CROP LOADING STUDIES WITH 'JONAGOLD' APPLE TREE

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A B S T R A C T

The aim of the present study was to estimate the relationship between the crop load, number of fruits produced per unit of trunk cross-sectional area (TCA), the average fruit weight and the yield of 'Jonagold' apple trees. The trees apple (*Malus domestica* Borkh. cv. 'Jonagold') grafted on P 60 rootstock were planted at 3.5 x 1.25 m spacing. In order to achieve a high diversity of fruit load, light (L) as well as heavy (H) thinning were applied. The fruitlets were not thinned in the control (Control) trees. The yield and average fruit weight depended on the applied thinning. The correlation coefficient between crop density (CD) and yield was positive, whereas that between CD and average fruit weight was negative. The mean fruit weight was influenced not only by the number of fruit per unit of trunk cross-sectional area but also by the age of a tree.

Kay words: apple, crop density coefficient, 'Jonagold'

INTRODUCTION

Profitability of an apple orchard depends on producing high yields of marketable fruit. Fruit growers must continuously improve their orchard agricultural practices to meet the growing consumer demand for better quality fruit. High quality apples consistently cost more and financial returns to growers are closely related to fruit size (Dobbs and Rowling, 2006). The consistent production of fruit of optimum colour and size can only be accomplished, when a proper balance between the vegetative growth and fruiting is maintained (Reginato, 2002). Frequently, apple trees bloom abundantly and set too many fruits to optimize the fruit size

and return bloom. Therefore, fruit thinning is considered to be one of the most important cultural practices affecting fruit quality and cropping consistency (Link, 2000; Czynczyk et al., 2001; Byers and Carbaugh, 2002). However, the effects of thinning are hard to predict because one cannot be certain whether the number of fruitlets left on a tree will be sufficient to produce a good quality crop. Too heavy fruit thinning reduces the yield dramatically and increases fruit sensitivity to many physiological disorders during storage (Looney, 1986). For these reasons, it is important to know how many fruits should be retained to obtain optimum fruit quality, good storability and adequate yield. This is particularly important with high-density planting because the trees in such orchards have a tendency to bear small fruits with poor colour intensity (Hugard, 1980).

Very precise criteria are necessary to judge the effectiveness of thinning and the parameter called crop load is one of them. Crop load is generally defined as the number of fruits per tree (Francesconi et al., 1996; Wünsche et al., 2005). Fruit loads which are too heavy reduce fruit size but they increase the crop and vice versa (McArtney et al., 1996; Treder and Mika, 2001; Treder, 2008). The size of a tree is usually expressed as trunk cross-sectional area (TCA). It is the most common surrogate measurement to determine the tree size and, indirectly, the capacity of a tree to produce fruits (Jimenez and Diaz, 2004; Wright et al., 2006). When the number of fruits per area unit of the cross section of a trunk (Lombard et al., 1988) or per volume of a tree canopy (Wright et al., 2006) is counted, the so called crop density parameter is obtained. The studies by Bergh (1990), Marini et al. (2002) and Treder (2008) indicate that the number of fruits per TCA may predict the proper crop load in the most satisfactory way. It is possible to calculate the CD index late in the spring, after the fruit set. The CD index can be used as an important and valuable tool for considering accurate fruit thinning intensity, and therefore to ensure high quality yield in the autumn (Treder, 2008).

The aim of this study was to estimate different levels of hand thinning on yield, fruit size and colour of 'Jonagold' apples.

MATERIAL AND METHODS

The experiment was carried out in the years 1998-2004 at the Dąbrowice Experimental Station of the Research Institute of Pomology and Floriculture, Skierniewice, Poland. 'Jonagold' apple (*Malus domestica* Borkh.) trees grafted on P 60 rootstock were planted in the autumn of 1992 in sandy loam soil, spaced at 3.5 x 1.25 m (2286 trees per ha). Before the experiment started (in autumn 1997), the contents of available phosphorus (P), potassium (K), and magnesium (Mg) in the top layer (0-20 cm) of the soil were optimal: 65, 130, and 51 mg kg^{-1}, respectively. The level of organic matter and soil pH were 1.4% and 5.2 respectively. Because of the adequate amount of P, K, and Mg in the soil, these

