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Root distribution of apple tree under various irrigation systems within the hilly region of Romania

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A b s t r a c t. The present paper shows the effects of various irrigation methods on the distribution of roots in the Golden Delicious apple cultivar grafted on MM 106 rootstock under the specific conditions of the hilly region of Pitesti-Maracineni, Southern Romania. The results obtained here showed that a higher influence was induced by the different irrigation treatments to the active tree root cross-sectional area (TRCSA) versus the total TRCSA. A direct, linear and distinctly significant correlation was found between the sum of the total TRCSA and the fruit yield on the one hand, and between the total TRCSA and the annual growth in tree trunk cross-sectional area on the other hand. This study also revealed, from the TRCSA point of view, that in apple tree farming microsprinkler irrigation and drip irrigation would be the best methods to be used under the natural and technological conditions discussed here. They are fully recommended as the best irrigation methods in apple growing extension under similar soil and technology conditions in the temperate climate zone.

K e y w o r d s: root distribution, apple tree, irrigation

INTRODUCTION

Although the root systems of fruit trees have a heredity-determined pattern, the action of some external factors like soil, climate, presence of a shallow hard rock or groundwater, as well as the technological measures applied, can induce important changes in the fruit tree root system distribution in soil (Kolesnikov, 1971; Tudosescu and Parnia, 1975; Cotorobai, 1983). The ratio between the tree root system and the aerial system in grown fruit trees is relatively constant within the same soil, regardless of the cultivar and rootstock. In general, the tree root is as much as 25-30% of the total tree mass in intensive orchards (Westwood, 1978), and most of the roots are distributed within the 25-100 cm depth in temperate climate and mineral soils (Negrila, 1971). In this respect Huquet (1973) created a specific method for the study of tree root systems.

Orchard technologies and soil and groundcover management systems generally aim at intensifying tree root activity within smaller soil volumes, resulting in a decrease in renewal root growth as well as in an increase in tree aerial parts to produce a higher fruit yield (Zucconi, 1988).

Soil is a variable space and time entity due to the diversity of its components. Roots, therefore, adjust to the environmental growth conditions. As a consequence, high-amplitude variations in fruit-tree root growth conditions can deteriorate the root system. For instance, excessive irrigation application after a very dry period could induce different growth conditions and, implicitly, some necroses associated with basic leaf wilting and fruit fall (Zucconi, 1988).

While abroad, Trocme and Gras (1965) reported that tree root growth was a function of soil moisture. And in Romania, Iancu (1980) found a direct correlation between the distribution of tree root cross-sectional area (TRCSA) and soil moisture content for various soil types, while Teaci *et al*. (1985) described, in detail, aspects related to soil rating in fruit growing. In addition, Tanasescu (1999) and Voiculescu (1999) reported specific values of TRCSA for various irrigation methods and soils, respectively, in Romania. However, there is still a need for a more profound investigation in apple tree root distribution under varied irrigation conditions.

The objective of this study is to show the effects of various irrigation methods on the magnitude and distribution of TRCSA in the Golden Delicious apple cultivar grafted on MM 106 rootstock under the specific conditions of the hilly region of Pitesti-Maracineni, Southern Romania. Correlation between TRCSA and some tree growth and yield parameters are also discussed.

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MATERIALS AND METHODS

The investigations were performed under the temperate climate conditions of Pitesti-Maracineni, Romania, with a mean annual temperature of 9.6°C and rainfall of 650 mm, non-uniformly distributed during the year, with a maximum in May-June, while reference evapotranspiration (Penman-Monteith, ET_0) attained approximately 690 mm, with a maximum during July-August. This distribution generated severe water deficits in mid and late summer. Consequently, irrigation was used as a supplemental water source for trees and was generally applied during the June-through-August period. The experiment was conceived as a split-plot method. More than one irrigation method was utilized: sprinkler irrigation (SI), microsprinkler irrigation (MI), and drip irrigation (DI), as well as a control non-irrigated treatment (NI). The experiment was conducted over a period of 7 years, starting with year 7 after the orchard establishment. Trees were planted in rows 3.6 m apart, with 1.5 m spacing in the rows. Soil moisture content values generally varied between field capacity and half of the interval of available soil water during the growing season. The soil specific to this region had a loamy-clayey texture, and was developed on an almost horizontal terrace of the Arges river. The water table did not influence the soil water regime during the growing season.

