Agricultura 4: 1-7 (2006)

The influence of the width of the herbicide zone on growth and productivity of apples

Andrej VOGRIN

University of Maribor, Faculty of Agriculture, Vrbanska 30, 2000 Maribor, Slovenia

In an intensive apple orchard we examined the influence of the width of the herbicide zone on vegetative and generative activity of apple trees. In a factorial trial based on randomised blocks, which lasted four years, we studied three different widths of the herbicide zone under trees (25, 50 and 100 cm), and the zone under trees which was covered by weeds and other plant species, and mowed (the fourth treatment). We found out that the width of the herbicide zone had a significant influence on the growth and cropping of apple trees. The trees under which soil was covered by weeds and other plants, and trees on a 25 cm wide herbicide zone expressed lower vegetative and generative activity. The trees on a wider herbicide zone were characterised by more intense vegetative growth (expressed as the increase of the trunk diameter) and higher generative activity (expressed as the number of developed inflorescences, fruit yield and the first-class fruit yield). The study suggests that adequate width of herbicide zone is a necessity for achieving a higher yield and a high apple fruit quality.

Key words: fruit growing, apple *Malus domestica plantations*, weed control, herbicide zone, growth, fertility, plant communities/yield

INTRODUCTION

The bleak herbicide zones under tree rows and cultivated areas between these zones appear to be a common practice in European orchards. The same system is also found in the surroundings of Maribor. The herbicide zone under trees is of different widths because of different growing technologies and different ways of planting trees. The integrated production, which was introduced in Slovenia several years ago, provides the market with sufficiently large quantities of quality fruits and at the same time it represents a smaller risk for the environment. In the integrated production, phytopharmaceutical substances which are harmful to the environment are prohibited and even those that are used are applied in low concentrations. Orientation of fruit growing into more environment-friendly system requires the reduction of phytopharmaceutical substances. The reduction of herbicides in fruit growing is most easily attained by narrowing or abolishing the herbicide zone. In the integrated production system, the herbicide zone has to represent 1/3 of the total width. The width of the zone between rows used in modern dense plantations around Maribor is approximately 3 m. The use of modern tractors enabled to narrow this zone to 2.5 m in orchards which are not situated on sloping areas.

Correspondence to:
Andrej VOGRIN
Tel.: ++386 2 25 05 823
Fax.: ++386 2 22 96 071
e-mail: andrej.vogrin@uni-mb.si

But such orchards are rare. The majority of orchards around Maribor are situated on sloping grounds and the width of the zone between rows ranges between 3.0 and 3.5 m. Considering the rules of the integrated production system, the herbicide zone can be up to 1 m wide, while the zone covered with grass can be 2.0 to 2.5 m.

The use of herbicides has a very important antropogenic influence. By using them we perform a special selective pressure. The only plants that survive are weeds resistant to herbicides and plants which escape the use of herbicides due to their seasonal occurrence. In permanent plantations it is very important when and in what dosage to use the herbicide and what should be the width of the herbicide zone. It is an important technological issue which should help us to lessen the competitive ability of weeds towards fruit plants. But unfortunately we often don't think of what will be the consequences of using the herbicide on the entire life of the micro-system of an orchard. Perhaps it would be better not to reduce to much the competitive ability of weeds, so that they can take some nutrition from fruit plants, as they could otherwise grow too quickly and be more sensitive to infections (Schmidle et al. 1975; Rutz et al. 1990; Sutton et al. 1996; Sutton 2000). Perhaps more predatory insects and mites (e.g. Anthocoridae, Reduvidae or Phytoseiidae) will populate this lush weed population, which will help to reduce pest populations and, consequently, the use of insecticides and acaricides (Rode 1996; Lešnik et al. 2003).

The herbicide zone under tree canopies is kept bleak by using herbicides. In most cases, the producers use non

selective herbicides such as Glyphosate, which is applied late in autumn or in spring, following by a "corrective" spraying in summer. In this way the zone under tree canopies can be kept clean until autumn. In autumn the weeds mean no more threat to the trees and therefore (for ecological and economic reasons) it is not necessary to treat them with herbicides. In that time of the year, growing of small weeds under tree canopies is even welcome.