elements were not applied during the experiment. Only nitrogen (N) was applied annually at a rate of 60 kg ha^{-1}, as ammonium nitrate (34:0:0) at bud break, over the surface of herbicide strips (2 m-wide) along the rows. The trees were trained as a spindle by dormant and summer pruning, according to the principles recommended for intense apple planting. The trees were drip irrigated when the soil water potential at the depth of 20 cm fell below -0.03 MPa. To differentiate fruit load, hand-thinning of fruitlets was carried out each year, immediately after the June drop. Both light (L) and heavy (H) thinning were applied. The light thinning let developing all the fruitlets from the king flowers, while the heavy thinning let only those fruitless grow which were spaced at a distance of at least 20 cm from each other. The fruitlets were not thinned in the control (Control) trees. Each treatment was represented by ten trees. The fruitlets remaining on the tree (L and H treatments) were evenly distributed within the canopy.

The fruit yield per tree was measured and the mean fruit weight was calculated on the basis of a 15 kg fruit sample from each plot. This fruit samples were collected from the all of the tree canopies. The trunk diameter at 30 cm above ground was measured every year in autumn. Trunk diameter data were used to calculate trunk cross-sectional area (TCA).

The results were elaborated statistically by the analysis of variance and the significance of differences between the means were evaluated using Duncan's multiple range test at $p = 0.05$.

RESULTS AND DISCUSSION

The differentiation of the intensity of thinning resulted in different number of fruits per tree (Tab. 1). During the seven year experiment, the control trees bore on average 122 apples per tree per year. A tree produced on average 27 apples fewer per year when a low thinning was applied and 58 apples fewer when the thinning was high. In the year 1999 a spring frost spell occurred, which caused a significant decrease in the crop and no differences between the number of fruits per tree were noted. The lack of statistical significance for the same parameter among the variants of the experiment were also observed in the year 2003. It was probably caused by the high differentiation of fruit collected from the individual trees.

The fruit yield and its quality depended on the applied thinning. For the majority of the experimental years as well as for the total data, high thinning resulted in lower crop but the mean fruit mass increased (Fig. 1, 2; Tab. 2). These findings confirm the common opinion that thinning is an effective way to control the size and quality of apple crop (Link, 2000; Clever, 2007). The number of apples per tree and trunk cross-sectional area (TCA) measurements were used to calculate the crop density coefficient (CD). CD differed considerably from year to year and between the treatments (Fig. 3). Generally, the crop density values were lower in H treatment than in the Control (Tab. 2).

Table 1. The number of fruits per tree

Year	Thinning intensity		
	Control	light	Heavy
1998	102.7 b*	107.7 b	69.4 a
1999	53.7 a	59.2 a	44.9 a
2000	107.4 b	113.8 b	72.5 a
2001	137.3 c	108.4 b	69.7 a
2002	139.0 c	63.8 b	41.6 a
2003	106.9 a	88.4 a	77.5 a
2004	209.5 b	125.0 a	77.3 a
Average	122.4 c	95.0 b	64.7 a

*Means within the rows with the same letter are not significantly different at $p \leq 0.05$

