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Evaluation of Soil Physical and Chemical Properties in Poplar Plantations in North of Iran

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Abstract. Soil physical and chemical properties and some quantitative characteristics of *Populus deltoides* Marsh (clone 79.51) plantations and relationships between them were evaluated in Guilan plain of north of Iran. Two same aged poplar plantations with low and high qualities were selected. In each poplar plantation, fifteen sample plots with systematic sampling method were selected. In each sample plot diameter at breast height (DBH) as well as height of all trees within them was determined. Soil samples were taken from 0-20cm in each plot and soil texture, water holding capacity (WHC), bulk density (B.D) and particle density (P.D) as well as soil porosity, O.C, N, available P and exchangeable K were determined for each soil sample in laboratory. Tree data and soil properties between two plantations were analysed using independent samples t-test (Student's t test at $p < 0.05$). The results showed that among soil physical properties, percentage of clay, sand, B.D and WHC and amongst soil chemical properties O.C, N, available P and exchangeable K were significantly different between two plantations. Heavy textured soils with high B.D are undesirable for growing of *populus deltoides* in study area. The results also indicated that poor quality plantations has negative effect on soil nutrient and reduces its fertility. Reduction of nutrient availability had negative effects on quantity and quality of poplar trees.

Key words: Soil Properties, *Populus deltoides*, Soil Texture, Iran.

Introduction

The majority of northern Iran is covered by the Caspian forest, a deciduous temperate commercial forest, of about 1.8 million hectares located on the northern slopes of the Alborz Mountains overlooking the Caspian Sea (HOSSEINI, 2006). Between mountain region and Caspian Sea, there are plain areas that during last decades have been involved in agriculture, reforestation or deforestation activities.

Guilan province, as one of the provinces located in north of Iran, has vast plain areas (with about 3600 km^2) covered by natural forests, crops and poplar plantations. Because of population growth, increasing demand for wood and declining of forest harvesting, development in plantation of fast growing species especially poplars has occurred in the plain of Guilan province in recent years. Poplar has been planted by villagers and big companies at various level in north of Iran and the planted areas in Guilan province is about 30000 ha (KIADALIRI, 2003; ZIABARI, 1993). Although the majority of poplar plantations in this area have suitable quantitative and qualitative growth, some of these plantations don't show appropriate conditions. The efficiency of plantations can

depend highly on site properties especially soil characteristics and water availability. DICKMANN & STUART (1983) declared that poplars could grow almost everywhere, but perform up to their full potential only on the productive 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. Poplars in general require light textured, permeable, deep and moist, and well aerated soils (BIRLER, 1983). DICKMANN & STUART (1983) showed that poplars will grow well on both upland and bottomland sites, where the soil is well drained and has good water holding capacity. The surface water table of Guilan plain usually is high and on the other hand the soil texture of this area often is classified as heavy soil. Therefore, it seems that the conditions of soils and water table in some parts of this region can be considered undesirable for poplar stands.

On the other hand as SINGH & SHARMAN (2007) and AUGUSTO *et al.* (2002) stated 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 with various quality and quantity have been able to change some soil properties in recent years in Guilan plain.

Although in Iran and the other neighbouring countries, such as Turkey, there are some studies about soil characteristics for poplar planting, most of them are related to soil nutrition and classification (KIADALIRI, 2003; SAYYAD *et al.*, 2005), and a few studies have focused on the physical and chemical soil properties of poplar plantations lands. In this study, two adjacent, same age and same clone of poplar plantations (*Populus deltoides*, clone 79.51) with different growth performance were selected in west of Guilan plain/Iran. The topographic conditions and climatic factors are the same; therefore it seems that after about 30 years soil properties have a strong impact on growth of poplar plantations. On the other hand previous reports indicate that before plantation of poplar in these areas, both of these places covered by not-usable native covers, and after the cutting down of them, the poplar plantations were established. So it is predictable that through these years the quality and quantity of poplar plantations can impact on soil properties especially on surface layers of the soil. On the base of above mentioned matters, it seems that there are complex relationships between soil properties and poplar plantations. This study tries to assess the favourable soil properties for poplar stands and also explain influence of poplar plantations on soil attributes.

