ORCHARD MANAGEMENT IN SUSTAINABLE FRUIT PRODUCTION
Journal of Fruit and Ornamental Plant Research vol. 12, 2004 Special ed.

RESPONSE OF YOUNG APPLE TREES TO DIFFERENT ORCHARD FLOOR MANAGEMENT SYSTEMS

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(Received May 14, 2004/Accepted August 18, 2004)

A B S T R A C T

The effect of orchard floor management on soil moisture and temperature, and on apple tree growth and yield, was studied in 2002 and 2003 at the experimental orchard in Skierniewice. In April 2002, 'Gala Must' apple (*Malus x domestica* Borkh.) trees grafted on M.9 rootstock were planted 4.0 x 1.2 m apart. After planting, the following systems of soil management were employed: (i) mulching with wood chips; (ii) hand weeding with drip irrigation; and (iii) hand weeding without irrigation as a control. In the first two years after planting, both irrigation and mulching both improved apple tree growth because of low rainfall during both growing seasons. From spring to June, mulched soil had a higher water content. In summer, mulching conserved soil water and reduced water stress. Vigor, estimated from trunk diameter and total length of current season shoots per tree, was highest on irrigated and mulched plots. Irrigated trees had the highest fruit yield. Insufficient rainfall reduced yield by 20% in mulched plots, and by 71% in control plots. In autumn and winter, soil temperatures at a depth of 10 cm were higher in mulched plots, than in the irrigated and non-irrigated plots. Mulching also reduced diurnal fluctuations in soil temperature, and was very effective in controlling weeds.

Key words: mulching, irrigation, apple trees

INTRODUCTION

The climate of Poland is characterized by high temporal and spatial variation. The total amount and seasonal distribution of precipitation show significant variability. A quarter of the country is subject to a low water balance, with a deficit of more than 100 mm (Bac, 1980). Insufficient precipitation reduces fruit yield and quality (Treder, 1996). Soil moisture can be controlled by irrigation or mulching, which reduces evaporation and allows more economical use of water. The main aims of orchard floor management are to conserve and increase retention of soil moisture, increase rainfall infiltration, and prevent run-off on sloping ground (Rogers, 1943; Włodek et al., 1955; Mustaffa, 1988; Lipecki and Szwedo, 1994; Glenn and Welker, 1989)., There has been increased interest in using mulches in order to reduce the use of chemicals in fruit production (Merwin et al., 1994; 1995). Natural methods of orchard floor management, such as mulching with organic matter, are widely employed in integrated fruit production (Mika et al., 1998; Autio and Greene, 1991; Fausett and Rom, 2001; Neilsen et al., 2003). Recycled biomass mulches, such as wood chips, straw, grass clippings, municipal composts and shredded newspaper, have been used to control weeds, improve the soil, and increase water availability without the use of herbicides (Merwin et al., 1995). In Poland, non-composted mulches, such as pine bark or sawdust, increase growth and yield in young apple trees, but can reduce nitrogen availability. Organic mulches control weeds effectively only in the first year. In subsequent years, leaf-active herbicides are needed to effectively control weeds. When straw is used, rodent control is more difficult (Mika et al., 1998).

The aim of this study was to examine the effects of orchard floor management on soil moisture and temperature, and on apple tree growth and yield.

MATERIAL AND METHODS

The experiment began in the spring of 2002 at the Experimental Orchard of the Research Institute of Pomology and Floriculture in Skierniewice. The soil is a sandy loam (medium IV class), low in organic matter (1.5%), and well drained, with a low capacity for water retention. ‘Gala’ apple trees grafted on M.9 rootstocks were planted 4.0 x 1.2 m apart. Trees were trained as spindles. Insects and diseases were controlled according to standard commercial production practices. After the trees were planted, the following systems of soil management were employed: (i) mulching with wood chips; (ii) hand weeding with drip irrigation; and (iii) hand weeding without irrigation as a control. The treated strip along the tree rows was 1.5 m wide. Wood chips were applied in a 20 cm thick layer. Irrigation was applied from May to October. On-line PC drippers were placed 0.30 m from the trunk on both sides of the tree, and set to deliver four liters per hour to ensure a soil moisture of 80-100% of soil water capacity. Soil moisture was measured with a moisture meter (Diviner 2000, Sentec Australia). There were three replicates of five trees per plot in a randomized block design. Immediately after planting, vigor was estimated using trunk circumference at 30 cm above the soil surface. Vigor was also estimated every year at the end of vegetative growth. These data were transformed to trunk cross-sectional area (TCSA) before analysis. When seasonal growth was complete, the total length of shoot growth produced per tree was measured. In 2003, flower buds, yield, and fruit quality were also recorded.

