RELATIONS BETWEEN TREE AGE, FRUIT LOAD AND MEAN FRUIT WEIGHT

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A B S T R A C T

Hand fruit thinning was performed for four successive years on 'Gala' apple trees grafted on dwarf P 2 rootstock and planted at a density of 3333 trees/ha. Trees were 5 years old when the experiment started. Three thinning treatments were done with the assumption that apples at harvest should be medium sized (8 fruits per kg), large (7 fruits per kg), or very large (6 fruits per kg). To obtain such results, 84; 74 or 63 fruitlets were left per tree in the beginning of June. Two other treatments included thinning fruitlets with any defects, and no thinning in the control. To avoid subsequent effects of fruit load on blooming intensity, each year new trees were chosen for the experiment. The results indicated that with tree aging fruit load must be decreased to assure the same mean fruit weight.

Key words: 'Gala' apples, tree aging

INTRODUCTION

Over the years, the length of time for full orchard productivity has become shorter and shorter. In Europe, at the turn of the XX century, orchards were used for about 50 years and in the USA even longer. Old orchards used to be rejuvenated by cutting or grafting (Filewicz, 1917). In the second half of XX century orchards were used for only 30-40 years (Pliszek-Słowińska, 2008), and today it is only 10-15 years. This is why it is necessary to replace old trees with new ones. Other reasons for replacing old trees are new technologies of orchard production, and new cultivars. Observations have confirmed that scions of rootstock that are dwarfer age more quickly. Apple cultivars grafted on the dwarfest rootstocks (P 22, P 59, M.27) show the first symptoms of senescence several years after plating. Symptoms are in the form of shorter shoot growths in the subsequent years and fruit which does not reach the required size (Mika, 2004). Quick senescence of apple cultivars grafted on the dwarfest rootstocks (P 22, M.27) is seen as disadvantageous (Hrotko, 1999). Similar symptoms can be observed on apple trees grafted on M.9, though the symptoms appear more slowly. Farmers claim that it is very hard to obtain the required quality of fruits when the trees are 15 years old (Kulig, 2009). In order to meet the fruit size requirements it is necessary to thin the fruitlets. The symptoms of senescence can be observed in all species but in some of them the process is very quick. Non-pruned peach trees grow old so quickly that after several years the lower branches die out (Tukey, 1980). In the production of peaches it is essential to shorten the branches or rejuvenate the branches (rotate the fruit bearing branches) the third year after planting. The sour cherry cultivar ‘Morello’ grows old very quickly and can be cultivated for only 15 years providing the branches are intensely cut. In pears and sweet cherries senescence does not play an important role in their cultivation. The trees might grow old quicker if they were planted in poor soil or on the site of a replanted orchard. White and Tustin (2000) compared the growth and fruit crop of ‘Royal Gala’ apple cultivar grafted on the semi-dwarf rootstock M.26, and on moderately growing MM 106. The trees were planted in two areas; in the soil of a farm field, and on the site of a replanted orchard. The trees grafted on M.26 produced a 20% higher crop than those grafted on MM 106, but their crowns were 60% smaller, which means they were more productive. In the "worn" soil the effect was reverse. In semi-dwarf trees, as well, a negative relationship was observed between the fruit density coefficient and the size of fruits. Fruits from the trees growing in the "worn" soil were smaller than those growing in the soil of the farm field at the same fruit density coefficient. The profitability of an apple orchard depends on fruit quality and, more precisely, on fruit size. Apples, whose circumference is less than 6.5 cm, are not accepted on the market as salable. These small apples go to fruit processing factories bringing in a minimal price. Estimation of the quality of apple rootstocks takes into consideration their influence on fruit size. The relationship between the fruit density in the canopy and the fruit size is quite complex. The fruit density can be precisely measured with the crop density coefficient (CD), i.e. the number of apples per cm^2 of the cross-sectional area of the trunk (TCA). The mean weight of an apple, as well as its size, signifies a negative correlation with the number of apples in a tree. In order to precisely estimate the mean weight of an apple, the analysis of covariance has to be used, where the changeability of fruit weight depends on the fruit density in the canopy (Forshey and Elfing, 1977). Experiments related to the value of a series of apple rootstocks carried out in the USA, generally showed that apple cultivars grafted on the slowest growing rootstocks (M.27, P 1) produce the smallest fruits. Those grafted on quicker growing rootstocks (M.9, EMLA, B 9, Mac 39), produce bigger apples. However, the size of apples depends more on their density in the crown than on the kind of rootstock (Marini et al., 2002).

