SOIL PHYSICAL AND CHEMICAL CHARACTERISTICS AND ROOT SYSTEM DEVELOPMENT IN A WALNUT PLANTATION IN NORTHERN ALBANIA

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Abstract

Zeneli G., Kola H.: Soil physical and chemical characteristics and root system development in a walnut plantation in Northern Albania. Ekológia (Bratislava), Vol. 25, No. 4, p. 442–449, 2006.

Soils are the physical and biological matrix in which most of the life-sustaining activities of the tree/soil relationship occur, but to date information on how soils affect walnut fruit production is lacking in Albania. We measured the physical and chemical soil characteristics and their effect on root development system as well as the above-ground biomass and tree characteristics in a walnut (*Juglans regia* L.) plantation of seedling origin located in the north-eastern part of Albania. Soil of this site with moderately fine texture, slightly acid, reasonably well-drained and sufficient amounts of nutrients favoured the growth of walnut. Trees have developed an intricate extensive root system with the taproot penetrating to 3.7 m deep and many lateral roots which are mainly located in the horizon B at depth 60–80 cm. A soil description indicating the favourable characteristics for growing the species is presented.

Key words: *Juglans regia*, growth, tree/soil relationship, plant nutrition, biomass.

Introduction

English walnut (*Juglans regia* L.) (Juglandaceae) is a very important hardwood species in Albania, with a long tradition of use for both timber and fruit production (Çiçi, 1973). Located in the north-eastern part of Albania, the Dibra region is well known for the quality of its fruit and timber walnut production and the trees are generally tolerant to winter cold and late spring frost (Zeneli et al., 2005). In this region, walnut grows from the valley of Drini river (350 m a. s.l.) to the highlands of Lura, Selishta and Golloborda (1200 m a.s.l.) (Kola, 2001).

Production of high-value walnut is a long-term investment (50+ years), the success of which is highly dependent upon proper soil site selection. Although walnut demonstrates strong genetic variability for adaptive and wood quality traits across Europe (Fady et al., 2003), ecological factors especially soil has a great effect on this trait, and especially depth to a gravel layer influence significantly height growth (Losche, 1973). Soil texture and structure affect soil water-holding capacity, influence the ease at which water and air moves into and through the soil, and root penetration. Water supply is considered to be the most important environmental factor for the differentiation of plant communities of walnut with other species (Epple, 2001), while differences in soil texture are shown to have a greater influence on tree height than differences in soil pH, O, C, P, K, Mg, Ca, and Zn levels (Ditsch et al., 1996).

Element transformations, water and element uptake, interactions with a host of other organisms, all are soil centered. The roles of the root system are to colonize and hold resource-containing space (Coutts et al., 1999). The variability in root elongation, radial expansion, lateral root development, material transport, nutrient storage, and element processing, all dependent on different soil physical properties (Pini et al., 1999). Soils facilitate survival and thriving of trees, but can also stress, strain, and inhibit tree growth through impacts on roots. Root growth and number of growing roots decrease sharply as soil water potential decreases (Kuhns et al., 1985). Differences in tree height appear to be related to the occurrence of suitable soil types (Ditsch et al., 1996).

Through the observation in a plantation of seedling origin, we aimed (i) to measure the physical and chemical soil characteristics (ii) to evaluate the development of root system of English walnut in plantation and (ii) to validate the importance of edaphic conditions to the root system in this site for the growth of the species.

Material and methods

Site description and plantation techniques

The plantation was located in the longitude of 41°43' N and latitude 20°27' E and altitude 520 m. The climate is mild continental; the mean annual temperature 12.9 °C, amplitude of temperature 18.6 °C and the annual rainfall 1765 mm (Zeneli et al., 2005). Previously (till two year before the walnut plantation) the area has been cultivated with agricultural plants (mainly *Brassicaceae*). Right before the plantation of the walnut seedlings was established, the site was ploughed (30 cm depth) and rototilled (15 cm depth). Seedlings imported from Italy were 2 years old at the time of planting and belonged to the same cultivar (Sorento). The area planted was approximately 5 ha and trees were planted in row (8x8 m). Seed derived trees are not normally used in nut plantations since the offspring does not inherit the mother trees properties, therefore they were excavated. Trees were excavated in spring of 1998 and were 16 years old at the time of this investigation. Dendrometric measurements (diameter at breast height and height) were performed in the same year on all trees in the plantation and based on them, five representative trees for further analysis were chosen.

