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Abstract: In this study, the effects of some physical and chemical soil properties on the growth of hybrid poplar were investigated in the Terme-Gölardı region where a poor growth of trees was observed. Soil samples were taken from both poor and good growth areas. Chemical soil properties such as pH, exchangeable Na^+, K^+, Ca^{++} and Mg^{++} content, CEC, phosphorus content and salinity were determined. Physical soil properties such as field capacity, permanent wilting point, water holding capacity and available water were measured. Ground water depth was measured in the field during soil sampling. Clay and Mg^{++} content and pH of the soils showed a significantly negative correlation while phosphorus and sand content of the soils had a positive correlation with the growth of hybrid poplar. Mg^{++}, K^+, and ground water depth explained 43% of the variation of mean annual height growth. The results indicated that soil conditions had a strong influence on the growth of hybrid poplar in the Terme-Gölardı region.

Key Words: Hybrid poplar, soil characteristics, mean annual height growth, plantation

Bazı Toprak Özelliklerinin Terme-Gölardı Yöresindeki Melez Kavakların Büyümesi Üzerine Olan Etkileri

Özet: Bu çalışmada, Terme-Gölardı yöresinde, bazı alanlarda zayıf büyüme görülmesi üzerine, fiziksel ve kimyasal toprak özelliklerinin melez kavakların büyümesi üzerine olan etkileri araştırılmıştır. Toprak örnekleri zayıf ve iyi büyüme gösteren alanları temsil edecek şekilde alınmıştır. Alınan toprak örnekleri üzerinde pH, değişebilir Na^+, K^+, Ca^{++} and Mg^{++}, katyon değişim kapasitesi, fosfor, tarla kapasitesi, solma noktası, faydalı su ve tuzluluk özellikleri belirlenmiştir. Ayrıca arazide taban suyu derinliği ölçülmüştür. Toprakların kil ve magnezyum içeriği kavakların büyümesi ile negatif ilişki gösterirken, kum ve fosfor içeriği pozitif ilişki göstermektedir. Magnezyum, potasyum ve taban suyu derinliği ortalama boy artımındaki varyasyonun % 43'ünü açıklamaktadır. Bulgular, Terme-Gölardı yöresinde toprak koşullarının melez kavakların büyümesi üzerinde önemli etkiye sahip olduğunu göstermektedir.

Anahtar Sözcükler: Melez kavak, toprak özellikleri, yıllık ortalama boy artımı, plantasyon

Introduction

Wood harvest from forests has been steadily increasing in the world. According to the Food and Agricultural Organization (FAO), forest production of the world was going to be 1.6 billion m^3 $year^{-1}$ and consumption was going to be 2.6 billion m^3 $year^{-1}$ in 2000. As of 1990, total wood production from Turkey's forests is about 16 million m^3 $year^{-1}$. It is known that fuel wood consumption is 9 million m^3 $year^{-1}$ with rest being timber. Apart from this, about 3.5 million m^3 $year^{-1}$ cottonwood was produced. When the total wood production from poplar plantations and state forests in Turkey is taken into consideration, wood consumption is below 0.5 m^3 per capita in Turkey, whereas it is over 4 m^3 worldwide (K.O.A.E., 1994).

Poplar trees are becoming extremely important as fast growing species due to the increasing need for wood and decreasing productivity of the landbase in Turkey (Işık and Toplu, 2003). However, to maximize their growth, it is important to understand the relationship

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between growth rate, plant nutrient requirements and the ability of soil to supply nutrients (Kelly and Ericsson, 2003). In Turkey, there are no studies related to the influence of soil properties on the growth of hybrid poplar. Most studies focused on the aboveground production of hybrid poplar in Turkey (Tunçtaner, 1988).

Soil properties have a strong influence on the growth of trees. While plants compete primarily for a single resource, light, above ground, they compete for a broad range of soil resources, including water and essential mineral nutrients that differ in, valence, oxidation state, and mobility within the soil (Casper and Jackson, 1997). Mineral, nutrient concentrations need to be in certain ranges in soil to support plant growth. Thus, excess amounts of nutrients in soil cause toxicity for plants while lower amounts create deficiency and impede plant growth. In a review article, Ayık (1989) reported that poplar trees grow best in soils having 35% or less clay content, 6.5–8.0 pH, and >10% soil porosity.