The zone covered by grasses in the area between rows is kept by regular mowing. The number of mowings differs from year to year and depends mainly on the quantity of precipitations. Fruit producing farms in Slovenia are differently equipped with machines. The width of the flail mowers varies from 1.6 to 1.8 m, although there are also wider ones. The main reason for using this type of flail mowers are sloping grounds, on which wider flail mowers are less suitable and require stronger tractors. Larger flail mowers, 2 or more meters wide, are usually used only in orchards which are not situated on slopes. In such orchards it is possible to mow all the zone covered with grass only by driving in one direction. With narrower flail mowers it is necessary to pass the area twice, what requires more time and fuel. In some plantations where rows are 3 m apart, according to the integrated production system, there should be a 2 m zone covered with grass, the width of the herbicide zone sometimes increases because of 1.8 m wide flail mowers. Such widening of the herbicide zone leads to a greater use of herbicides, so we have to see whether such a wide herbicide zone is really necessary or it could be narrowed. According to some experiments which were done elsewhere, a wider herbicide zone is necessary with younger trees (Baarends 1995; Van der Mass et al. 1990; Zadravec et al. 1997). In order to get an answer to our question about the width of the herbicide zone, we set the experiment in an apple plantation in full productivity.

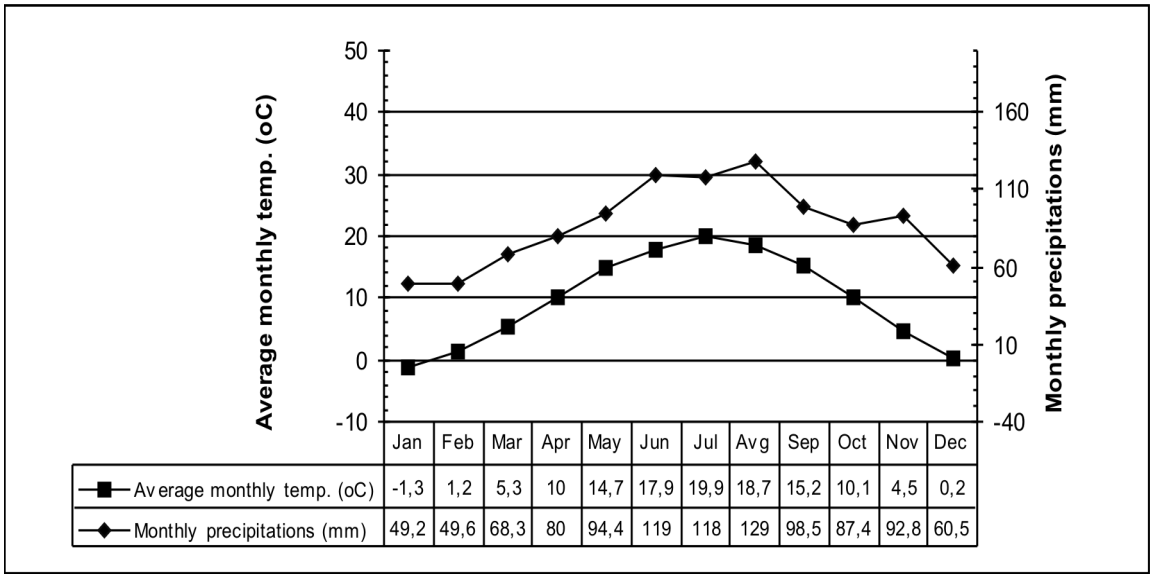
METHODS

Maribor and its surroundings are situated in the area between the Pannonian plane and the Alpine heights. As a result its climatic conditions have characteristics of both the eastern and the central Slovenia (early springs, hot summers, long and relatively warm autumns and cold winters). Such climatic conditions (Fig. 1) are good for apple trees, so this area has been long known for producing high-quality apples.

A long-time average of annual precipitations is 1045 mm. They vary from month to month. A year starts with the driest months (January and February), after that the quantity of precipitations is increasing until July and August, when it reaches its peak. After that, the quantity decreases again. In that way as much as 730 mm of rain falls during the vegetation period. In summer months, a considerate amount of precipitations comes in the form of heavy rainshowers and as a result the water runs off instead of penetrating to the soil (most of the orchards are situated on sloping grounds). In the last years we have experienced several relatively dry seasons, and one of the consequences was that irrigation systems were installed in many orchards.