Mowed sod strips between tree rows and clean cultivation strips on the row were used as a groundcover management system in this experiment. Tree crowns were conducted as palmettes. Trees were selected from those possessing similar crown volumes and tree trunk cross-sectional areas. Tree root system analysis was carried out after the method improved by Oskamp-Dragavtev and described by Dragavtev (1956), described as follows. At the end of the growing season in the last year of the experiment, L-shaped soil profiles in four replications were excavated down to a depth of 1 m at mid-distance between the representative trees under study. Various tree root diameter classes were determined on a 1 m^2 soil wall area with the aid of a 10 x 10 cm square grid framework. The mid-distance between the trees was taken at 0.75 m on both directions of the profile used: along the row and towards the interval between tree rows, respectively. Within each square grid area, tree root positions and diameter were localized. Immediately after soil profile performance, tree root cross-sectional area for different root diameters (<1, 1-2, 2-3, 3-4, and >4 mm), as well as the total root area in each 100 cm^2 grid square, were measured and calculated as an average along the row and towards the interval between the rows. These data were related to their positions in the soil and were also expressed as values for 1 m^2 of soil area. Special attention was devoted to roots with diameters <1 mm. They were called here the '*active* or *absorbent* roots'. Tree trunk cross-sectional area (TTCSA) values taken at about 30 cm above the soil surface and fruit yield were also measured within each treatment under investigation.

Data obtained from the experiment were analyzed through analyses of variance and the t and Duncan tests. In addition, regression equations and the Fisher test were also used to find and test correlation significance between the factors studied. In the text that follows, ** mean distinctly significant ($P < 0.01\%$). Root distribution data were also processed using the geostatistical kriging procedure (SURFER program) in order to interpolate between the points measured.

RESULTS AND DISCUSSION

The results obtained showed that the irrigation method used in apple orchards induced a specific tree root distribution in the soil profile and also a specific value of the sum of TRCSA.

Spatial distribution of the tree root cross-sectional area

Spatial distribution of the active tree root cross-sectional area

Comparison between treatments revealed that in the case of NI, unlike the other treatments, TRCSA distribution of the active roots showed a maximum value (6 mm^2) at the depth of 20-40 cm (Fig. 1). Deeper in the soil, the isolines were approximately parallel to the horizontal direction, meaning a decrease in TRCSA downwards. At the depth of 90-100 cm there were practically no more tree roots in the soil.

Within the SI treatment, the maximum TRCSA value (7 mm^2) occurred in the 0-20 cm depth. From there downwards, its value decreased with depth. The 0 isoline was noticed below the 100 cm depth. In the MI treatment, the maximum value (6 mm^2) of TRCSA was found within the 0-50 cm depth. However, TRCSA showed higher values deeper in the soil, as opposed to the other treatments. For instance, at a depth of 90-100 cm, the TRCSA isoline attained about 2 mm^2. The DI treatment showed the highest (9-10 mm^2) TRCSA values, from all treatments studied, within the 0-30 cm soil layer. In this treatment, the highest value of the vertical gradient regarding TRCSA was found between the depths of 0 to 50 cm. From this depth, the TRCSA decrease downward occurred almost uniformly and similarly to the other treatments.

Differences in TRCSA spatial distribution were most probably due to the specific influence of the irrigation method used in this experiment, as the other natural or technological parameters were similar. It was interesting to discover that the DI treatment, through its almost continuous water application in summer time, induced a higher TRCSA concentration down to a depth of 30-40 cm. This TRCSA distribution pattern showed that irrigated trees explored the soil around the roots more intensively, despite being in a smaller soil volume and using less energy.