In this study, the Terme-Gölardı hybrid poplar (*Populus x euroamericana* (Dode) Guinier) plantation was selected to determine the effects of soil properties on the growth of poplar trees due to poor growth performance in some parts of the area. The objectives of the study were to examine the influences of soil properties on the growth of hybrid poplar and to determine how soil properties changed with soil depth.

Materials and Methods

The study area is located in Terme-Gölardı, Samsun, on the Black Sea coast of Turkey (41° 12' 42'' - 41° 20' 32'' N, 36° 49' 18'' - 37° 01' 15'' E). Mean annual precipitation in the area is 900 mm and mean relative humidity is 72%. Mean annual temperature is 14.3 °C with the maximum and minimum temperatures being 39 and -9.8 °C, respectively (D.M.G.M., 1990). The soils of the study area were alluvial, established mostly from fine sediments (mostly clay in the surface and subsurface layers and sand in the deeper layers) deposited by the Yeşilırmak River (Erdaş et al., 1992). Hybrid poplar trees were planted by 6 x 6 m distances in 1980.

Thirty-eight sample plots (30 x 30 m) representative of the study area were selected in sites supporting low, medium and high productivity stands in the study area. The climate, fire and establishment history of the sites were the same. Diameter at breast height (dbh) and the height of each tree were measured. A soil profile was dug in each of 38 sample plots from which 135 soil samples were taken from different soil layers. The soil layers were given numbers I, II, III etc. due to the lack of diagnostic soil horizons as the soils were alluvial in the area.

Analyses were conducted to determine some chemical and physical properties of the soil samples. The samples were air-dried, ground and sieved through a 2 mm-mesh-sized sieve (Gülçur, 1974). The field capacity, wilting point and available water content of samples were determined following the procedure described by Gülçur (1974) after Briggs and Shantz (1911). Soil texture was determined by Bouyoucos' hydrometer method (Bouyoucos, 1962). Organic matter content was determined by wet digestion (modified Walkley-Black procedure) (Walkley, 1947; Kalra and Maynard, 1991). Soil pH was determined by a combination glass electrode in H_2O (soil-solution ratio 1:2.5) (Gülçur, 1974). Cation exchange capacity (CEC) was determined by saturating soil samples with NH_4^+ by leaching buffered NH_4OAc solution (Kalra and Maynard, 1991). Phosphorus was determined according to Bray's (dilute acid-fluoride) procedure (Bray and Kurtz, 1945; Kalra and Maynard, 1991). Exchangeable cations (Na^+ Ca^{++}. Mg^{++}, K^+) were extracted from the neutral ammonium acetate solution and measured by atomic absorption spectrophotometry according to Kacar (1996). Salinity was determined by following the procedure described by Gülçur (1974). Ground water depths were measured in the field during soil sampling.

The relationship between soil properties and mean annual height growth was determined using linear regression and correlation analyses with height growth as the dependent and soil properties as the independent variables. We used the average of 4 soil layers in these analyses. Changes in soil properties with soil depth were analyzed using analysis of variance. Differences between specific soil depths were determined with a least significant difference (LSD) test (P = 0.05).

Results and Discussion

Soil Texture

The textures were mainly heavy clay or loamy clay in the surface and subsurface soils. The mean clay, silt and sand content of the soils were 48.9%, 29.7% and 21.4%, respectively. There was a significant positive correlation between the sand content of soils and mean annual height growth (MAHG) ($r = 0.31$, $P < 0.05$) (Table 1). Both silt and clay content had a negative correlation with MAHG but the relationships were only significant at $P < 0.10$ (Table 1). An increase in sand content in soils results in an improved soil aeration. In contrast, soils containing too much clay may have high water-holding capacities but inadequate aeration (Troeh and Thomson, 1993). In a review article, Ayık (1989) reported that poplar grows best in soils having 35% or less clay content. Our results indicate that hybrid poplar prefers well-aerated soils. The clay, silt and sand content of the soils did not vary significantly with soil depth.

