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Relationships between some soil properties and growth indexes in plum and apple trees within the hilly regions of Romania

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A b s t r a c t. Investigations were carried out in an expeditionary regime under various soil, climate, and tree-age conditions in the hilly regions possessing plum tree and apple tree orchards from this country. The climate zone is temperate having a continental character in the eastern regions and an oceanic character in the western regions of Romania. Soil analyses were performed on the soil genetic horizons regarding the main soil physical and chemical properties: particle size distribution, bulk density, resistance to penetration, gley or surface gley intensity, humus content, pH, etc. Plant analyses consisted of measurements on the principal tree growth parameters: total tree root frequency and tree trunk and tree root cross-sectional area. Afterwards, the root distribution index and the real tree diameter as well as the conventional age tree trunk diameter were calculated. Significant correlations were found between some tree growth parameters on the one hand and some soil properties on the other hand. The correlations that were found between the various soil properties and tree parameters could allow us to better understand the process of nutrition and fruit bearing for plum and apple trees under different ecological conditions met in the hilly regions of this country. The results obtained here contributed to a better knowledge of the soil-plant relationships and could be utilized in the zoning of plum tree and apple tree crops along with soil management systems in orchards.

K e y w o r d s: soil properties, orchard land use, tree growth indexes

INTRODUCTION

Soil is a basic ecological component and a life environment for crops. Plum tree and apple tree orchards occupy the largest area, about 48 and 38%, respectively, from the total fruit growing area in Romania. Reports previously published abroad (e.g., Kwarazkhelia, 1931; Gras, 1961; Henin and Gras, 1962; Trocmé and Gras, 1965; Black, 1968; Gautier, 1983; etc.) described relationships between soil conditions and fruit tree behavior and development. In Romania, the influence of soil on plum and apple favorableness was tested and reported by different authors: Amzar (1981), Teaci (1980), Teaci *et al.* (1985), Iancu *et al.* (1986), Voiculescu (1999), Paltineanu *et al.* (2000, 2003), etc. Based on the data accumulated in time the soil and the homogeneous ecological territories were characterized regarding various fruit trees favorableness for yield (The Research Institute for Soil Science and Agrochemistry, Bucharest, 1987). However, detailed aspects on the correlation of some growth indexes for fruit trees with the main soil properties remained to be completed afterwards.

The objective of this paper is to provide more data on soil-plant relationships in this country and to find correlations between some tree growth indexes and some of the main soil physical and chemical properties in order to: 1) better know the soil-plant interrelationships for the largest fruit growing regions in this country; 2) use them in land use organizing, and 3) improve some technological measures in plum and apple tree growing.

MATERIALS AND METHOD

Investigations were carried out using an expeditionary regime under various soil, temperate climate and tree age (5–25 years) conditions in the hilly regions of this country: Falticeni, Baia Mare, Bistrita and Cluj in the northern part, Campulung, Valcea and Tg. Jiu in the southern part, and Caransebes, Lipova, Oradea and Zalau in the western part. The plum cultivars studied here were: Anna Späth, Stanley, Tuleu Gras, Agen, Centenar and Vanat Romanesc, all grafted

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on Mirobolan, whereas the apple cultivars were Golden Delicious and Jonathan grafted on rootstock MM 106. The soils investigated belonged to 14 soil types, from the chernozem-like soils to albic luvisols and erodisols (according to the Romanian Soil Classification System, Research Institute for Soil Science and Agrochemistry, Bucharest, 1979).

The soil profiles analyzed here were 1.2 m wide, 1.5 m long and 1.2 m deep. They were located 1 m away from the representative fruit tree selected from the orchard under investigation. The soil profile walls analyzed were parallel to the tree rows. Soil and plant analyses were performed employing the current methods used in this country (Canarache, 1990) on soil genetic horizons regarding: a) the main soil physical and chemical properties: particle size distribution, bulk density, total porosity and air porosity, resistance to penetration (RP), gley or surface gley intensity represented by the non-affected gley volume, saturated hydraulic conductivity, skeleton content, humus reserve, pH, etc., and b) standard measurements on the principal tree growth indexes: the tree root system analysis after the method improved by Oskamp-Dragavtev and described by Dragavtev (1956): total tree root frequency (TRF), dead and alive root frequency, total tree root cross-sectional area (TRCSA) and afterwards the root distribution index (RDI), real tree trunk diameter (RD) and tree trunk cross-sectional area (TTCSA) as well as the conventional-age tree trunk diameter (CD) were calculated (Amzar, 1981).

