JOURNAL OF FRUIT AND ORNAMENTAL PLANT RESEARCH

VOL. X
2002

SKIERNIEWICE, POLAND

Ireneusz Sosna
Agricultural University, Department of Horticulture
Rozbrat 7, 50-334 Wrocław, POLAND

REDUCING VEGETATIVE GROWTH OF 'GOLDEN DELICIOUS' APPLE TREES BY ROOT PRUNING AND WAYS OF PLANTING

ABSTRACT. The influence of root pruning and different ways of tree planting on the growth, cropping and fruit quality was estimated in the experiment conducted in 1993-2001 at the Fruit Experimental Station near Wrocław. Trees on M.26 rootstock were planted at two densities: 3077 trees/ha (control and root pruning) and 6154 trees/ha (ridge). The experiment was carried out in 4 replications, with 11 trees per plot. In some trees the shoots were mechanically pruned (from 1994 at the end of blooming) from both sides of a row, 50 cm from the trunk, to a depth of ~30 cm. Results of the study proved that trees placed on the soil and earthed up gave the highest yield per hectare. Fruits from trees densely planted on a ridge were significantly smaller as compared to the control. Root pruning reduced the vegetative growth of apple trees and significantly increased their productivity. There was no observed adverse effect of root pruning on fruit quality.

Key words: apple, root pruning, ridge, planting, vegetative growth, yield, quality of fruit

INTRODUCTION. In modern fruit growing of the 21st century one of the crucial problems is an effective limitation of vegetative growth of fruit trees. Vigorous trees quite often start cropping late, their yield is poor and fruits, due to over-density of shoots, are of a lower quality. Also, chemical protection is less effective and fruit picking more difficult. The vegetative growth can be reduced in many ways, among which the most important and commonly used is tree grafting on dwarf rootstocks. Unfortunately, such rootstocks cannot be widely used for all species (e.g. peach, apricot) and will not be suitable for all soil/climate conditions. The reaction of a given cultivar can also be different, which in extreme cases, can lead to incompatibility. Due to such limitations of applying dwarf rootstocks other methods may play a significant role in everyday use. Much attention has been given to controlling the balance between tree growth and fruit production in high-density plantings. Although dwarfing rootstocks are of prime importance for controlling the growth, cultural techniques such as pruning and orchard design also have an influence on tree development (Wagenmakers, 1988; Elfving, 1988). Denser tree planting can restrict their vegetative growth but it is not economically justified (Martin, 1989).

In Poland, fruit trees are planted traditionally in dug holes but in other countries, like Holland, Belgium or Germany, a number of apple and pear orchards are trained in ridges made from earthing up their root system with soil mixed with compost. Such method reduces tree growth, enabling to increase their density in a row without the need of heavy pruning (Bootsma, 1995). Some apple cultivars, e.g. ‘Elstar’ planted in ridges yielded much better in comparison to the traditional planting. However, yield enhancement was not observed for ‘Jonagold’ cv. (Wagenmakers and Tazelaar, 1998) nor for ‘Red Delicious’ mutants in American research (Perry, 1996). Tree planting in 30-cm-high ridges covered with plastic foil appeared to be a very useful method in the severe climate of Finland. Apple trees grew and yielded better and were more

resistant to frost in comparison to those planted traditionally into soil. Such an improvement of tree efficiency resulted from better humidity and higher temperature of soil (Sako and Laurinen, 1986). In Germany, to weaken the growth of apple trees and more important, to reduce negative effects of soil fatigue in “orchard after orchard” planting, materials isolating the roots from the soil are used, e.g. non-woven polypropylene or plastic foil. The root system is earthed up with “fresh” soil from outside the orchard. In Poland, such modifications of tree planting are not used mainly due to a great risk of root freezing in soil ridges during severe winters without snow. But some experiments connected with tree growth reduction have been undertaken through tree planting in ditches covered with non-woven polypropylene (Buler and Mika, 2000).