Fruit potential of a tree depends on its size. Trees grafted on vigorously growing rootstocks, after reaching their ultimate size, produce higher crops than dwarf trees (Czynczyk et al., 2009). An abundance of fruit in an apple tree results in a smaller sized fruit. This relationship is influenced by weather conditions. A required fruit size is based on market demand. The size directs the way of orchard cultivation, mainly the intensity of fruitlet thinning. Preston (1969) observed on the basis of a 7-year-long experiment with fruit thinning, that the cross-sectional area of a tree trunk can be used to determine the required number of apples in a tree crown. According to Webb et al. (1980), the tree trunk circumference is a slightly better parameter, but the weather conditions in the area where the trees are growing must be taken into account. Lauri et al. (2004) agreed to take the cross-sectional area of the branches to estimate the intensity of fruit thinning in ‘Galaxy’ apple trees grafted on M.9, and ‘Pajam’ grown in the form of “Solaxe”. The fruitlets were thinned leaving 4-6 fruits per cm^2 of a cross-sectional area of the branch. Intensive and detailed cutting of trees produced the best results if four fruits were left per $1cm^2$ of the branch. Mika (2004), using the results of several experiments and numerous observations of orchard production, suggests fruit thinning up to a determined number of fruitlets which equals the distance (in centimeters) between the trees in the row. According to this rule, 100 fruitlets should be left in a dwarf apple tree crown, planted every 1 m in a row. In the orchard literature, there are results of many experiments in which the influence of fruit thinning done at difference growth stages (from pink bud to natural fruit fall) on fruit crop, fruit quality and fruit bearing regularity were determined. Authors of orchard literature claim that the earlier the fruit thinning is done, the larger the resulting leaf area, and the easier the availability of assimilates to fruits becomes, thus larger the fruits grow (McArtney et al., 1996).

The aim of this work was to determine the relationship between the age of an apple tree and its potential to nurture the given number of fruits in the tree. Finding such a relationship may make it possible to understand the process of tree senescence.

MATERIAL AND METHODS

The experiment was carried out for four years (1997-2000) in the orchard of the Institute of Pomology and Floriculture in Prusy, near Skierniewice. ‘Gala’ apple trees grafted on P 2 rootstock, planted in the spring of 1993 were the experimental material. The trees planted on sandy loam podzolic soil (pH 6-6.6) were spaced at 3.5 x 1.0 m (3333 trees/ha). The trees were not irrigated. The soil in tree rows was clean cultivated. Alleyways were grassed down and the grass was mowed 6-8 times a season. The mineral fertilization was moderate, an average of 60 kg/ha of macro-elements, were applied annually. The chemical control against pests was applied according to the recommendations for commercial orchards. Each year, investigations were carried out on selected trees of similar size, growth rate and blooming intensity. Both growth rate and blooming intensity were taken as calibration variables. Every year a new selection of trees was chosen in order to avoid the consequent influence of fruiting on blooming. The experiment was randomized and carried out in five replications. An individual tree constituted a replication.

The apple trees were thinned with various intensity after the natural June fruit drop. A determined number of fruitlets were left, and this number was calculated in such a way as to get a crop of about 30 t/ha (Weber, 1996). The fruitlets were thinned according to the assumption that 1 kg of 'Gala' apples contains eight apples of "medium" size or seven "big" apples, or six "very big" ones. According to this assumption, the mean mass of one apple measures 125 g, 143 g and 166 g, respectively. In order to obtain the calculated crop of 30 t/ha, 63, 74 and 84 fruitlets should be left on a single tree.

The following combinations were used in the experiment:

A – thinning to obtain fruits with a mean mass of 125 g (ca. 84 fruits were left on a tree),

B – thinning to obtain fruits with a mean mass of 143 g (ca. 74 fruits were left on a tree),

C – thinning to obtain fruits with a very big mass of 166 g (ca. 63 fruits were left on a tree),

D – thinning applied only to damaged, malformed or very small fruitlets, Control – no thinning applied.

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

RESULTS

Measurements carried out in the experiment showed a dynamic of annual growth of the tree trunk cross-sectional area (Fig. 1). During the last three years of the investigations (6, 7 and 8th year of the experiment) the cross-sectional area of the tree trunk grew to approximately 9.77 cm^2, which constitutes as much as 57.64% of increase.