More details are given here for tree parameters. Thus, the RDI was defined as a synthetic parameter used to characterize the tree root distribution pattern in soil for 10 cm deep layers (Amzar, 1981). Theoretically, the RDI ranges between 1, when all tree roots are within the 0–10 cm depth, and 10, when all tree roots are between 90 and 100 cm deep. The RDI is a function of both genetic factors (rootstock, cultivar) and soil conditions. It was calculated according to the formula:

$$RDI = \sum_{i=1}^{10} \left(i\, s_i \right) / S \qquad (1)$$

where i – soil depth order (from 1 to 10), s_i – tree root area (cm^2) of the i level, and S – total tree root area (cm^2) over the 0 through 100 cm soil depth.

In order to remove the orchard age influence for this study the CD term was used in data processing (Amzar, 1981). CD is a tree parameter meant to transform the real tree age to a standardized 30 years tree age by using an annual tree growth rate characteristic under various soil and climate conditions: critical, moderate or optimum. Thus, the CD was calculated using the relation:

$$CD = \left(RD \pm \sum_{i=1}^{30} r_i \right) C \qquad (2)$$

where RD – the real tree diameter (cm), $\sum r_i$ – the sum of annual tree diameter growth rates to the tree age of 30, with the addition of the sums if the trees are below 30 years old and their subtraction if trees are older than 30 years, C – the equivalence index used for tree cultivars other than the reference ones: Jonathan for apple and Tuleu Gras for plum.

Significant correlations obtained through the least square method with various probability degrees (P 0.05) were found between tree growth indexes on the one hand and some soil properties on the other hand. Correlations were calculated using the average values from the soil profile and the associated tree, for tree age classes. From those correlations only the significant ones are shown here. They were obtained for plum and/or apple trees.

RESULTS AND DISCUSSIONS

Influence of some soil physical properties on some tree growth indexes

Influence of coarse sand (CS)

CS content (particles with a diameter between 0.2–2.0 mm) in soil had, in general, a negative effect on plum and apple tree growth indexes studied here, regardless of tree age.

Correlations between RD, CD and CS had a curvy-linear aspect and were significant and negative (R^2 between 0.26** and 0.46***), except for the CD in plum trees where the correlation was parabolic (R^2 = 0.12*) (Fig. 1).

The TRF also correlated curvy-linearly and indirectly with CS (R^2 between 0.28** and 0.33***) for both fruit tree species (Fig. 2a), whereas between the TRCSA and CS a strong exponential, indirect correlation (R^2 = 0.44***) was obtained for plum trees (Fig. 2b).

The TTCSA and the RDI also showed a negative effect induced by CS, as revealed by the indirect correlation (R^2 of values 0.12** and 0.46***) presented in Fig. 3.

The general negative influence exerted by CS on tree growth indexes could be attributed to the fact that CS had a rather inert character in soil, by participating to a low extent in holding soil water and exchanging cations (Teaci, 1980). High values of CS content in soil usually increased drainage and losses of soil water, and hampered normal tree development.

Influence of fine sand (FS)

Soils possessing high amounts of FS (particles having a diameter between 0.2–0.02 mm) in their mineral constituents usually have loamy, sandy-loamy or loamy-sandy textures as characterized by the Romanian Soil Classification System (1979) in use. Such soils have an equilibrated physical texture showing intermediate properties between the extreme textures represented by sand or clay. The favorable influence of FS on the RD (R^2 = 0.279**) or TRF (R^2 = 0.293**) in apple trees is shown by the direct and linear correlations (Fig. 4a and b).

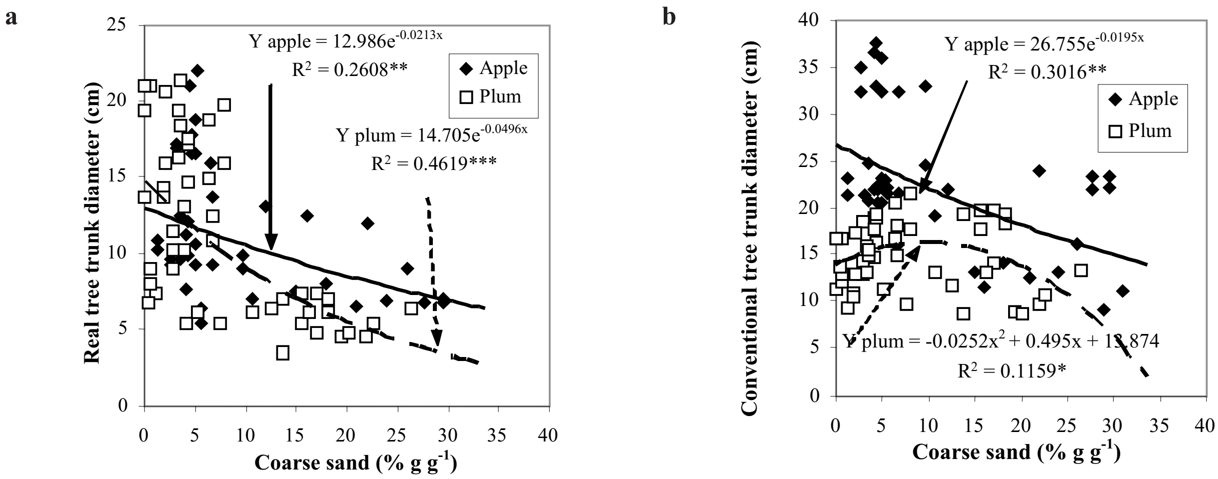

Fig. 1. Correlations between CS and the RD (a) and the CD (b), respectively, for plum and apple trees under various soil and climate conditions in the hilly regions of Romania.

