Effects of different bud loading levels on the yield, leaf and fruit characteristics of Hayward kiwifruit

R. Cangi[1], **D. A. Atalay**[2]

[1]*Faculty of Agriculture, Gaziosmanpaşa University, Tokat, Turkey*
[2]*Faculty of Agriculture, Dicle University, Diyarbakır, Turkey*

ABSTRACT: The effects of different levels of bud loading on the yield and some leaf and fruit characteristics in Hayward cultivar (*A. deliciosa*) in the province of Ordu, Turkey were examined during two growing seasons in 2000–2001. Six years old kiwifruit vines were pruned to carry the loads of 120, 180, 240 or 300 buds/vine on the canes with 12 buds. The study determined probable total leaf area (PTLA), probable total leaf number (PTLN), probable total leaf weight (PTLW) and yield per vine. Mean fruit weight (MFW) and soluble solid contents (SSC, %) of fruits were expressed. In addition, unit leaf area/100 g fruit weight (ULA/FW) was calculated. Leaf characteristics were examined in 3 periods of the growing season. Correlations between yield, leaf and fruit characteristics and treatments were determined. The result of the experiment, namely mean leaf area (MLA), mean leaf weight (MLW), PTLA, PTLN, PTLW ranged between 185.51–194.17 cm^2, 7.98–8.67 g, 21.047–58.61 m^2/vine, 1,129.6–3,035.3 number/vine, 9.04–25.68 kg/vine, respectively. The mean yields of vines loaded with 120 and 300 buds were 34.84 and 100.96 kg/vine (12.19 and 35.34 ton/ha), respectively. Mean leaf area and mean leaf weight increased with increasing levels of bud loading, whereas MFW and ULA/FW decreased. There was a negative relationship between MFW, SSC and yield, and a positive relationship between MLA, PTLA and yield. ULA/FW ratio was between 581.88–611.54 cm^2 according to the bud loading level. Fruit size diminished as a consequence of dense canopies in both levels of bud loading (120 and 300 buds/vine). Unit leaf area per fruit weight ranged between 581.88–611.54 cm^2/100 g, with respect to the bud loading applications. Increasing levels of bud loading resulted in reduced ULA/FW ratio and affected yield and some leaf and fruit characteristics.

Keywords: kiwifruit; *Actinidia deliciosa*; Hayward; pruning; fruits; leaf area; characteristics; bud loading

All *Actinidia* species are perennial and known for a climbing, vigorous growth and strangling plant characteristics. The kiwifruit (*A. deliciosa*) was not popular several decades ago, but it has become a major worldwide fruit crop in recent years. Several researches were carried out to understand the growth management practices of kiwifruit and to maximize yields (Ferguson 1984; Davison 1990; Lai et al. 1990).

Several researchers also reported that pruning is one of the most important aspects of vine management and plays a major part in obtaining good yield of fruit every season (Sale, Lyford 1990; Ryugo 1994). Bud loading level in winter pruning is one of the most important factors affecting the yield and fruit characteristics (Costa et al. 1987; Standardi, Romani 1990; Inglese, Gullo 1992; Samanci et al. 1995; Samanci, Uslu 1996). Considering the entire cane, the highest efficiency per mixed bud is attained by 12-node-long canes (Giorgio et al. 1987).

Among the kiwifruit cultivars grown, Hayward is the most popular in the world. The canopy of a typical Hayward (*A. deliciosa)* vine occupies around 20 and 60 m^2 surface area, carries around 2,000 to 5,000 leaves, and mean leaf area changes between 100–200 cm^2 (20 cm in diameter) (Davison 1990; Samanci 1990; Snowball 1997; Cangi, Karadeniz 1999). Leaf area in kiwifruit can be calculated using different methods. For example, total leaf area and leaf area index can be used with a geometric approach for modeling the kiwifruit canopy (Succi et al. 1997). Snelgar and Thorp (1988) recommended the use of total number of leaves per vine and mean leaf area for a precise calculation of total leaf area.