Materials and Methods

The study was carried out in Guilan province, on the northern parts of Iran (45°25′N, 36°45′E). Experimental plots were located at an altitude of 80 m above sea level. Average annual rainfall is 1542.2 mm without dry season. Annual mean temperature is 19.7°C and average minimum and maximum temperature vary from 2.5°C in January to 30.3°C in July. The area is placed on flat and uniform terrain with poor drainage and has low water permeability. The soils predominantly have clay and clay loams texture, and the soils of the study site are classified as Inceptisols on the base of soil taxonomy (Shafarood Company, 2004).

In this area two adjacent poplar plantations apparently with different quantitative and qualitative performance were selected, (in this article they are referring as good and poor plantations (GP and PP)). The area of each plantation is about 70 hectare and the distance between them is about 3 km. Both of these plantations were on flat and uniform terrain and *Populus deltoides* Marsh. (Clone 79.51) were planted by 3 × 4 m distances in each plantation in 1982 (Shafarood Company, 2004). Approximately 30 years ago, these areas were dominated by natural forests containing native tree species such as *Carpinus betulus, Alnus glutinosa, Parrotia persica and Pterocarya fraxinifolia.* This natural stands were cleared cut and were planted by poplar.

In each plantation, fifteen sample plots (100×100m) by systematic sampling method were selected. Height and diameter at breast height (DBH) were measured for all of trees within sample plots. In each sample plot, three soil samples were taken from 0-20cm and after mixing, composed one soil sample from one plot (MARANON *et al.*, 1999). In this way, thirty soil samples were taken from both of stands and transferred to soil laboratory for analyzing. All of soil samples were air-dried and passed through a 2mm mesh. Soil texture by hydrometric method (BOUYOUCOS, 1962), soil pH in water suspension of 1:2.5 (soil: liquid ratio), bulk density (B.D) by clod method, water holding capacity (WHC) (GHAZANSHAHI, 1999), total nitrogen (N) by Kjeldal method (BREMNER, 1996), organic carbon (O.C) by Walkely and Black method (WALKLEY & BLACK, 1934) were determined. Available P (P) was analyzed according to the standard methods (OLSEN *et al.*, 1954), and exchangeable K (K) was analyzed after extraction using 1M ammonium acetate at pH7.0 was determined by flame-photometer (BLACK *et al.*, 1965). The differences of quantitative characteristics of trees and soil properties between two plantations were analyzed based on independent samples t-test (Student's t test at $p < 0.05$), and correlation between variables were determined by Pearson correlation coefficient. In order to find the most effective factors on the separation of two plantations, PCA (Principal Component Analysis) was used. For statistical analysis, SPSS (version 15.0) and "PC–ORD"program version 4.17 were used.

Results

Height and DBH (Diameter of Breast Height), as two main quantitative features of tree differed significantly between two poplar stands (Table 1). Means of height and DBH in GP were higher than the value of these variables in PP. It has been specified that after about 30 years although the clone of poplar plantations has been the same, the trees in GP are able to produce further biomass.

As Table 2 shows, soil physical properties between GP and PP are significantly different. The percentage of clay as well as B.D is higher in PP, while the amount of sand is lower. WHC as a factor showed maximum capacity of moisture holding in each soil was higher in GP compare to PP. As it can be seen in Table 3, the majority of the chemical soil properties differ significantly between two plantations. The amount of the main nutrient elements (N, P, and K) is higher in GP compared to PP. No significant difference was found between C/N ratios of two plantations. The amounts of N, P and K, as the most important nutrient elements and also C are higher in GP. Higher amounts of these elements indicate superior conditions of soil fertility which have been provided by poplar trees of GP.

Table 1. Means ± SD of DBH and height of trees in GP and PP and probability values

	Height (m)	DBH*** (cm)
GP*	24.2 ± 1.45	32.65 ± 3.95
PP**	18.08 ± 1.28	21.73 ± 1.99
P value	0.000	0.000

*GP: Good Plantation, **PP: Poor Plantation, ***DBH: Diameter of Breast Height

Table 2. Means ± SD of physical soil properties in GP and PP, and probability values.

