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Herbigation in a Cherry Orchard – Translocation and Persistence of Pendimethalin in the Soil

K.S. Koumanov, Z. Rankova and K. Kolev
Dept. of Fruitgrowing Technologies
Fruitgrowing Institute
Plovdiv, Bulgaria

S. Shilev
Dept. of Microbiology
Agricultural University
Plovdiv, Bulgaria

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Abstract

Application of herbicides with irrigation water (herbigation) has many advantages – uniformity, flexibility, avoidance of heavy machinery, cost efficiency etc. On the other hand, localized water and chemical applications are associated with a possibility of undesirable impacts on the crops and the environment. The subject of the present paper is the fate of the soil herbicide pendimethalin in the root zone and its effects on soil microbial activity. Three variants of herbicide application – microsprinkling, drip irrigation, and a back sprayer, as well as a non-treated control, were set in three replications in a sweet cherry orchard. In all treated variants, the herbicide was applied at a dose of 6.0 L/ha in 2.0 m wide row strips, after a water application rate of 5.0 mm. The investigation objectives were addressed from periodical soil sampling – 30, 60, 90 and 120 days after the treatment from the 0-5 cm and 5-10 cm layers for studying the herbicide migration and decomposition in the soil, and 7, 30, and 45 days after the application from the 0-10 cm and 10-20 cm layers for the soil microbial activity. Bioassay, with oat as a test plant, and standard microbiological methods, respectively, were used for analyzing the soil samples. The herbigation, especially by microsprinkling, increased herbicide efficiency – biological and economical – and did not have a negative effect on the fruit trees and the environment.

INTRODUCTION

Microirrigation systems can be used for both providing favorable water regime to crops and applying of agrochemicals (Aitken, 1985; Ajwa et al., 2002; Burt, 2003). The application of herbicides with irrigation water (herbigation) has many advantages – uniformity, flexibility, avoidance of heavy machinery, cost efficiency, independency of the weather conditions, and reduced environmental contamination (Trimmer et al., 1992; Burt, 2003). According to some authors (Dale, 1986; Mannini, 1990), the herbicide efficiency may even increase under herbigation. On the other hand, one should be aware of eventual undesirable effects on the cultivated plants and of possible environmental pollution. Some crops are susceptible to soil herbicides, the phytotoxicity being more pronounced in the conditions of increased soil moisture, characteristic of microirrigation. The permanent soil moistening and the favorable nutritional regime induce vigorous growth of weeds and may intensify the degradation of soil herbicides (Fisher et al. 1985; Devine, 1988). Most important for the herbicides breakdown are the soil microorganisms (Kerle et al., 1996; Curran et al., 1998). On the other hand, the application of biologically

active substances with the irrigation water may affect soil microbial activity, respectively some processes important for soil fertility such as biomass accumulation, soil respiration, nitrogen mineralization as well as the microbial diversity and soil fauna (Alef and Nannipieri, 1995; Schloter et al., 1995; Atlas and Batha, 1998).

The application of chemical agents with the irrigation water, including herbicides, has been developed to a high technical level using variety of devices for mixing, injecting and dosing (Rolston et al., 1986; Burt, 2003). From technological point of view, however, the investigations on herbigation are rare and the information is scarce, especially concerning the herbicide efficiency, selectivity, durability of the effect, mobility and persistency in the soil, as well as the herbigation and fertigation effect on soil microcenoses. Therefore, there is a necessity of refining the herbicide control on weeds under herbigation and fertigation.

In order to clarify some technological and environmental aspects of herbigation, an investigation was undertaken at the Fruitgrowing Institute in Plovdiv. Subject of the present paper is the fate of the soil herbicide pendimethalin in the root zone and its effect on soil microbial activity. The presented results are for the period 2006-2007.

MATERIAL AND METHODS

The experimental work was carried out in three plots, located in a 0.6 ha sweet cherry plantation. In the first plot, cherry trees (‘Lapins’ cultivar on the clone rootstock ‘Gisela 5’) were planted in the spring of 2001 at distances 4 x 2 m. In the second plot, the trees (‘Bigareaux Burlat’ on *Prunus Avium*) were planted in the spring of 2003 at distances 6 x 4 m. And in the third plot, the cherry trees (‘Bing’ on ‘Gisela 5’) were planted in the spring of 2003 at distances 5 x 3 m. In each experimental plot, three variants of application of the soil herbicide pendimethalin (Stomp 33EK) were set in three replications as follows: V1-MS – application through microsprinkling and fertigation; V2-DI – application through drip irrigation and fertigation; V3-Std – application by back sprayer and fertigation; and V4-Ctrl – non-treated control under drip irrigation and fertigation. In the first and the second experimental plots, the investigated variants were set in series along the row and each included three experimental trees, each tree representing a replication. These plots were used for studying the soil and tree water regimes, the fertilizers migration and localization in the soil, and the herbicide efficiency end selectivity. The third plot served for studying the herbicide mobility and decomposition in the soil as well as the soil microbial activity, by soil sampling, without taking in account the yield and the growth. In this plot the investigated variants were set in row strips with length of 45 m.