Temperature and leaf position can affect the leaf area expansion of kiwifruit shoots and the leaves can be grouped into three zones along the shoot. Temperature had no effect on final leaf area in the first zone; for the rest of the leaves, temperature affected final leaf area indirectly, through the timing of leaf expansion (Seleznyova, Dennis 2001). Simulations of photosynthesis for vines on a T-bar trellis, assuming spatially variable leaf area distributions as measured under field conditions, indicated disproportionate contributions from different regions of the canopy. Within canopy, shading was more important on sunny days than on cloudy days, while the spatial distribution of leaf area was important especially on cloudy days (Buwalda et al. 1993).

Canopy leaf area development and daily rates of carbon acquisition of kiwifruit vines growing in orchard conditions were modeled from the mathematically-based physiological descriptions of leaf area expansion and the photosynthesis of individual leaves. Close agreement occurred between the simulated and measured canopy leaf area development, as well as between simulated and measured rates of photosynthesis (Greer et al. 2004).

The previous studies also reported that fruit size was reduced by increasing crop loading and a negative correlation was found between fruit number/unit leaf area and fruit size (Richardson et al. 1994; Antognozzi et al. 1992; Snelgar et al. 1997). In a study on the effect of canopy density on fruit quality the relationships between leaf area index and fruit size in Hayward cultivar was investigated. The results showed that the fruit size decreased as the crop load increased at a rate of 0.2 g/fruit/m^2 (Snelgar et al. 1997, 1998).

Cooper and Marshall (1992) also reported that leaf number/fruit ratio had a greater effect on fruit size than the crop load, and that the greatest fruit size and extra yield were obtained with 3:1 ratio. Famiani et al. (1997) pointed that it is necessary to have 2 to 4 fully exposed leaves per fruit to get enough sun and to ensure a normal fruit development and quality, and that assimilates can be easily translocated within the plant to support the fruit growth on shoots with an inadequate leaf/fruit ratio. Snelgar and Thorp (1988) also reported that leaf areas from 230 to 335 cm^2 produced fruit of an average weight 110 g and 104 g. In addition, on whole vines final fruit weights increased linearly with leaf area at a rate of 5–6 g per fruit per 100 cm^2 leaf over the range 300–700 cm^2. A similar research by Snelgar et al. (1986) with Hayward cultivars showed that the mean fruit weight increased with an increasing L:F ratio. However, this increase in weight of individual fruits was not sufficient to compensate for the corresponding reduction in fruit numbers.

Seasonal changes in photosynthetic capacity of leaves of kiwifruit vines were studied by Buwalda et al. (1991) who reported that an increase of photosynthetic capacity during 3–5 months after the leaf emergence was closely related to concomitant changes in leaf N and chlorophyll contents in kiwifruit.

Objectives of this study were to determine and obtain the basic data on the effects of different bud loading levels on the yield and some leaf and fruit characteristics of Hayward cultivar of kiwifruit.

MATERIALS AND METHODS

The research was carried out on Hayward (*A. deliciosa*) cultivar using 6 year-old kiwifruit vines. The vines were T-bar trained, situated and planted at 5 × 5 m (5 male vines per 35 male vines) plots, grown in Ordu (Northern Turkey) ecological conditions. The vines were pruned in winter, pruning as canes on 120, 180, 240, 300 bud levels (bud/vine), 12-noded, separately. The experiment orchard was fertilized with 150 kg N/ha (as urea), 100 kg K/ha (as K_2SO_4) and irrigated during summer using mini sprinklers. No fruit thinning was applied during the experiment. Pruning shoots without flowers were removed in early summer and fruitful shoots were shortened back to four leaves beyond the last fruit in mid-spring.

