Phyton (Austria) Special issue: "Plant Physiology"	**Vol. 39**	Fasc. 3	(101)-(106)	30. 11. 1999

Influence of Leaf Area on Net Photosynthesis, Yield and Flower-Bud Formation in Apple (*Malus domestica* Borkh.)

By

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K e y w o r d s : Apple, defoliation, photosynthesis, fruit quality.

S u m m a r y

ŠTAMPAR F., HUDINA M., USENIK V., ŠTURM K., VIRŠČEK MARN M. & BATIČ F. 1999. Influence of leaf area on net photosynthesis, yield and flower-bud formation in apple (*Malus domestica* Borkh.). - Phyton (Horn, Austria) 39 (3): (101) - (106).

The influence of the artificial leaf area reduction (control, 30%, 50%, 70% defoliation) was studied on irrigated and non-irrigated apple trees of cvs. 'Elstar' and 'Jonagold' in two growing seasons. Photosynthesis was measured before and 12 days after defoliation in the first and second decade of July. The reduction of the assimilation area did not cause additional fruit dropping. Individual leaf photosynthesis varied significantly between different degrees of defoliation and different water treatments. Defoliation did not have any effect on the yield in the first growing season, whereas influence of defoliation on fruit quality was detected. Significant negative effect of defoliation on the reduction of flower bud formation as well as flowering and consequently yield in following year was found. The assimilation area had a substantial effect on quantity, quality and yield regularity of apple trees.

Introduction

Photosynthetic productivity of fruit trees depends on internal and environmental factors. The internal factors range from leaf structure and leaf chlorophyll content to water conducting ability, osmotic adjustment by the tree and the presence of the strong sinks such as fruits. The environmental factors include

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light penetration through the canopy, night and day temperatures and the availability of water, which together with air humidity determines stomatal opening and has a major influence on CO_2 exchange and consequently on photosynthesis (FAUST 1989). High yields of good quality fruits depend on photosynthetic intensity and assimilate transport through the entire plant (CHEN & al. 1997). For this reason a correct illumination of individual leaves and the whole canopy is very important (JACKSON 1980, PALMER 1988). In high density planting systems overlapping of leaves can decrease photosynthetic activity of the plant (FLORE & LAKSO 1989) and influence vegetative and generative tree growth (JACKSON & PALMER 1977, JACKSON 1980, WERTHEIM 1985).

Modern training and planting systems therefore demand better illumination of the canopy (WIBBE & LENZ 1989). GIULIANI & al. 1997 found higher net photosynthesis in the fruiting canopy than in the non - fruiting canopy. Artificial defoliation can simulate leave damages caused by leaf miners or fungal diseases. In the experiments of BAUFELD & FREIER 1991 heavy defoliation reduced fruit number, mean size of fruit and total yield and also had an adverse effect on fruit quality (dry matter substance, total sugar and acid content). Heavy leaf losses also caused reduction of flower bud formation and flowering in the following year.

The objectives of this study were to determine net photosynthesis before and after artificial defoliation and its influence on fruit quality, yield and flower bud formation and flowering in following year.

Material and Methods

The experiment was performed at Fruit Growing Center Maribor - Experimental Center Gačnik in the years 1996 and 1997. Cvs. 'Jonagold' and 'Elstar', grafted on M9, were planted in 1991 on 3 x 1.2 m and trained as spindle. The experimental design included 8 treatments (A-I: irrigated trees with 30% defoliation, B-I: irrigated trees with 50% defoliation, C-I: irrigated trees with 70% defoliation, K-I: irrigated trees without defoliation, A-N: non-irrigated trees with 30% defoliation, B-N: non-irrigated trees with 50% defoliation, C-N: non-irrigated trees with 70% defoliation, K-N: non-irrigated trees without defoliation) with 3 trees per treatment. In 1996 artificial defoliation was performed on 1st of July and in 1997 on 5th of July. Before defoliation the leaves per tree were counted and than proportionally removed by hand.

Photosynthesis was measured on rosette leaves by portable infrared photosynthesis measuring apparatus LCA-3 (Analytical Development Co. Ltd.) on 11th of July 1996 (after defoliation), 4th of July 1997 (before defoliation) and 16th of July 1997 (after defoliation). On each date 3 measurements per tree were performed. In both years the number of flower clusters per tree, the number of fruits per tree after June drop, yield per tree, fruit firmness (kg/cm^2), and soluble solids (° Brix) were also recorded. The average values of net photosynthesis per tree were statistically analysed by analysis of variance. Statistically significant differences among treatments were tested with Duncan's multiple range test at $p = 0.05$.

Results and Discussion

In the year 1996 the influence of artificial defoliation on net photosynthesis of individual leaves, yield and fruit quality (soluble solids and fruit firmness) was determined. The number of flower clusters and fruits after June drop in 1997 as well as net photosynthesis of individual leaves before repeated defoliation also reflect the influence of defoliation in 1996. Results of net photosynthesis measurements after repeated defoliation as well as quality and quantity of yield in 1997 are the consequence of defoliation in both years.

Results obtained by cv. 'Jonagold' are given in Table 1. The experimental trees showed quite uniform number of flower clusters and fruits, especially within irrigated and within non-irrigated plots. Defoliation did not cause any additional fruit drop despite of leaf area loss and high fruit set. Net photosynthesis of individual leaves was lowest on control trees (irrigated and non-irrigated trees without defoliation). The highest values were achieved on 70% defoliation. Yield per tree varied between 10.4 to 18.4 kg and was not affected by defoliation, whereas soluble solids were higher on control trees, especially irrigated ones. The lowest content of soluble solids was found on trees with 70% leaf loss. Similar trends were noted also for fruit firmness. Defoliation had the most pronounced effect on flower bud differentiation expressed as flower cluster and fruit number in 1997. Satisfactory fruit number and consequently yield were reached only on control trees and surprisingly in treatment A-I. Measurements of photosynthesis before defoliation in 1997 showed up to 20 times lower net photosynthesis of individual leaves on trees without or with only few fruits in comparison with normal cropping trees. Similar results were obtained by GIULIANI & al. 1997. After defoliation net photosynthesis of individual leaves was much higher than before defoliation on all trees with low number of fruits. Soluble solid content in 1997 was the highest on treatments with the low fruit number. As in 1996 fruit firmness was the highest in control trees.