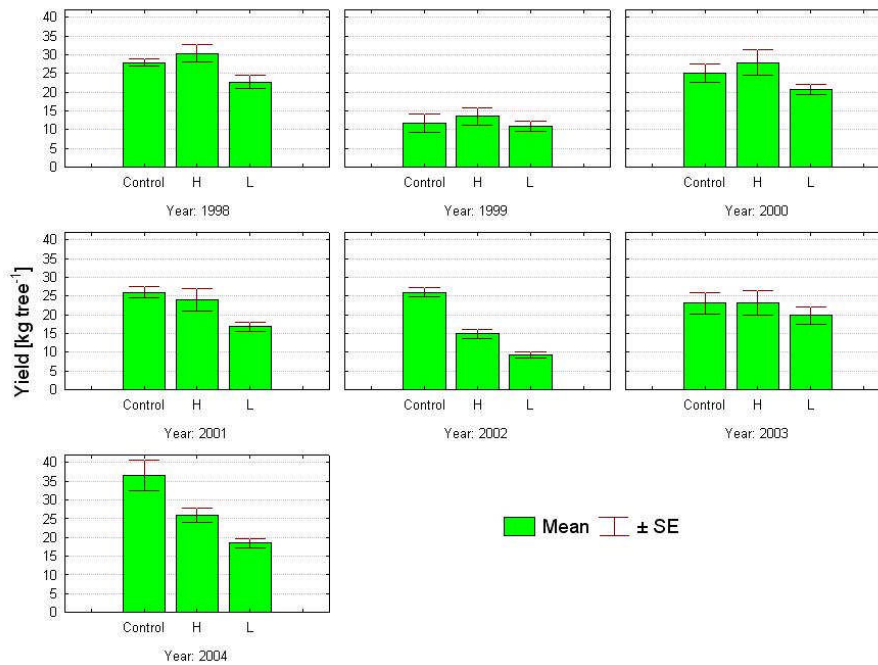

Figure 1. Yield of 'Jonagold' apple trees as affected by different levels of thinning in the years 1998-2004. L – light thinning, H – heavy thinning

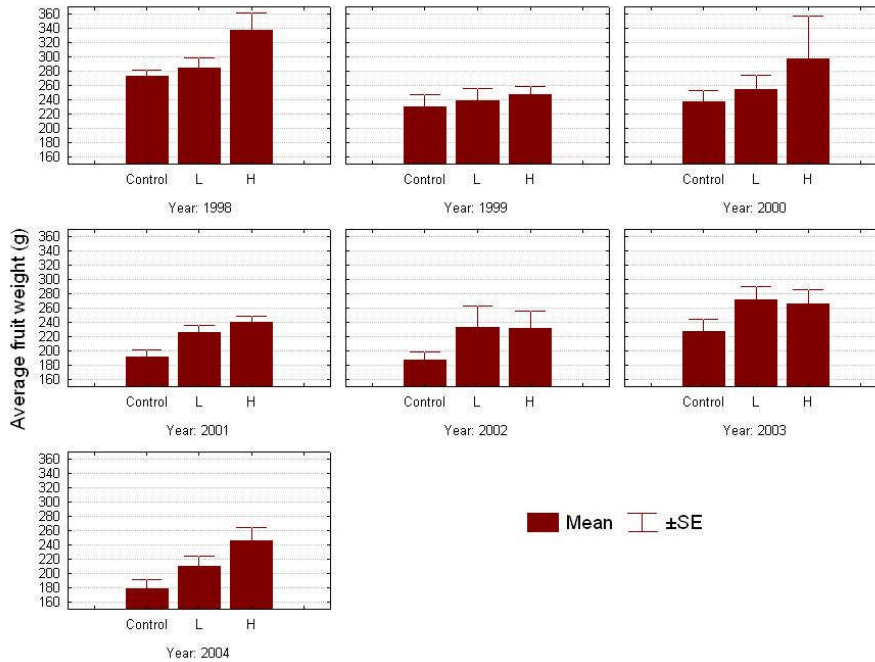

Figure 2. Average fruit weight of 'Jonagold' apple trees as affected by different levels of thinning in the years 1998-2004. L – light thinning, H – heavy thinning

Table 2. Effect of level of hand thinning on yield, mean fruit weight and crop density coefficient for the whole experimental period

Parameter	Thinning level		
	control	light	heavy
Average yield [kg tree^{-1}]	25.19 b*	22.85 b	17.00 a
Total yield [kg tree^{-1}]	176.33 c	159.94 b	119.01 a
Total crop decrease vs Control [t ha^{-1}]	–	37.47	131.06
Mean fruit weight [g]	218 a	245 b	266 c
Mean crop density coefficient [fruit no cm^{-2} TCA]	2.71 b	2.30 b	1.72 a

