THE EFFECT OF HAND AND CHEMICAL FRUIT THINNING ON 'GOLDEN DELICIOUS CL. B' APPLE FRUIT QUALITY

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Abstract

The effect of hand vs. chemical fruit thinning with 1-naphthaleneacetamide and carbaryl on apple fruit quality has been studied. The thinning method had no effect on trunk cross-sectional area (TCSA), yield and yield efficiency but chemicaly thinned trees had lower crop density. The fruits from hand thinned trees had lower fruit weight (FW), higher firmness, soluble solids content (SSC), SSC/titratable acid ratio (SSC/TA), Hue angle and lower ripening index (RI) than the fruits from chemically thinned trees. A negative correlation between FW and firmness was noticed in booth hand and chemical thinning. In chemical thinning, FW has been in negative correlation with SSC/TA and in positive correlation with RI. RI was in positive correlation with the TA and in negative correlation with SSC/TA for booth thinning methods. SSC was in negative correlation with starch content in chemical thinning only. In hand thinning, the correlation between Hue and RI was negative. The principal component analysis of FW, TA, SSC/TA, RI and Hue showed that the first two principal components (PC) were significant and they comprised 72.4 % of total variability. PC1 was mostly composed of TA, SSC/TA and RI, and PC2 of FW and Hue. PC1 and PC2 well separated fruits by the thinning method.

Key words: Malus domestica Borkh., hand thinning, carbaryl, naphthaleneacetamide, fruit quality

Introduction

The fruit thinning is regularly applied in apple in order to achieve regular yield and uniform quality. Application of chemical thinners is justified for three reasons: they reduce biennial bearing effect, they reduce need for expensive manual thinning and they improve the quality of the remaining fruits (23). The later is not always true, since contrary to positive effects such as increase in fruit mass (18, 3) and reduction in biennial bearing (14, 23), the chemical thinning of fruit may sometimes cause adverse effects such as reduced yield (21, 20, 5, 8, 9, 14, 17, 16), reduced fruit growth (12), fruit russeting (18, 5, 3), fruit deformation (20), poor fruit colour (5, 13), and lower calcium concentrations in fruit (9).

Chemical thinners include different chemicals, but plant growth regulators and some insecticides are used for thinning in most cases. Results from the recently published literature

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point to advantages of combining certain growth regulators and insecticides for thinning. Combination of carbaryl and 1-naphtaleneacetic acid has given good results in some years but caused excessive thinning in others (20). Generally, mixtures of growth regulators (9), or growth regulators and insecticides (5, 16) are used, particularly for cultivars which are not easily thinned (5). In such cases, it is possible to reduce the concentration of individual thinner. This is important from the environmental point of view.

Most of the thinning literature is focused on the effect of thinners on yield or other production aspects, while the fruit quality becomes a secondary issue. Link et al. (14) have reviewed the Germany experience with chemical thinning accumulated over three decades and concluded that there are two groups of quality components. First group includes size, colour, skin performance, firmness, sugar and acid content. The second group includes calcium and potassium levels which are important for storability and occurrence of physiological disorders. Thinning intensity differently effects these two groups, therefore it is important to select an optimal thinning strategy by growing and local market conditions. The data reported in literature on the effect of chemical thinners on fruit quality differ. Hess et al. (10) reported lower firmness and sugar content in chemically thinned apples, but there are also opposite results (7, 2, 4, 15). In some cases fruit quality did not appear to be affected by the treatments (19, 1). 'Golden Delicious' apple often asks for additional thinning of the fruits by hand after chemical thinners (22) or for combining of 1-naphthaleneacetamide (NAD) with carbaryl (23) to achieve optimal results. These two strategies might have different effect on fruit quality. Therefore our aim was to determine the effect of hand and chemical thinning (NAD + carbaryl) on the most important quality parameters of 'Golden delicious clone B' apple.

Material and methods

ORCHARD

The thinning experiment was conducted in 2002, at the 'Golden delicious clone B' orchard near Daruvar (45º36' N and 17º14' E). The trees were grafted on M9 rootstock and planted at 0.7 m within a row and 3 m between rows. Training form is slender spindle and trees were 4 years old. Space between rows is grassed and all cultural practices are applied regularly.

THINNING EXPERIMENTS

Two thinning methods were tested. The first treatment was hand thinning to achieve one fruit per cluster when fruit diameter (FD) was between 12-16mm, and the second treatment included chemical thinning with carbaryl (1000 ppm at 8-12 mm FD) and NAD (40 ppm at 12-16 mm FD). Sprying volume vas 1200 L per ha.

MEASUREMENTS AND CHEMICAL ANALYSIS

Measurements in the orchard included trunk cross-sectional area (TCSA) 15 cm above grafting place, yield per tree, crop density and yield efficiency. All measurements have been done at harvest on 10 trees per treatment. Harvest date has been determined according to the standard method and fruits were harvested on September 13, 2002.

The fruits were transported to the laboratory where other analyses were done on samples of 30 randomly selected fruits for each thinning method.

The fruits were weighted on analytical balance to determine the fruit weight before colour measuring according to CIE Lab colour system on colorimeter. The colorimeter calibration was done with black and white plates supplied with the instrument and the fruit colour was represented with Hue angle (Hº).

Firmness was measured using Effegi penetrometer with 11 mm probe as an average value from four measurements made at opposite fruit sides.