The microsprinkling system consisted of one irrigation lateral per row with microsprinklers located at a 1.0 m distance along the row; operating pressure of 0.2 MPa, discharge 25 L/h and effective radius of 1.0 m. Thus, the irrigation water and the dissolved agrochemicals were evenly spread within a row strip, 2.0 m wide. The drip irrigation system had two parallel irrigation laterals per row, located at 0.5 m on both sides of the trees, with 1.0 m spacing of the drippers along the laterals; discharge of 2.0 L/h at operating pressure of 0.1 MPa. Drip irrigation was designed to wet a row strip of a 2.0 m width, too. The BS and Ctrl variants were drip-irrigated in the same way as the DI variant. Separate proportional dosing pumps (DOSATRON INTERNATIONAL, Bodeaux, France) were used for the injection of the herbicide and the fertilizers in the irrigation system. The water, herbicide, and fertilizer application rates were equal in all variants.

The irrigation was scheduled on the basis of the reference evapotranspiration ET_0, estimated using the evaporation values measured in a "Class A" evaporation pan with a pan coefficient $K_P = 0.8$. The evapotranspiration of the cherry crop ET_C was calculated using the FAO crop coefficient K_C values (Allen et al., 1998). An automatic meteorological station provided the necessary meteorological information. Rainfalls were measured using a GGI-3000 pluviometer.

The complex fertilizer 'Labin 15-15-15' was used for fertigation. The annual fertilization rate was split into 10-14 doses and applied in one- or two-week intervals according to the crop needs.

The soil herbicide pendimethalin (Stomp 33EK – 330 g L^{-1} active substance) was applied at a dose of 6.0 L/ha after a water application rate of 5.0 mm. In the variants of herbigation, the herbicide concentration in the water was equal to the one under standard spraying. The treatments were done in March, before the beginning of vegetation and on soil surface free of weeds. The weed species, the weed density and the herbicide efficiency were estimated in 30-day intervals. For studying of the herbicide migration and decomposition in the soil, soil samples were taken 30, 60, 90 and 120 days after the treatment from the 0-5 cm and 5-10 cm layers in each variant. In the variants with drip irrigation, soil sampling was done below the dripper as well as midway between the drippers along the lateral – in 2006, and midway between the laterals, i.e. in the middle of the row strip – in 2007.

The herbicide concentrations in the soil were estimated by a bioassay (McDowell et al., 1996) with oat as a test plant based on the oat sprout-length response curve obtained for six herbicide concentrations – 0, 0.012, 0.05, 0.20, 0.80, and 3.2 mg kg^{-1}. Petri dishes with diameter of 9 cm were filled with 60 g soil (< 2 mm), free of herbicides and wetted to field capacity (25 %) by adding of 15 mL water-herbicide solution. Five pre-germinated oat seeds were sown in each dish providing five dishes/replications for each herbicide concentration. The dishes were covered and kept in dark at 22 °C for five days, after which the sprout lengths were measured. The same procedure was applied to the herbicide-treated soil samples, wetting the soil with only water instead of using water-herbicide solution.

The soil microbial activity was studied in dynamics. Soil samples were taken from the same locations as those for the herbicide concentrations – in three replications per variant from the 0-10 cm and 10-20 cm layers. Soil sampling was done before the herbicide application and 7, 30, and 45 days after the application. Subject of investigation were the microorganisms responsible for some of the most important processes in the soil – nitrification, nitrogen fixation, denitrification, mineralization etc. Soil respiration was estimated on the basis of the CO_2 released for 24 hours. Standard microbiological methods and instrumentation (Alef K. and P. Nannipieri, 1995) were used for isolation, determination, cultivation and characterization of the soil inhabiting microorganisms.