Average annual temperature for the last 30 years has been 10 °C. For fruit-growing, however, the oscillations between temperatures are more important. Cold winters, when temperatures can be – 20 °C or even lower, are followed by relatively early springs. At that time there is a danger of frosts, but in the last few years they have not occured. Then there are hot summers with average temperatures of nearly 20 °C. In this time of year there is the highest quantity of precipitations. Finally, autumn periods are long and relatively warm, which enable fruit-trees to prepare for the winter season.

In modern fruit plantations around Maribor and in other surrounding areas, a new way of cultivating the soil is being used. The area between rows is covered with grass and mulched, while the soil under the trees is treated with herbicides and bleak. Due to the use of tractors, the distance between rows is 3 to 3.5 m. Because the area under tree canopies, which is treated with herbicides is usually 1 m wide, the width of the zone covered with grass is 2 to 2.5 m. The aim of this experiment was to find out whether this width of the herbicide zone is necessary or it can be narrowed down without endangering the normal development of trees.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Avg	Sep	Oct	Nov	Dec
Average monthly temp. (oC)	-1,3	1,2	5,3	10	14,7	17,9	19,9	18,7	15,2	10,1	4,5	0,2
Monthly precipitations (mm)	49,2	49,6	68,3	80	94,4	119	118	129	98,5	87,4	92,8	60,5

Fig. 1. A modified Walter and Gaussen climatic diagram (for Maribor) for a 30-year long period (1961-1990). The average ratio between temperature and precipitations ratio is 1 : 4.

Four different treatments were included in this trial:

1-25 cm wide herbicide zone,
2-50 cm wide herbicide zone,
3-100 cm wide herbicide zone.
4 - the zone is covered with weeds and mowed.

The experimental design was a randomised complete block design, comprising 4 replications and 15 trees per replication. The total number of trees included in the trial was 240.

The zone under canopies was treated with herbicide twice, once in spring and once in summer. In spring (in April), the systemic non-selective herbicide based on Glyphosate was used. We tried to clear the zone under trees from all the weeds which could compete with apple trees. The concentration used was 4 l/ha with 300 l of water per ha. The spraying in spring took place on different time periods, depending on weeds' growth. For the summer corrective spraying the herbicide based on Gluphosinate was used.

In autumn, the herbicides were not used, because the recover of weedy plant communities in zone under canopies is welcome in that time of year. In autumn weeds don't have negative impact on the growth of apple trees, so it would be unreasonable both for environmental and economic reasons to treat them with herbicides. The zone under canopies, which were part of the fourth treatment, was not treated with herbicides. Weeds were left to grow and were mowed from spring to autumn. The number of mowings varied from 4 to 6 in different years.

The trial was established in a orchard near Pekre, in the vicinity of Maribor. The studied cultivar was 'Jonagold' and trees were 4 years old (at the beginning of the experiment). They were planted at a distance of 3 x 0.5 m. The total area of the trial was 4 ha and was part of a 100 ha plantation belonging to the Company Vinag d.o.o. At the time of planting the drip irrigation system was installed which enabled irrigation and fertirrigation of the orchard. The plantation was situated on 280 m a.s.l. and the rows were oriented from North to South.

In the year of the establishment of the trial, we selected the trees that were similar (regarding their appearance, number of inflorescences and vegetative activity). The trunk diameter was measured 20 cm above the grafted place.

During the next three years (from 1995 to 1997), vegetative and generative parameters of tree activity were followed. In spring, we measured trunk diameter and counted inflorescences. At harvest we counted and weighed the fruits. The yield of the first and of the second fruit quality class was separated. The experiment was completed in spring 1998, by re-measuring trunk diameters and the number of inflorescences. After the fieldwork had been done, we calculated cropping coefficient (which shows how many fruits developed from inflorescences), the number and weight of fruits per tree, the average weight of one fruit, the portion of first class fruits, yield efficiency (the yield in kg per trunk area), the increase of trunk diameter and yield per ha.

After getting the data for individual years we extended these parameters for the total studied period. The data were statistically analysed using SPSS 10.0 programme for Windows.

RESULTS AND DISCUSSION

The trial included trees that were similar by appearance. Trunk diameters which varied from 23.34 and 24.34 mm were enabling the same starting-point for all the examined widths of herbicide zones. The average number of inflorescences at individual treatments varied from 27.27 to 28.58 per tree (Table 1.).

