*Bulgarian Journal of Agricultural Science, 4 (1998), 745-753*
*Agricultural Academy of Bulgaria*

# Investigations on Fertigation of Peach on Three Soil Types - Patterns of Soil Wetting

K. KOUMANOV, D. DOCHEV and G. STOILOV

*Institute of Fruit-Growing, BG-4004 Plovdiv, Bulgaria*

## Abstract

KOUMANOV, K., D. DOCHEV and G. STOILOV, 1998. Investigations on fertigation of peach on three soil types - patterns of soil wetting. *Bulg. J. Agric. Sci.*, 4: 745-753

The results presented in this article are part of a larger investigation aimed at clarifying of fertilizers' migration and localization in the root zone of arborescent fruit plants under fertigation, predicting the ecological consequences of applying this method of fertilization, and verification of the currently used application rates.

The experiment was carried out in lysimeters on three soil types: alluvial-meadow soil (Fluvisol) - sandy loam, cinnamon-forest soil (Luvisol) - clay loam, and smolnitsa (Vertisol) - clay.

Single peach trees, grown in every lysimeter, were drip-irrigated by single drippers with discharge of 4.6 l/h and located at 0.75m from the trunk. The fertilizers - urea $[CO(NH_2)_2]$ and phosphoric acid $(H_3PO_4)$, were supplied through the irrigation system, the annual amounts being partitioned to monthly doses. Investigation results were based on soil analyses, analyses of lysimetric waters, and electrometrical readings (gypsum blocks).

It was found that in soil types with different hydraulic characteristics the same irrigation regime resulted in essentially different patterns of soil wetting. Root activity was also proven to play a substantial role in the irrigation water redistribution into the soil volume.

The application efficiency proved to be closely related to the hydraulic conductivity of the soil and varied considerably between soil types. Investigation results suggested the need of changing the methodology for scheduling and management of localized (drip/trickle) irrigation.

*Key words:* drip-irrigation, fertigation, lysimeters, peach, patterns of soil wetting, root water uptake

## Introduction

The supply of fertilizers through the irrigation water (fertigation) is widely used in micro-irrigation (Francis, 1977; Bucks and Nakayama, 1980; Uriu et al., 1980; Rolston et al., 1986), which is subject of standing interest because of its effectiveness in the conditions of increasing water and energy deficits. Fertilization dose is supplied during the whole vegetation period, in parts precisely dosed out according to the biological curve of the crop nutrient-assimilation (Bresler, 1977; Hillel, 1985; Wolff, 1987; Decroix, 1988). The combining of the irrigation process with fertilization through the micro-irrigation systems creates specific conditions of local wetting and zonal concentration of solutes in the soil (Goldberg et al., 1971; Rauschkolb et al., 1976; Dochev et al., 1979; Bacon and Davey, 1982; Rolston et al., 1986), which involve some differences in the intensity and the direction of processes taking place in the relevant zones.

Water is the main carrier of nutrients and determines to a great extent the fertilizers' migration and localization in the soil volume. Hence, the space distribution of soil moisture is the key to a correct interpretation of the soil-samples analysis data.

In a series of several articles, the accent will be put also on aspects of the problem related to: the changes in soil properties caused by the local wetting (and overwetting) and by the increased salt concentration in the zones of fertilizers' migration and localization; the actualities of plant nutrition under fertigation; a prognosis for the after-effects of this fertilization method on the soil; an ecological estimate of the fertilization by the micro-irrigation systems; and a relevant verification of the currently used application rates. The article is based on results from an investigation carried out at the Institute of Fruit Growing - Plovdiv during the period 1994-1997.

## Material and Methods

The investigation was carried out in a concrete lysimetric unit (Figure 1) with cells 2.00x3.00 m filled up to 1.00 m with soil, and on three soil types: alluvial-meadow soil, cinnamon-forest soil, and smolnitsa. According to the FAO-Unesco-ISRIC (Boyadgiev, 1997) these soils are