The number of fruits on a tree before harvest time reflects quite accurately the intensity of thinning (Fig. 2). The differences among the A, B, C combinations, and the control were statistically significant (Fig. 3). The statistical analysis of the results showed significant negative correlation (except

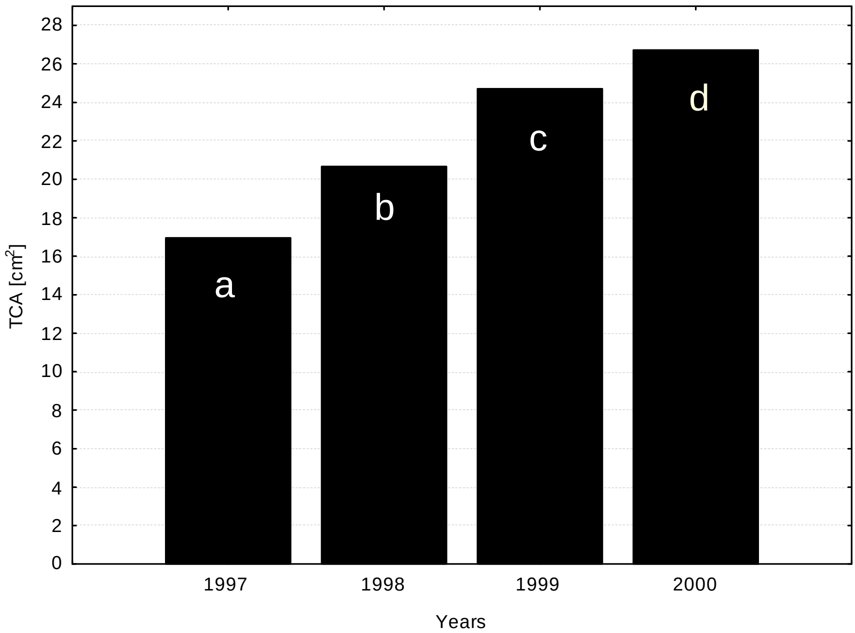

Figure 1. Tree trunk cross-sectional area of 'Gala' apple trees grafted on P 2 in 1997-2000