Soil moisture was measured every week from May to October. One PVC tube (50 mm in diameter and 60 cm long) was installed on each plot as an access tube for the moisture meter probe. Soil moisture is expressed in percent as the ratio of soil moisture to the oven-dried mass of the soil. Soil temperatures at a depth of 10 cm were recorded with a temperature data logger (AZ 8818). Air temperature and rainfall were recorded using the automated meteorological station "Metos". Weed infestation was observed two or three times during the growing period. The plants of each weed species were counted.

Data were statistically elaborated by analysis of variance. Significance of differences was calculated using Duncan's t-test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Mean monthly temperatures and precipitation were graphed at a ratio of 1°C per 4.5 mm of rainfall, according to the scheme proposed by Walter and Lieth (1970)(Fig. 1). This allows easy estimation of periods of drought. In our experiment, long periods of drought were observed in both years. In 2003, an exceptionally long drought started in June and lasted for four months.

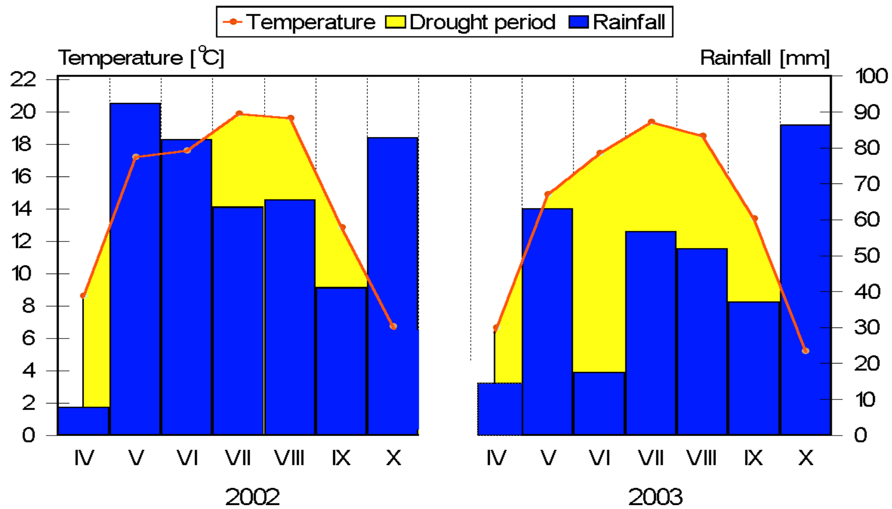

Figure 1. Climatic graph

Soil water availability

From 28 April to 2 June, soil moisture was significantly higher in mulched plots than in control plots at 10 and 20 cm, but less so at 30 cm (Fig. 2). In both mulched and control plots, soil moisture at all depths tended to decrease until heavy rainfall occurred. Soil moisture decreased more slowly in mulched plots than in control plots. In irrigated plots, soil moisture decreased quickly when irrigation was stopped in September. On 28 April, soil water content in the top 30 cm layer was 30% higher in mulched plots than in control plots (Fig. 3). Soil moisture was higher in mulched plots than in control plots during several dry periods in 2003. Mulching improves water availability by reducing evaporation and improving infiltration (Skroch and Shribs, 1986; Mustaffa 1988; Fausett and Rom, 2001). Mulching also results in more uniform water distribution, both vertically and horizontally (Lakatos et al., 2000). Mulches conserved soil moisture and reduced water stress in orchards which would have otherwise required irrigation (Neilsen et al., 2003).

Soil temperature

Mulching affected soil temperature. However, no differences in soil temperature were found between the control and irrigated plots. For this reason, temperature data from irrigated plots were excluded from further analysis. During the winter, soil temperatures at 10 cm were higher in mulched plots than in control plots (Fig. 4). The lowest air temperature recorded during the winter of 2002-2003 was -22.1ºC. Soil temperature dropped to -5.7 ºC in control plots, but only to -0.4ºC in mulched plots. Soil temperature in mulched plots was very stabile despite the large changes in air temperature.

In summer, soil temperature in mulched plots was slightly lower than in control plots (data not presented). Mulching reduced fluctuations in soil temperature, especially during winter, when the average diurnal amplitude of soil temperature in the mulched plots was only one-fourth as much as in the control plots (Tab. 1).

Mulched soil proved less susceptible to cooling and freezing in winter, which agrees with the results obtained by Merwin et al. (1994). The influence of orchard floor management on soil temperature fluctuation was also noted by Hołubowicz and Gruca (2000) and Hołubowicz and Łysiak (2001).