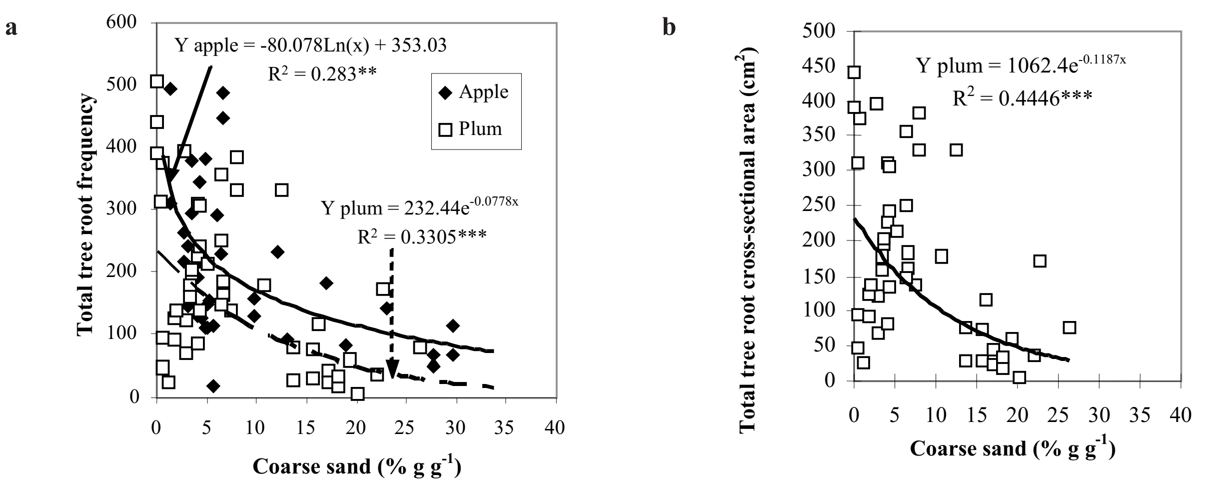

Fig. 2. Correlations between CS and the TRF (a) and the TRCSA (b), respectively, for plum and apple trees under various soil and climate conditions in the hilly regions of Romania.

Influence of clay (CC)

Due to the diversity of the soil and ecological factors analyzed, CC was correlated strongly with RD and CD (Fig. 5). So, the correlation between CC and the RD was, under the conditions given, inverse, linearly and distinctly signifi- cant ($R^2 = 0.259$**), and that between CC and the CD was polynomial (degree 2) and distinctly significant ($R^2 = 0.238$**) for apple trees, with a maximum around 35% g g^{-1}CC, and linearly and negatively for plum trees ($R^2 = 0.15$**).

Between the TRF and CC there was a parabolic correlation ($R^2 = 0.15$**) with the maximum point at about 35–40 % g g^{-1} CC, whereas between the TRCSA and CC there was a direct parabolic correlation ($R^2 = 0.13$**) (Fig. 6a and b), both in the case of plum trees.

These results are consistent with previous results indicating an optimum favorableness for apple trees in the CC range of 34–36% g g^{-1} (Teaci, 1980). Later on Teaci *et al.* (1985) and Voiculescu (1999) reported results showing that the optimum CC interval was between 30 and 40% g g^{-1} for apple trees and between 40 and 50% g g^{-1} for plum trees, respectively. Below 25% and higher than 45% g g^{-1} CC for apple trees and beyond the 30–50 % g g^{-1} CC interval for plum trees the root system distribution became superficial.

It was found here that the highest CC values induced a cut in tree root frequency and an increase in tree roots for plum trees. The heavy clay, waterlogging soils associated with the conditions described above also prevented apple and plum tree trunk growth, even from early crop stages.