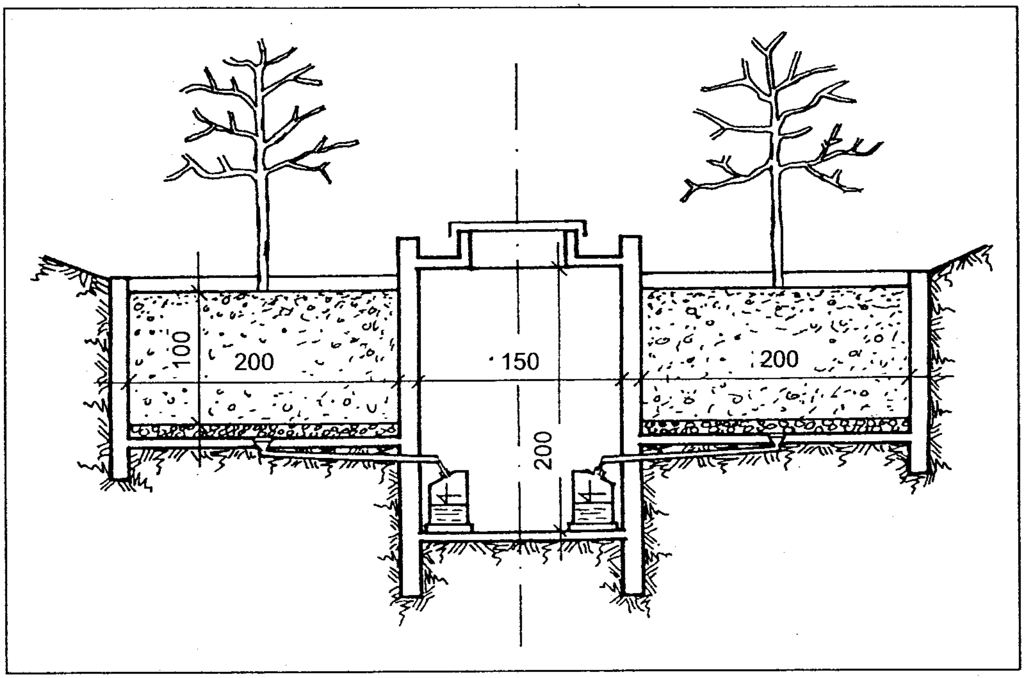


**Fig. 1. Transversal section of the lysimetric unit**

classified respectively as Fluvisol, Luvisol (chromic), and Vertisol. Texturally they are determined respectively as sandy loam, clay loam, and clay, after the USDA-classification (Soil Survey Staff, 1975). The values of particle density, bulk density, porosity, field capacity (FC), as well as the percentage of sand, silt and clay are presented by soil types in Table 1.

In the spring of 1994, single peach trees (cultivar Redhaven on GF-677 rootstock) were planted in every one of the lysimetric cells. Plants were supplied with water and fertilizers through a drip-irrigation system: one emitter per tree, with an average discharge of 4.6 l/h, and located at 0.75m from the tree trunk. Nutrient solution - urea $[CO(NH_2)_2]$ and phosphoric acid ($H_3PO_4$), was injected in the irrigation water by an automatic dosing pump (DOSATRON INTERNATIONAL, Bordaux, France).

The irrigation was scheduled on the basis of evapotranspiration values calculated by the method of biophysical coefficients (Davidov and Gaidarova, 1983; Sharma, 1985), and in function of the average daily temperatures: $ET = Z\Sigma t_{av.d}$, where $Z$ is a biophysical coefficient, and $\Sigma t_{av.d}$ is the sum of the average daily temperatures for the period of consideration. The values of $Z$ for peach were adopted from Dochev (1972). The irrigation was realized on a daily basis, five days in a week except Saturdays and Sundays. The annual application rates per single plant and their partitioning by months are shown in Table 2.

**Table 1**
**Physical properties of the investigated soils**

| Soil properties | Soil types | | |
|---|---|---|---|
| | alluvial meadow | cinnamon forest | smolnitsa |
| Particle density, g/cm$^3$ | 2.7 | 2.6 | 2.7 |
| Bulk density, g/cm$^3$ | 1.43 | 1.19 | 1.23 |
| Porosity, % | 47.0 | 54.2 | 54.4 |
| Field capacity, kg/kg | 0.16 | 0.24 | 0.35 |
| Content of sand* (2÷0.05mm), % | 64.8 | 40.0 | 34.7 |
| Content of silt* (0.05÷0.002mm), % | 24.3 | 25.8 | 14.2 |
| Content of clay* (< 0.002mm), % | 10.9 | 34.2 | 51.1 |

* According to the classification of the USDA (Soil Survey Staff, 1975)