Strong vegetative growth of apple trees can also be restricted by root pruning, as it has been confirmed by numerous studies carried out throughout the world. However, an influence of root pruning on the productivity and fruit quality was not always positive, being determined by many factors, such as cultivar, rootstock and, first of all, time and way of execution. Apple trees with their roots pruned, especially those pruned on both sides of a row, showed a strong inhibition of growth without decreasing yield or deterioration of fruit quality (Baart, 1992; Schupp et al., 1992; Vanhellemont, 1993; Ran Xin Tuo, 1988). Sometimes, such trees cropped even better than those with not pruned roots (Ristevski et al., 1992; Mika and Krzewińska, 1994). On the other hand, there is some information about decreased yields of root-pruned apple trees, mainly caused by fruit size reduction (Hoying et al., 1992; Vercammen, 1995; Ferree and Knee, 1997; Khan et al., 1998). Root pruning can be very useful for older trees. In a young apple orchard planted on fertile soil and irrigated, this treatment is of no practical application (Miller, 1995).

The aim of the present experiment was to define the effects of different ways of planting and root pruning on the vegetative growth and cropping of ‘Golden Delicious’ trees.

MATERIAL AND METHODS. The experiment was established in the spring of 1993 at the Fruit Experimental Station, Samotwór near

Wrocław. One-year-old trees without feathers of 'Golden Delicious' cultivar were planted on pseudo podsolic soil, IIIb class. Trees on M.26 rootstock were placed in shallow holes holding half of their root system, or arranged directly on the soil surface, on non-woven polypropylene or on plastic foil. Then, the roots were covered with soil with an addition of peat, forming ridges up to 30 cm. Trees were spaced in rows at 0.5 m, whereas a distance between the rows was 3.25 m (6154 trees/ha). Feathered trees in the control were planted in traditionally deep holes holding their whole root system, at a spacing of 3.25 x 1.0 m (3077 trees/ha). From 1994, within the control treatment, roots of some trees were mechanically pruned at the end of blooming. This practice was performed with a steel shield to the depth of about 30-50 cm from the trunk at both sides of a row. The experiment was carried out in 4 replications, with 11 trees per plot. Apple tree canopies were formed as a spindle or super-spindle (depending on density) without shoots bent down. Tree pruning was performed annually only after blooming. During the first 2 years after planting, trees trained in ridges were drip irrigated. Since the first year, there was herbicide fallow in the rows and sward between them. Chemical protection was carried out according to the current recommendations of the Orchard Protection Programme.

In 1993-2001, the following measurements were taken: blooming intensity, yield in kg per plot, mean fruit weight, percentage of fruit in respective grades and fruit colouring. Vegetative growth was estimated upon the trunk diameter and length of annual shoots. The results were statistically elaborated by an analysis of variance. The significance of differences between means was evaluated by Duncan's multiple range t - test at P=0.05.

RESULTS AND DISCUSSION. During 9 years of the experiment, only one winter 1996/97 was frosty and without snow, with temperatures about minus 20 ^{o}C and strong winds. At that time, in many orchards throughout the country many apple trees on M.26 rootstock froze, especially at exposed areas and on sandy soils. On the contrary, in this experiment no frost damage was recorded for trees grafted on the same rootstock and planted in ridges. Thus, the

obtained results do not eliminate this way of planting also in the climate of south-western Poland, at least for rootstocks more resistant to frost. The suitability of this method was also verified by Sako and Laurinen (1986) in the severe climate of Finland.