RESULTS AND DISCUSSION

One of the herbicide-concentration response curves is shown in Fig. 1. For easier reading, it is rendered into a semi-logarithmic scale, too. The bioassay results for the pendimethalin migration and decomposition in the soil under herbigation are shown in Fig. 2 and 3, for 2006 and 2007 respectively. Seven days after the herbicide application, the highest concentrations were found in the 0-5 cm layer. This was especially evident for the variants of microsprinkling and back spraying, where the concentrations in the 5-10 cm layer were times lower. Under drip irrigation, the herbicide concentrations in the 0-10

cm layer were considerably low and approximately equal, which suggested the possibility of eventual leaching in depth. The concentrations varied significantly at a distance of 50 cm from the dripper, probably due to a non-uniform horizontal infiltration of the herbicide solution in the soil. It could be seen from Fig. 1, 2 and 3, that the herbicide concentrations in the soil fell below the oat phitotoxicity threshold of 0.012 mg kg^{-1} 90 to 120 days after the herbigation. This was in accordance with the results for the duration of the herbicide effect estimated by the number of weeds per square meter (Rankova et al., in print). Moreover, the pattern of pendimethalin decomposition with time was the same in all variants of application.

The soil microbial activity after the application of pendimethalin is characterized here by the total number of bacteria (expressed in colony forming units, c.f.u. x 10^6 g^{-1}) and the soil respiration (expressed in mg CO_2 kg^{-1} h^{-1}), Fig. 4 and 5. Soil respiration is a measure of the activity of the entire microbial population – cultivable and noncultivable microorganisms. It also serves as an indicator for improper and atypical substances in the soil microhabitats. In 2007, the total c.f.u. number did not considerably vary, although there was a slight tendency for a decrease with time in all investigated variants. Generally, more c.f.u. were found in the variant without herbicide applications and less – under drip irrigation. Soil respiration in the 0-10 cm layer showed slight tendency for increasing for 30 days after the treatment, while in the 10-20 cm layer it was firstly little depressed by herbigation and then recovered to the initial values. Some depression in soil respiration was registered 45 days after the herbigation in both the non-treated control and the treated variants. Hence, the decreasing of soil respiration rate was rather due to some other factors, than to the herbigation. Possibly, the frequent fertigation with 'Labin', a low-pH fertilizer, might affect the soil micro-flora in such a way, but this hypothesis was not investigated.

CONCLUSIONS

The effect of microsprinkler herbigation with pendimethalin on both the herbicide concentrations and the microbial activity in the soil is similar to those under the standard herbicide application by spraying.

Drip herbigation has to be used with caution because the concentrated application of the water-herbicide solution may result in leaching below the 0-10 cm layer as well as in non-uniform distribution of the herbicide throughout the row strip.

Microirrigation systems, and especially microsprinkling, can be successfully used for the application of soil herbicides with the irrigation water. The herbigation increases the herbicide efficiency – biological and economical – and does not have a negative effect on the fruit trees and the environment.

ACKNOWLEDGEMENTS

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Figures

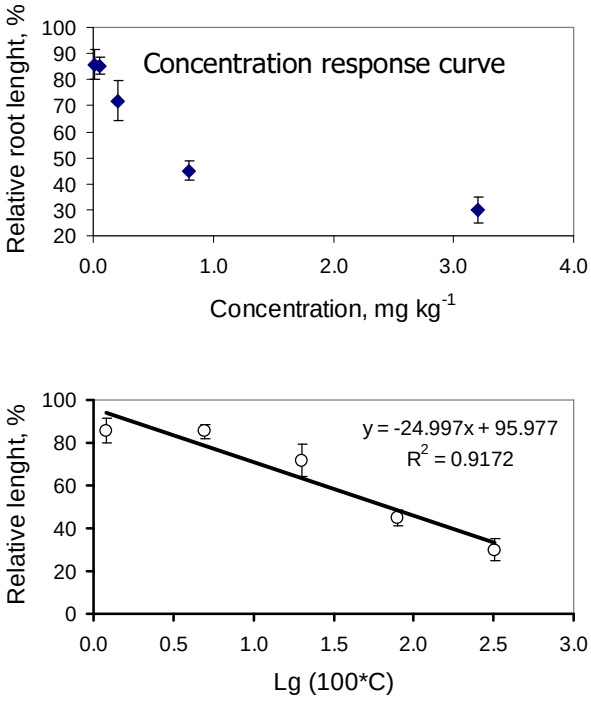

Fig. 1 Bioassay concentration response curve.