**Table 2**
**Annual application rates (liters per tree) and their distribution during the months of the irrigation season**

| Year | Application rate, liters/tree | Monthly parts of the application rate | | | | | |
|---|---|---|---|---|---|---|---|
| | | April | May | June | July | August | September |
| | | liters/tree | | | | | |
| 1995 | 2228 | - | 420 | 540 | 542 | 436 | 290 |
| 1996 | 1890 | 39 | 100 | 241 | 754 | 608 | 148 |
| 1997 | 2330 | - | 432 | 701 | 1050 | 147* | |

* The experiment was ceased on 02.08.1997

The pattern of irrigation water redistribution in the three soils was examined by soil sampling 20 hours after the last application. Soil samples were taken by drilling radially from the dripper at 10cm, 25cm, 50cm, 75cm and 100cm, and by layers of 10cm. In 1997, however, soil samples were taken from a soil profile in 10cm square grid, after digging a trench along the line tree-dripper. Root system's configuration throughout the profile was also established. The soil moisture values were estimated gravimetrically.

Moreover, sensors of electrical resistance (gypsum blocks) (Kirkova, 1984; Varlev et al., 1989; Vichev et al., 1989) were installed in every lysimeter for soil moisture measurement and for an operative control on the wetted soil volumes. They were fixed radially from the dripper at 10cm, 25cm, 50cm, 75cm, and 100cm, and in depth respectively at 10cm, 30cm, 60cm and 80cm.

The development of wetted soil volume under a dripper was studied electrometrically in 1996. For that reason, soil water content was decreased almost to the point of wilting (50% of the FC), and then irrigation water was supplied to the trees during 27 hours. Readings from the gypsum blocks were taken right before the irrigation as well as 2, 4, 6, 8, 24, and 48 hours after the water supply had been started.

The water amounts drained from lysimeters were regularly collected and measured during the vegetation.

## Results and Discussion

A distinct notion for the patterns of soil wetting in the three soil types could be obtained from Figures 2, 3, and 4 based on the results from 1996.

In the alluvial-meadow soil (Figure 2), wetting front has reached only 30-40cm in depth. On the other hand, one could see a wider surface spill of the irrigation water and a larger radius of lateral wetting reaching 75cm at the soil surface (invert type).

In the cinnamon-forest soil (Figure 3), wetting front has reached 60cm in depth and 50-60cm radially with the largest radius of soil wetting at a depth of 30cm. The zone of surface ponding is smaller, thus decreasing the evaporative losses, and the wetted soil volume has increased

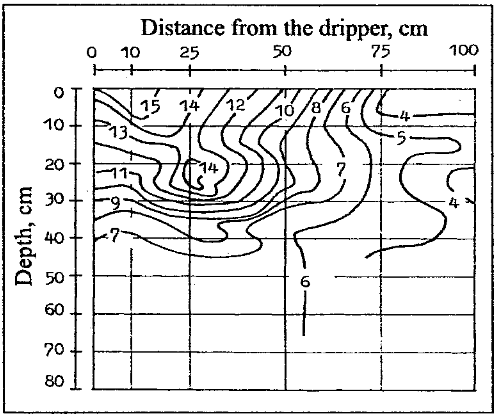


**Fig. 2. Field of the soil moisture (gravimetrical %) in the alluvial-meadow soil; 10.07.1996**

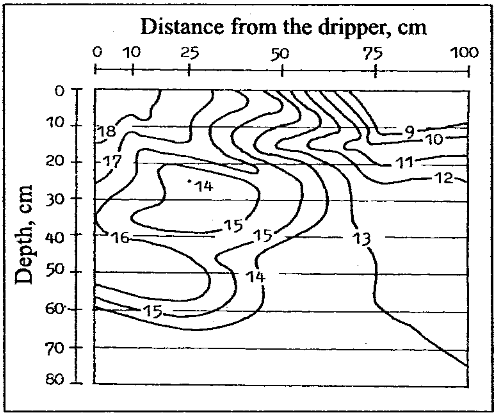


**Fig. 3. Field of the soil moisture (gravimetrical %) in the cinnamon-forest soil; 10.07.1996**

approaching the normal for this type drip-irrigation size and shape.

