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Effect of physicochemical characteristics of soil on growth and wood production in Cottonwood Plantation (*Populusdeltoides Marsh*) (Stury area: Masal forests of Iran)

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ABSTRACT

Poplar is one of the most important species for fast wood production. Several factors affect the growth of Poplar plantations including the presence of species or clones, site fertility, climate and planting distance. In the present study, the effect of several physicochemical characteristics of soil such as texture, acidity, organic content and Nitrogen, Phosphorus and Potassium concentrations in the Masal region, north of Iran was investigated. For this purpose, three different compartments in the Sheikhneshin district which were selected. Then, 5 hectares (250 × 200 meter) of a stand was selected in each compartment and was divided into 10 sample plots of 4 acres with a dot grid of 50 × 50 meter in a systematic random statistical method. In each plot, the diameter of all trees at breast height was measured. Furthermore, in each 5 hectare plot, 3 soil profiles were dug. Statistical analysis was performed using the SAS software. After analysis of the variance, the LSD group comparison test was used foranalysing the group mean data. In this study, at the optimum content conditions in a hectare, a stand of 89.5$m^3$with an average annual growth rate of 5m^3 was achieved at the age of 18. The results of this study showed that the studied stands were in one of the poorest sites with respect to soil nutrients. Furthermore, the results showed that Poplar is highly influenced by soil quality, texture and pH,Nitrogen, Phosphorus and organic.

Keywords: Plantation, Sheikhneshin district, Poplar, Physicochemical characteristics of soil

INTRODUCTION

Approximately 35% of the global wood supply is produced from plantations while only 3% of the earth's surface is belonged to these plantations. It is expected that plantations would supply 46% of the global wood demand by 2040 [16]. Forests in the north of Iran are used for production of pulp wood in the paper and relevant industries. Most of the trees in these forests are broad-leaved and grow moderately; as a consequence, production does not meet demand. Therefore, large areas of plantations by fast-growing species in the north of Iran are allocated to such species. Most of the species considered for this purpose are non-native such as the Loblolly pine (*Pinustaeda*), slash pine(*Pinuselliottii*) and Poplar species. Among these species, Poplar has been more popular because of the following reasons: 1) it is one of the most important species for fast production of wood in the northern hemisphere, and 2) this fast-growing species may have an annual production rate of 29 m^3 at the age of 12 in some sites[9].Poplar was first imported to Iran from Germany in 1936 to develop the match and paper industries[7]. The Shafarud Company also began its plantation 40 years ago in the Guilan province, Iran. Primary studies showed that some species could produce up to 30 m^3ha^{-1}[6]. Among environmental factors, soil is one of the most important which plays a significant role in the growth and distribution of vegetation. It is recognized that soil properties is one of the components of forest management, and influence most of the silviculture and plantation considerations, including species selection, determining site fertility, stand growth rate, predicting survival rate and seedling growth. The most common factors that influence Poplar plantations are the presence of species or clones, site fertility, climate and planting spacing. In this study, the effects of physicochemical characteristics of soil such as texture, pH and

Nitrogen, Phosphorus and Potassium contents on wood production of Poplar in Masal (one of the regions that cultivate Poplar) were investigated.

