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OPTIMIZATION OF LIGHT INTERCEPCION IN INTENSIVE SWEET CHERRY ORCHARD

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Abstract

In high density sweet cherry orchards the crop canopy is fragmented, arranged in linear lanes. In between the tree lanes the alleyway provides the space for technology measures and machinery. The area rate of orchard covered by canopy considerably influences the PAR (photosynthetic active radiation) absorption potential of the orchard. Our first step in Hungary towards intensification of cherry orchard was the "modified Brunner Spindle" in spacing 6x4 to 5x3 m, introduced in the 80-es of last century. The canopy covered rate of the orchard area increased from 0.4-0.5 to 0.6-0.7 with decreasing spacing. The denser "Hungarian Cherry Spindle" with spacing of 4x2m slightly increased the rate of canopy covered orchard area (0.6-0.8) but in this system the leaf and shoot population is more and more crowded in a reduced space. This situation may provide both advantages and disadvantages considering environmental physiology and technology aspects. The total leaf area of trees and the leaf area index (LAI) is considerably influenced by the cultivar and rootstocks. The LAI and so the PAR absorption capacity of orchard shows typical course during the season, influenced by the applied pruning too. On dwarfing rootstock GiSelA 5 or 6 the LAI values of trees reach a maximum of 2 to 3, while the LAI of tree on vigorous rootstocks can achieve 7 to 8. At the stage of LAI_{max} *the canopy walls of trees intercept 60-90% of PAR, which means 40-75% PAR absorption calculated for the whole orchard area. Environmental factors considerably influence the performance of net* CO_2 *assimilation of leaves in daily and seasonal course as well. Our investigation confirmed the role of water supply and temperature of leaves affecting the stomatal conductance. The stomatal conductance of leaves on different rootstocks at appropriate water supply showed daily maximum in the* T_{leaf} *range of 30 – 40 °C, while in the* T_{leaf} *range of 40 – 45 °C the conductance rapidly decreased. This down regulation on dwarfing rootstock is faster, while on vigorous rootstocks slower. Since the water supply of leaves on dwarfing rootstocks due to their hydraulic system is more vulnerable, and the exposition of leaves to solar radiation is higher due to the scarse canopy, the leaves get faster into the critical* T_{leaf} *range. In contrary trees on vigorous rootstocks with higher LAI, which is linked with higher shading, may show more efficient PAR utilization. The research was supported by TÁMOP-4-2.1.B-09/1/KMR- 2010-0005 project and by Hungarian Scientific Research Funds OTKA 109361project.*

Key words*: PAR absorption, orchard systems, rootstocks, stomatal conductance,* CO_2 *fixation.*

INTRODUCTION

The assimilating leaf canopy of trees convert the light energy into assimilates and finally produces marketable fruits in cherry orchards. Several authors in apple orchards showed linear correlation between yield and light interception (Robinson et al., 2005), which suggest increasing the light interception towards maximum.

Several factors influence the light interception in modern orchard systems (Jackson, 2003). Modern orchard systems are characterized by more or less fragmented canopy, the alleyway is needed for machinery. Further on several factors influence the light interception of the orchard, such as tree architecture, canopy covered area vs. alleyway rate, LAI (leaf area index), leaf density, and shading.

On the other hand the further factors influence the PAR (photosynthetic active radiation) use efficiency of leaves, like leaf exposition to solar radiation, leaf turgor, stomatal conductance and leaf temperature.

In our overview we discuss the above factors based on our investigations and literature data.

CANOPY COVERED RATE OF ORCHARD SURFACE

In traditional sweet cherry orchards on high trunks with spherical canopy or modified central leader, the machinery and labor craft was moving under the canopy, the orchard surface was covered by leaf canopy around 70-90%. Compared to those in modern orchard systems the leaf canopy is more fragmented, larger alleyway rate is required for machinery, or more and more narrowed leaf walls (in hedge forms) are established. Table 1 gives a comparison of canopy covered rate of some recently tested orchard systems in Hungary.