Table 1. Average values of trunk diameters (in 1994 and 1995), number of inflorescences (in 1995) and increase of trunk diameters (in 1994), for individual treatments.

Treatments	Trunk diam. 94 (mm)	Number of inflorescences	Trunk diam. 95 (mm)	Increase of trunk diameters (mm)
1	24.02	48.73	28.50	4.47
2	23.54	45.72	28.07	4.52
3	24.34	46.02	28.58	4.25
4	23.34	48.95	27.27	3.92

In the year of establishing the trial we wanted to determine the changes of trunk diameters and study the vegetative growth of trees. In order to do that, the next spring, 1995, we measured the fruits and calculated the increase. Trunk diameters were still very similar. We presumed that already after the first year differences in growth parameters would appear. The answer to the question why there were no differences can partly be explained by weather conditions in 1994. The year was in overage warmer more than 2 °C comparing to long time average temperatures (for the period from March to September). The quantity of precipitations was also higher than a long time average, but they were unusually spread. In the four months which are crucial for tree growing the precipitations were above the average, so there was enough humidity for the trees and also for competitive plants under the trees. If in the remaining months when there was not enough moisture, some negative effects of weedy plant communities under trees became evident, we used irrigation to enable constant growth to all trees. The consequence of high temperatures and sufficient humidity was that the increase of trunk diameters in the first year was constant and much higher than in the following years.

All data, however, showed no statistically significant differences.

In Table 2 average values for the years since 1994 to 1997 are shown.

Table 2. Average values for the increase of trunk diameter (for the period 1994-1997), weight of fruits, share of the first-class fruits in t/ha (for the period 1995-1997), for individual treatments.

Treatments	Increase of trunk diameter (mm)	Weight of fruits (t/ha)	Share of the first-class fruits (%)	Weight of the first-class fruits (t/ha)
1	11.02	107.70	77.91	86.08
2	13.01	130.01	83.26	109.98
3	12.24	126.85	86.66	110.01
4	10.46	106.78	82.44	86.48

Increase of trunk diameter

The increase of trunk diameters was observed during a period of four years. In those years, the trees with a 50 cm herbicide zone had the highest average increase of diameters. Then follow the trees with the widest, 100 cm herbicide zone. Looking just at the increase of trunk diameters we could say that a 50 cm herbicide zone is sufficient and that it is not necessary to widen it. By narrowing the herbicide zone, on the other hand, the average increase of trunk diameters is getting smaller and reaches its lowest point with trees which had no herbicide zone at all. Statistical analysis of the data showed significant difference in the average increase of trunk diameters between the treatments 2 and 4.

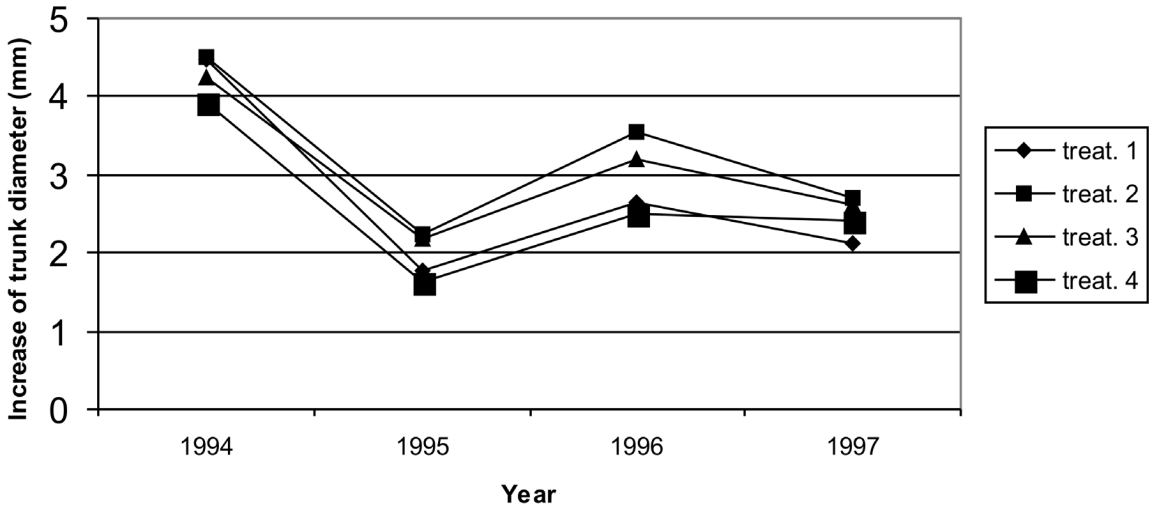


Fig. 2. Average increase of trunk diameter for individual treatments, for the period 1994-1997.