Table 1. Number of flower clusters (C), number of fruits (F), yield in kg (Y), soluble solids in ° Brix (SS), firmness in kg/cm^2 (FR) and net photosynthesis of individual leaves (NP) µmol CO_2 m^{-2} s^{-1} per tree in cv. Jonagold.

Treat.	1996						1997						
	C	F	NP	Y	SS	FR	C	NP	F	NP	Y	SS	FR
A–I	339	91	12.3 bc	18.7	13.7	7.2	84	13.1 c	58	8.2 ab	11.3	13.6	6.9
B–I	312	86	12.6 bc	18.6	12.0	6.7	0	3.9 ab	0	7.3 a	0.0	-	-
C–I	304	80	12.3 bc	17.3	11.9	6.8	1	6.4 b	2	12.6 d	0.4	14.7	6.6
K–I	314	66	10.1 a	15.2	14.1	8.1	114	15.7 c	91	9.3 abc	13.7	12.9	6.9
A–N	261	65	12.9 c	12.5	12.5	7.1	16	0.7 a	8	12.6 d	1.7	12.2	6.9
B–N	253	79	13.0 c	16.4	13.5	7.2	10	2.7 ab	22	10.3 bcd	5.0	15.9	7.1
C–N	292	58	15.2 d	10.4	11.5	7.6	1	4.4 ab	4	11.0 cd	0.6	16.0	7.1
K–N	277	86	11.1 ab	18.4	13.7	7.6	164	13.8 c	92	11.6 cd	13.8	13.2	7.3

Mean separation in each column by Duncan's multiple range test at 5 % level (means within a column followed by the same letter are not significantly different).

Results obtained by cv. 'Elstar' are given in Table 2. In 1996 the experimental trees flowered abundantly and uniformly, while fruit set was very uniform within irrigated trees and varied from 62 to 135 fruits per tree within non-irrigated trees. Again no fruit drop was observed after defoliation. As with cv. 'Jonagold' the net photosynthesis of individual leaves in 1996 was the highest on trees with the highest leaf loss. Defoliation had no apparent effect on yield in 1996 but significantly reduced the flowering and fruit set in 1997. Less reduced bearing was observed also in control trees. Except for treatment A-N the highest soluble solids content was found in control trees. The high soluble solids content in non-irrigated trees with 30% defoliation (treatment A-N) can be explained by lower yield. The differences in fruit firmness among treatments were less expressed than with cv. 'Jonagold'. Similarly as by cv. 'Jonagold' the trees of cv. 'Elstar' without or with only few fruits showed significantly lower net photosynthesis of individual leaves before defoliation and an increase of photosynthetic activity after defoliation in 1997.

Table 2. Number of flower clusters (C), number of fruits (F), yield in kg (Y), soluble solids in ° Brix (SS), firmness in kg/cm^2 (FR) and net photosynthesis of individual leaves (NP) µmol CO_2 m^{-2} s^{-1} per tree in cv. Elstar.

Treat.	1996						1997						
	C	F	NP	Y	SS	FR	C	NP	F	NP	Y	SS	FR
A–I	191	100	10.0 ab	19.0	13.0	6.28	2	3.3 a	0	9.6 a	0.0	-	-
B–I	196	115	10.8 ab	22.9	13.6	6.72	36	12.8 b	53	13.8 b	9.4	12.3	6.5
C–I	212	102	11.8 b	16.0	12.8	6.14	0	8.4 ab	0	10.8 ab	0.0	-	-
K–I	207	115	9.8 ab	22.7	14.8	6.72	32	14.8 ab	94	11.1 ab	15.0	14.4	6.6
A–N	215	62	10.1 ab	10.2	14.9	6.24	5	8.0 ab	14	10.7 ab	2.1	16.9	5.5
B–N	242	96	9.4 a	14.0	13.2	6.25	2	0.0 a	7	7.8 a	1.0	14.5	5.8
C–N	256	135	10.6 ab	22.0	13.6	6.43	2	9.7 ab	0	10.8 ab	0.0	-	-
K–N	208	106	9.4 a	20.1	14.0	6.27	32	10.6 a	73	9.1 a	11.0	14.7	6.6

Mean separation in each column by Duncan's multiple range test at 5 % level (means within a column followed by the same letter are not significantly different).

Reduction of leaf area at the time of intensive assimilate use in first decade of July enhanced net photosynthesis of individual leaves in both studied cultivars. In spite of higher individual leaf net photosynthesis of defoliated trees defoliation decreased fruit quality and especially flower bud differentiation.

We can conclude that reduced leaf area of trees with heavy fruit set has a pronounced negative effect on flower bud differentiation and consequently on flowering, fruit set and yield in following year. The assimilate production is unsufficient for both fruit enlargement and flower bud differentiation (FAUST 1989). Our results confirm the findings of BAUFELD & FREIER 1991.

The results obtained on control trees show that spindle training system at the planting density of 2800 trees per hectare can allow good photosynthetic activity and assimilate distribution in whole plant, the prerequisites for high yield and quality (CHEN & al. 1997).

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