*Explanation: see Table 1

The lowest CD values were observed in the year 1999 due to spring frost damage. During the whole period of the experiment, for all combinations, the biggest number of fruit per tree was observed in 2004. However, the highest CD – more than 4 fruits per cm² of TCA for the control combination or light thinning, was obtained in the first year of experiment (1998). In the year 2004 the cross-sectional area of the trees was significantly bigger compared with the cross sectional area of the trees in 1998 (Fig. 4). The correlation between CD and yield was positive in all consecutive years, indicating that the higher the CD level. the higher the yield (Fig. 5). Tree yield is the result of the number of fruits on a tree and their weight (Link, 2000; Jimenez and Diaz, 2004). It has been known that the potential productivity of trees grows if their size becomes bigger. Since there is a close correlation between tree size and the diameter of its trunk, the size of a tree may be described using the trunk cross-sectional area parameter (Lombard et al., 1988; Strong and Azarenko, 2000). Because of the annual growth of the trunk diameter, quite significant differences can be observed between crops obtained from different trees which have the same level of CD parameter. On the basis of the formulae of linear regression (Fig. 5) it can be stated that in the year 1999, with a crop density of 3 fruits per cm² TCA, the total crop of approximately 30 T/ha was obtained. Five years later (2004) with the same fruit density there was twice as much crop. It means that the assumed values of the optimal fruiting density obtained in the subsequent harvesting seasons are not universal data for the whole period of orchard cultivation. The lowest average fruit weight was observed in the control trees, whereas the highest one was obtained from the heavily thinned trees. The correlation coefficients between CD and average fruit weight were negative in all years, which shows that the weight of individual fruits decreased with an increasing number of fruits per unit of TCA (Fig. 6).The mean fruit mass was influenced not only by the number of fruits per unit of trunk cross-sectional area but also by the age of a tree. The phenomenon of fruit size reduction along with the age of trees has been widely reported (Filewicz, 1917). An analysis of the curve of the formula of linear regression demonstrating the correlation between the value of the fruit density indicator and mean fruit mass shows that in the course of years the mean fruit mass decreased but the value of CD was similar (Fig. 6). This phenomenon results in a changeable proportion between the TCA and canopy volume. At the moment of tree planting, the distance between the trees is defined, which influences the canopy volume of an individual tree. To maintain the proper type and size of the crown, pruning is applied until the tree becomes mature, which in consequence gives a constant volume to the crown along with the growing trunk diameter. Increasing the fruit number per TCA unit decreases the ratio of leaf area to TCA and

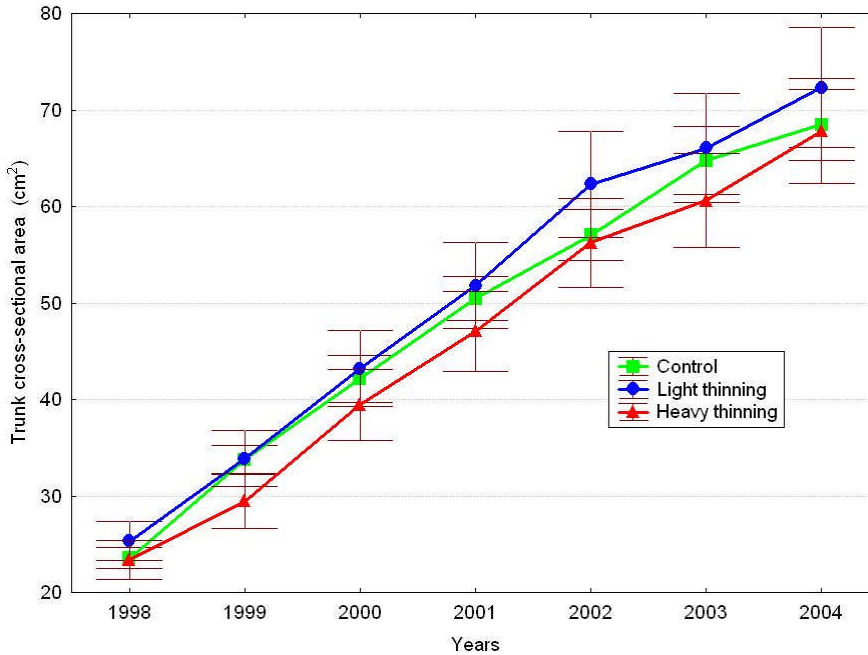

Figure 4. Trunk cross-section area of 'Jonagold' apple trees as affected by different levels of thinning in the years 1998-2004