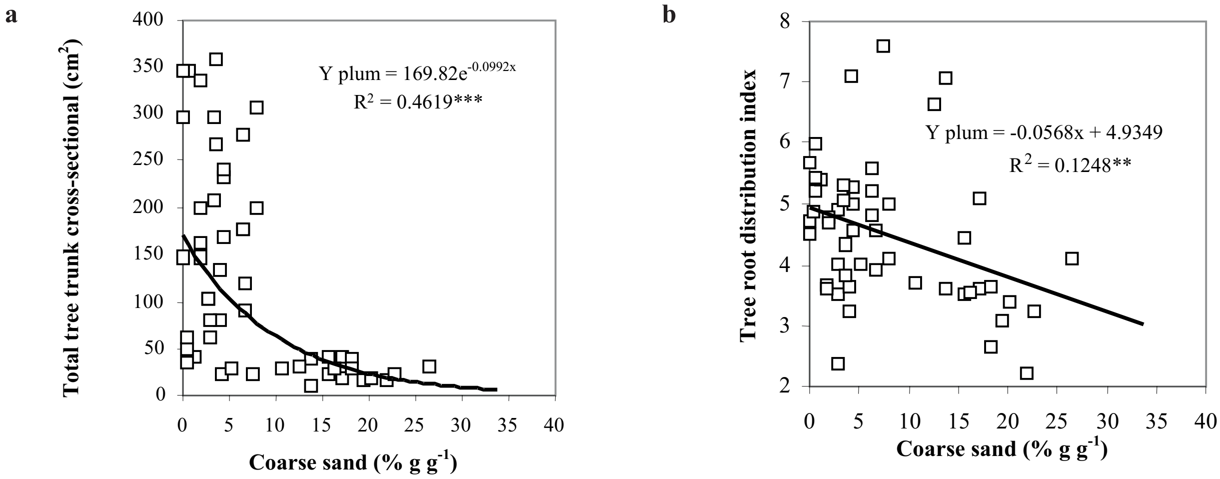

Fig. 3. Correlations between CS and the TTCSA (a) and the RDI (b), respectively, for plum trees under various soil and climate conditions in the hilly regions of Romania.

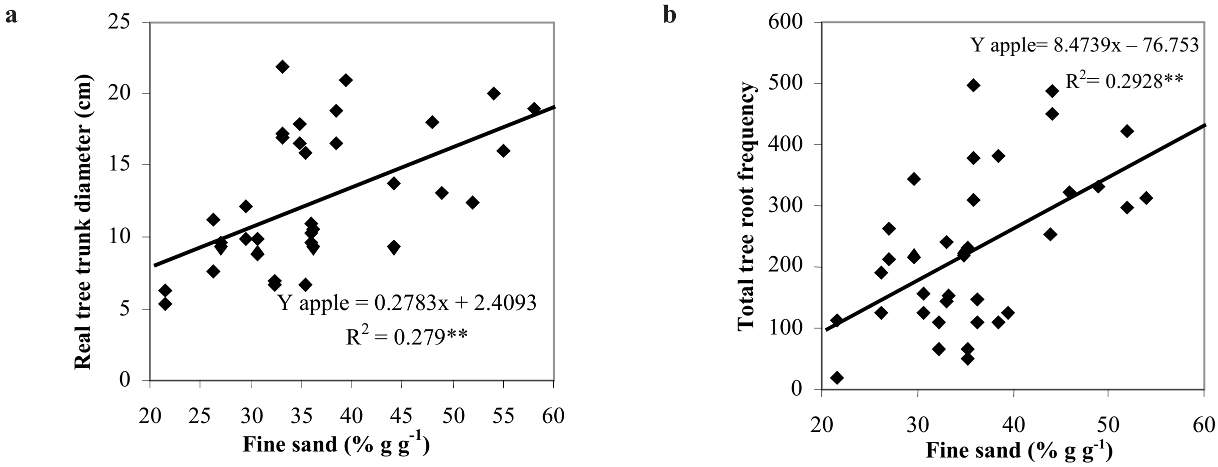

Fig. 4. Correlations between FS and the RD (a) and the TRF (b), respectively, for apple trees under various soil and climate conditions in the hilly regions of Romania