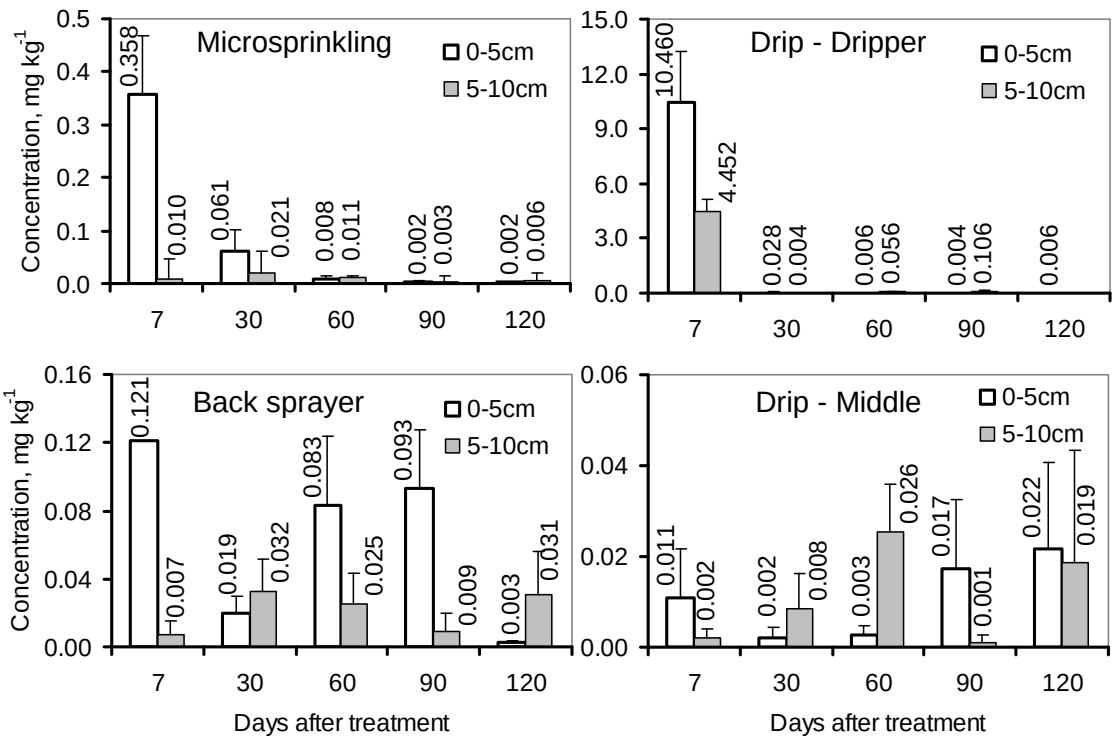

Fig. 2 Dynamics of pendimethalin concentrations in the soil – 2006.