Tree growth, fruit bud formation and cropping

Young apple trees are very sensitive to different orchard floor management systems. Trunk diameter, shoot growth and yield were higher in mulched and irrigated plots than in control plots (Tab. 2). In Poland, drought can reduce vigor and yield in apple trees (Rzekanowski, 1989; Pacholak, T a b l e 1 . Monthly averages of daily temperature fluctuation in 2002 and 2003

Measurement	Average daily temperature fluctuation [ºC]		
	air	mulched plots	control plots
November 2002	5.34	0.49	1.78
December 2002	6.09	0.24	1.22
January 2003	5.48	0.35	1.41
April 2003	10.64	1.31	5.34
May 2003	12.12	1.54	5.92
July 2003	11.61	1.60	4.66
August 2003	13.21	1.81	3.90
September 2003	12.98	1.77	3.07

T a b l e 2 . Effect of different orchard floor management systems on the growth and bloom of 'Gala'/M.9 apple trees

Treatment	TCSA [cm^2]		Total shoot growth [no per tree]		Number of flower clusters per tree	Bloom density [clusters cm^{-2}] of TCSA
	2002	2003	2002	2003	2003	2003
Mulching	2.78 b*	4.69 b	210 b	742 b	60.42 a	13.08 a
Irrigation	2.96 b	4.82 b	226 b	654 b	75.92 b	16.05 a
Control	2.21 a	3.61 a	118 a	422 a	87.33 b	24.52 b

*Means followed by the same letter do not differ significantly. Mean separation within columns was calculated with Duncan's t-test at $P \leq 0.05$

T a b l e 3 . Effect of different orchard floor management systems on the yield and productivity of 'Gala'/M.9 apple trees and mean fruit weight

Treatment	Yield [kg $tree^{-1}$]	Compared to irrigation [%]	Mean fruit weight [g]	Productivity [$kg \cdot cm^{-2}$]	Crop density [number of fruits per cm^2 of TCSA]
Mulching	3.16 b*	80	169 a	0.68 b	3.60 b
Irrigation	3.97 c	100	168 a	0.84 b	4.90 c
Control	1.14 a	29	165 a	0.32 a	1.76 a

*Means followed by the same letter do not differ significantly. Mean separation within columns was calculated with Duncan's t-test at $P \leq 0.05$