Fig. 2 shows that increases of trunk diameters were very similar throughout the years. The highest increase of trunk diameters (in all treatments) was determined in 1994, due to good weather conditions. In the following years the increases were lower and varied from year to year. Trees with a 50 cm herbicide zone had greatest average increases of trunk diameters. Trees without the herbicide zone had the lowest increases. This tendency was determined in all four years, with the exception of 1994, when the treatment 1 showed higher increases than the treatment 3, and in 1997 when the treatment 4 exhibited higher increases than the treatment 1.

In general we can conclude that trees with a wider herbicide zone exhibited greater increase of trunk diameters than trees with a narrower herbicide zone or with no herbicide zone at all.

Oscillations in increases of trunk diameters from year to year can be explained by the alternation of higher vegetative growth and lower yield, and lower vegetative growth and higher yield. Thus in the years with higher yield lower increases of trunk diameters and also lower vegetative growth of trees were determined, and contrary, in the years with lower yield increases of trunk diameters and the vegetative growth were higher.

The trees examined in our trial were subject to alternating productivity even prior to our treatment. But in spite of the fact that the trees we had chosen were very similar in growth, in the course of our trial they experienced the so called alternating bearing of individual plants, which can mean an even greater problem. Different widths of herbicide zones had no influence on decreasing or increasing of alternating productivity of the plantation.

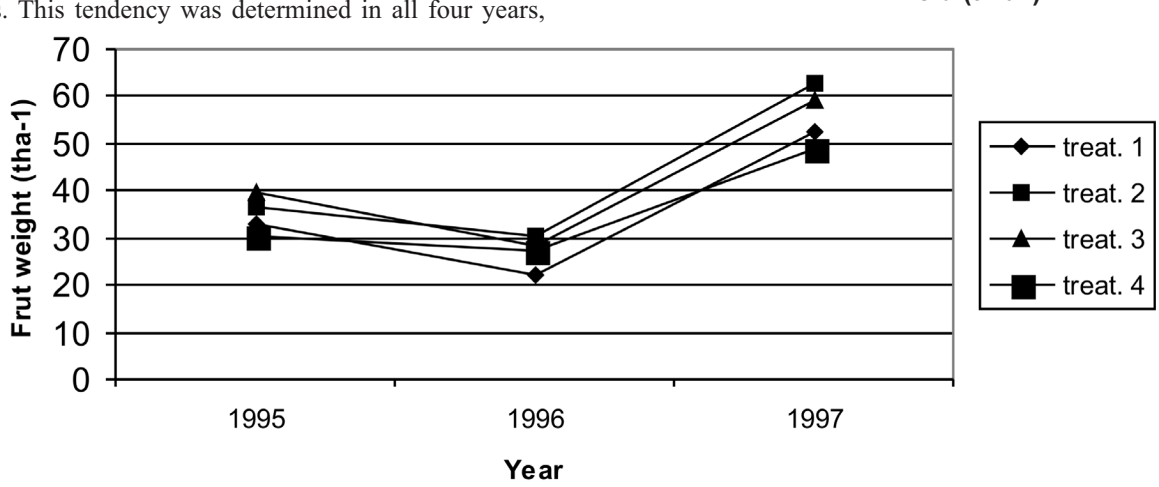


Fig. 3. Average weight of fruits for individual treatments, for the period 1995-1997.

The weight of fruits was measured during three years. Similarly as in the increase of trunk diameters, the higher values were established in trees with a 50 cm herbicide zone. Only a slightly lower yield was established in trees with a 100 cm herbicide zone. Once again the results are not in

favour of a herbicide zone wider than 50 cm. By narrowing this zone to 25 cm or by eliminating it, the average yield becomes considerably lower. Although the difference between the treatments 2 and 3 is small, the only statistically significant differences are between the treatment 2 on one and the treatments 1 and 4 on the other hand.