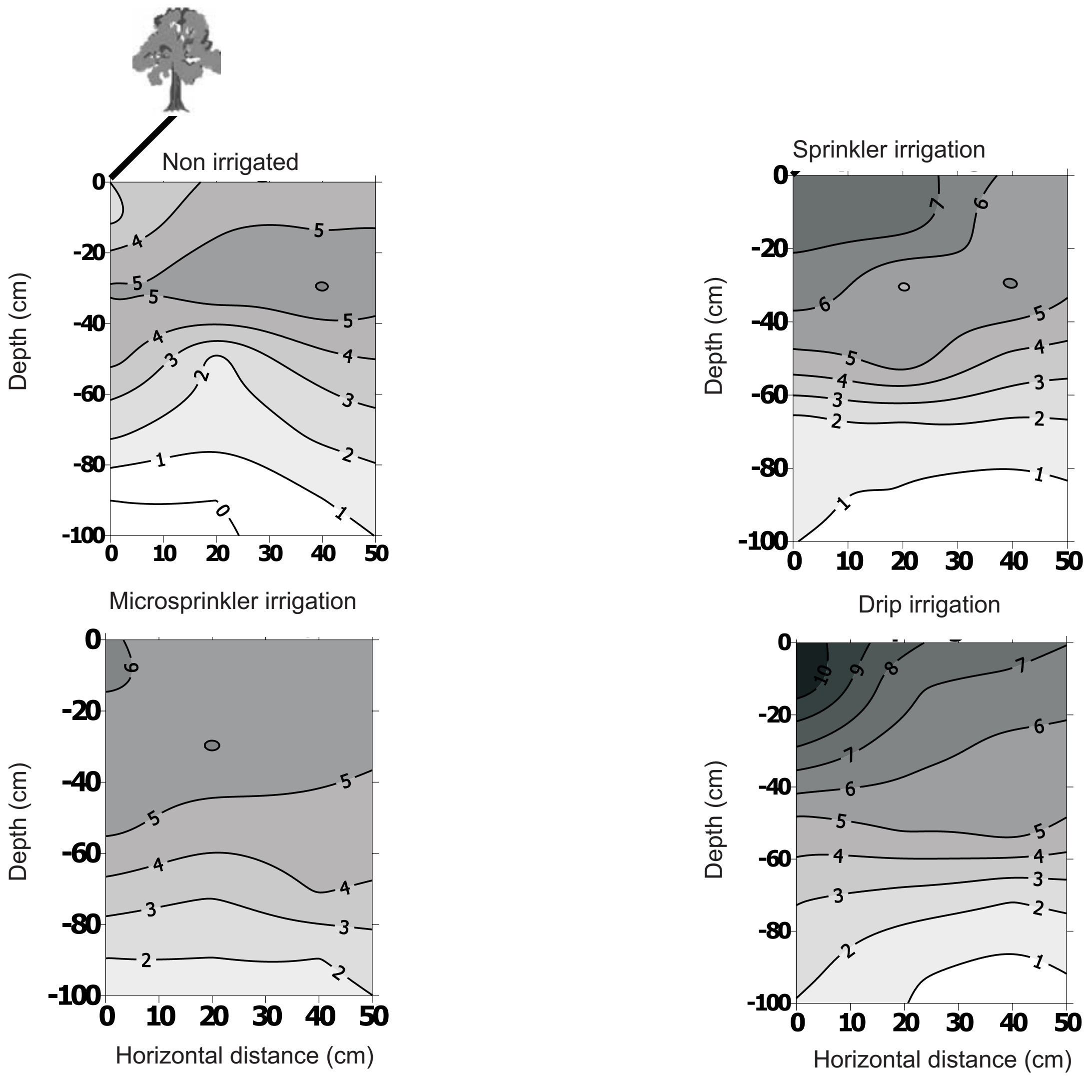

Fig. 1. Spatial distribution of the active TRCSA (mm^2) with a depth and width of half of the 1 m^2 vertical plane situated at 0.75 m distance from the representative tree in the treatments used, integrated after 7 years of irrigation application; horizontal distance below graphs is related to the tree projection on the vertical plane of root area measurement that was located 0.75 m away.