Soil Organic Matter

Soil organic matter was only marginally correlated with MAHG ($r = 0.297$, $P = 0.07$). Mean soil organic matter content of soils was 1.15% (Table 2). This value shows that the soil organic matter contents of the soils in the study area were relatively low according to the soil-organic matter classification of Kantarcı (2000). Similarly, our organic matter values were very low compared to the findings of Eruz (1979). He observed mean organic matter values of 9.9% and 6.4% in the surface horizons of low elevation oak and beech forests in İstanbul, Turkey, respectively. The organic matter content of the soils did not vary significantly with soil depth ($F = 0.91$, $P = 0.43$).

Soil pH

Soil pH was negatively correlated with MAHG ($r = -0.45$, $P = 0.005$) (Table 1, Figure 1). The mean pH value of the soils was 7.91 (Table 2). According to Ayık (1989), hybrid poplar shows the best growth at pH values of 6.5-8.

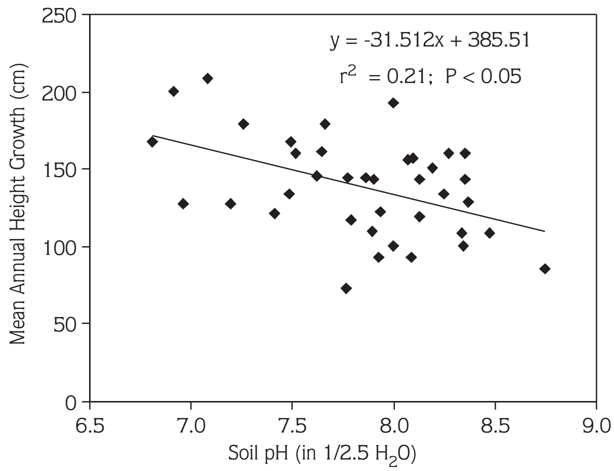

Figure 1. Relationship between pH and mean annual height growth in the Terme-Golardı hybrid poplar plantation.

The pH values of the soils were within the optimum pH range that favor the growth of poplar. However, the negative correlation between soil pH and MAHG indicates the possibility that hybrid poplar prefers soils with neutral pH. Leavengood et al. (2002) observed a similar response to high soil pH in a hybrid poplar trial in Oregon, USA. They reported that the MAHG of hybrid poplar clones ranged from 101.6 cm in the replication with lower pH (7.9) to 83.2 cm in the middle replication and 76.2 cm in the highest pH (8.5) replication. pH values of the soils increased significantly with soil depth ($F = 5.69$, $P < 0.05$).

Potassium

There was no significant relationship between height growth and the exchangeable potassium content of the soils ($r = 0.08$, $P = 0.62$). The mean exchangeable potassium content of the soils was 186 mg kg^{-1} (Table 2). The exchangeable potassium concentrations in the soils

Table 1. Correlations between mean annual height growth and some soil properties in the Terme-Gölardı hybrid poplar plantation. Variables that did not show significant correlation are omitted.

	Soil Properties								
	Sand %	Silt %	Clay %	pH 1/2.5 H_2O	Exc. Mg* mg kg^{-1}	CEC** meq/100 g	P mg kg^{-1}	OM*** %	Water Depth (cm)
Correlation	0.31	-0.28	-0.26	-0.45	-0.52	-0.28	0.43	0.30	0.39
P > F	0.056	0.093	0.107	0.005	0.001	0.094	0.007	0.070	0.014
n	38	38	38	38	38	38	38	38	38

*Exc: Exchangeable, **CEC: Cation Exchange Capacity, ***OM: Organic Matter

Table 2. Changes in some physical and chemical soil properties according to soil depth in the Terme-Gölardı hybrid poplar plantation. Values are averages of 38 sampling plots.