Average yields per ha are varying in all the treatments. The first observed yield, which was not too high, was

Portion of first-class fruits

Trees with the widest herbicide zone were characterised in all three years by the highest portion of first-class fruits (86.66 %). In the other treatments this share was lower (again trees with a 25 cm herbicide zone had the lowest part of first-class fruits (77.91 %)). The difference between the two treatments was statistically confirmed. In general, we could say that the portion of the first-class fruits was not high enough. It can

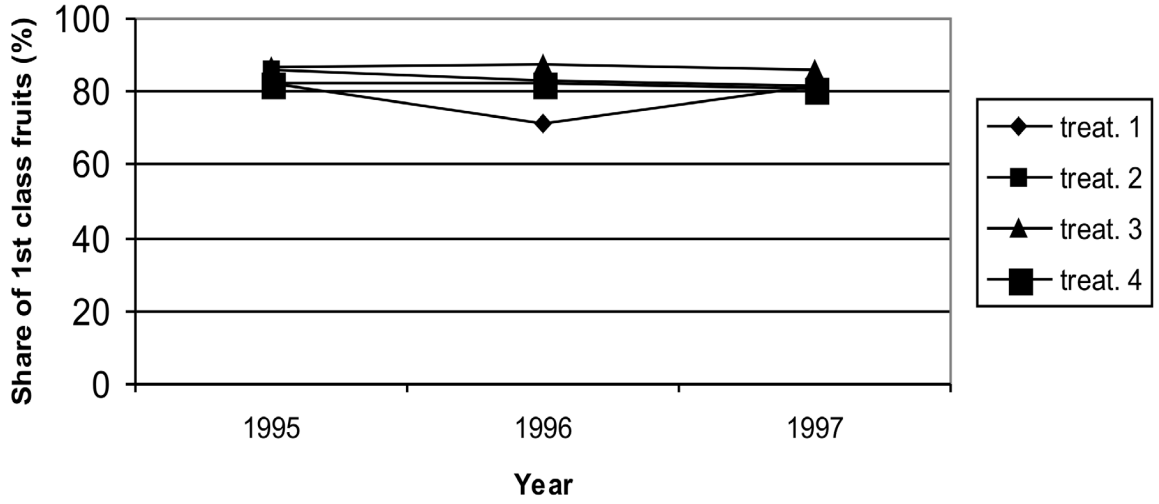


Fig. 4. Average share of the first-class fruits for individual treatments, for the period 1995-1997.

followed by a decrease in the next year and by an increase in the third year (Fig. 3.).

In all the years wider herbicide zones (50 and 100 cm) resulted in higher yields than narrow (25 cm) or non-existing herbicide zones. Although this difference in various years is only slight and cannot be statistically confirmed, the total yield for all three years suggests that the treatments with wider herbicide zones resulted in higher yield than the other

be considered as a result of alternating bearing of individual plants. Trees which in one year have low yield or none at all, in the next year had higher yield, but with a lower share of first-class fruits. Due to the fact that in the same year there were trees with high and those with low yield, the final result was an average, but low-quality yield. The oscillation between average parts of first-class fruits in individual treatments during our experiment is shown in Fig. 4.