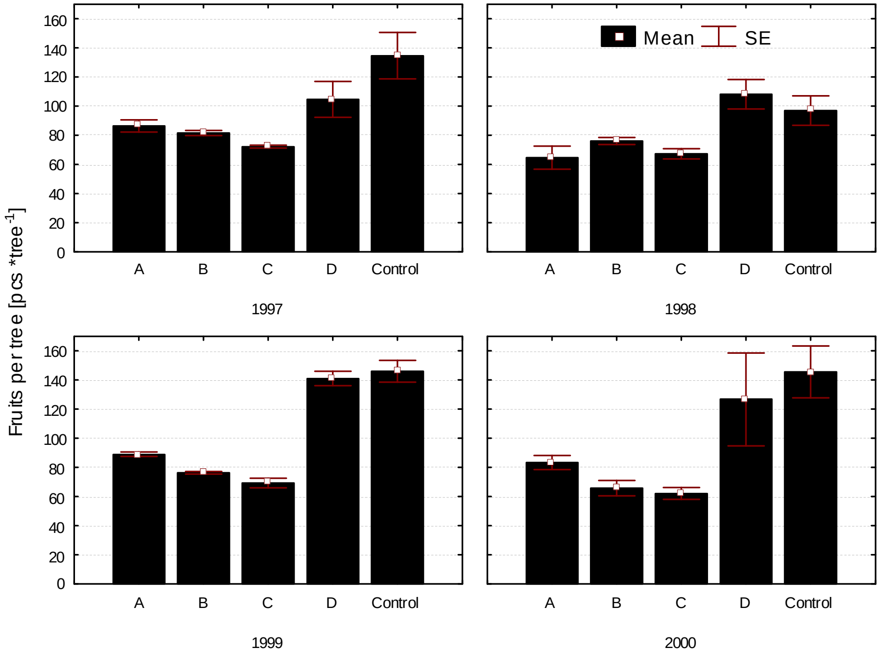

Figure 2. Number of fruits per 'Gala'/P 2 tree in the years 1997-2000

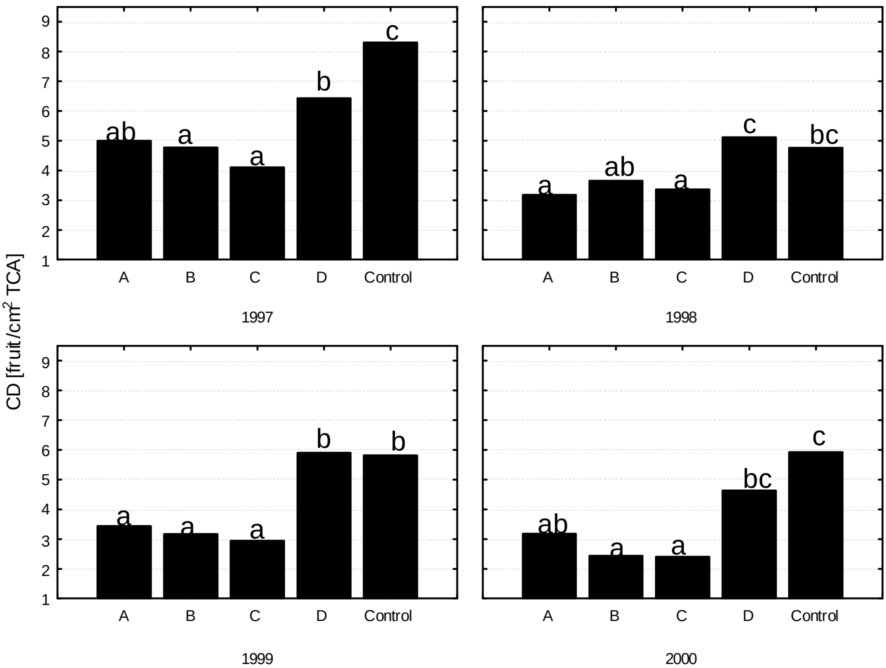

Figure 3. Fruit crop density coefficient of 'Gala'/ P 2 tree in the years 1997-2000

for the results from the year 2000) between the fruit density coefficient and the mean fruit mass. Along with the growing number of fruits per one unit of the cross-sectional area of tree trunk, there was a significant decrease in the mean mass of the apples (Fig. 4). The equations of linear regression also show a decrease in the mean fruit mass as the trees get older. Having maintained the same level of fruit density coefficient, the obtained mean fruit mass in the following years was lower and lower. On the basis of the analysis of multiple regression, an equation was worked out whose variables (fruit density coefficient and age of tree) appeared to be significant: mean fruit mass (g) = 272 -7.6 * CD – 14.4 * number of the consecutive years of cultivation. The analysis showed that the fruit density and age of tree have a significant influence on the mean fruit mass (R = 0.81). On the basis of the results obtained, it could be stated that along with the increase of fruit density by one unit (1 fruit/cm^2 TCA), the mean fruit mass lowers by 7.6 g. Maintaining the same level of fruit density coefficient in the consecutive years of fruit bearing (1997-2000, from the 5th to 8th year of cultivation), the mean fruit mass lowered by 14.4 g per year. In order to maintain mean fruit mass on the same level in the consecutive years of the investigations, it would be necessary to lower the fruit density by as much as 1.89 fruit/cm^2 TCA.

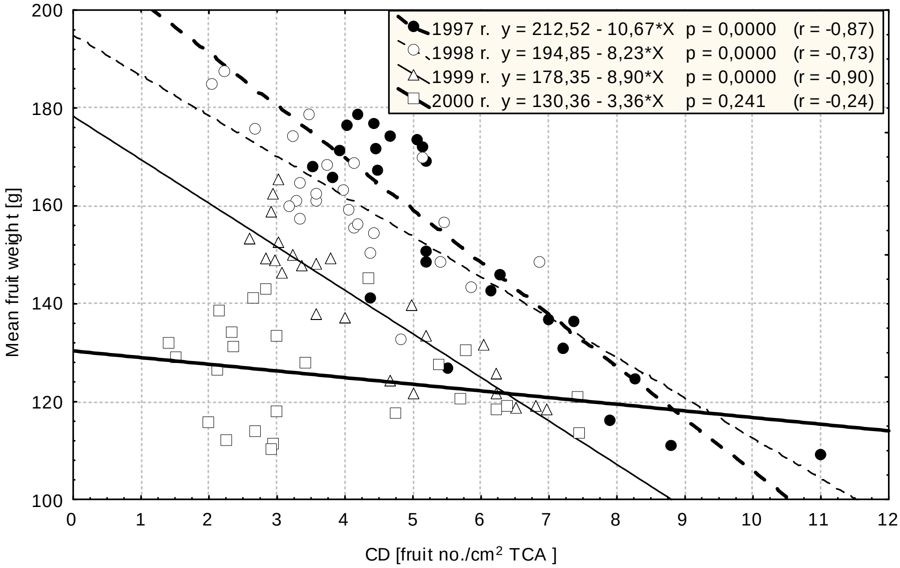

Figure 4. Relationship between the fruit crop density coefficient and mean fruit mass of 'Gala'/P 2 trees in the years 1997-2000