Soil Parameter / Site	P.D (g/cm3)	B.D (g/cm3)	WHC (%)	Sand (%)	Silt (%)	Clay (%)
GP	2.27 ± 0.14	1.55 ± 0.07	40.86 ± 2.52	24.22 ± 7.78	38.01± 6.12	37.73 ± 7.52
PP	2.32 ± 0.15	1.65 ± 0.09	38.39 ± 2.27	18.91 ± 3.11	37.08 ± 3.39	44.01 ± 3.41
P value	0.412	0.003	0.009	0.021	0.610	0.006

Table 3. Means ± SD of chemical soil properties in GP and PP, and probability values

Soil Parameter / Site	O.C (%)	N (%)	P (mg/kg)	K (mg/kg)	C/N	pH (1:2.5)
GP	3.4 ± 0.66	0.32 ± 0.09	10.02 ± 8.37	164.93 ± 71.98	10.78 ± 1.06	5.42 ± 0.28
PP	1.92 ± 0.62	0.17 ± 0.05	2.20 ± 1.33	104.67 ± 26.25	10.88 ± 1.13	5.38 ± 0.30
P.value	0.000	0.000	0.002	0.005	0.814	0.677

Table 4. Pearson Correlation coefficient between D.B.H and height of trees and soil properties in PP

	Sand (%)	Silt (%)	Clay (%)	WHC (%)	P.D (g/cm³)	B.D (g/cm³)	pH (1:2.5)	O.C (%)	N (%)	P (mg/kg)	K (mg/kg)	C/N
D.B.H* Pearson Correlation	-0.16	0.01	0.13	-0.25	0.25	0.27	-0.03	-0.22	-0.04	-0.26	0.04	-0.47
Sig.(2-tailed)	(0.579)	(0.969)	(0.640)	(0.377)	(0.365)	(0.332)	(0.914)	(0.436)	(0.889)	(0.346)	(0.089)	(0.078)
Height Pearson Correlation	0.50	0.26	-0.72**	-0.50	-0.04	0.35	0.27	0.27	0.40	0.33	0.01	-0.14
Sig. (2-tailed)	(0.057)	(0.346)	(0.003)	(0.057)	(0.890)	(0.208)	(0.338)	(0.328)	(0.136)	(0.235)	(0.964)	(0.623)

Table 5. Pearson Correlation coefficient between D.B.H and height of trees and soil properties in GP

	Sand (%)	Silt (%)	Clay (%)	WHC (%)	P.D (g/cm³)	B.D (g/cm³)	pH (1:2.5)	O.C (%)	N (%)	P (mg/kg)	K (mg/kg)	C/N
D.B.H Pearson Correlation	0.34	0.15	-0.47	-0.55*	0.17	-0.12	0.40	0.54*	0.62*	0.67**	0.42	-0.49
Sig.(2-tailed)	(0.209)	(0.594)	(0.077)	(0.035)	(0.557)	(0.671)	(0.144)	(0.039)	(0.014)	(0.007)	(0.118)	(0.064)
Height Pearson Correlation	0.39	0.26	-0.62*	-0.05	-0.14	-0.31	-0.10	0.22	0.23	0.52*	0.16	-0.21
Sig. (2-tailed)	(0.146)	(0.344)	(0.014)	(0.872)	(0.633)	(0.268)	(0.716)	(0.427)	(0.408)	(0.048)	(0.563)	(0.444)

The results of Pearson correlation coefficient in PP showed that among soil properties, clay content has considerable negative correlation with height of trees (Table 4). Among soil properties in GP, percentage of C, total N and P correlated positively with D.B.H and soil saturated moisture content showed negative correlation to it. Height of trees in GP and clay content showed negative correlation, but P is correlated positively with height of trees (Table 5).

Figure 1 and Table 6, resulted from PCA analysis, show that DBH, height of poplar as well as O.C, N, P and K negatively correlated to the first axis of PCA. While clay content shows significant correlation with positive direction of the first axis of PCA.

Table 6. The Pearson and Kendall correlation coefficient between D.B.H, height of trees, soil properties and the axes of PCA

	r (Axis 1)	r-sq (Axis 1)	r (Axis 2)	r-sq (Axis 2)
D.B.H	-.854*	.730	.172	.030
Height	-.847*	.718	.054	.003
PD	.284	.080	.740*	.548
BD	.568*	.322	-.262	.069
WHC	-.310	.096	-.250	.063
Soil Porosity	-.259	.067	.881*	.776
pH	-.205	.042	-.633*	.400
Clay	.777*	.603	.089	.008
Sand	-.708*	.502	-.163	.027
O.C	-.924*	.855	-.059	.004
N	-.949*	.900	.026	.001
P	-.881*	.777	-.030	.001
K	-.750*	.562	.010	.000
C/N	.237	.056	-.339	.115