Table 1. Vegetative growth and blooming intensity of trees depending on way of planting and root pruning

Treatment	Total shoot length [cm] 1993-1996	Trunk cross-sectional area [cm^2]			Blooming intensity	
		autumn 2001	increment 1994-97	increment 1997-01	0-5 scale 2000	0-5 scale 2001
Control – traditional planting	6096 b*	35.6 b	14.5 c	16.6 c	0.2 a	4.0 ab
Root pruning	4708 a	32.9 b	12.3 b	16.4 c	1.0 ab	4.3 ab
Shallow holes + earthing up	3661 a	21.7 a	7.9 a	9.0 ab	1.4 b	4.5 b
Only earthing up	3703 a	20.2 a	7.3 a	8.1 a	1.6 b	4.3 ab
Non-woven polypropylene + earthing up	3741 a	20.2 a	7.5 a	8.6 ab	1.9 b	3.9 a
Plastic foil + earthing up	3452 a	21.3 a	7.4 a	10.0 b	1.0 ab	3.8 a

* Means followed by the same letters do not differ at P=0.05 according to Duncan's multiple range t - test

Different ways of planting and a high density of trees in a row caused a significant reduction of tree growth in comparison with the control (Tab. 1). Trunk growth was negatively related to plant density, confirming the reports by Sansavini et al. (1986), Callesen (1994) and Mika (1995), and this effect can be attributed to an enhanced inter-tree competition. Also competition for light may play an important role in densely planted orchards, where shading of adjacent trees can reduce their growth (Jackson and Palmer, 1977). These observations are not consistent with those reported by

Meland and Hovland (1997), who considered that the largest trunk cross-sectional area (TCSA) of 'Summerred' apple trees grown in "V-system" resulted from the highest planting density. In the first years after planting, the weakest growth was typical for apple trees earthed up on plastic foil. After a partial decomposition of this material, which was also overgrown by roots, trees in this treatment grew much stronger (the largest TCSA increment in 1997-2001). Until 9th year after planting, trees only earthed up were less vigorous in comparison to other treatments, but there were no significant differences. The growth of trees with roots pruned was stronger than of those planted in ridges but clearly weaker as compared to the control, especially until the 5th year after planting. Significant differences were observed for the total length of annual shoots in 1993-1996 and for TCSA increment up to 1997. In the following years, the influence of root pruning on the vegetative growth was rather small and insignificant. In conclusion, the clearest effect of root pruning on tree growth was observed in the first years after planting. However, this is not supported by Miller's (1995) study showing that root pruning in young orchards proved to be ineffective.

Until the 7th year after planting, apple trees in all treatments cropped annually. In 1999, in spite of chemical fruit thinning (Pomonit R-10; 0.6 l/ha directly after blooming), the trees gave heavy yields and then started alternate bearing. As a result, in 2000 they hardly bloomed and cropped (Tab. 1 and 2). Small crowns of trees formed as a super-spindle and planted densely in ridges decreased their productivity in kg per tree but increased the yield in tones per hectare. Up to 2001, crops in t/ha were from 39% (plastic foil) to 64% (soil surface) higher in comparison to the control. Trees planted on plastic foil gave significantly lower yields in kg/tree. The highest crop efficiency index (kg/cm^2) was found for trees planted directly on the soil and those on non-woven polypropylene. Root pruning significantly increased tree yield and this result is consistent with some data in literature (Ristevski et al., 1992; Mika and Krzewińska, 1994). Other scientists however, found that root-pruned apple trees gave lower crops (Hermon van, 1994; Ferree and Knee, 1997).

T a b l e 2 . Yielding and crop efficiency index (CEC) as dependent on a way of planting and root pruning

Treatment	Yield [kg per tree]						Cumulative yield [kg/tree] 1994-2001	CEC [kg/cm^2] 1994-2001
	1994-1995	1996-1997	1998-1999	2000-2001	1994-1997	1998-2001		
Control – traditional planting	11.3 d*	16.1 b	25.5 b	19.3 b	27.4 c	44.8 c	72.2 c	2.03 a
Root pruning	11.1 d	19.5 c	34.3 c	24.0 c	30.6 d	58.3 d	88.9 d	2.71 bc
Shallow holes + earthing up	8.2 b	12.6 a	18.3 a	18.7 b	20.8 ab	37.0 b	57.8 b	2.67 bc
Earthing up only	9.7 c	13.1 a	19.6 a	17.0 b	22.8 b	36.6 b	59.4 b	2.95 c
Nonwoven polypropylene + earthing up	9.0 bc	13.9 ab	18.3 a	16.9 b	22.9 b	35.2 ab	58.1 b	2.90 c
Plastic foil + Earthing up	6.6 a	12.6 a	17.1 a	13.9 a	19.2 a	31.0 a	50.2 a	2.39 ab