Three soil pits (1×1×1 m) were opened to help in describing soil horizons using a standard protocol (NRCS, 2001). Samples (cca 500 g) were collected in each soil horizon in order to make complementary physical and chemical soil analyses in the laboratory. Each soil sample was analysed for pH, organic carbon, soil levels of phosphorus (P), potassium (K), and particle size distribution. Soil bulk density was measured at the centre of each sample. In order to determine the relationship between tree height and individual soil characteristics, linear regression analysis was performed by using the SPSS for Windows version 10.1 (SPSS Inc. Chicago). Soil analysis was performed following the methods described by Natural Resources Conservation Service (NRCS, 2001).

Investigation on tree characteristics

We measured both the below- and above-ground parts of the selected trees. For the above-ground parts; the height of the trees, diameter at 40 cm above-ground, diameter at breast height (1.30 m), diameter of crown in north-south and east-west directions, dripline (the outermost area of the tree canopy), stem circumference at different tree heights, area of crown projection, weight of above-ground tree including main stem, branches and leaves were measured. For the below-ground parts; the main and secondary roots, the depth of root penetration, depth of the soil where the majority of roots developed, root protection zone (the area within a radius equal to the greatest distance from the trunk to any overhanging foliage in the tree canopy), and area of root projection compared with area of crown projection, were measured.

Results

Edaphic features of site

According to the FAO (2002) System of Soil Classification, the soil of this plantation belongs to the group of Mollisols (brown grassland soils) with dark brown surface horizons, but becoming lighter-coloured beneath. The common morphological feature of brown grassland soils is an abrupt texture change between the A and B horizons.

The rate of root penetration is not only affected by the distribution of pores and clay particles in the soil profile but also by the strength of the soil. Soil texture at this site is sandy clay loam, with a granular structure allowing for both moisture and aeration. The ratio between sand and clay is 53.7 to 36.3. The slope of the plantation is southwest oriented, with an aspect of 7%. Since, the area had been cultivated for agriculture it was well-drained. Nutrient status of soils is a major edaphic constraint for walnut productivity in spite of favorable climatic conditions. The soil chemical analyses are given in Table 1. The soil is slightly acid, can be considered as moderate in humus content, varying from 1.5% to

T a b l e 1. Soil chemical and physical properties of the sampling sites. (Values represent the mean and the standard deviation of three soil pits).

Horizon	Depth [cm]	pH	Humus [%]	N [%]	P2O5 [%]	K2O [%]	Bulk density [g/cm^3]	Porosity [%]
A0	0–24	6.6	3.115 ± 0.094	0.448 ± 0.033	0.089 ± 0.003	1.42 ± 0.081	0.85 ± 0.03	53.7 ± 0.88
A	24–48	6.6	3.367 ± 0.045	0.290 ± 0.023	0.096 ± 0.003	1.35 ± 0.113	1.0 ± 0.038	50.3 ± 0.74
AB	48–64	6.6	3.159 ± 0.052	0.290 ± 0.030	0.098 ± 0.004	1.30 ± 0.124	1.24 ± 0.0.25	47.8 ± 0.86
B	64–76	6.8	1.204 ± 0.0346	0.270 ± 0.021	0.109 ± 0.003	1.30 ± 0.083	1.18 ± 0.032	50.2 ± 1.55
BC	76–116	6.8	1.204 ± 0.0331	0.251 ± 0.024	0.119 ± 0.004	1.13 ± 0.056	1.25 ± 0.028	44.3 ± 2.21

3.4%, but poor in phosphate. As a result of heavy leaching, a slight increase in phosphate content in deep horizons was observed. The water holding capacity (WSC) of the soil is considered to be average (20–30%). Table 1 shows the average soil bulk density for each sampling depth. As expected, soil bulk density increased with increasing soil depth (range 0.85–1.25 g/cm3).