* Significant Pearson and Kendall correlation coefficient ($p<0.05$)

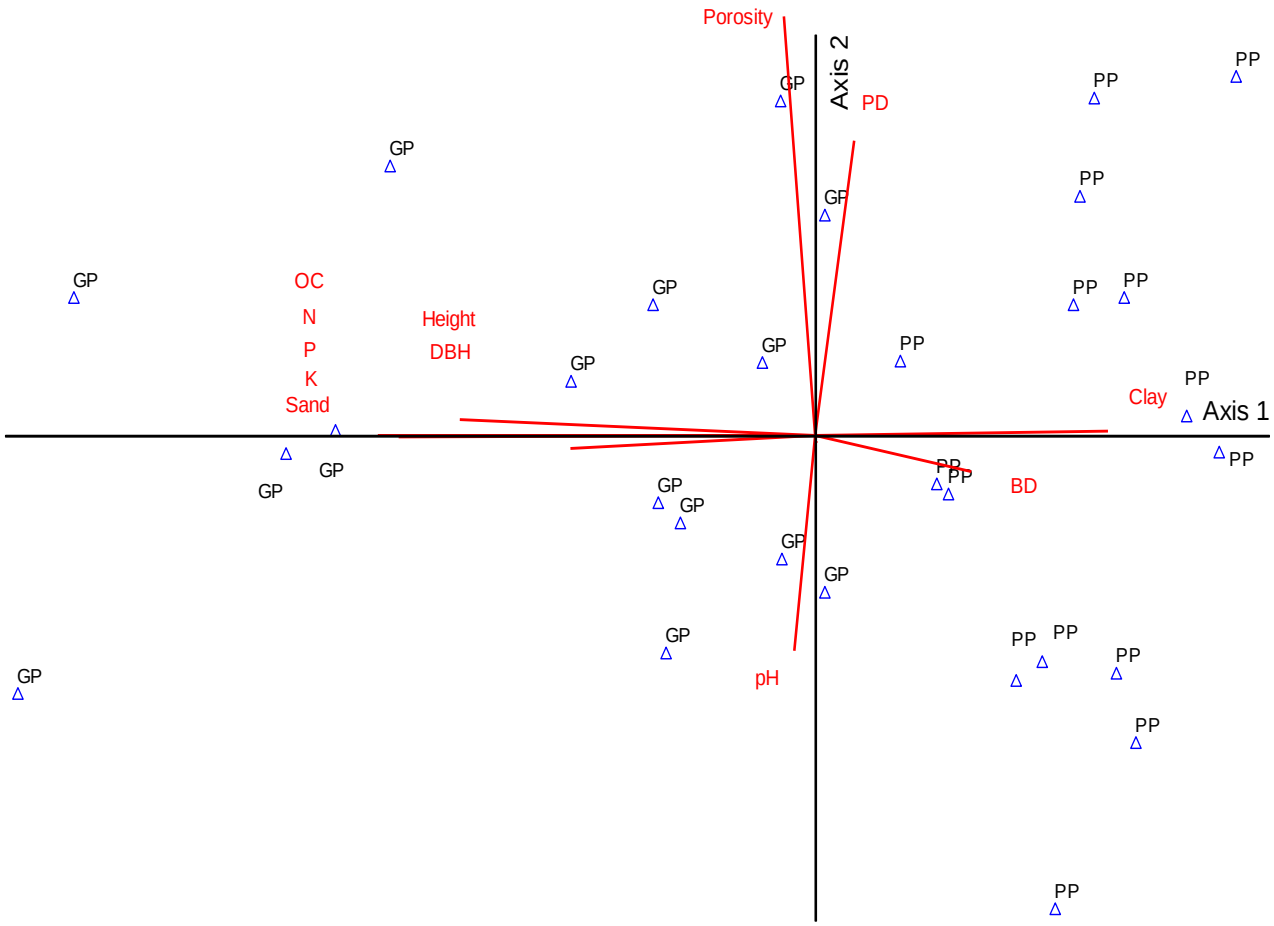

Fig 1. Distribution of soil factors, DBH and height of trees in relation to axes of PCA.