MATERIALS AND METHODS

The study area was located in the forests of the Sheykh-neshin district in the North and Northeast of Masal and Shanderman, Guilan province which were situated at latitude 37°, 20' N, longitude of 49°, 10' E withapproximate height of 20–80 meter above sea level. Poplarspecies were planted since 18 years ago and currently covers most compartments in these regions. The present study was conducted in compartments number 5, 7 and 12. Aspedology aspect, there were two orders of soils: Alfisol and Inceptisol. In the region, the average precipitation was recorded 1215 mm and the average temperature was 15.8°C. The climate was very wet with moderate winters according to the Amberje climate classification. Due to old age (over 18) and failure of reforestation of Poplar stands in Masal region, they were selected for this study. Based on the study objectives, after field observations, 3 stands were selected that were similar in species, age, planting distance and physiographic conditions. At first, the forest was considered and each compartment was examined. Then, 3 stands with good, average and poor content were selected, namely compartment number 5, 7 and 12. Then, a sampling plot of 200 × 250 meter was selected in each compartment with total area of 5 hectares. The random systematic sampling method was used. According to previous studies [6, 14], and the necessity of having at least 10–15 trees in each plot [12, 13]the area of each plot was restricted to 4 acres (400 m^2) with a circular shape. Then, 10 sample plots of 4 acres with statistical dimensions of 50 × 50 meter were measured[6, 14, 10]. In each sample plot, the diameter at breast height of all trees was measured using a calliper with an accuracy of 1 millimetre. Then, based on the local volume table of Poplar species, the volume of each stand was estimated in each plot. Furthermore, after recognizing the stands, the similarities of the soil sampling profile locations for each stand were found so that the 3 selected soil sampling profiles of each stand were closely similar in altitude, aspect and slope percentage. After analysing the soil sampling profiles, samples were taken from specific horizons. Then, the samples were dried in the shade under similar conditions and taken to the laboratory to determine their physicochemical characteristics. Soil texture, pH, organic matter and Nitrogen, Phosphorus and Potassium concentrations were measured in all samples. Statistical analysis was conducted on random blocks using the SAS 9.2 software. After analysis of the variance, the groups were compared using LSD.

RESULTS

Stand characteristics

The results showed that the basal area and volume of the 3 stands were significantly different ($p < 0.01$) which is shown in figure 1 and 2. Table 1 show the highest and lowest survival rates in the good and poor stand groups.

Table 1 Characteristics of good, average and poor stands in the studied region

	Number of trees	Survival rate	Volume per hectare (m^3)	Basal area in hectare (m^2)	Mean annual volume growth (m^3)
Good stand	562.5	51	89.1	11.8	5
Average stand	465	42	61.8	8.6	3.43
Poor stand	410	37	37.6	5.96	2.1

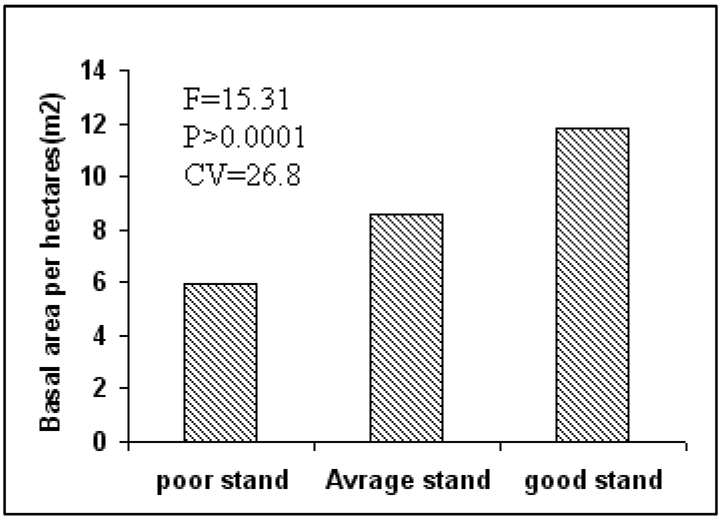

Figure 1-Basal area of the three stands (good, average and poor)

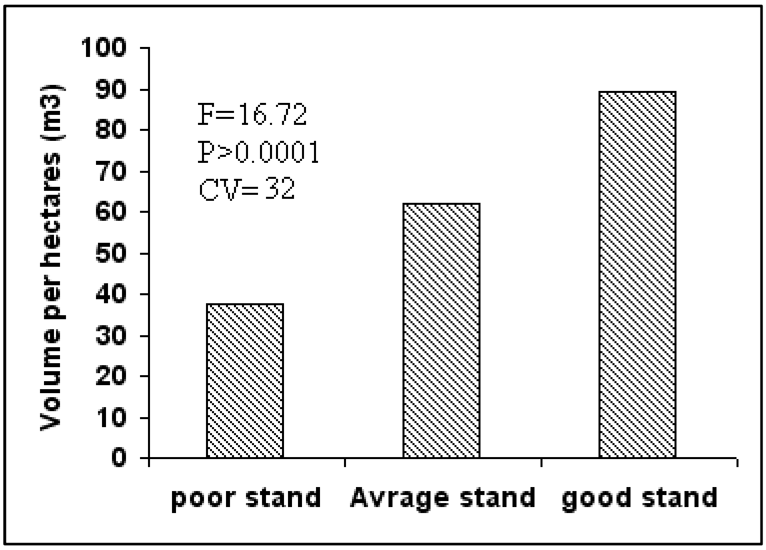

Figure 2- Inventory of three stands (good, average and poor) in hectares.