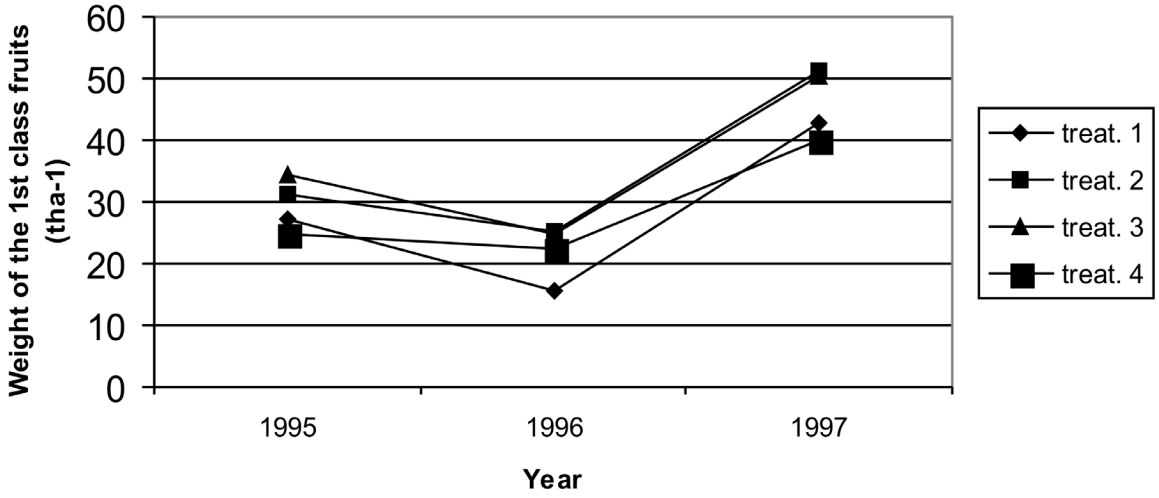


Fig. 5. Average weight of the first-class fruits in tha-1 for individual treatments for the period 1995-1997.

two treatments. If we continued to examine the plantation in the following years, we would probably get a similar result which would confirm that a year with a higher yield is followed by a year with a lower yield and it has as a consequence higher vegetative growth.

In Fig. 4, it is obvious that the share of the first-class fruits was not much different neither in individual treatments in one year nor in different years. It ranged between 81 and 87 %. The only exception is 1996, when trees with a 25 herbicide zone had only 71 % of first-class fruits. This figure also suggests that the two treatments with wider herbicide zones always had higher parts of first-class fruits.

Yield of first-class fruits in (t ha^{-1})

Trees with wider herbicide zones gave more first-class fruits than trees with the narrowest or non existing herbicide zone, as is also seen in Fig. 5.

Trees with 50 and 100 cm herbicide zone gave in all the years higher yields of first-class apples comparing with trees with a 25 or non existing herbicide zones.

Summing up the weights of first-class fruits for all three years we could conclude that yields for trees with 50 and 100 herbicide zones were very similar. The difference between them was negligible, as it was only 30 kg per over 100 tons of apples. On the basis of our trial we can clearly affirm that keeping a 100 cm herbicide zone under trees is unnecessary, as the width of 50 cm gave the same results.

It is also evident that the values we got by summing the yields of first-class fruits in trees having a 25 cm herbicide zone and trees which had no herbicide zone at all were very similar. The difference between the two values is also very small (400 kg). Therefore, we can conclude that a 25 cm herbicide zone is too narrow and the results we get are no better than those with no herbicide zones under trees.

On the other hand, the difference we get in the total weight of first-class fruits (for three years) between trees with a 50 or 100 cm herbicide zone on one side and trees with a 25 cm or no herbicide zone at all on the other, is considerate – approximately 24 tons (Fig. 6). The differences between the treatments 2 and 3 on one and the treatments 1 and 4 on the other side are statistically different.

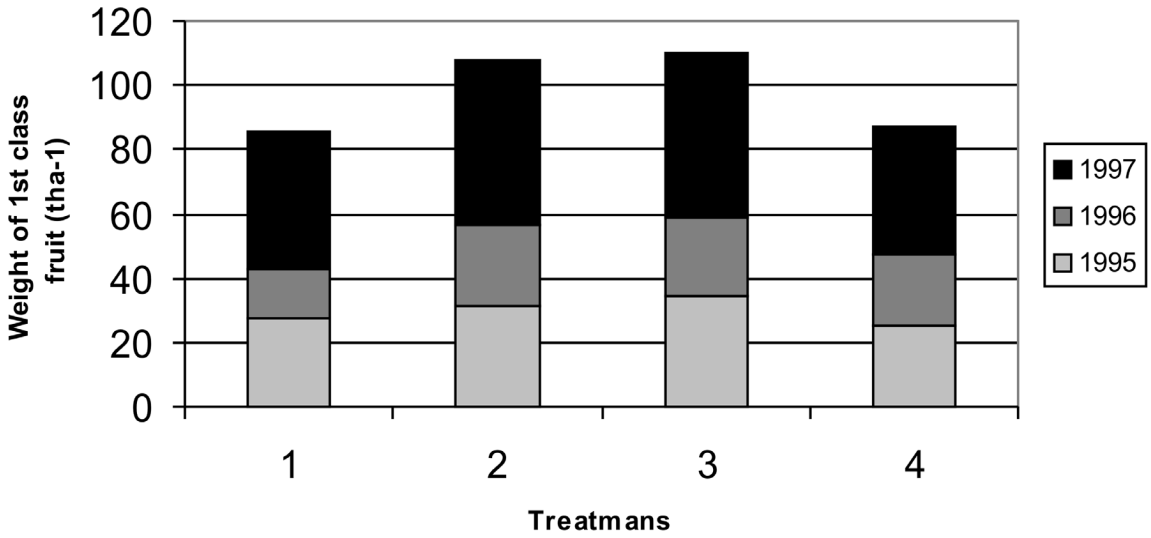


Fig. 6. Average weight of the 1st class fruits together, for the years 1995, 1996 and 1997 (for individual treatments).