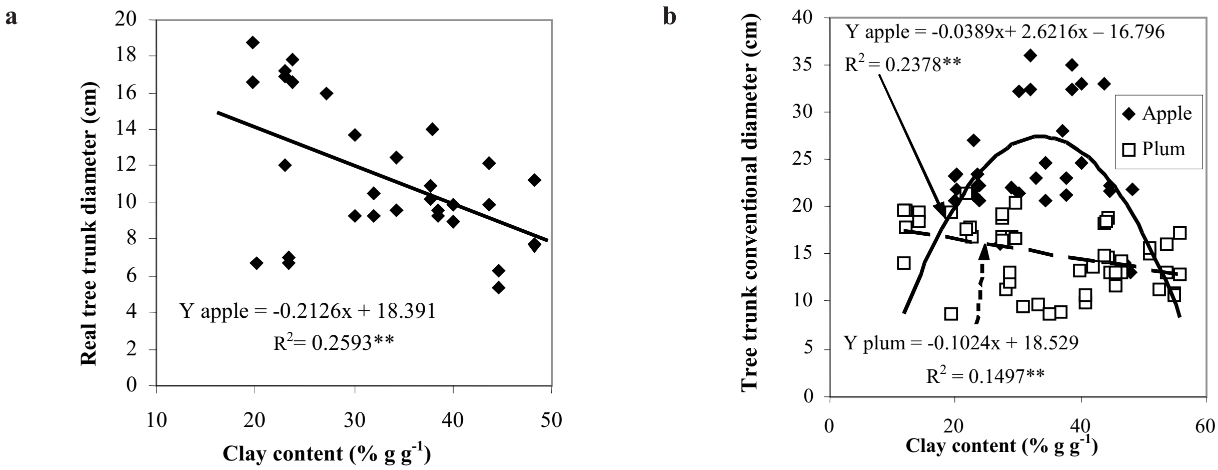

Fig. 5. Correlations between CC and the RD (a) and the CD (b), respectively, for apple or plum trees under various soil and climate conditions in the hilly regions of Romania.

Influence of resistance to penetration (RP)

The higher values of RP negatively influenced fruit tree growth represented by some tree growth indexes investigated. The correlations shown in Fig. 7a present the moving trend of the rooting system (RDI) towards the topsoil horizons when RP increased in the case of apple trees (R^2 = 0.48***). In addition, Fig. 7b, and Fig. 8a and b stressed the negative effect of RP on the TTCSA, RD and TRCSA, respectively, in plum trees (R^2 values of 0.13** and 0.11*, respectively). However, the CD manifested the most favorable conditions at RP values of 6–7 MPa, and decreased dramatically after 8 MPa (Fig. 9, R^2 = 0.09*).

So, both soil compactions, as a result of natural soil evolution and man-made soil compaction induced by mechanical traffic, significantly influenced tree growth parameters under all soil and climate conditions met here.

Influence of the useful edaphic volume (UEV)

The UEV was considered here as the whole soil volume down to the 1.5 m depth from which the skeleton and rock constituents were subtracted. Regardless of tree age the UEV correlated directly and curvy-linearly with the CD (R^2 = 0.25***) and the TRCSA (R^2 = 0.10*), (Fig. 10a and b).

Although the UEV variation range was relatively narrow (between 45 and 100% $cm^3\ cm^{-3}$) in this study, the trend was increasing for the tree growth indexes analyzed. As previously reported by Teaci *et al.* (1985) these authors published penalty multiplying yield coefficients from 1 (neutral) in the case of 51–100% $cm^3\ cm^{-3}$ UEV to 0.9 for the 36–50% $cm^3\ cm^{-3}$ UEV. Situations where UEV < 36 % $cm^3\ cm^{-3}$ were not met in this study.

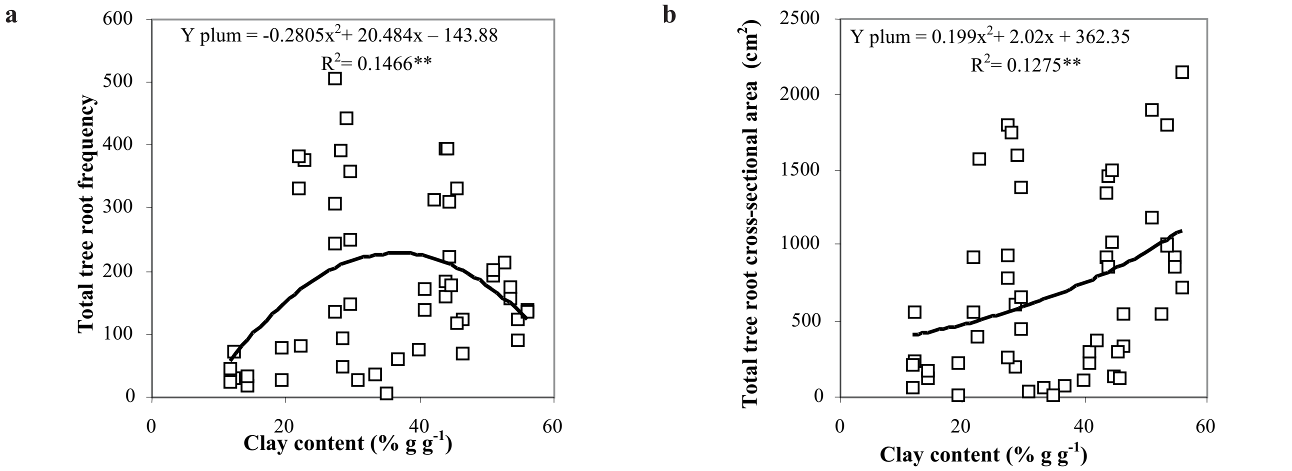

Fig. 6. Correlations between CC and the TRF (a) and the TRCSA (b), respectively, for plum trees under various soil and climate conditions in the hilly regions of Romania.