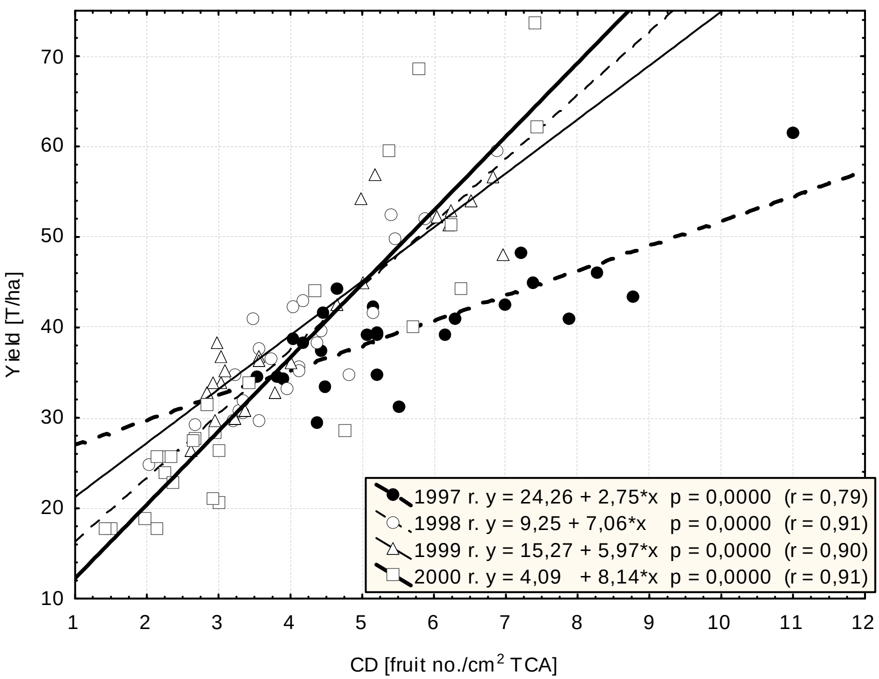

Figure 5. Relationship between the fruit crop density and fruit crop (t/ha) of 'Gala'/P 2 trees, in the years 1997-2000

The analysis of multiple regression proved (R = 0.81) that the crop depends on the fruit density coefficient and age of tree:

Crop (T/ha) = 2.4 + 5.5 * CD + 1.8 * number of consecutive years of cultivation.

On the basis of the model obtained, it can be stated that along with the increase of fruit density by one unit the crop increased by 5.5 t/ha. By maintaining the same level of fruit density coefficient in the consecutive years of cultivation, the crop increased by 1.8 t/ha/year. A high positive correlation between the fruit density coefficient and fruit crop was observed in all the years of investigation (Fig. 5).

DISCUSSION

The results obtained in this experiment do not confirm the results obtained by Preston (1969) in the experiment with thinning of fruitlets in vigorously growing apple trees. Preston writes that the fruits reached the required size in the consecutive seven years of cultivation, at the constant fruit thinning coefficient expressed as the number of apples in relation to the tree trunk diameter. Such a result can be interpreted with the fact, that apple trees grafted on quickly growing rootstocks show symptoms of senescence much later and the process of growing old is slower than in the dwarf apple trees. Treder and Mika (2001) showed a significant lowering of the fruit crop (smaller fruits) along with the age of the intensive (3.5 x 0.3 m) planting of ‘Lobo’ grafted on rootstock M26. The authors proved that in the period of four years of cultivation (from the 3rd to 6th year after planting) the fruit density coefficient should be lowered from the initial level of 6.2 fruit/cm^2 TCA to a mere 1.6 fruit/cm^2 – on the average decrease of 1.15 fruit/cm^2/year. This must be done in order to maintain the mean fruit size on the level of Ø 75 mm (148 g).