CONCLUSION

The investigation of growth and cropping of apple trees through a three year period indicated that there was a similarity between trees with the narrowest herbicide zone (treatment A) and trees with a green cover (treatment D), and trees with wider herbicide zones (treatments B and C) on the other hand. The trees from the treatments A and D had, on average, a lower growth rate of trunk diameter and less first-class fruits. The other investigated and calculated parameters such as number of developed inflorescences, number of fruits, fertility coefficient, yield per ha and yield efficiency also showed the same trends. The differences in results lead us into a conclusion that, in order to have high and high-quality yields, trees need to have a herbicide zone somewhat wider than 50 cm. The comparison of the results obtained with trees having 50 and 100 cm wide herbicide zones indicated that the differences were insignificant. It was not possible to confirm that the trees with the widest herbicide zone performed better than the trees with the 50 cm herbicide zone. The 100 cm wide herbicide zone is very common in apple production (it is also allowed in the integrated production). However, the results of our experiment showed that this herbicide zone is too wide, especially for older trees. It could be reduced to 50 cm with no negative consequences on the quantity and quality of the yield. In this way, we would reduce the use of herbicides which are used twice a year (to spray the zone under the trees). A wider green cover would also help to reduce the difficulties associated with erosion, because the majority of orchards are situated on sloping grounds. The fertility of the soil would improve, the proportion of the organic substances would increase, and the biotic diversity of flora and fauna would be preserved.

REFERENCES

1. Baarends JL. Zwartstrookbreedte en onderstam bij appel Wi92027. Excursiegids Groot Fruit 1995. Wilhelminadorp (Nederland), Proefstation voor de Fruitteelt, 1995;89.
2. Lešnik M, Tojnko S. Vpliv dolžine presledkov med škropljenji na učinkovitost varstva jablan pred boleznimi in škodljivci pri uporabi zmanjšanih odmerkov pripravkov. Zbornik predavanj in referatov 6. slovenskega posvetovanja o varstvu rastlin, Zreče, 4.-6. marec 2003;367–379.

3. Rode F. Pflanzenschutz im integrierten Obstbau. Stuttgart, 1996;494.
4. Rutz CH, Hugentobler U, Chi H, Baumgartner JU, Oertli JJ. Energy flow in an apple plant-aphid (/Aphis pomi/ De Geer) ecosystem, with respect to nitrogen fertilization. Proceedings of the Eleventh International Plant Nu-trition Colloquium, Wageningen, 1990;625–631.
5. Schmidle A, Dickler E, Seemuller E, Krezal H, Kunzle L. Einfluss von Düngung und Bodenpflegemassnahmen auf den Krankheits- und Schadlingsbefall in einer Apfelanlage. Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz. 1975;82:8/9:522–530.
6. Sutton DK, Machardy WE, Lord WG. Effect of shredding or treating apple leaves litter with urea on ascospore dose of /Venturia inaequalis/ and disease buildup. Plant disease, 2000;84:1319–1326.
7. Sutton TB. Changing options for the control of deciduous fruit tree diseases. Ann. Rev. Phytopathol. 1996;34:527–547.
8. Van der Maas MP, Bolding PJ. Project PFW 79: De invloed van fertigation op de groei en vruchtbaarheid bij pit- en steenvruchten. Wilhelminadorp (Nederland), Proefstation voor de fruitteelt. Jaarverslag, 1990;124.
9. Zadravec P, Vogrin A. Vpliv širine herbicidnega pasu na rast in rodnost jablan v mladostnem obdobju. Zbornik predavanj in referatov s 3. Slovenskega posveta o varstvu rastlin, Portorož, 4. – 5. mar. 1997, Ljubljana, 1997;345–348.

Received: December 6, 2005
Accepted in final form: February 14, 2006