Spatial distribution of the total TRCSA

Figure 2 reveals the distribution of the total TRCSA in depth and width for the experiment studied. Generally, the maximum values of the total TRCSA were found about 30 cm below the soil surface (80 mm^2) for the NI and MI treatments. The SI and DI treatments had their maximum values (60-80 mm^2) a little shallower than the previous ones, at a depth of about 10 cm. However, the total TRCSA was slightly deeper for the irrigated treatments versus the NI.

Spatial distribution of the active and total TRCSA percentage of their sums within 1 m^2 *soil area*

It was also important to see what the spatial distribution of the active and total TRCSA percentages was between the treatments (Fig. 3). For the DI and SI treatments, about 35% of the active TRCSA was developed within the 0-20 cm depth, and 27-30% in the 20-40 cm depth (Fig. 3a). NI had 26% in the top 0-20 cm soil layer and its maximum value (37%) in the next 20 cm layer. From there, NI decreased uniformly downwards. However, in the MI treatment lower active TRCSA values (25%) were found in the topsoil, and higher values below the depth of 60 cm.

Total TRCSA showed two distinct groups of treatments (Fig. 3b). In the NI and MI treatments, the TRCSA percentage was much lower within the 0-20 cm depth, 10% and 20%, respectively, and higher in the next soil layer, 50% and 47%, respectively. From this depth the TRCSA percentage decreased dramatically downwards. In the DI and SI treatments, this parameter decreased continuously from the topsoil, where the values attained about 38-42%, to values of about 5-10% deeper in the soil. At 90 cm all the treatments showed insignificant values.