Although the smolnitsa is known with a high retention capacity and is characterized by an intense lateral infiltration under point water supply, the pattern of soil wetting shown in Figure 4 surprisingly represents it highly permeable. After digging a trench in 1987, it was found that this discrepancy was due to an improperly sealed drilling hole located 10cm away from the point of dripping. Hence, the established in 1996 pattern of soil wetting should be considered rather as a simulation model of highly permeable soil. The prevailing water flow is in vertical direction and forms a clearly outlined transmission zone with radius of 25cm. The transit transport of water throughout the whole depth of soil profile results in a drainage of 155.3 liters, registered only in this soil for the period of vegetation. An area of rapidly decreasing soil moisture values is located all around the transmission zone, at a radial stretch of 25-50cm.

Obviously, the different hydraulic characteristics of the studied soils determine essentially different patterns of soil wetting despite of the same irrigation regime. The water stored in the wetted soil volumes, estimated under an assumption for axisimetry of the bulb, is roughly 59dm$^3$ in the alluvial-meadow soil, 89dm$^3$ in the cinnamon-forest soil, and 239dm$^3$ in the smolnitsa. The relatively small volume of wetting in the alluvial-meadow soil suggests significant evaporative losses of irrigation water from the increased superficial ponding area. The magnitude of these losses is not estimated in the present investigation but according some authors (Andreu et al., 1997; Matthias et al., 1986) they could reach up to 30-49% of the application rate.

Figures 5, 6, and 7 give a notion about the development of wetted soil volumes during an application and in the period to the next one, based on the gypsum blocks readings.

The low hydraulic conductivity of the alluvial-meadow soil presumes higher gradients of the soil water potential provided by a zone of overwetting, formed almost immediately under the point of

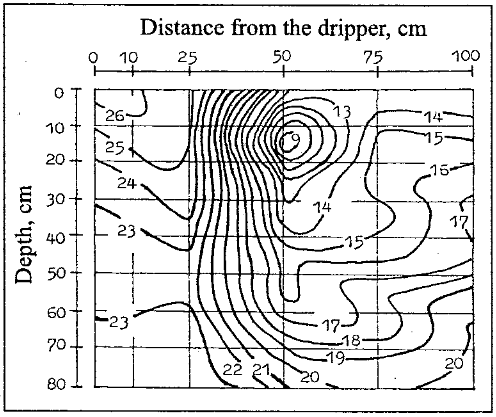


**Fig. 4. Field of the soil moisture (gravimetrical %) in the smolnitsa; 10.07.1996**

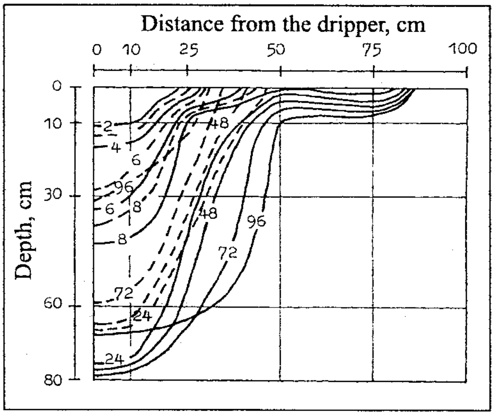


**Fig. 5. Development of the wetted soil volume (by hours after the beginning of water supply) in the alluvial-meadow soil during a 27-hour application and in the period to the next one. Solid line - periphery of the bulb; dashed line - zone of overwetting**

dripping, and the closely located wetting front (Figure 5). The volume of wetting increases slowly, due to an intensive root water uptake and probably to high rates of evaporation from the superficial ponding area. The process of infiltration intensifies considerably during the night when the transpiration is absent and the physical evaporation from the soil surface is significantly decreased. After twenty four hours of water supply, the wetting front has reached 80cm in depth but this has not resulted in drainage, yet. A normalization of the irrigation regime during the next days results in some shrinkage of the wetted soil volume.