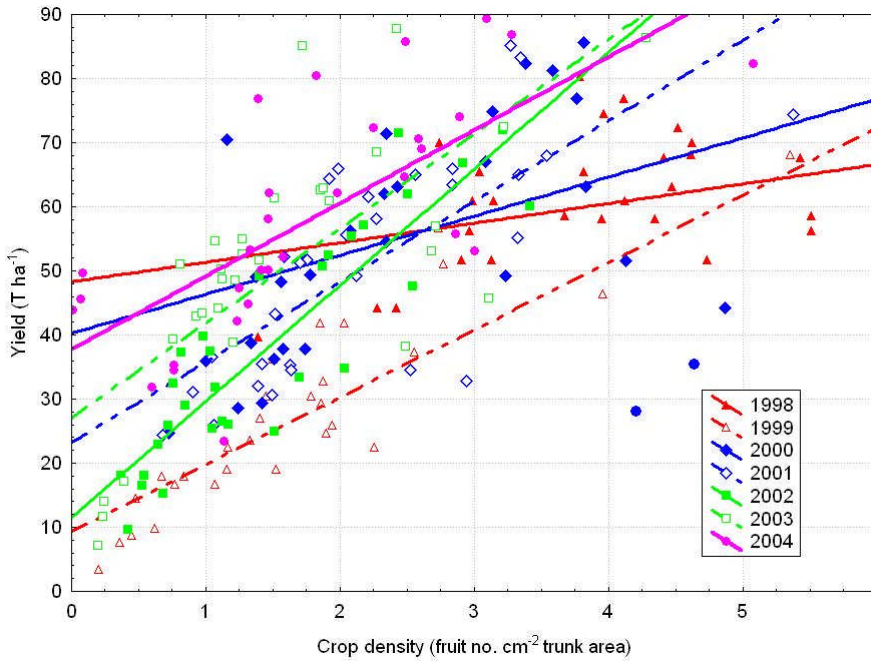

Figure 5. Effect of crop density on yield of 'Jonagold' apple tree in the years 1998-2004

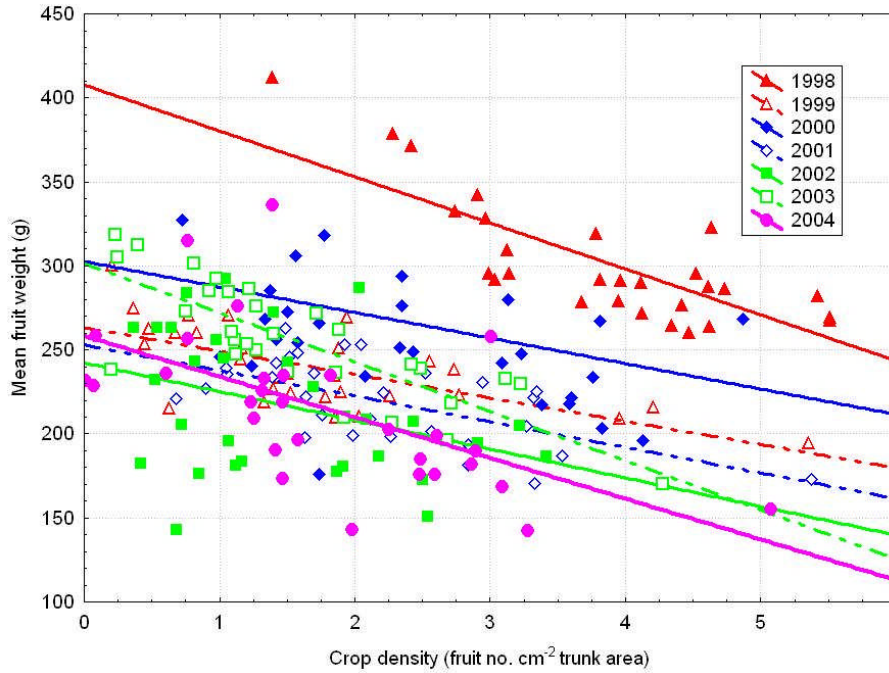

Figure 6. Effect of crop density on mean fruit weight of Jonagold in the years 1998-2004