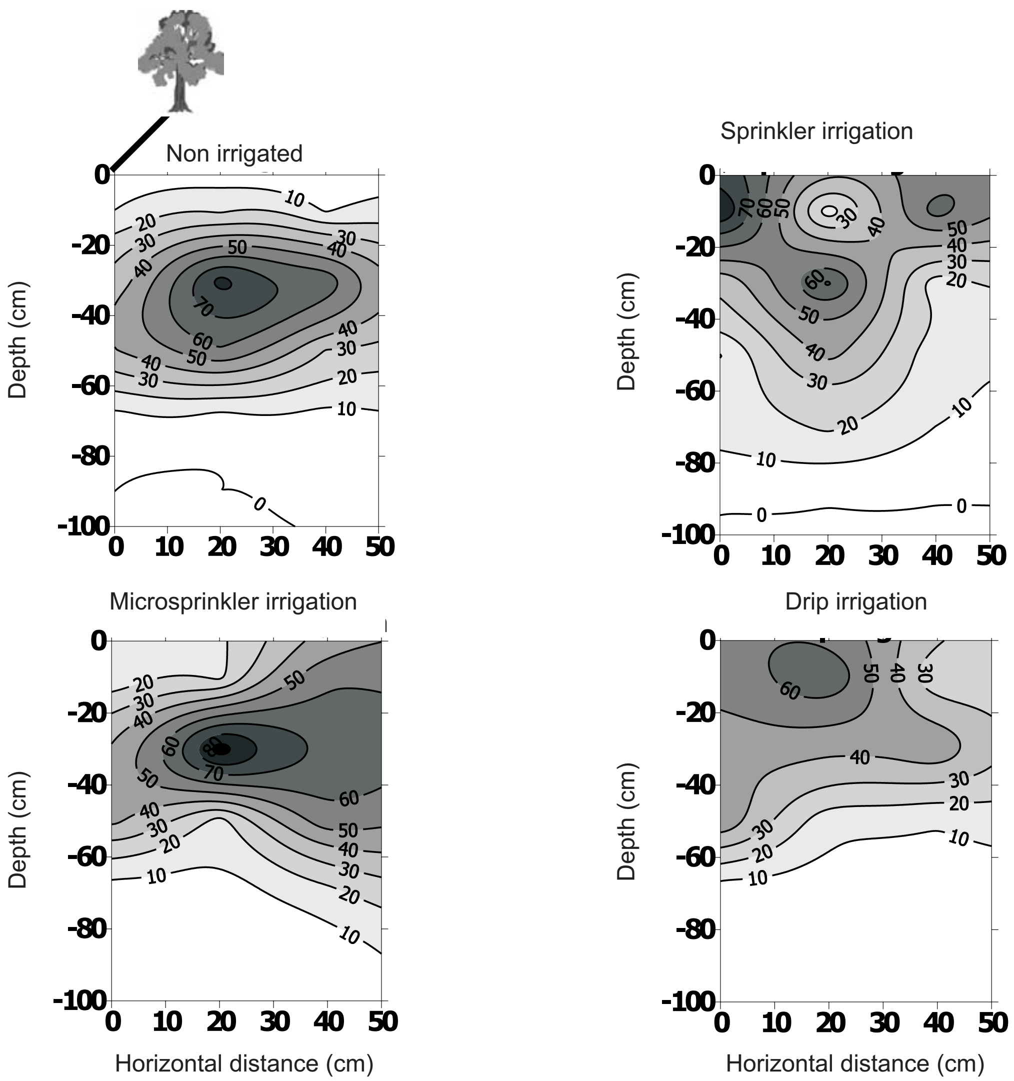

Fig. 2. Spatial distribution of the total tree root cross-sectional area (mm^2) with a depth and width of half of the 1 m^2 vertical plane situated at 0.75 m distance from the representative tree in the treatments used, integrated after 7 years of irrigation application; horizontal distance below graphs is related to the tree projection on the vertical plane of root area measurement that was located 0.75 m away.

Sum of cross-sectional area of tree roots

The sum of the cross-sectional area of both active and total tree roots was different between the treatments (Fig. 4). Thus, there were significant differences in the active TRCSA between all the treatments investigated (Fig. 4a). DI and MI showed maximum values, 146 and 130 mm^2, respectively, whereas NI had a minimum value (92 mm^2). In return, total TRCSA only showed a significant difference between MI (876 mm^2) and NI (725 mm^2), the comparison showing non-significant differences between the other treatments (Fig. 4b).

These results revealed that a higher influence was induced by the different irrigation treatments studied to the active TRCSA versus the total TRCSA.

TRCSA correlation to fruit yield and growth parameters

A direct, linear and distinctly significant correlation was found between the sum of total TRCSA in 1 m^2 soil section and the fruit yield (Fig. 5a). Another direct, linear and distinctly significant correlation was found between the sum of total TRCSA and the annual growth in tree trunk cross-sectional area (Fig. 5b).

These relationships demonstrated that the differences in TRCSA induced by various irrigation methods used in this experiment, as an effect of their particularities in spreading water over the field, also contributed to a different influence in the specific tree yield and growth parameters.