In our experiment with the trees grafted on rootstock P 2, fruit density was 1.89 fruit/cm^2/year. Treder (2008) describes the influence of the age of an orchard on the lowering of the mean fruit mass. The author carried out long-term experiments on ‘Gala’ apple trees (3.5 x 1.25m) grafted on rootstock P 60. The results showed that in the period of 6 – 12 years after planting, while maintaining the same level of crop density, the mean fruit mass lowered by 5.1 g/year. In the present experiment, with the intensive planting of trees grafted on dwarf rootstock, the mean fruit mass lowered by as much as 14.4 g/year, on the average. There is proof for the fact that fruits become smaller as the tree ages caused by the change in the age structure of fruit bearing branches. The proportion between the one-year and two-year old stems to several-year-old stems changes in favor of the earlier. Even in very general observations of trees it can be seen that the most attractive apples grow on two-year old stems. Such stems grow in the outer part of the crown; the older stems grow inside the canopy. This is one of the factors causing the apples growing on the outside of the crown to be bigger than those growing inside the canopy (Mika et al., 2002). Another factor is the better insolation of the peripheral parts of the crown. The age related change in the structure of the stems can be easily observed in apple trees grafted on very dwarf rootstocks of P 22 and P 59. This age change can especially be observed if the trees are planted in a former orchard area. Several years after planting, the tree canopies are full of several-year old stems because only a few new stems appear. The lack of new growth causes the trees to be unable to fill the space in vertical and horizontal directions; as a result the harvest does not increase (Mika and Piskor, 1997). Similar changes in the age proportion of stems can be observed in dwarf sweet cherries grafted on PH-L rootstock. Only several-year old trees produce many long stems, which bear a lot of fruits. Between the 5th and 10th year of cultivation the proportion between the one-year old stems and older ones changes negatively. This change is to such a degree that fruits do not grow to the required size. The size of fruits also depends on the fruit load, quality of buds, competition between fruitlets and vegetative buds (Link et al., 2000). Fruit bearing potential of the apple tree can be modified in the individual stages of tree development. This modification includes, among others, the production of stems able to form flower buds (Webb et al., 1980). Cutting of trees should secure the right stem age proportions. The majority of cutting methods leave behind the cutting of small, old stems from inside the crown. It is too much work; too time consuming. Lauri et al. (2004) point out the necessity of the change in the proportion between the young and old stems in apple trees grafted on M.9 rootstock grown as spindle. For dwarf apple trees in the full fruiting period, they suggest a crown form called “centrifugal”. It can be obtained by cutting off all small stems growing in the middle of the crown around the leading stem. The young stems on the outside of the crown are left.

To maintain a constant crop of apples with a determined size of stems, a balance between various factors is necessary. First of all, there must be a balance between vegetative growth and fruit bearing. Such proportions are subject to change along with the age of a tree and its natural tendency to form too many fruits. The intensification of orchard production and the growing demand for quality, make it necessary to work out a method for evaluating the fruit potential of fruit trees. The presented results have shown that the size of apples can be modified within a certain range. However, dwarf rootstocks and dense planting can have a significant negative influence on this characteristic in aging orchards.

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ZWIĄZEK MIĘDZY WIEKIEM DRZEW, GĘSTOŚCIĄ ROMIESZCZENIA OWOCÓW W KORONIE I ICH WIELKOŚCIĄ

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

Zawiązki owocowe przerzedzano ręcznie przez cztery kolejne lata na jabłoniach odmiany ‘Gala’ szczepionych na podkładce P 2, rosnących w zagęszczeniu 3333 drzew/ha i prowadzonych w formie wrzecionowej. Doświadczenie rozpoczęto, gdy drzewa miały 5 lat. Zastosowano trzy intensywności przerzedzania przy założeniu, że jabłka w czasie zbioru powinny być średniej wielkości (8 owoców w kg), duże (7 owoców w kg), bardzo duże (6 owoców w kg). Aby zyskać oczekiwany rezultat pozostawiano na drzewie odpowiednio: 84; 74 lub 63 zawiązki owocowe po ich przerzedzeniu pod koniec czerwca. Jako kontrolę pozostawiono zawiązki bez przerzedzania i drzewa, z których usunięto tylko zawiązki z defektami. Aby uniknąć wpływu następczego przerzedzania na owocowanie, wybierano co roku nową partię drzew z jednakową intensywnością kwitnienia. Doświadczenie wykazało, że z upływem lat trzeba zmniejszać gęstość rozmieszczenia owoców w koronie jabłoni, aby utrzymać ich niezmienną wielkość. Drobnienie jest wynikiem starzenia się drzew i zmiany struktury pędów w koronie.

Słowa kluczowe: ‘Gala’, jabłoń