Leaf characteristics

Leaf characteristics (leaf number, leaf area, leaf weight) were determined in three periods (the time of fruit set; about 8–9 week after fruit set; about 4 months after fruit set) during the growing season. Leaf number was determined by counting of all leaves on four canes randomly chosen from vines in each period. Leaf area and leaf weight were determined by measuring selected leaves (3., 5., 7., 9., 11. leaf in the first period; 3., 5., 7., 9., 11., 13., 15. leaf in the 2. and 3. period) on three lateral shoots on canes in each period. Leaf area values were measured using a digital planimeter. Mean leaf area (MLA, cm^2) and mean leaf weight (MLW, g) per leaf were calculated as average of the three measurements.

For each measurement time the values of total leaf number (TLN), total leaf weight (TLW) and total leaf area (TLA) per vine were determined by calculating (TLN = canes number × number leaf per canes; PTLA = MLA × PTLN, respectively). Finally, probable total leaf area (PTLA m^2/vine), probable total leaf number (PTLN, number/vine), probable total leaf weight (PTLW, kg/vine) values were determined by calculating average values of three periods (Snelgar, Thorp 1988).

Yield and fruit characteristics

Fruits were harvested when they reached the commercial maturity (SSC, 7%). Harvested fruits were weighed and mean fruit weight (MFW) was

Table 1. Relationship between leaf characteristics and different bud loading levels (average of two years)

Treatments (bud/vine)	MLA (cm^2)**	MLW (g)**	PTLA (m^2/vine)	PTLW (kg/vine)	PTLN (number)
120	185.51 b	7.98 c	21.047	9.014	1,129.55
180	185.62 b	8.64 a	32.313	15.158	1,754.48
240	194.17 a	8.67 a	48.097	21.478	2,477.26
300	193.05 a	8.46 b	58.610	25.678	3,035.25

, * – means with different letter in a column are statistically at $P < 0.01$ and $P < 0.05$ level of probability; LSD (MLA) – 1.281; LSD (MLW) – 0.176**

recorded as the average weight of 100 fruits. Total soluble solid contents (SSC) were measured using a hand-held refractometer on 10 fruits. Also, unit leaf area/100 g of fresh fruit weight (ULA/FW, cm^2/100 g) was calculated. The experiment was randomized block design with three replicates and each replicate included one plant. The total data of two years were analyzed by ANOVA and means were compared by the least significant difference (LSD) with the probability of 0.05.

RESULTS AND DISCUSSION

Mean leaf area changed between 185.50–194.17 cm^2 and mean leaf weight was 7.98–8.67 g. Significant differences among treatments were observed for MLA, MLW (Table 1). MLA and MLW increased with increasing bud loading levels, as well as the values of probable total leaf area, probable total leaf weight and probable total leaf number.

On whole vines, PTLA, PTLW and PTLN ranged between 21.047–58.610 m^2, 9.014–25.678 kg/vine, 1,129.55–3,035.25, respectively, according to bud loading level. Briefly, the increase in bud loading levels affected the leaf characteristics.

Several studies stated that the values were around 2,000–5,000 for mean leaf numbers on vine, 100 to 200 cm^2 for mean leaf area, 20 and 60 m^2/vine for probable total leaf area, 3,000–6,000 m^2 for leaf area per a decare, as average (Davison 1990; Sale, Lyford 1990; Samanci 1990; Snowball 1997; Cangi, Karadeniz 1999). Similarly, Snelgar and Thorp (1988) reported that the mean leaf numbers and total leaf areas on standard-pruned and T-trained vines were determined as 3,200 (43 m^2), 6,200 (79 m^2) and 3,900 (51 m^2), respectively. Our findings of MLA and MLW were similar to the results of previous studies of bud loading levels. The leaves in the canopy density were influenced fewer by sunlight intensity as reported by Davison (1990). Yield per vine was increased with increasing of bud loading levels, and mean yield values were between 34.84 and 100.96 kg/vine (12.19 and 35.34 ton/ha).