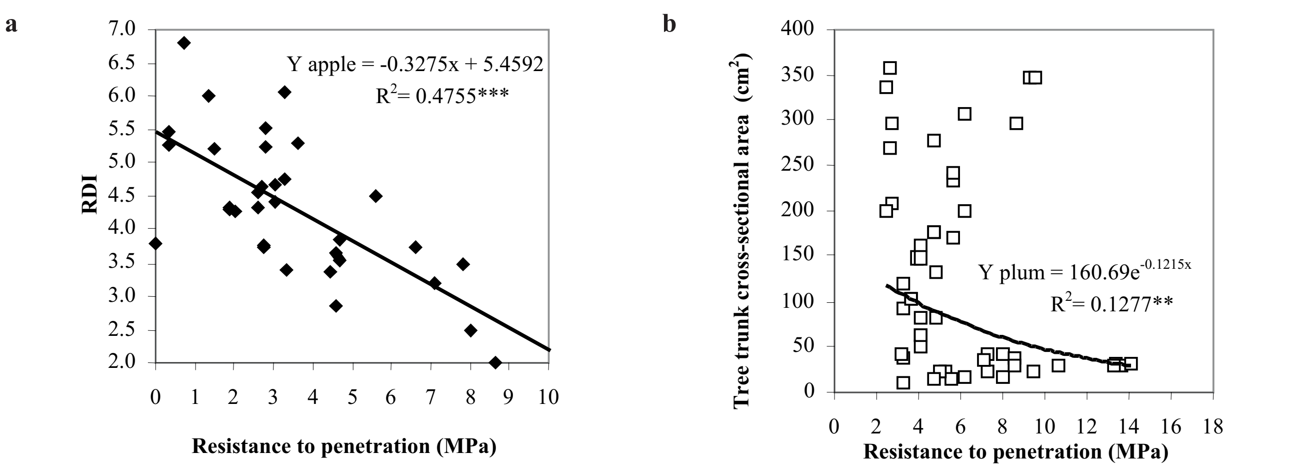

Fig. 7. Correlations between RP and the RDI (a) and the TTCSA (b), respectively, for apple or plum trees under various soil and climate conditions in the hilly regions of Romania.

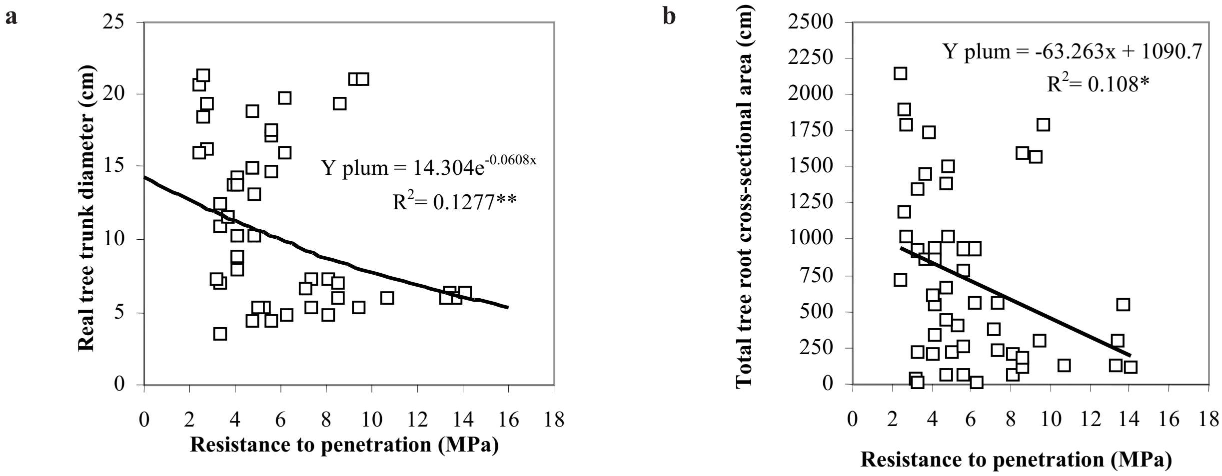

Fig. 8. Correlations between RP and the RD (a) and the TRCSA (b), respectively, for plum trees under various soil and climate conditions in the hilly regions of Romania.

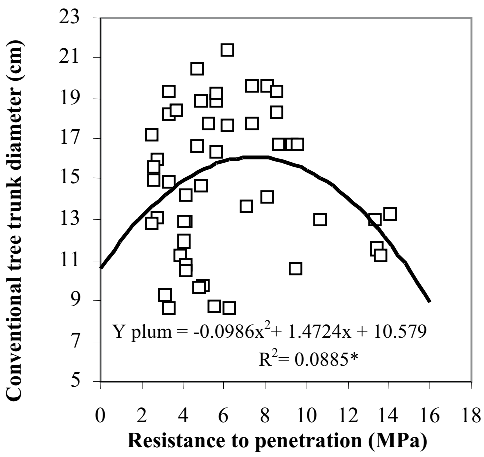

Fig. 9. Correlations between RP and the CD for plum trees under various soil and climate conditions in the hilly regions of Romania.