Table 1. Comparison of canopy covered rate (canopy area/orchard space allotted for one tree) of different orchard systems

Growth vigor of rootstock	Traditional mod. central leader 8x7 m	Modified Brunner Sp. 6x4 m	Modified Brunner Sp. 5x3 m	HU Cherry Spindle I. 4x2 m	HU Cherry Spindle II. 4x2 m	Super spindle 3x0.6 m
Vigorous	0.7 – 0.9	0.47	0.70	0.76	0.69	
Moderate vigorous	-	0.38	0.61	0.60	0.62	
Low vigor	-	-	-	0.43	0.51	0.2 – 0.25

Our first step in Hungary towards intensification of cherry orchard was the "modified Brunner Spindle" in spacing 6x4 m to 5x3 m, introduced in the 80-es of last century. The canopy covered rate of the orchard area increased from 0.4-0.5 to 0.6-0.7 with decreasing spacing. The denser "Hungarian Cherry Spindle" with spacing of 4x2m slightly increased the rate of canopy covered orchard area (0.6-0.8) but in this system the leaf and shoot population is more and more crowded in a reduced space. This situation may provide both advantages and disadvantages considering environmental physiology and technology aspects.

PERFORMANCE OF LEAF AREA, LAI (LEAF AREA INDEX)

Rootstock and cultivars considerably influence the size of single leaves and so the LAI of the orchard (Gyeviki et al., 2012).

Table 2. The single leaf area (SLA) of 'Petrus' and 'Rita' sweet cherry trees on different rootstocks, 2008-2009 (Gyeviki et al., 2012)

	2008				2009			
Rootstock	Extension shoots (cm^2)		Spurs (cm^2)		Extension shoots (cm^2)		Spurs (cm^2)	
'Petrus'								
'Prob'	45.45	a	34.12	a	43.30	a	34.67	a
'Gisela 6'	57.50	b	37.41	a	47.10	a	37.13	ab
'Magyar'	66.02	c	48.15	b	65.26	b	51.55	b
'Bogdány'	72.07	d	53.65	c	73.19	b	56.15	c
Average SLA	60.26	y	43.33	x	57.21	Y	44.88	X
'Rita'								
'Gisela 6'	42.81	a	30.95	a	46.41	a	31.95	a
Mazzard	61.17	c	45.61	c	54.33	a	38.14	ab
'Korponay'	55.28	b	36.18	ab	57.12	a	39.31	ab
Prunus mah. sdlg.	67.22	c	39.84	bc	67.11	b	43.39	b
Average SLA	56.62	y	38.15	x	56.24	Y	38.20	X

Note: Means in columns are separated by Duncan's multiple range test, values marked with different letters differ at p=0.05. Average SLA is separated by T-test of paired samples.

The leaf area related to crop load considerable influences the fruit size of cherry orchards.

Accepting the data of Cittadini et al. (2006), production of 1 kg cherry in good size (mean fruit weight 10 g) requires around 1.25 m² leaf area. Continuing this calculation along, the production of 20 t/ha cherry in 10 g MFW requires around 30-35 000 m² leaf surface (LAI 3-3.5).

The total leaf area of trees and the leaf area index (LAI) is considerably influenced by the cultivar and rootstocks. The LAI and so the PAR absorption capacity of orchard shows typical course during the season, influenced by the applied pruning too. On dwarfing rootstock GiSelA 5 or 6 the LAI values of trees reach a maximum of 2 to 3, while the LAI of tree on vigorous rootstocks can achieve 7 to 8.