Soil texture

In the present study, except for the first soil layer, the other parts were heavy clay. Only the first layer of the good stand was clay-loamy, which resulted in better fertility because of improved drainage. The mean content of clay, silt and sand in the three stands is shown is Table 2. Furthermore, the sand and silt content decreased and the clay content increased with depth in all three stands. This means that the soil gets heavier in the deeper horizons. On the other hand, the sand and silt content decreases and the clay content increases from the good to poor stands, making the soil heavier

pH

The pH of the first soil layer was 6.4, 5.8 and 5.9 for the good, average and poor stands, respectively. In the second layer, the pH values were 5.9, 5.7 and 5.4, respectively. No significant difference was found between these two layers, but the pH in the third layer of the poor stand was significantly different from that in the other two layers (Table 2). pH was 6.3, 6 and 5.1 in the good, average and poor stands, respectively.

Organic matter content

The organic matter content of the first layer of the good stand was significantly different from that of the average and poor stands. The difference was not significant in the second layer of the good and average stand, but was significant between the poor and two other stands.

Nitrogen

Significant difference was found between the different soil layers with respect to Nitrogen. In the first layer, Nitrogen was significantly different among the three stands ($p < 0.01$). In the second layer, this difference was significant only when comparing the average stands with the good and poor stands ($p < 0.01$). There was no significant difference between the poor and good stands ($p < 0.01$, and $p < 0.05$).

Potassium

Comparing the different soil layers in all stands showed a significant difference in the Potassium content of the first and third layer ($p<0.01$). The second layer showed no significant difference between the good and poor stands, but significant between the average and two other stands ($p< 0.01$, Table 2).

Phosphorus

The Phosphorus content difference in the first layer was significant between the good and the two other stands, but not significant between the average and poor stands ($p <0.01$ and $p = 0.05$). In the second and third layers, the difference among all the three stands was significant (Table 2).

Table 2 Mean physical and chemical soil data in 3 stands

Soil characteristic	Soil layers	Good stand	Average stand	Poor stand	F	P	CV
Sand content	0–20	23.2 (a)	18.7 (a)	10.4 (b)	19.65	0.0023	14.6
	20–50	26.7 (a)	16.6 (b)	13.2 (b)	22.78	0.0016	13.5
	50–100	23.2 (a)	14.5 (b)	13.6 (b)	12.1	0.0078	15.5
Clay content	0–20	35.8 (a)	45.3 (b)	53.2 (C)	30.86	0.0007	6.1
	20–50	43.2 (b)	55.1 (a)	62.4 (a)	8.25	0.0191	10.9
	50–100	56.3 (b)	63.2 (ab)	69.7 (a)	10.16	0.0118	5.8
Silt content	0–20	41 (a)	36.2 (a)	36.4 (a)	1.31	0.3376	10.9
	20–50	26.7 (a)	28.3 (a)	24.5 (a)	0.46	0.6546	18.5
	50–100	20.5 (a)	21.9 (a)	16.7 (a)	2.2	0.1922	16.1
pH	0-20	6.4 (a)	5.8 (a)	5.9 (a)	2.61	0.1532	5.8
	20-50	5.9 (a)	5.7 (a)	5.4 (a)	1.14	0.3791	7.5
	50-100	6.3 (a)	6 (a)	5.1 (b)	2.61	0.1532	5.9
Organic matter (%)	0-20	19.9 (a)	14 (a)	13 (b)	19.65	0.0023	9.4
	20-50	9.4 (a)	8.5 (a)	3.9 (b)	33.7	0.0005	12.1
	50-100	4.6 (a)	4.4 (a)	3.7 (a)	1.08	0.3967	18.7
Potassium (ppm)	0-20	234.3 (a)	105.7 (c)	124.7 (b)	380.8	0.0001	4
	20-50	193.3 (a)	167.2 (b)	191.8 (a)	16.06	0.0039	3.5
	50-100	170.3 (b)	141.7 (c)	317.7 (a)	195.4	0.0001	5.6
Phosphorus (ppm)	0-20	16 (a)	8.2 (b)	6.3 (b)	71.03	0.0001	10.3
	20-50	6.83 (a)	2 (c)	5.13 (b)	71.5	0.0001	10.8
	50-100	2.6 (b)	1.93 (c)	3.8 (a)	33.1	0.0006	10.3
Nitrogen (%)	0-20	0.7 (a)	0.43 (b)	0.28 (c)	61.28	0.0001	10.1
	20-50	0.47 (a)	0.25 (b)	0.36 (a)	29.84	0.0008	10
	50-100	0.88 (a)	0.27 (b)	0.27 (b)	124.03	0.0001	11.6