Among the treatments significant differences were observed when mean fruit weight, soluble solid content and unit leaf area/100 g fruit weight were considered (Table 2). MFW, SSC and ULA/FW decreased with increasing bud loading levels.

Average fruit weights and soluble solid contents were between 120.44–128.63 g, 7.68–49%, respectively. MFW and SSC values decreased more rapidly, while the bud loading levels increased. However, all of the MFW and SSC values were sufficient for standard (Table 2). These results may also suggest that the higher crop loads and consequent limitations on photosynthate could support the fruit growth. Variations of the MFW may arise from an insufficient pollination.

Several studies reported that the mean fruit weight decreased with increasing crop loading levels (Antognozzi et al. 1992; Richardson et al. 1994; Snelgar et al. 1997; Xiloyannis et al. 1997). In a similar study, Snelgar and Martin (1997) reported that the SSC of kiwifruit was not influenced by leaf area.

Table 2. The effects on some characteristics of different bud loading levels (average of two years)

Treatments (bud/vine)	Yield (kg/omca)	MFW (g)**	SSC (%)*	ULA/FW* (cm^2/100 g)
120	34.84	128.63 a	9.49 a	611.54 a
180	55.03	123.64 b	8.60 ab	599.28 b
240	81.68	120.44 b	8.24 b	593.88 b
300	100.96	121.20 b	7.68 b	581.88 c

, *– means with different letter in a column are statistically at $P < 0.01$ and $P < 0.05$ level of probability; LSD (MFW) – 3.528; LSDD – SSC – 1.102*; LSD (ULA/FW) – 9.517*

Table 3. Correlations between yield, leaf and fruit characteristics

	Treatment	MLW	MLA	MFW	SSC	ULA/FW	Yield	PTLA	PTLW
Treatment	1.000	0.585*	0.858**	–0.846**	–0.797**	–0.152	0.983**	0.991 **	0.996**
MLW		1.000	0.497	–0.0845**	–0.0487	–0.252	0.592*	0.569	0.636*
MLA			1.000	–0.796**	–0.614*	–0.143	0.879**	0.883**	0.881**
MFW				1.000	0.608*	0.274	–0.850**	–0.834**	–0.878**
SSC					1.000	–0.374	–0.691*	–0.838**	–0.797**
ULA/FW						1.000	–0.281	–0.068	–0.151
Yield							1.000	0.969**	0.982**
PTLA								1.000	0.992**
PTLW									1.000

Unit leaf area per fruit weight changed between 581.88–11.54 cm^2/100 g according to the bud loading applications. ULA/FW ratio reduced with the increasing bud loading levels. Although the fruit size reduced with higher bud loading levels, the sizes were not statistically significant (Tables 2 and 3).

Snelgar and Thorp (1988) obtained 100 g fresh weight per 210–315 cm^2 leaf area in their research, and reported that the biggest fruits (192 g) were obtained from the highest leaf (2,570 cm^2) area per fruit. Antognozzi et al. (1992) reported that a fruit density of 23–24 per m^2 leaf area allowed an average size class above 90 g to be reached while maintaining a Leaf Area Index with a good light penetration in the canopy in Hayward kiwifruit. Comparable figures for grapes are 600–1,300 cm^2 per 100 g (Winkler 1930), and for grapefruit 1,200–1,800 cm^2 per 100 g (Fishler et al. 1983). From Table 2 is clear that the production of large fruit required disproportionately larger leaf areas.

These results were similar to the findings of many previous reports (Costa et al. 1987; Lai et al. 1990; Standardi, Romani 1990; Inglese, Gullo 1992; Samanci et al. 1995; Samanci, Uslu 1996).

The correlations between the traits and the treatments are presented in Table 3. Significant correlations were determined among yield, leaf and fruit characteristics.

