in tropical tree plantation: effects of management and relations with soil carbon and nutrient use efficiency. In: Reddy M.V. (ed.): Managment of Tropical Plantation-Forests and Their Soil Litter System. Enfield, Science Publishers: 289–301.

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