Influence of pH on some tree growth indexes

There was a strong decrease in RD versus pH in plum trees (R^2 = 0.21**) and apple trees (R^2 = 0.57***), (Fig. 11a). It was known (Teaci, 1980; Teaci *et al.*, 1985; Voiculescu, 1999; etc.) that apple tree yield decreases with increasing pH, and this study found that not only fruit yield, but also the growth in real trunk diameter showed the most favorable conditions to be a pH value between 5 and 5.5. A similar trend between these parameters was found here for plum trees even if the correlation strength was weaker. At the same time an indirect correlation between the CD and pH (R^2 = 0.31***) was obtained with the data from this experiment (Fig. 11b), as well as between pH and the TTCSA (R^2 = 0.26***), both for plum trees (Fig. 12).

In addition to the tree trunk, the tree rooting system was observed to be negatively influenced by the increase in pH

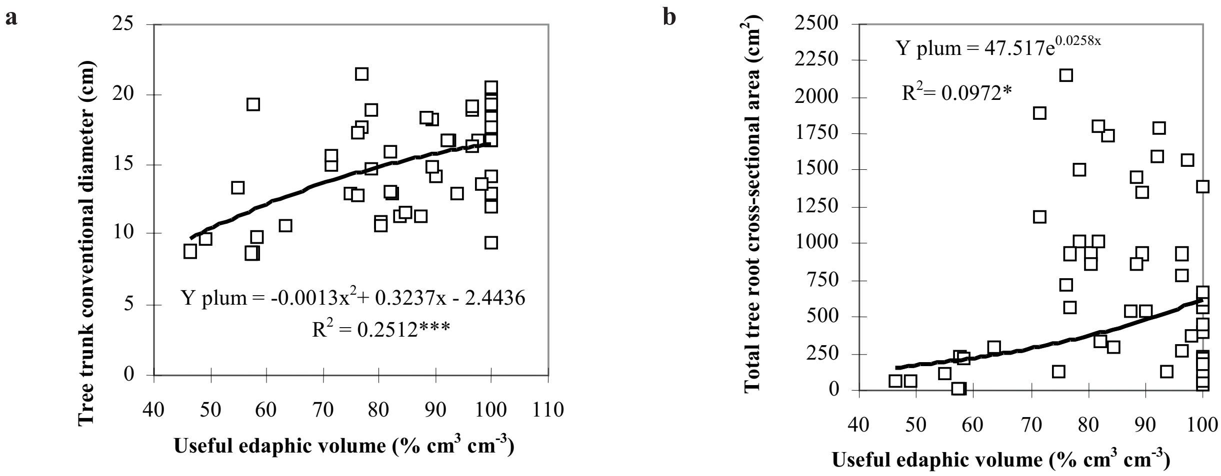

Fig. 10. Correlations between the UEV and the CD (a) and the TRCSA (b), respectively, for plum trees under various soil and climate conditions in the hilly regions of Romania.

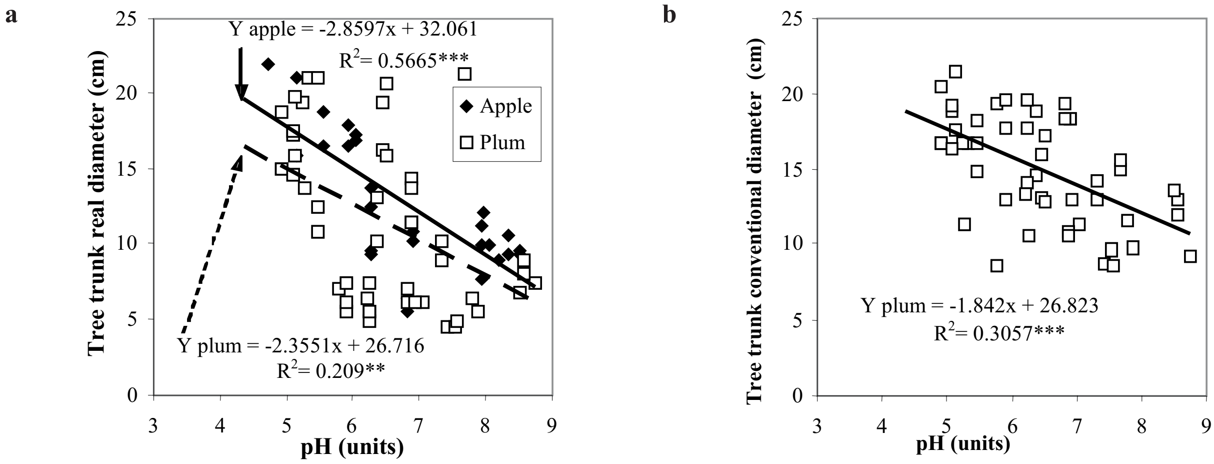

Fig. 11. Correlation between pH and the RD (a) and the CD (b), respectively, for plum and apple trees under various soil and climate conditions in the hilly regions of Romania.