Discussion

The results showed that the main quantitative indicators of tree stands included DBH and height differ significantly between two poplar plantations. Growth of poplar depends upon various factors such as clone, quality of planting stock, spacing of trees, intercrops, site quality, climate and management practices (TEWARI, 1995). In this study, as two poplar plantations are the same age, the clones of them and the spacing of trees is also the same, it seems that environmental conditions effect the growth of the trees in two plantations. As these two plantations are almost close to each other, the environmental conditions such as climatic and topographic factors are similar to each other; however there are some soils properties are significantly affected on growing parameters.

According to the results, soil texture differs between two plantations and it can be one of the most important factors that influenced poplar trees. The content of clay is higher in PP compare to GP and in both stands height of trees showed negative correlation to clay content. TUFEKCIGLU *et al.* (2003) and ISEBERANDS (2007) declared that soil texture is one of the most important factors for poplar plantations. TUFEKCIGLU *et al.* (2003) also showed that the amount of sand in the soils had a positive correlation with growth of hybrid poplars and also they found a negative correlation between clay content and mean annual height growth. Light texture, high soil porosity and high soil water content in GP create suitable conditions related to aeration and moisture content in this poplar plantation. BIRLER (1983) stated poplars require soils of light textured, permeable, deep and moist and good aerated. As STANTURFT *et al.* (2002) reported heavy soils are considered less favourable for poplar growth than coarser textured soils, it seems that in our experimental sites also increasing of B.D and clay content in soil resulted lower growth of poplar trees. In contrary, increasing sand content has improved soil aeration and porosity and provides a better soil condition for poplars growth. According to above mentioned matters, soil texture have very important role in differences between two plantations. The important issue is that although theses plantations are almost close to each other, soil texture is different. Variability of soil chemical, physical and biological properties in small scale declared in several studies. WANG *et al*. (2008) stated that local spatial variability is the variation of the property within allocation at a finer scale, related to spatial configuration of the data locations within the neighbourhood. Heterogeneity of soil properties may be occurred at large scale (region) or at small scale (community), even in the same type of soil or in the same community (DU FENG *et al.*, 2008). WEINDORF & ZHU (2010) and KAVIANPOOR *et al*. (2012) in their studies mentioned the variations of soil texture in small scale. Since the soil texture can not change in a short time (SHAHOEI, 2006), it seems that soil texture was differed between two plantations before deforestation. The important note that it is not subject to forest managers in that time.

According to the results, GP contains higher main nutrient contents compare to PP. On the base of related reports (preliminary studies before plantation) for this region, the majority of soil chemical properties did not have significant differences in about 30 years ago, when these poplar plantations were established. According to quantitative growth of trees in two plantations, it seems that over the time, appropriate quantitative and qualitative growth of trees in GP has been able to create positive conditions to improve soil chemical and nutrient properties. BINKLEY & SOLLINS (1990), AUGUSTO *et al.* (2002), SINGH & SHARMA (2007) noted the effect of poor quality and quantity of litter on inappropriate decomposition of them and weak nutrient release to the soil. Due to appropriate quantitative growth of trees in GP, it seems that the amount of litter falls in this plantation is more than PP. The rates of forest litter falls and decomposes of them contribute to the regulation of nutrient cycling, primary productivity, and the

maintenance of soil fertility in forest ecosystems (FIORETTO *et al.*, 2003, ONYEKWELU *et al.*, 2006). As WANG *et al.* (2008) demonstrated that litter decomposition provides organic and inorganic elements for the nutrient cycling processes and controls nutrient return to the forest ecosystem. On the other hand in GP, DBH shows positive correlation with C, N and P and also height of trees with P. CHANG-BING *et al.* (2004) showed the effect of N on increase of DBH and also TUFEKCIGLU *et al.* (2003) stated positive correlation between height of hybrid poplar and P availability of soil.

Above mentioned matters declare multifaceted relationships between trees and nutrient availability in the soil of these plantations. The better quality and quantity of trees in GP improve soil nutrient availability and higher contents of these elements have caused better quantitative conditions of poplar trees. High availability of nutrient was related to high productivity of poplar trees as evidenced by their higher height and greater diameter. Poor stand reduces soil fertility and reduction in availability of nutrient elements has had negative effects on growth and quality of stand. The results showed that after about 30 years, not only biomass and wood amount in the poor quality stand have been reduced, but soil nutrient availability was also diminished. It seems that in the early years after plantations soil physical properties, especially soil texture had an important role in trees growth of two plantations. These results demonstrate the essential role of soil properties and detail studies for careful selection of the sites for poplar plantation.

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