Soil Depth	OM* %	CEC** meq/100 g	Exchangeable Cations: Na mg kg^{-1}	Exchangeable Cations: K mg kg^{-1}	Exchangeable Cations: Ca mg kg^{-1}	Exchangeable Cations: Mg mg kg^{-1}	P mg kg^{-1}
I	1.35	74.0	270	251	7231	3374	19.3
II	1.17	74.8	312	154	7771	3441	17.3
III	1.11	75.5	351	173	8125	3470	18.1
IV	0.95	81.2	453	166	8538	3577	13.1
Mean	1.15	76.4	346	186	7916	3465	17.0

Soil Depth	Sand %	Silt %	Clay %	Soil Texture	Available Water %	Salinity mlmh cm^{-1}	pH 1/2.5 H_2O
I	20.80	33.89	45.32	Heavy Clay	11.90	0.608	7.57
II	16.51	31.59	51.90	Heavy Clay	13.45	0.441	7.98
III	26.03	25.31	50.52	Heavy Clay	13.99	0.472	7.84
IV	30.19	28.92	40.90	Clay	11.57	0.522	8.26
Mean	23.38	29.92	47.16	Heavy Clay	12.73	0.510	7.91

*OM: Organic Matter, **CEC: Cation Exchange Capacity

were sufficient for the normal growth of plants based on Scheffer and Schachtschabel's (1989) classification of soils for their potassium needs and for normal poplar growth according to Zengin (1991). The exchangeable potassium content of the soils differed significantly with soil depth ($F = 2.80$, $P < 0.05$). It increased up to the third depth class and decreased slightly at the fourth depth class.

Sodium

There was no significant relationship between the exchangeable sodium content of the soils and MAHG ($r = -0.22$, $P = 0.17$). The mean exchangeable sodium content of the soils was 346 mg kg^{-1} (Table 2). Although sodium concentrations in forest soils are generally low, they were higher in the study area. The relatively higher concentration of sodium might have resulted from the deposition by the wind from the sea. The exchangeable sodium content of the soils did not differ significantly with soil depth ($F = 0.97$, $P = 0.40$).

Calcium

There was no significant correlation between available calcium and MAHG ($r = -0.24$, $P = 0.14$). The mean exchangeable calcium content of the soils was 7916 mg kg^{-1} (Table 2). Exchangeable calcium concentrations were quite high in the study area and sufficient for the normal growth of poplars according to Zengin (1991). The exchangeable calcium content of the soils increased significantly with soil depth ($F = 2.72$, $P < 0.05$). The lowest amount of exchangeable calcium was observed in the surface soil layer.

Magnesium

There was a strong negative correlation between the exchangeable magnesium content of the soils and MAHG ($r = -0.52$, $P < 0.001$) (Table 1, Figure 2). The mean exchangeable magnesium content of the soils was 3465 mg kg^{-1} (Table 2). Exchangeable magnesium concentrations were quite high in the study area and sufficient for the normal growth of poplars according to Zengin (1991). The findings of this study are consistent with those of other studies. A study conducted in lowland and alluvial soils indicated that the exchangeable magnesium concentration increased depending on the amount of clay (Eruz, 1984). The magnesium content of the soils did not vary significantly with soil depth ($F = 0.83$, $P = 0.47$).

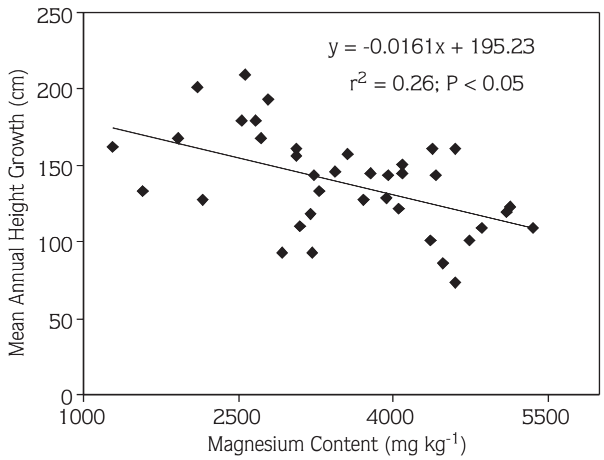

Figure 2. Relationship between magnesium contents of soils and mean annual height growth in the Terme-Golardi hybrid poplar plantation.