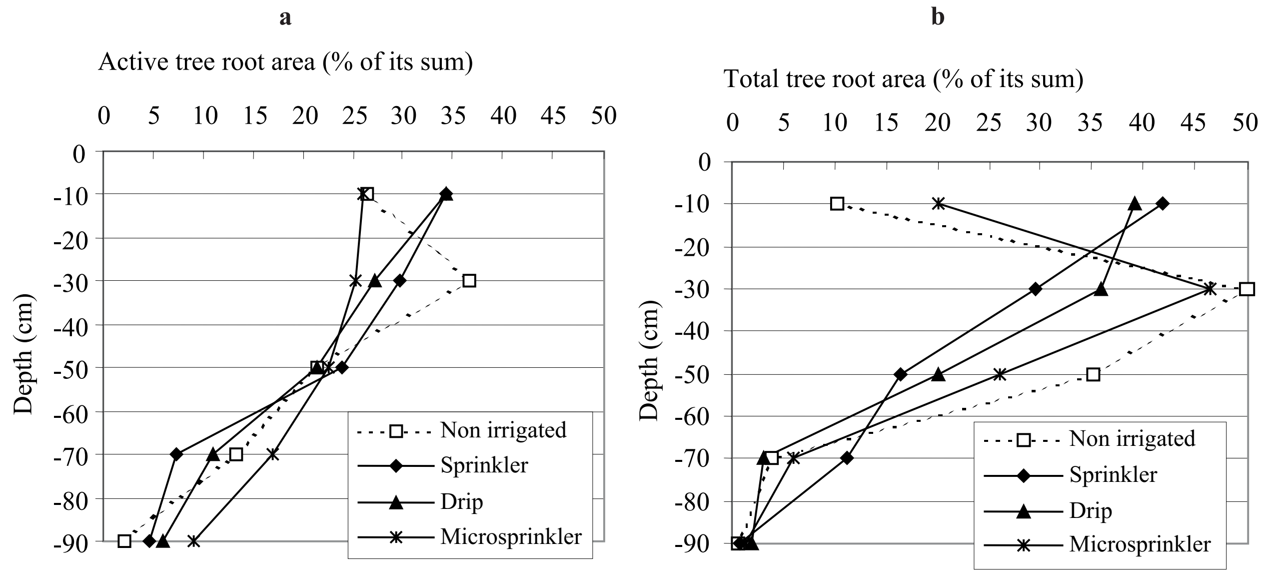

Fig. 3. Distribution of the percentage of the active and total TRCSA from their sum over a 1 m^2 vertical plane of measurement with depth for various locations at 0.75 m distance from the representative tree, respectively, integrated after 7 years of irrigation application.

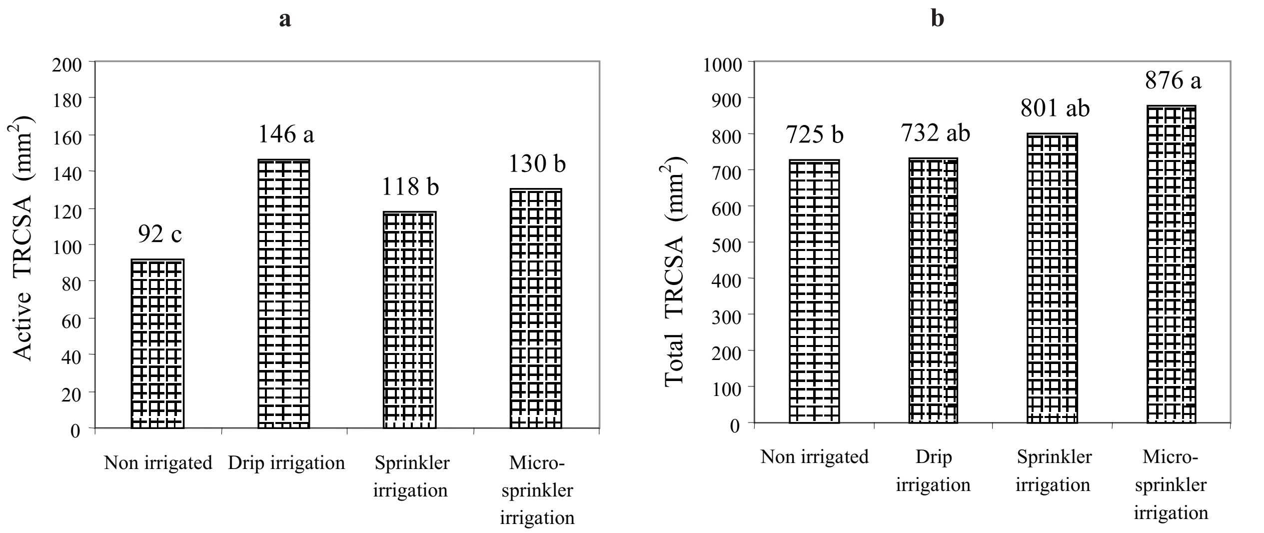

Fig. 4. Sum of TRCSA for both active (diameter < 1 mm) (a), and total roots (b) from the 1 m^2 vertical planes of measurement situated at 0.75 m distance from the representative tree in the treatments studied, integrated after 7 years of irrigation application; means with the same letter are not significantly different at the 5% probability level by the LSD test

CONCLUSIOINS

1. Most of both active and total TRCSA showed maximum values within the top 40 cm from the soil surface and almost all their roots were found in the 1st meter of soil depth for all treatments studied.