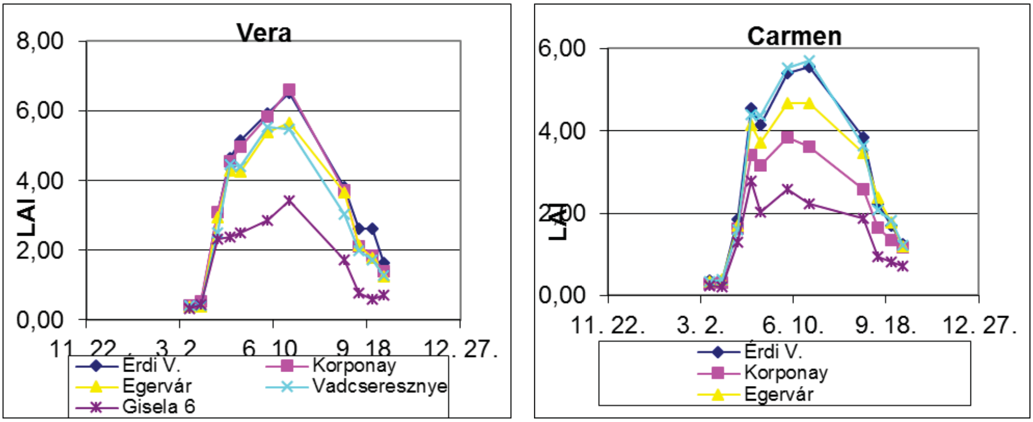

Figure 1. Performance of LAI of ‘Vera’ and ‘Carmen’ on different rootstocks related to canopy area

Considering that the canopy covered area rate is smaller, the orchard surface related LAI calculation is showed in the Table 3 and 4 in 2014 for ‘Vera’ and ‘Carmen’ cultivars.

Table 3. Canopy parameters and calculated LAI for the orchard surface of ’Vera’ on different rootstocks at spacing 4x2 m.

Rootstock	Canopy area (m²)	Canopy diameter (m)	crop covered rate	LAI (Orchard)
Mah Sdlg	5.32	2.60	0.65	4.34
Mazzard	5.93	2.75	0.69	4.23
Egervár	5.32	2.60	0.65	3.76
Korponay	5.78	2.71	0.68	2.61
Gisela 6	3.52	2.12	0.53	1.50

Table 4. Canopy parameters and calculated LAI for the orchard surface of ’Carmen’ on different rootstocks at spacing 4x2 m.

Rootstock	Canopy area (m²)	Canopy diameter (m)	crop covered rate	LAI (Orchard)
Mah Sdlg	5.94	2.75	0.69	4.11
Mazzard	5.88	2.74	0.68	4.19
Egervár	4.88	2.49	0.62	2.86
Korponay	5.26	2.59	0.65	2.37
Gisela 6	3.64	2.15	0.54	1.02

Related to the total orchard surface in our test orchards planted in light sandy soil on the Hungarian flatland, only moderate vigorous and vigorous rootstocks can produce LAI meeting the target orchard LAI of 3 – 3.5.

By our measurements at the stage of LAI_{max} the canopy walls of trees intercept 60-90% of PAR, which means 40-75% PAR absorption calculated for the whole orchard area.

PHOTOSYNTHETIC ACTIVITY, PAR USE EFFICIENCY

Environmental factors considerably influence the performance of net CO_2 assimilation of leaves in daily and seasonal course as well. Our investigation confirmed the role of water supply and temperature of leaves affecting the stomatal conductance. The stomatal conductance of leaves on different rootstocks at appropriate water supply showed daily maximum in the T_{leaf} range of 30 – 40 °C, while in the T_{leaf} range of 40 – 45 °C the conductance rapidly decreased. This down-regulation on dwarfing rootstock is faster, while on vigorous rootstocks slower. Since the water supply of leaves on dwarfing rootstocks due to their hydraulic system is more vulnerable, and the exposition of leaves to solar radiation is higher due to the sparse canopy, the leaves get faster into the critical T_{leaf} range.

In contrary trees on vigorous rootstocks with higher LAI, which is linked with higher shading, may show more efficient PAR utilization. Results of Centritto et al. (2000) and Beppu and Kataoka (2005) suggest that even with appropriate irrigation the shading of trees by net may decrease the evaporative demand of ambient air and overheating of leaves. As the frequency of such days is much larger in continental climate or in high density orchards on low vigor rootstocks, this practice may create optimal conditions for PAR utilization.

CONCLUSIONS

Summarizing the literature data, our results and experiences, we can confirm that light interception is one element only in the „puzzle" named orchard system. At optimizing of light interception the site factor (solar radiation intensity, weather characteristics), cultivar, rootstock, tree architecture and pruning protocol should be considered. As our preliminary results suggest, the light penetration in an average dense canopy could be sufficient in a depth of 70-80 cm, this radius of the conical canopies can be considered as optimum. However, further research is needed to get further information on the interactions between the above elements and light interception.

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