consequently, leaf area to fruit, resulting in a decreased amount of available assimilates supporting fruit growth (Palmer et al., 1991). Additionally, the phenomenon of smaller productivity of older trees is observed. These points have to be taken into consideration if the orchard is to deliver fruit of expected quality to the market. CD coefficient can be useful in determining the optimal number of fruit of the assumed size on a tree. The negative correlation between CD and average fruit weight found in this study, as well as the positive correlation between CD and yield, confirms the earlier findings of Wertheim (1997) Lepsis and Blanke (2004), Treder (2008). The levels of thinning applied in the experiment also influenced the fruit size classification schedule. High thinning resulted in an increased number of very big fruits (diameter > 90 mm). In the years 1998 and 2000 the total mass of the overgrown fruits which grew on the thinned trees was bigger than the mass of fruits with optimal market size (70-90). The tendency of 'Jonagold' to produce overgrown fruit can be observed even on trees which were not thinned (1998, 2000; the fifth and seventh year of bearing fruit). Wertheim (1987) says that in the case of 'Jonagold' a crop load adjusted to achieve the required fruit

size is too large for good colour development. When optimized for an acceptable red coloration, a considerable portion of the fruit is too large for the market. Fruit thinning positively increases the ratio between the leaf area and fruit number, resulting in an increased availability of assimilates and potentially higher fruit quality at harvest (Palmer et al., 1991). When the area of leaves is smaller, apples might not reach the required size. Too intensive thinning may reduce both yield and effectiveness of photosynthesis, which means that the productive potential of trees is not realized (Giuliani et al., 1997). An important factor influencing the size of fruit at the predetermined level of CD is the type of rootstock used (White and Tustin, 2002; Marini et al., 2002). In order to practically use the relationships described in this paper to establish the intensity of thinning of apple fruitlets, such a model should be calibrated for the specific cultivar and rootstock, weather conditions and additionally, the age of the trees. The key role is played by the individual genetic properties of the plants. The CD values obtained in the experiment for the control combination were lower than those obtained in a similar experiment with the cultivar Gala (Treder, 2008). In the 'Gala' control trees, during the seven-year period of the experiment, in as many as four vegetative seasons, the level of CD was bigger than six fruit per cm² PPP, and in one of the seasons it was bigger than ten fruit per cm² PPP. 'Gala' is a cultivar with small fruit with a tendency to produce too many fruit. This tendency in turn reduces the mean mass of an individual fruit, so it is necessary to thin 'Gala' trees. In the case of the investigated cultivar 'Jonagold' the situation is quite different, as the trees as well as the fruit grow relatively big and the low intensity of fruit bearing causes the big size of the fruit, the overgrown fruit are eliminated from the market crop. On the basis of the findings obtained in the experiment it can be recommended to selectively thin the fruitlets on 'Jonagold' trees grafted on P 60 rootstock, being at the prime bearing period.

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BADANIA NAD INTENSYWNOŚCIĄ OWOCOWANIA JABŁONI ‘JONAGOLD’

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S T R E S Z C Z E N I E

Celem badań było określenie zależności pomiędzy intensywnością owocowania wyrażoną liczbą owoców przypadających na cm^2 powierzchni przekroju poprzecznego pnia a plonowaniem oraz średnią masą owoców jabłoni odmiany Jonagold. Jesienią 1992 roku drzewa zaszczepione na podkładce P 60 posadzono w rozstawie 3,5 x 1,25 m w Sadowniczym Zakładzie Doświadczalnym w Dąbrowicach. Dla osiągnięcia dużego zróżnicowania zagęszczenia owocowania zastosowano dwa poziomy przerzedzania zawiązków oraz nieprzerzedzaną kontrolę. Otrzymane wyniki wykazują istotną dodatnią korelację pomiędzy poziomem WGO a plonowaniem drzew i ujemną korelację pomiędzy tym wskaźnikiem a średnią masą owoców. Dla szczegółowego opisania tych zależności wyznaczono parametry ich równań liniowych. Wielkość średniej masy owoców uzależniona była nie tylko od intensywności owocowania, lecz także od wieku drzew.

Słowa kluczowe: jabłoń, wskaźnik gęstości owocowania, ‘Jonagold’