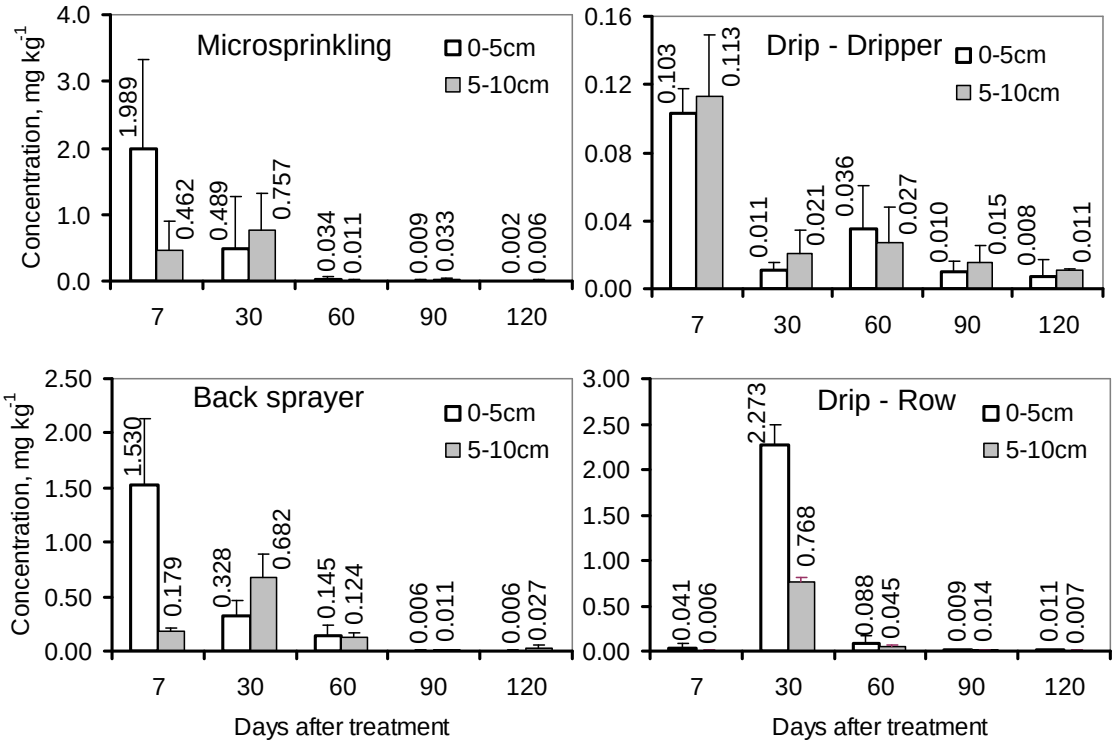

Fig. 3 Dynamics of pendimethalin concentrations in the soil – 2007.

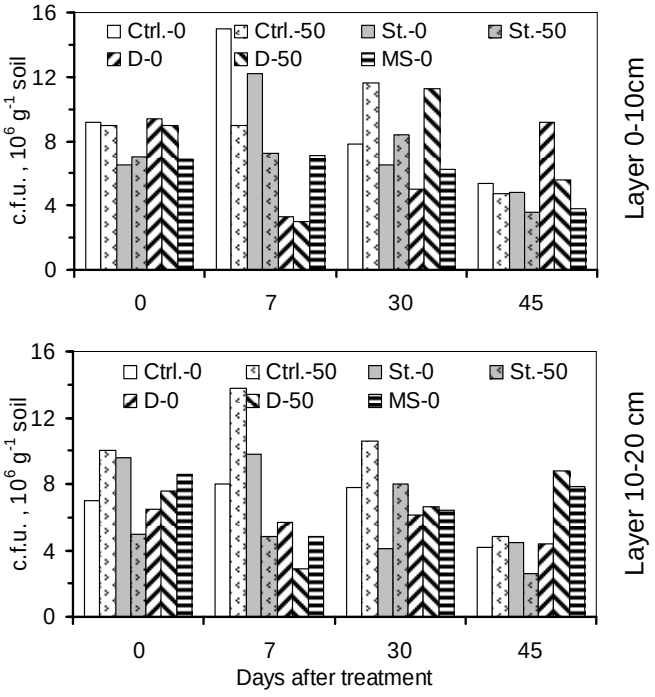

Fig. 4 Dynamics of the total number of bacteria in the root zone of the sweet cherry trees after herbigation with pendimethalin; the suffix "-0" after the variants abbreviations denotes the values obtained under the dripper, while the suffices "-50" denotes the values obtained 50 cm aside from the dripper between the laterals, i.e. in the middle of the row strip. Results obtained in 2007.

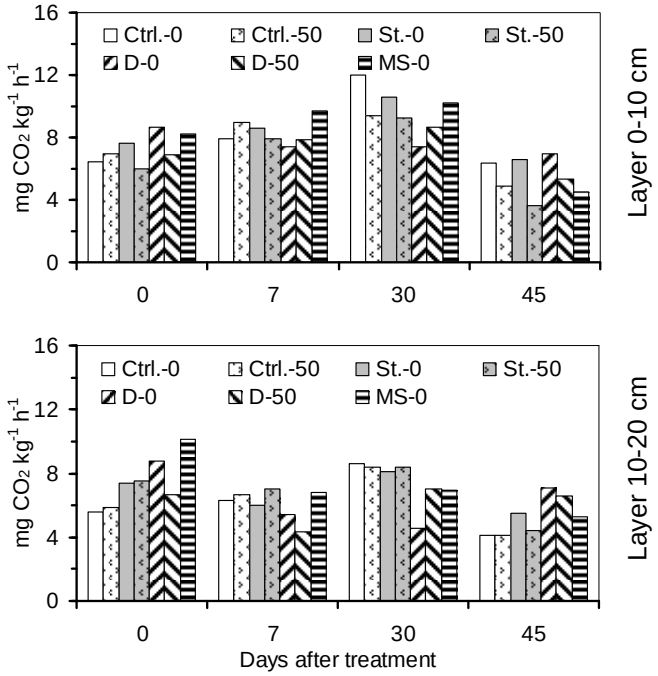

Fig. 5 Dynamics of the soil respiration in the root zone of the sweet cherry trees after herbigation with pendimethalin; the suffix “-0” after the variant abbreviations denotes the values obtained under the dripper, while the suffices “-50” denotes the values obtained 50 cm aside from the dripper between the laterals, i.e. in the middle of the row strip. Results obtained in 2007.