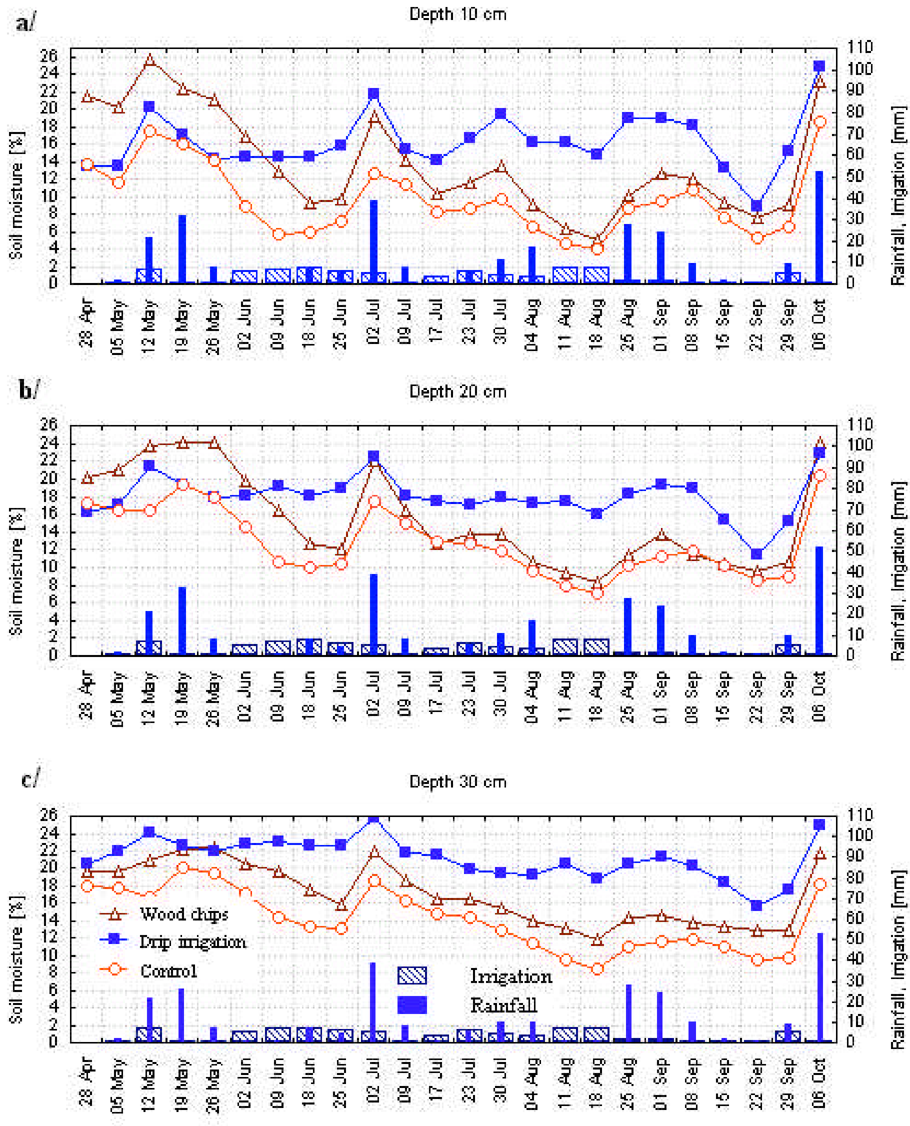

Figure 2. Soil moisture (% volume) with three systems of orchard floor management at 10, 20 and 30 cm

1994; Treder and Czynczyk, 1997). This experiment demonstrated the benefits of organic mulching in a young apple orchard. Other researchers have also noted that mulching improves tree vigor (Rogers, 1943; Mustaffa, 1988; Lipecki and Szwedo, 1994; Mika et al., 1998; Neilsen et al., 2003).

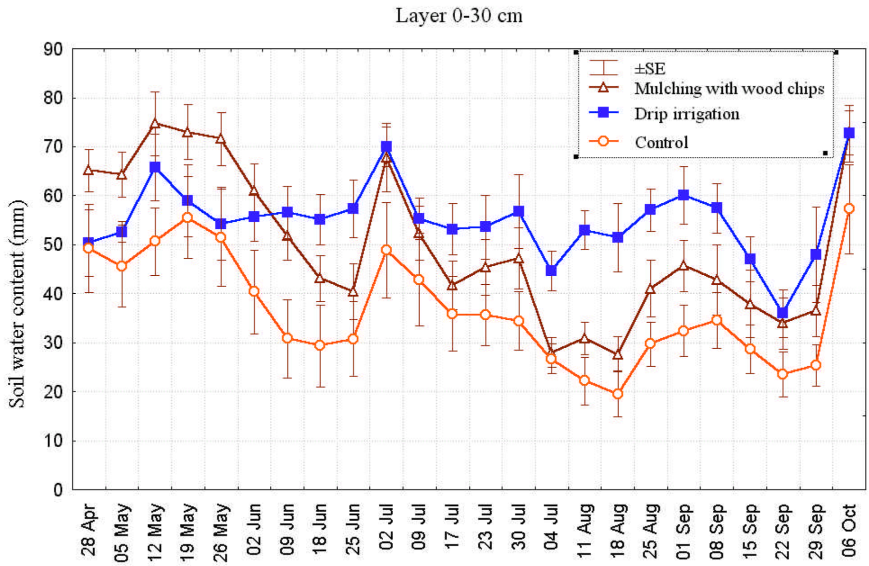

Figure 3. Soil water content in upper 30 cm during the 2003 growing season

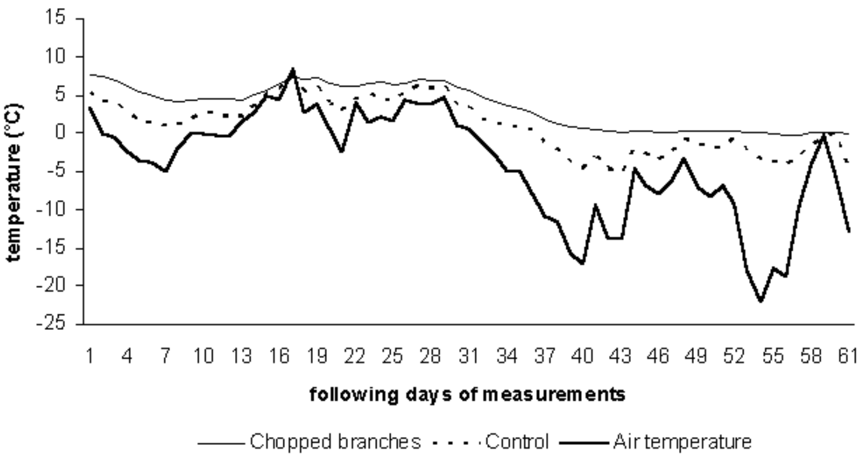

Figure 4. Minimum air and soil temperatures recorded during the winter (November-December 2002)