Phosphorus

A positive correlation was found between height growth and the amount of phosphorus (r = 0.43, P < 0.007) (Table 1). The highest phosphorus levels were found in the upper layers. The mean phosphorus content of the soils was 16.95 mg kg^{-1} (Table 2). This value was lower than the phosphorus threshold values of McDowell et al. (2001) (<30 mg kg^{-1}) and Scheffer and Schachtschabel (1989) (18 mg kg^{-1}), but was slightly higher than the threshold value of Ayık (1989) (<15 mg kg^{-1}).

Tisdale and Nelson (1975) and Brady and Weil (1999) state that both native and applied phosphorus is tied up with highly insoluble calcium and magnesium phosphates in alkaline soils, rendering the added phosphorus only sparingly available for plant uptake. Similarly, Pritchett and Fisher (1987) argued that the availability of phosphorus largely depends on the amount of calcium in the soil. In this study, negative correlations between height growth and Ca^{++} and Mg^{++} concentrations of the soils support these possibilities. The phosphorus content of the soils did not vary significantly with soil depth (F = 0.46, P = 0.70).

Available Water Content

MAHG did not correlate significantly with available water content (r = -0.02, P = 0.89). This was no surprise given the relatively high water table and clay content of soils in the area. When the ratio of clay, silt, organic matter, salt and carbonates in the soil increases, the capacity of the soils to retain water increases as well (Brady and Weil, 1999; Kantarcı, 2000). The mean available water content of the soils was 12.73% (Table 2). Available water content did not vary significantly with soil depth (F = 0.71, P = 0.54).

Salinity

Salinity in the study area did not reach levels of toxicity for poplars (Eruz, 1979; Troeh and Thomson, 1993). The highest value was 2.1 millimhos cm^{-1}, in the plot 30. The mean salinity content of the soils was 0.51 millimhos cm^{-1} (Table 2). There was no significant relationship between salinity and MAHG (r = 0.22, P = 0.18). Salinity did not vary significantly with soil depth (F = 1.08, P = 0.36). Salinity was highest in the surface horizons, indicating the possibility of deposition by the wind from the sea (Table 2).

Ground Water Depth

Ground water depth was positively correlated with MAHG (r = 0.39, P < 0.01) (Table 1). The mean ground water depth was 49.74 cm (Table 2) from the soil surface. This indicates that poplar grows better in soils having a relatively deep water table. Our results show that a relatively high water table might be a growth limiting factor in Terme-Gölardı soils.

Regression Equations between MAHG and Soil Properties

Available magnesium content of the soils was the best predictor of MAHG. It explained 26% of the variation of MAHG. The equation was:

MAHG(cm) = -0.0161 (Mg^{++} (mg kg^{-1}) + 195.2277, r^2 = 0.26, P < 0.01, F = 13.02

When we add depth of ground water (DGW(cm)) to the equation using step-wise regression, the equation and r^2 change as below:

MAHG(cm) = -0.0141 (Mg^{++} (mg kg^{-1}) + 0.5244 (DGW) + 162.1095, r^2 = 0.35, P < 0.05, F = 4.68

Entering potassium (K) as the final variable, the equation changes as below:

MAHG(cm) = -0.0174 (Mg^{++}) + 0.5100 (DGW) + 0.1056 (K^+) + 155.5099,

r^2 = 0.43, P < 0.05, F = 4.71, where Mg and K are in mg kg^{-1}. Three variables explained 43% of the variation in MAHG.

Conclusions

MAHG was strongly influenced by the soil properties in the study area. Sand content, phosphorus content and ground water depth were positively correlated with MAHG, while exchangeable magnesium content, pH, clay and silt content were negatively correlated with MAHG. Magnesium content accounted for 26% of the total variation of MAHG, while ground water depth and potassium content accounted for 9% and 8%, respectively. The negative correlation between MAHG and clay content suggests poor aeration in the soils of the study area. Therefore, soils need to be deeply plowed before establishing any poplar plantation in the area. The positive correlation between ground water depth and MAHG indicates that drainage channels should be dug in the areas with a high water table.

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