Development of vertical roots

Belonging to the class of dicotyledonous plants, walnut has a main taproot, supplied by many different secondary roots. The taproot of the trees which, started from the trunk flare, had a diameter between 27 and 30 cm and at the depth of 60 cm it branched into three to four vertical roots with diameters of ca 68 to 97 mm. In total, they had between 560 and 578 vertical roots, out of which 116 to 123 (cca 20.5%) were located directly under the trunk flare. These were usually thinner than lateral roots, and very dense, especially at the depth of 150 to 170 cm. The majority of them were found within a radius 130–180 cm from the axis of the taproot and penetrated to 370 cm deep. Root lengths were between 0.8–5.3 m long at 0.9 m depth, indicating that a few roots grew at greater depths. Root development in different soil depth is given in Fig. 1. With this growing habit, walnut trees on these soils are able to draw their moisture and nutrients largely from the more fertile shallow soil while still being able to rely on the deeper soil layers for survival during times of drought.

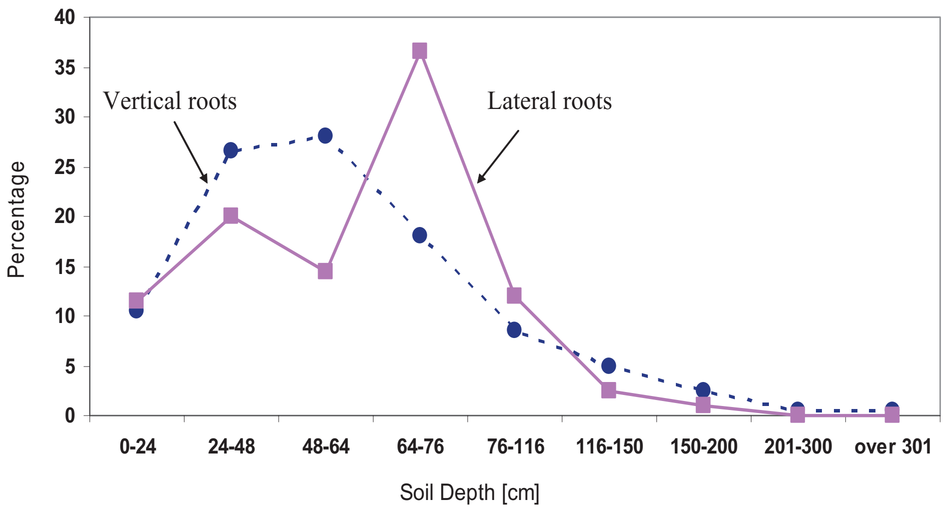

Fig. 1. Development of vertical and lateral roots in different soil depth. (Each value represents the number of roots found at this depth compared with the total number of roots found).

Development of lateral roots

The walnut has an intricate extensive root system, and the roots extend far from the tree and excrete toxins to keep other plants with deep roots systems from growing. From the main tap-root, 12–15 lateral roots extended. Most of tree roots were located in horizon B at depth 60–80 cm from the trunk flare and sometimes extended to a distance exceeding the tree height and/or width as can be depicted in Fig. 1. There were no obstructions that may affect the development of the root system. The bark of lateral root trees was dark and scaly but became darker with rounded intersecting ridges in older roots. There were many dried up or dead lateral roots. This might have been caused by mechanical damage or infection by the fungus *Armillaria mellea* that was present in the studied trees. There are more tap roots (vertical roots) than fibrous roots (lateral roots) and the ratio between them varies from 1.45 to 1.51. The depth of walnut lateral roots may also vary in response to root competition with its associates. In the present study, each tree had to compete only with trees of the same species.

Dendrometric characteristic of model trees

Walnut can produce large healthy trees in many parts of the country and is frequently cultivated for its edible seed. In this plantation, trees were planted in rows in a distance 8x8 m, thus having enough space for a normal development reaching between 9.3 m and 10.6 m at age 16 years. This can be also depicted from the Table 2. The tree crowns were not equally

T a b l e 2. Dendrometric and root system parameters for the selected trees. (Values represent the mean and the standard deviation of five trees).