DISCUSSION

Several major factors that influence Poplar tree growth are the presence of species or clones, site fertility, climate and planting distance. In the present study, the effect of several physical and chemical characteristics of the soil such as texture, pH and Nitrogen, Phosphorus and Potassium contents on wood production of Poplar in Masal region were investigated. The results showed that Poplar is strongly influenced by soil characteristics. Soil texture is one of the most important factors that determine the functionality of the Poplar growth site. The best function can be expected in soils with good aeration, suitable moisture, sufficient nutrients and deep water level (lower than 1 meter) and loamy-sand texture[3]. Generally, the more clay there is in the soil, the better and faster soil particle aggregation are formed. Furthermore, clay increases the water maintenance capacity of the soil, and increases the moisture storage of the soil [11].During the growth season, water-saturated and anaerobic soils suffocate the root system, which gradually weakens and eliminate the trees. Most Poplar species do not tolerate long-term anaerobic conditions in spring. Some varieties do not even tolerate soil saturation with water in winter. Heavy soils (clay, clay-loamy, silt clay-loamy) are the least eligible soil type for Poplar, especially with respect to coarse soils[3]. In this study, except for the first soil layer in the good site, the other sites were mostly covered by heavy clay soil. Because of its good drainage, only the first layer of the good stand, which was clay-loamy, was more fertile than the rest. Furthermore, the amount of sand and silt significantly decreased and clay increased as we moved from the good to the poor stand. This change means that the soil gets heavier. A positive correlation between the sand content of the soil and Poplar growth in Turkey was found[2]. Also it was found, both the silt and clay content of the soil negatively correlated with Poplar growth. As the sand content increases, the aeration of the soil gets better. In general, soils with high clay content keep water better, but have low aeration [15]. Poplar grows better in soils with clay content less than 35% was reported[4].In the present study, except for the first layer of the good stand, the other soil types had more than 35% clay, which can restrict Poplar growth. Among the soil characteristics, pH is one of the most important in determining the potential power of the site for plant growth. The absorption of nutrients at different pH values is different. The best pH range is 6.5–7, which makes most of the nutrients available to the plant. pH less than 4 or over 8.5 makes some nutrients poisonous. At pH greater than 5.5, elements such as Calcium and Potassium are abundant. Under these conditions, several plants absorb some nutrients but others cannot do so. This imbalance is toxic for the plants.In this study, the pH in the first soil layer was 6.4, 5.8 and 5.87 for the good, average and poor stands, respectively. In the second layer, pH was 5.93, 5.73 and 5.37, respectively. No significant difference was seen between the two layers. However, the pH in the third layer of the poor stand was significantly different from the other two stands. The pH in the third layer was 6.27, 5.97 and 5.10 in the good, average and poor stands. The best pH range for Poplar was reported 6.5 to 8 [4].Furthermore, pH at the different soil layers was not significantly different at $p < 0.01$ and $p < 0.05$. The pH in the good stand was from 5.93 to 6.27, which neither disturbs the absorption of Potassium, Nitrogen, Calcium and Phosphorus nor is optimal. In the average stand, the soil pH was from 5.73 to 5.97. This range does not disturb Potassium and Calcium absorption but it is not optimum for Phosphorus and Nitrogen; however, it not critical [8]. In the poor stand, soil pH ranged from 5.10 to 5.87 especially in the third soil layer (50–100 cm deep), the pH value of 5.10 is critical for elements like Phosphorus and Potassium, but it is not optimum for Nitrogen and Calcium absorption. The comparison of our results with those of other studies shows that soil pH limits the absorption of some useful nutrients and macro-elements. As a result, the volume growth and basal area of the three stands are not the same. Regarding the organic matter of the three stands, organic Carbon significantly decreases as we go deeper into the soil, which is caused by the presence of plant remains on the