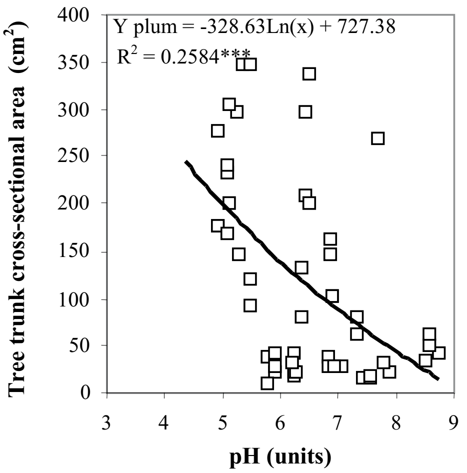

Fig. 12. Correlation between pH and the TTCSA for plum trees under various soil and climate conditions in the hilly regions of Romania.

values for plum trees too, either as TRF (R^2 = 0.14**) or TRCSA (R^2 = 0.13*), (Fig. 13a and b). From the figures presented above a new conclusion resulted about the influence of pH on plum tree behavior, namely that pH values between 5 and 6 were in the optimum pH interval for this species. This was found to be in contradiction to the ideas previously reported by other authors for these regions (e.g., Teaci *et al.*, 1980 and Voiculescu, 1999) who found optimum pH values between 6.5 and 7. However, this aspect remains to be confirmed by future soil-plant studies in these regions.

CONCLUDING REMARKS

1. Under the soil and climate conditions of the hilly regions studied here the coarse sand had a strong negative influence in the case of both plum tree and apple tree growth, whereas the fine sand showed a positive effect for apple trees.

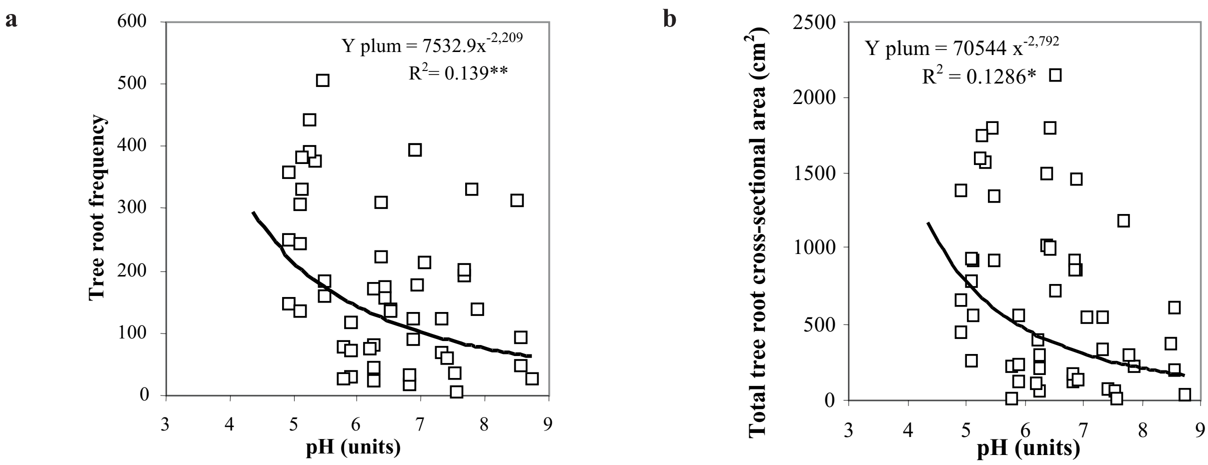

Fig. 13. Correlation between pH and the TRF (a) and the TRCSA (b), respectively, for plum and apple trees under various soil and climate conditions in the hilly regions of Romania.

2. Values of more than 40–45 % g g^{-1} clay content had a general negative effect to both fruit species investigated and characterized by either of the tree parameters. However, a direct correlation between the tree trunk cross-sectional area and the soil clay content was noticed for plum trees.

3. Increasing the soil penetration resistance induced a clear negative effect in plant development for both fruit tree species, particularly when its values exceeded 8–10 MPa. This seems to be a very representative soil property in a land characteristic for an orchard establishment.

4. pH values ranged between 5 and 6 seemed to be optimum for both plum and apple trees under the soil and climate conditions studied here. This was found to be in contradiction to the ideas previously reported by other authors who found optimum pH values between 6.5 and 7. However, this aspect remains to be confirmed or denied by future soil-plant studies in these regions.

5. Correlations found in this paper are aimed at contributing to better plum tree and apple tree zoning in this country and in other regions abroad under similar ecological conditions.

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