Control trees set the most blossoms, but yielded the least fruit. The most fruit were produced by irrigated trees, 20% more than mulched trees, and 71% more than control trees (Fig. 3). If productivity is expressed as yield in kg per cm^2 of trunk cross-sectional area (TCSA), irrigated and mulched trees out-performed control trees. In an experiment similar to ours, Mika et el. (1998) found that mulching with pine bark or sawdust increased growth and yield in young "Idared" apple trees grafted on M. 26. When apple trees were irrigated, mulching with polypropylene spinwool did not improve yield and fruit quality (Szewczuk and Sosna, 2001). Autio and Greene (1991) reported that in Massachusetts (USA), mulching newly planted apple trees did not significantly affect growth, except in one year when rainfall was below normal. In dry growing seasons, organic mulches significantly increased shoot growth in apple trees. In our experiment, choice of orchard floor management system did not affect fruit mean weight, though irrigated and mulched trees had much higher crop density coefficients (CD), expressed as the number of fruit produced per cm^2 of TCSA**.** Treder and Mika (2001) reported that the weight of individual apple fruit decreases as the number of fruit per cm^2 of TCSA increases. Mulching with organic matter can be useful in non-irrigated orchards. Himmelsbach (1992) concluded that mulching with organic matter can be more economical than chemical weed control.

Weeds

No weeds grew in mulched plots. In the second year after planting, Thirteen species of weeds were found growing on irrigated plots, and eleven species were found growing on control plots (Tab. 4).

Table 4. Weed species observed in a organic orchard in Skierniewice

Irrigated plots (hand weeding with drip irrigation)	Control plots (hand weeding without irrigation)
Weed species	
Agropyron repens	*Agropyron repens*
Anthemis arvensis	*Amarantua retroflecsus*
Chenopodium polyspermum	*Anthemis arvensis*
Erysimum cheirantoides	*Chenopodium polyspermum*
Lamium amplexicaule	*Lamium amplexicaule*
Poa annua	*Poa annua*
Polygonum aviculare	*Polygonum aviculare*
Setaria glauca	*Polygonum persicaria*
Sinapsis arvensis	*Sinapsis arvensis*
Sonchus asper	*Taraxacum officinale*
Taraxacum officinale	*Trifolium repens*
Thlaspi arvense	
Trifolium repens	

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REAKCJA MŁODYCH JABŁONI NA RÓŻNE SPOSOBY PIELĘGNACJI GLEBY

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STRESZCZENIE

W doświadczeniu badano wpływ systemu utrzymania gleby w sadzie na zmiany jej wilgotności i temperatury oraz na wzrost i plonowanie jabłoni. Doświadczenie prowadzono w latach 2002-2003 w Sadzie Doświadczalnym w Skierniewicach. Drzewka jabłoni 'Gala' szczepione na podkładce M.9 posadzono w kwietniu 2002 roku w rozstawie 4,0 x 1,2 m. Gleba w sadzie była utrzymywana wnastępujących systemach: (i) ściółkowanie z użyciem drewnianych zrębków (zpociętych gałęzi); (ii) ręczne odchwaszczanie z nawadnianiem; (iii) ręczne odchwaszczanie bez nawadniania jako kontrola.

Z powodu niedoboru opadów w trakcie pierwszych dwóch latach po posadzeniu zaobserwowano silną reakcję drzew na zastosowane nawadnianie i ściółkowanie gleby. W okresie od wiosny do lipca gleba na poletkach ściółkowanych charakteryzowała się wyższą wilgotnością w porównaniu z kontrolą. Ściółkowanie zmniejszyło utratę wody z gleby, ograniczając wystąpienie stresu wodnego w trakcie miesięcy letnich. Siła wzrostu drzew wyrażona sumą długości pędów jednorocznych i polem przekroju poprzecznego pnia była największa dla jabłoni rosnących na poletkach nawadnianych i ściółkowanych. Drzewa nawadniane wydały najwyższy plon. Brak opadów w trakcie sezonu wegetacyjnego ograniczył owocowanie o 20% drzew rosnących na poletkach ściółkowanych i aż o 71% w przypadku kontroli (bez nawadniania). Temperatura gleby na głębokości 10 cm w trakcie okresu jesienno-zimowego była wyższa na poletkach ściółkowanych w porównaniu do poletek kontrolnych. Ściółkowanie zmniejszyło także dobowe wahania temperatury gleby oraz skutecznie ograniczyło zachwaszczeni.

Słowa kluczowe: ściółkowanie, nawadnianie, jabłonie