In the more permeable cinnamon forest soil (Figure 6) water transport is possible under lower gradients of the water potential. That is why, a zone of overwetting has been formed eight hours after the beginning of irrigation. Again, the evapotranspiration delays the increasing of wetted soil volume during the day. Through

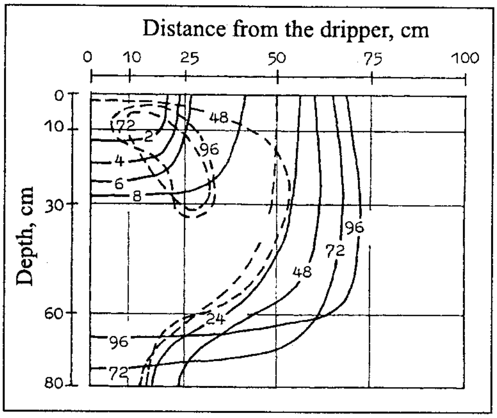


**Fig. 6. Development of the wetted soil volume (by hours after the beginning of water supply) in the cinnamon-forest soil during a 27-hour application and in the period to the next one. Solid line - periphery of the bulb; dashed line - zone of overwetting**

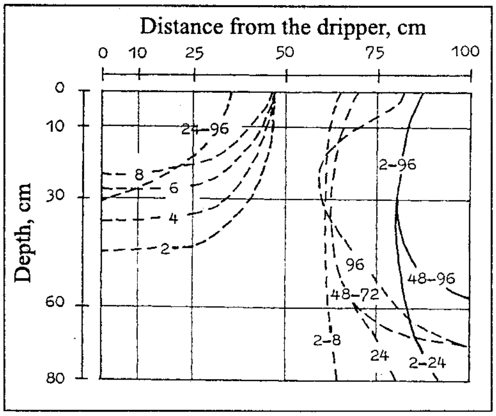


**Fig. 7. Development of the wetted soil volume (by hours after the beginning of water supply) in the smolnitsa during a 27-hour application and in the period to the next one. Solid line - periphery of the bulb; dashed line - zone of overwetting**

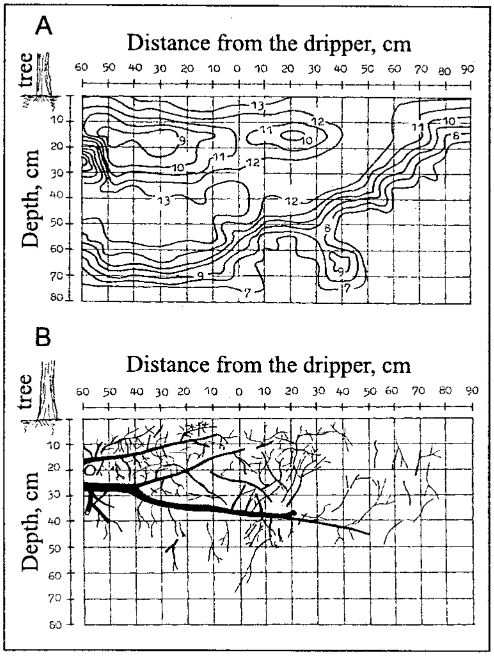


**Fig. 8. Field of the soil moisture (gravimetrical %) - a; and configuration of the peach-tree root system in the alluvial-meadow soil - b; 04.08.1997**

the night, however, the bulb has expanded considerably tending to form drainage below the point of dripping. The irrigation regime being normalized, the volume of overwetting shrinks significantly.

The smolnitsa absorbs irrigation water almost without losses from surface evaporation which, with the remarkable water-holding capacity of this soil, provides a good water regime for the peach plant. In this soil (Figure 7), a considerable zone of overwetting is observed already before the application. The irrigation water is easily transmitted in depth at relatively low gradients of the soil water potential. The bulb gradually *fills up*. Part of the drained water spills on the bottom of lysimeter, thus feeding a capillary rise to the lowest soil layers. The switch over of the normal irrigation regime results in decreasing of soil water content immediately under the dripping point due, apparently, to an increased concentration of active roots in this area.

The presence or the absence of root activity is of great importance for irrigation water distribution and redistribution in the soil. Figures 8, 9, and 10 represent both the pattern of soil wetting and the root system configuration in soil profiles along the row, found in 1997. Well outlined areas of decreased water content are observed in the wetted volumes of all three soils. They are located along the skeletal roots - from tree trunk to the very well watered zones under the dripper. As far as most of the active roots are concentrated in these zones, the soil drying is apparently caused by an intensive root water uptake. Moreover, water redistribution, driven by the