surface. The remains, which are more abundant on the surface than deeper in ground, increase the organic Carbon. The organic Carbon increase improves the physical and biological characteristics of the soil [5].Organic matter plays an important role in the physical, chemical and biological characteristics of the soil and influences Cation exchange, micro-organism activity and soil particles aggregation[6]. The first layer of the good stand significantly differed with the first layer of the average or poor stand with respect to organic matter. This was not true for the second layer of the good and average stand, but the organic matter content was significantly lower in the second layer of the poor stand compared with the two other layers. Soil type, plant coverage, climate and the quality of humus influence the organic content in an area was showed[8]. It was reported that the organic matter content should be more than 2% for Poplar [5]. In the present study, all three layers in all three stands have more than 2% of organic matter. The mean organic matter content of soil at the surface horizon of beech and acorn stands in Turkey was reported as 9.9% and 6.4%, respectively [2].The soil organic matter content in Poplar stand was found 1.15%, and expressed it lower than the standard. In this study, the height of the Poplar trees increased as the organic matter increased. The results showed that the stands were not poor in organic matter although an increase in the organic matter can increase the inventory of the stand. Management programs of forest projects aim to maximize the growth and production of forests by minimizing the limitations of nutrients in the sites. Nitrogen is one of the most important and influential limiting elements for Poplar growth in all sites [3]. In contrast to other forest trees, Poplar hybrids need more nutrients. It is necessary to meet the high demand for nutrients in Poplar forests to increase fast production [8, 3]. The needed Nitrogen can be supplied by different sources such as mineralization of Nitrogen from soil organic matter and the decomposition of plant remain. The results show that most soil layers have significantly different amounts of nitrogen. The balance between Nitrogen and other essential nutrients is necessary for the optimum production of Poplar. For instance, some stands of Poplar do not respond to Nitrogen without other nutrients like Phosphorus and Potassium [4, 5].In this study, although the amount of Potassium is significantly different in the different stands, this discrepancy did not follow a general trend. That is, the amount of Nitrogen in all three layers in good and poor stands is better than that in the average stand. Therefore, we could not find a logical relation between production and Potassium in this study.The significant relation between nitrogen content and Poplar growth was not found. The absorbable Phosphorus is significantly different in the three layers and reduces with depth. In a study it was stated that Phosphorus is available in organic and mineral forms in the soil[11]. In rich soils most of the absorbable phosphorus is organic, and in forest soils, most of the absorbable phosphorus is in superficial horizons. The most of the phosphorus in Poplar stands is in the surface soil layers [2]. Therefore, it seems the results of this study agree with theirs. The mean phosphorus content was 10.15, 4.65 and 78.2 in good, average and poor stands, respectively. Most of the phosphorus was found in the first soil layer in good stand (15.97) and the least amount was found in the third layer of the average stand. The phosphorus content in Poplar stands in Turkey was found 15 mg/kg [4] and in another research 16.95 mg/kg was reported and was mentioned that the increase in phosphorus enhances Poplar growth [2].In general, all three stands were poor in nitrogen, but the increase in nitrogen content significantly increased the inventory.

CONCLUSION

Poplar is one of the most important species for fast wood production. In this study, the best inventory was found to be 89.5 m^3 within the 18-year olds with a mean annual growth of 5 m^3. The results showed that the study stands were among the poorest sites with regard to stand inventory. The results also showed that Poplar production is highly influenced by soil characteristics. Soil texture, pH and Nitrogen, Phosphorus and organic contents are the major determining factors of Poplar growth in the study region.

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