* Explanation – see Table 1

T a b l e 3 . Mean fruit weight as dependent on a way of planting and root pruning

Treatment	Mean fruit weight [g]							Mean fruit weight [g]
	1994-95	1996	1997	1998	1999	2000	2001	1994-2001
Control – traditional planting	168 b*	161 ab	171 c	184 b	151 ab	196 ab	128 ab	166 c
Root pruning	155 ab	164 b	171 c	168 a	156 b	209 b	139 b	166 c
Shallow holes + earthing up	151 a	146 a	152 a	156 a	141 a	184 ab	120 a	150 a
Earthing up only	162 ab	159 ab	157 ab	161 a	151 ab	182 a	130 ab	157 ab
Non-woven polypropylene + earthing up	156 ab	152 ab	164 ac	163 a	153 ab	182 a	138 b	158 b
Plastic foil + earthing up	162 ab	150 ab	168 bc	167 a	157 b	189 ab	140 b	162 bc

* Explanation – see Table 1

T a b l e 4 . Percentage of fruit in respective grades and colouring (mean for 1997-1999)

Treatment	Grade [%]					Colouring [%]		
	> 8 cm	7.5-8 cm	7-7.5 cm	6-7 cm	5.5-6 cm	yellow	yellow-green	green
Control – traditional planting	4.7	25.0	34.8	30.9	4.6	74.8	20.2	5.0
Root pruning	6.1	22.7	33.9	33.2	4.1	78.6	17.6	3.8
Shallow holes + earthing up	1.5	23.8	35.2	34.7	4.8	66.8	25.4	7.8
Only earthing up	1.3	14.0	34.4	45.4	4.9	74.4	22.2	3.4
Non-woven polypropylene + earthing up	2.8	25.1	34.9	34.9	2.3	63.9	28.3	7.8
Plastic foil + earthing up	4.8	20.1	39.8	32.9	2.4	60.3	33.8	5.9

Dense planting of trees in ridges caused a significant decrease in the mean fruit weight during 1994-2001 in comparison to the control (Tab. 3). The only exception were the trees planted on plastic foil. Trees planted in shallow holes produced the smallest fruit, although the differences were statistically insignificant. Due to a stronger shading of crowns, the colouring of fruit from trees planted in ridges was slightly worse (Tab. 4). In spite of a higher productivity, apples from root-pruned trees had a similar size and colouring than those from trees not subjected to such practice. This is in agreement with observations by Vanhellemont (1993) and Ran Xin Tuo (1988).

CONCLUSIONS

1. Root pruning reduced the vegetative growth of 'Golden Delicious' apple trees, especially in the first years after planting. Root-pruned trees yielded significantly better in comparison to the control and their fruit was of a higher quality.
2. Apple trees on M.26 rootstock can be grown in ridges in south-western Poland. Trees planted this way are characterised by a weaker growth, which allows for a higher planting density and in consequence a higher crop per hectare.
3. Placing apple trees on the soil surface and earthing them up during planting had the most positive influence on tree productivity and quality of fruit.

REFERENCES

Baart J. 1992. Research experiences with root pruning. FRUITTEELT-DEN-HAAG 82: 21-23.

Bootsma J. 1995. Replanting is improved by planting on a ridge. FRUIT-TEELT-DEN-HAAG 85: 10-11.