Positive correlations were observed among MLA, MLW, PTLA, PTLW and yield with treatments; negative correlations were between MFW and SSC with treatments. The results showed that there was a negative relationship between MFW and SSC with yield and a positive relationship between MLA and TLA with yield (Table 3).

Richardson et al. (1994) informed that average fruit weight decreased more rapidly with increasing fruit number at low crop loads than at higher loads, suggesting that vines become more efficient as crop loads increase. Antognozzi et al. (1992) found a negative correlation between fruit number per unit leaf area and fruit size.

Cooper and Marshall (1992) emphasized that leaf/fruit ratio had a greater effect on fruit size than crop load, and a ratio of 3:1 or 2:1 was necessary to give an adequate return bloom the following year. Famiani et al. (1997) noted that it is necessary to have 2–4 fully exposed leaves per fruit in order to get adequate sunlight and to ensure a normal fruit development and quality in kiwifruit.

Our results are in agreement with most of these findings. This work clearly showed that the level of bud loading in winter pruning is the most important factor affecting the yield, leaf and fruit characteristics in kiwifruit.

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Vliv různého zatížení očky na výnos, listovou plochu a plody u kiwi odrůdy Hayward

ABSTRAKT: Během dvou vegetačních období (r. 2000 a 2001) se v provincii Ordu v Turecku zkoušelo různé zatížení očky u keřů *A. deliciosa* (odrůda Hayward) v závislosti na výnosu, listové ploše a plodech. Šestileté sazenice kiwi se řezaly na 120, 180, 240 nebo 300 oček na rostlinu při 12 očkách na výhon. V článku se sleduje: pravděpodobná celková listová plocha (PTLA), pravděpodobný celkový počet listů (PTLN), pravděpodobná celková hmotnost listů (PTLW) a výnos na rostlinu. U plodů byly stanoveny tyto charakteristiky: průměrná váha plodů (MFW) a rozpustný pevný obsah (SSC, %). V dodatku se počítalo s jednotkou listové plochy na 100 g váhy plodů (ULA/FW). Listové charakteristiky se stanovovaly ve třech periodách vegetačního období. Sledovala se korelace mezi výnosem, listy, plody a variantou pokusu. Výsledkem pokusu byly v následném pořadí: průměrná listová plocha (MLA), průměrná hmotnost listů (MLW), PTLA, PTLN, PTLW v rozsahu mezi 185,51–194,17 cm^2, 7,98–8,67 g, 21,047–58,61 m^2/rostlina, 1 129,6–3 035,3 počet/rostlina, 9,04–25,68 kg/rostlina. Průměrný výnos rostliny se 120 a 300 očky byl 34,84 a 100,96 kg na rostlinu (12,19 a 35,34 t/ha). Průměrná listová plocha a průměrná hmotnost listů narůstaly se vzrůstajícím počtem oček při poklesu MFW a ULA/FW. Negativní poměr byl mezi MFW, SSC a výnosem a pozitivní poměr mezi MLA a PTLA u výnosu. Podle počtu oček byl poměr mezi ULA/FW 581,88–611,54 cm^2. Zvyšující se hustota porostu u obou počtů oček měla za následek pokles velikosti plodů. Jednotka listové plochy na hmotnost plodů byla v rozsahu mezi 581,88–611,54 cm^2/100 g v závislosti na počtu oček. Poměr ULA/FW se snížil se zvyšujícím se počtem oček. Vzrůstající počet oček měl vliv na výnos, listy a plody.

Klíčová slova: kiwi; *Actinidia deliciosa*; Hayward; řez; plody; listová plocha; charakteristiky; počet oček

Corresponding author:

Ass. Prof. Dr. Rüstem Cangi, Gaziosmanpaşa University, Faculty of Agriculture, Department of Horticulture, 60250 Tasliciftlik-Tokat, Turkey
tel.: + 90 356 252 1480, fax: + 90 356 252 1488, e-mail: rcangi@gop.edu.tr