2. Even if irrigation was applied during a short annual period in summer time, it induced differences in the development of TRCSA in the soil. The TRCSA was slightly deeper for the irrigated treatments versus the NI.

3. A stronger influence was induced by the different irrigation treatments studied here to the active TRCSA versus the total TRCSA.

4. A direct, linear significant correlation was found between the sum of the total TRCSA and the fruit yield on the one hand, and between the total TRCSA and the annual growth in tree trunk cross-sectional area on the other hand.

5. This study also revealed, from the TRCSA point of view, that in apple tree farming microsprinkler irrigation

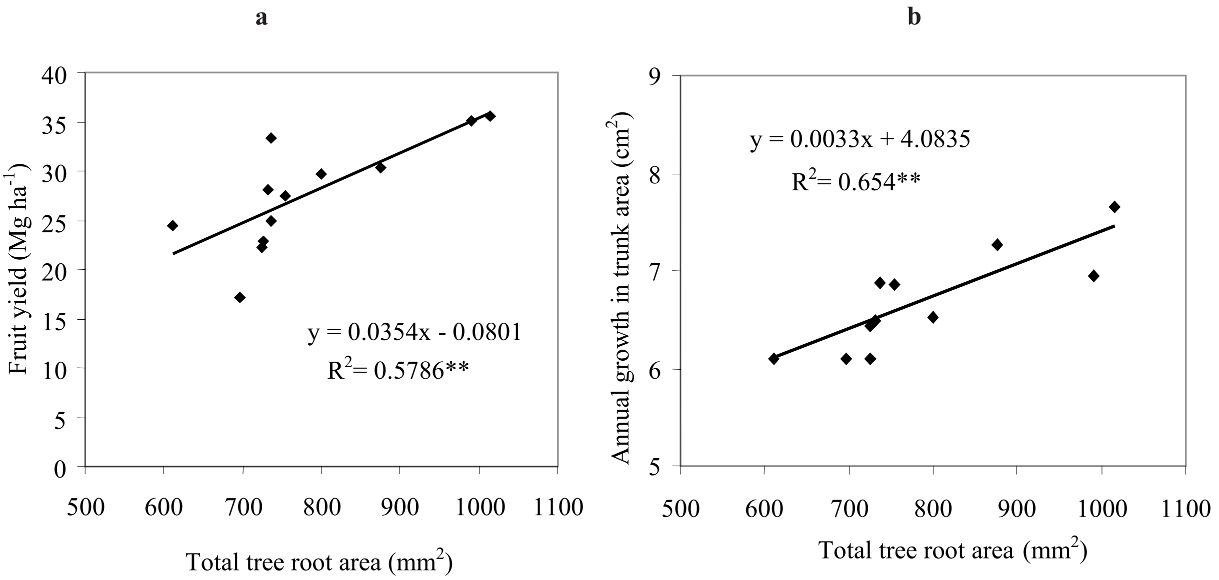

Fig. 5. Correlation between the sum of total TRCSA from the 1m^2 vertical planes of measurement situated at a 0.75 m distance from the representative tree in the treatments studied and fruit yield (a) and annual growth in tree trunk cross-sectional area (b), respectively, after 7 years of irrigation application.

and drip irrigation were the best methods used under the natural and technological conditions discussed here. They can be recommended as the best irrigation methods in apple growing extension under similar soil, climate and technological conditions in the temperate climate zone.

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