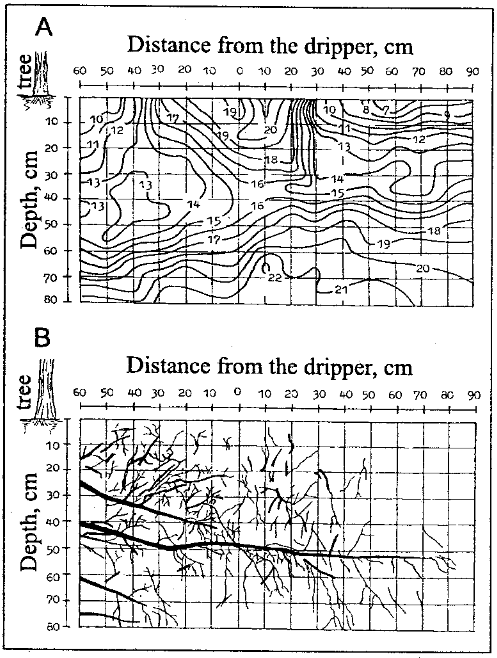


**Fig. 9. Field of the soil moisture (gravimetrical %) - a; and configuration of the peach-tree root system in the cinnamon-forest soil - b; 15.07.1997**

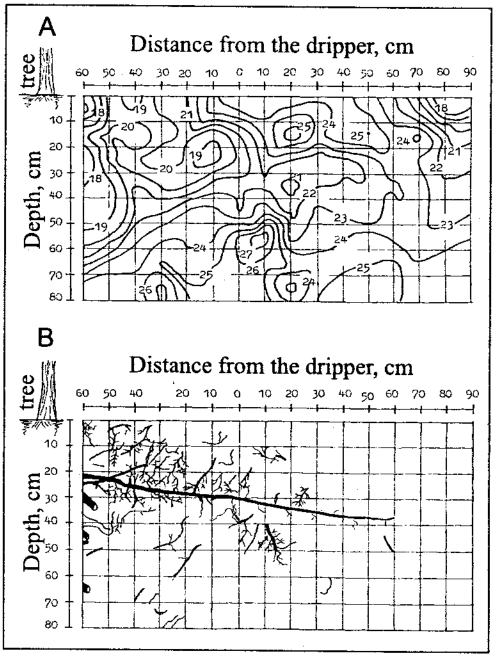


**Fig. 10. Field of the soil moisture (gravimetrical %) - a; and configuration of the peach-tree root system in the smolnitsa - b; 14.07.1997**

created gradients of soil water potential, is too slow to compensate the high rates of extraction. As a result, only 20 hours after the water supply has been ceased, soil moisture values around the active roots are decreased almost to the wilting point (about 50% of FC) while in the rest of the bulb they are still above 80% of the field capacity. Similar non-uniform distribution of the root activity was established also in experiments with micro-sprinkler irrigation (Koumanov, 1996).

It turns out that, even under drip-irrigation, water is not equally available for the fruit trees throughout the wetted soil volume. It may well be that plants undergo water stress pretty soon after the irrigation, although such a statement has not been proven in the present study. Hence, in the majority of cases, a daily or even permanent supply of irrigation water would be the most favorable for the plant water regime.

## Conclusions

In soil types with different hydraulic characteristics, the same amount of applied irrigation water results in different volumes of soil wetting (shape, size, and available water storage). The application efficiency is closely related to the hydraulic conductivity of the soil and varies essentially between soil types. Investigation results suggest the need for changing of scheduling and management of micro-irrigation taking in account both the specific climatic conditions and the soil hydraulic characteristics.

For the fruit trees, irrigation water is not equally available throughout the wetted soil volume, even under drip-irrigation. Zones of rapidly decreasing soil moisture values are being formed along the skeletal roots and the root water uptake is most intensive in the vicinity of the tree trunk. The local depletion of soil water storage necessitates a shortening of the periods between applications. A daily or even permanent supply of irrigation water would be the most favorable for the trees' water regime.

### *Acknowledgements*

This investigation was carried out with the financial support by the National Science Fund, Ministry of Education and Science, Republic of Bulgaria, as well as with the kind equipment support by the DOSATRON INTERNATIONAL, Bordeaux, France.

## References

**Andreu, L., J.W. Hopmans and L.J. Schwankl,** 1997. Spatial and temporal distribution of soil water balance for a drip-irrigated almond tree. *Agricultural Water Management,* **35**: 123-146.

**Bacon, P.E. and B.G. Davey,** 1982. Nutrient availability under trickle irrigation. II. Mineral nitrogen. *Soil Sci. Soc. Am. J.,* **46**: 987-993.