Buler Z., Mika A. 2000. Próba ograniczania wzrostu korzeni drzew owocowych za pomocą tkaniny i włókniny poliestrowej (Trial of root growth restriction with polyester fabric and spoonweb). ZESZ. NAUK. AR W POZNANIU "OGRODNICTWO" 31: 25-31.

Callesen O. 1994. Performance of 'Discovery' apple on M.9, M.26 and MM.106 rootstocks at two densities. J. HORT. SCI. 69: 305-313.

Elfving D.C. 1988. Economic effects of excessive vegetative growth in deciduous fruit trees. HORTSCIENCE 24: 461-463.

Ferree D.C., Knee M. 1997. Influence of root pruning and rootstock on growth and performance of 'Golden Delicious' apple. HORTSCIENCE 32: 645-648.

Hermon van E. 1994. Pruning after flowering is a good growth retardant. FRUITTEELT-DEN-HAAG 84: 16-17.

Hoying S.A., Robinson T.L., Faust M, Miller S.S. 1992. Effects of chain saw girdling and root pruning of apple trees. ACTA HORT. 322: 167-172.

Jackson J.E., Palmer J.W. 1977. Effects of shade on the growth and cropping of apple trees. J. HORT. SCI. 52: 245-252.

Khan Z.U., McNeil D.L., Samad A. 1998. Root pruning reduces the vegetative and reproductive growth of apple trees growing under an ultra high density planting system. SCI. HORT. 77: 165-176.

Martin G.C. 1989. Control of vegetative growth. Manipulation of fruiting – Proc. of 47th University of Nottingham Easter School in Agri. Sci. England, pp. 363-376.

Meland M., Hovland O. 1997. High density planting systems in 'Summerred' apples in a northern climate. ACTA HORT. 451: 467-471.

Mika A., Krzewińska D. 1994. Wyniki trzyletnich doświadczeń nad cięciem korzeni jabłoni w Prusach. Mat. XXXIII Ogólnopol. Nauk. Konf. Sadow. Skierniewice, pp.156-158.

Mika A. 1995. Drzewa holenderskie i polskie po czterech latach. SAD KARŁOWY 6: 45-50.

Miller S.S. 1995. Root pruning and trunk scoring have limited effect on young bearing apple trees. HORTSCIENCE 30: 981-984.

Perry R.L. 1996. Planting stone fruit on ridges: effects on tree longevity. PENNSYLV.-FRUIT-NEWS 76: 44-50.

Ran Xin Tuo 1988. Study on the effect of root pruning on the root and shoot growth of apple trees. J. FRUIT SCI. 15: 203-206.

Ristevski B., Kolecevski P., Popovski H., Faust M., Miller S.S. 1992. Pruning and regeneration of the root system on pear and apple trees. ACTA HORT. 322: 305-310.

Sako J., Laurinen E. 1986. Apple trees in ridge planting. ACTA HORT. 160: 285-292.

Sansavini S., Marangoni B., Buscaroli C., Corelli L., Tazzari G. 1986. The relationship between spacing and rootstock effects in an intensive planting trial of two apple cultivars. ACTA HORT. 160: 23-37.

Schupp J.R., Ferree D.C., Warrington I.J. 1992. Interactions of root pruning and deblossoming on growth, development and yield of ‘Golden Delicious’. J. HORT. SCI. 67: 465-480.

Vanhellemont M. 1993. Experiences with root pruning in the Hageland. FRUITTEELT 6: 8–10.

Vercammen J. 1995. Root pruning of Boskoop. FRUITTEELT-NIEUWS. 8: 6-8.

Wagenmakers P.S., Tazelaar M. 1998. Good lighting gives efficient fruit production. FRUITTEELT-DEN-HAAG 88: 16-17.

Wagenmakers P.S. 1988. Effects of planting system, tree shape and additional summer pruning on growth, production and flowering of apple trees at high plant densities. J. HORT. SCI. 63: 383-392.