Elements	Values
Height of the tree (m)	10.1 ± 0.45
Crown diameter (north-south component) (m)	7.8 ± 0.47
Crown diameter (east-west component) (m)	9.2 ± 0.77
Stem circumference 40 cm above ground (cm)	64 ± 3.65
Distance from tree to tree (m)	8 x 8
Crown projection (m^2)	56.7 ± 2.15
Weight of the above-ground part of tree (kg fresh weight)	253 ± 5.84
Leaf number	14572 ± 108
Maximum depth of lateral root penetration (cm)	180 ± 10.45
Depth of majority of lateral roots (cm)	80
Maximum diameter of lateral roots extension (m)	1050 ± 50.61
Diameter of the area of extension for the majority of lateral roots (cm)	270 ± 13.83
Maximum depth of vertical taproot extension (cm)	370 ± 18.62
Depth of majority of vertical roots (cm)	160 ± 10.5
Number of lateral roots	390 ± 18.0
Number of vertical roots	567 ± 16.52
Projection of lateral roots (m^2)	86.5 ± 4.87

distributed and the east-west components were usually larger than north-south ones. When comparing the root protection zone with the canopy, one can see that the first is larger. The ratio between canopy horizontal projection and root lateral projection is 0.655 or in other words, canopy horizontal projection is only 66% of root lateral projection. Almost 50% of the root horizontal projection lies out of the canopy horizontal projection. However, differences in the soil chemical properties measured at the various soil depths did not relate to differences in tree height (Table 3), as indicated by non-significant correlation coefficients.

T a b l e 3. The relationship between various soil chemical characteristics and walnut tree height as indicated by linear regresive analysis (R^2 values). Each value represents the mean of three soil pits and five trees.

Soil depth [cm]	Chemical characteristic				
	pH	Organic carbon	Nitrogen	Phosphorus	Potassium
0–24	0.09	0.17	0.12	0.22	0.11
24–48	0.15	0.08	0.09	0.12	0.21
48–64	0.10	0.18	0.11	0.20	0.07
64–76	0.17	0.19	0.07	0.11	0.18
76–116	0.08	0.12	0.16	0.09	0.12
All R^2 values shown are not significant.					

Conclusion and implications for walnut growth

The root system of walnut trees reported here, with their rapidly growing juvenile taproot and wide spreading laterals, is characteristic of species that grow on deep, fine-textured soils in regions with well-distributed summer rains (Fernández-López et al., 2000). Because of the very limited sample size for both soil and tree measurements, it might be too speculative to draw conclusions about soil characteristics and their effect on above-ground biomass. However, comparing our results with similar studies for the walnut in the region (Çiçi, 1973; Kola, 2001; Zeneli et al., 2005), with an introduced species (Zeneli, Marku, 2005) or walnut elsewhere in Europe (Fady et al., 2003), at least part of the good development can be attributed to soil.

The results from this study are in accordance with those of Catlin (1998) who reported that in deep soils a few roots grow to a depth of 3 m but even in these soils, more than 75% of the roots are found in the upper 60–100 cm of soil. Measurements of root length and root mass did show that more roots occupied the soil from the surface to a depth of 60–80 cm than below this to 90–120 cm. The results are encouraging because the ability to grow walnuts where the bulk of the root system is confined to the surface soil may suit many Albanian soils that are shallow and have poor structure.

Research is needed to test and explain the development of walnut root system in different climatic and soil condition and at different developmental stages as well as the development of walnut root system when is planted together with other species.

Translated by the author

Acknowledgement

The financial support from the Albanian Ministry of Agriculture and Food is gratefully acknowledged. We are also grateful to T.M. Fenning (Max Planck Institute for Chemical Ecology, Jena) for useful discussions and for English editing.

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Received 2. 11. 2004

Zeneli G., Kola H.: **Fyzikálne a chemické pôdne vlastnosti a vývoj koreňového systému na orechovej plantáži v severnom Albánsku.**

Pôdy sú fyzikálnymi a biologickými živnými pôdami, v ktorých prebieha väčšina životných procesov vo vzťahu strom-pôda, ale čerstvé informácie o tom, ako pôda ovplyvňuje produkciu plodov orecha v Albánsku chýba. Zmerali sme fyzikálne a chemické pôdne vlastnosti a skúmali ich vplyv na vývoj koreňového systému ako aj nadzemnej biomasy na orechovej plantáži u (*Juglans regia* L.) v severovýchodnom Albánsku. Pôdy na tomto stanovišti majú stredne jemnú zrnitosť, sú jemne kyslé, dobre odvodnené s dostatočným množstvom živín, čo prispieva k rastu orecha. Stromy vyvinuli rozsiahly koreňový systém s kôlovými koreňmi až do hĺbky 3,7 m a veľa bočných koreňov v horizonte B v hĺbke 60–80 cm. Článok popisuje priaznivé pôdne vlastnosti pre rast tohto druhu.