**Boyadgiev, T.,** 1997. Soil map of Bulgaria according to the FAO-Unesco-ISRIC revised legend. A brief explanation note. *Bulgarian Journal of Agricultural Science,* **3**(1): 6pp.

**Bresler, E.B.,** 1977. Trickle-drip irrigation: Principles and application to soil-water management. *Advances in Agronomy,* **29**: 343-393.

**Davidov, D. and S. Gaidarova,** 1983. On the exactness of equations for estimation of the evapotranspiration. In: Support of the thechnical progress in the water affairs, **6**: 12-22 (Bg).

**Decroix, M.,** 1988. La Microirrigation dans le Monde. CEMAGREF, Aix en Provence, 208 pp..

**Dochev, D.,** 1972. Investigation on some biological and physiological manifestations of peach under irrigation. Ph.D. thesis, Institute of Fruit-Growing, Plovdiv, 318 pp.(Bg).

**Dochev, D., G. Stoilov and I. Iovchev,** 1979. Investigations on drip irrigation of peach trees. I. Distribution of water and mineral nitrogen in the soil. *Horticultural and Viticultural Science,* **16**(2): 3-11 (Bg).

**Goldberg D., B. Gornat and J. Bar,** 1971. The distribution of roots water and minerals as a result of trickle irrigation. *J. Am. Soc. Hort. Sci.,* **96**: 645-648.

**Hillel, D.,** 1985. Status of research in drip/trickle irrigation. Proceedings, 3rd International Drip/Trickle Irrigation Congress, Fresno, CA, USA, 18-21 Nov., Vol.1, p.13. In: Decroix M., 1988. Microirrigation dans le monde, CEMAGREF, Aix en Provence, pp.186-192.

**Kirkova, Y.,** 1984. Designing and studying of sorptive soil moisture transducers. Ph.D. Thesis, N. Poushkarov Institute of Soil Science and Agrochemistry, Sofia, 182 pp. (Bg).

**Koumanov, K.,** 1996. Application efficiency and soil water dynamics in the root zone of an almond tree under micro-sprinkler irrigation. *Final Scientific Report,* BUL/95010, International Atomic Energy Agency, Vienna, 76 pp.

**Matthias, A.D., R. Salehi and A.W. Warrick,** 1986. Bare soil evaporation near a surface point-source emitter. *Agricultural Water Management,* **11**: 257-277.

**Rauschkolb, R.S., D.E. Rolston, B.J. Miller, A.B. Carlton and R.G. Burau,** 1976. Phosphorus fertilization with drip-irrigation. *Soil Sci. Soc. Am. J.,* **40**:68-72.

**Rolston, D.E., R.J. Miller and H. Schulbach,** 1986. Fertilization. In: Nakayama, F.S. and D.A. Bucks (Eds.), Trickle Irrigation for Crop Production, *Elsevier Science Publishers B.V.,* pp.317-344.

**Sharma, M.L.,** 1985. Estimating evaporation. In: Hillel, D. (Ed.), *Advances in Irrigation,* **3**: 213-281.

**Soil Survey Staff,** 1975. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. *USDA - SCS Agricultural Handbook* 436, U.S. *Government Printing Office,* Washington, D.C.

**Uriu, K., R.M. Carlson, D.W. Henderson, H. Schulbach and T.M. Oldrich,** 1980. Potassium fertilization of prune trees under drip-irrigation. *J. Am. Soc. Hort. Sci.,* **105**: 508-510.

**Varlev, I., N. Vitchev, K. Penev, Z. Popova and B. Krustanov,** 1989. Automated system for surface irrigation. Proceedings, International Symposium "Water Management for Agricultural Development", Athens, pp.186-188.

**Vitchev, N., K. Penev, . B. Krustanov and Y. Kirkova,** 1989. Soil moisture meter. Proceedings, International Symposium "Water Management for Agricultural Development", Athens, pp.189-191.

**Wolff, P.,** 1987. On the development status of micro-irrigation. Gesamthochsule Kassel, Universitat, Fachbereich 21, Internationale Agrarvirtshaft, Kulturtechnik und Wasserwirtschaft - Arbeiten und Berichte No 19, *Wintersemester* 1987/88, 14 pp.

*Received August, 18, 1998; accepted October, 5, 1998.*