The fruits were cut in half. One half (from petal side) of each fruit was used to determine starch with starch-iodine test according to Lamburg scale (24). The juice from the second half was used for determination of soluble solids content (SSC) with refractometer (Carl Zeiss, Germany), and titratable acids (TA) by titration with 0.1 N NaOH and expressed in percent of malic acid per 100 ml of juice.

Data on firmness, starch and SSC were used for calculation of ripeness index (RI) from:

$$RI = \frac{Firmness}{Starch * SSC}$$

DATA ANALYSIS

Data analysis was conducted using the SAS software, version 6.12 (SAS Institute, Cary, NC, USA) using one way ANOVA. Since there were only two thinning treatments, F-test was sufficient for mean separation.

The data on fruit weight, TA, SSC/TA ratio, RI and Hue angle were subjected to the principal component analysis (PCA) after standardisation of all parameters to zero mean and unit variance.

Results and discussion

YIELD AND PRODUCTIVITY

The thinning method had no effect on tree size (TCSA), yield and yield efficiency (Table 1).

Table 1. Effect of thinning method on growth and productivity of 'Golden Delicious cl. B' apple

Thinning method	TCSA (cm2)	Yield (kg/tree)	Crop density (fruits/TCSA)	Yield efficiency (kg/TCSA)	Fruit weight (g)
Hand	14.13	15.83	6.59	1.14	173.59
Chemical	16.27	14.91	4.37	0.93	213.78
F-test	n.s.	n.s.	**	n.s.	**

Note: ** means are significant at P≤0.01 according to one-way ANOVA F-test

Our data are contrary to those obtained by some authors who report on yield reduction (21, 20, 5, 8, 9, 14, 17, 16); however, the results were also reported on yield not unaffected by thinners (7, 18) or even increased (7).

Crop density and fruit weight were significantly affected by the thinning method (P≤0.01) (Table 1). Carbaryl increases specific leaf weight, leaf area per spur and bourse shoot length on the most productive spurs, which increase fruit weight (15). NAD has a favourable effect on fruit growth (21). Therefore chemical thinners used in our study contributed, together with lower crop

density and beter leaf/fruit ratio, to the increase in fruit weight. This increase was sufficiently high to ensure yield and yield efficiency that were not significant to the hand thinned trees.

Weather conditions have strong influence on the thinner efficacy (23, 4) and another important factor is thinner concentration since when used in larger doses they could cause phytotoxicity in some cultivars (19). Crop load, age of wood, flower bud quality, competition within clusters and canopy are important factors affecting the response to thinning (14). Some authors reported considerable year-to-year variation in responses to thinning (19), but our experience is that the thinners do not cause yield reduction if they applied properly, at least not in the ecological conditions of the Croatian mainland.

FRUIT QUALITY

Fruits from the hand thinned trees had higher firmness ($P \leq 0.01$), SSC and SSC/TA ratio ($P \leq 0.001$), and colour ($P \leq 0.001$) than fruit from the chemically thinned trees. RI was significantly lower ($P \leq 0.05$) in the hand thinned fruits (Table 2). Starch degradation and TA were not affected by the thinning treatment. (Table 2).

Johnson (11) reports of increased fruit firmness as a direct result of the reduction in fruit number and yield. This is not in agreement with our data since the crop density was significantly lower in chemically thinned trees (Table 1) and the only possible explanation for that is direct effect of thinners on fruit softening due to an increased amount and/or activity of related enzymes. In the literature, mostly positive effects are reported of thinners on fruit quality. SSC and firmness were improved with endothal and benzyladenine (2, 4) and El Salhy (7) increased fruit SSC, SSC/TA ratio and sugar content by thinning with etephon. Carbaryl, also used in our study, increased SSC and TA (15). Contrary to the cited results, carbaryl in our study (Table 2) failed to improve the fruit quality with, probably due to negative effect of NAD (10) or its interaction with NAD despite the fact that the crop density was much lower than in the hand thinned trees. The cultivar effect should not be overlooked since carbaryl effect is also cultivar dependent (15).

Table 2. Effect of thinning method on fruit quality of 'Golden Delicious cl. B' apple

Thinning method	Firmness (kg/cm2)	Starch (1-5)	SSC (% Brix)	TA (% as malic)	SSC/TA	RI	Colour (Hue °)
Hand	6.90	4.23	13.38	0.39	34.88	0.13	104.30
Chemical	6.54	4.11	12.11	0.41	29.52	0.14	103.50
F-test	**	n.s.	***	n.s.	***	*	***

Note: *, **, *** means are significant at $P \leq 0.05$, 0.01 and 0.001 according to one-way ANOVA F-test

The correlation analysis (Table 3) showed negative correlation between fruit weight and firmness in booth thinning methods. RI was in positive correlation with TA and in negative correlation with SSC/TA. However, there were also some differences depending on the thinning method. SSC was in negative correlation with starch content in chemical thinning only. This method showed negative correlation between FW and SSC/TA and positive correlation between FW and RI. In hand thinning, the correlation between RI and Hue was negative. No correlation was determined between the Hue and firmness, which is contrary to data reported by Daugaard and Grauslund (6).

Table 3. Correlation coefficients between fruit characteristics of hand and chemically thinned fruits of 'Golden Delicious cl. B' apple

Correlation	Thinning method	
	Hand	Chemical
Fruit weight : Firmness	-0.435 **	-0.478**
Fruit weight : SSC/TA	-0.202 n.s.	-0.405 *
Fruit weight :RI	0.282 n.s.	0.353 *
RI : TA	0.368 *	0.397 *
RI :SSC/TA	-0.396 *	-0.450**
RI :Hue	-0.383 *	0.170 n.s.
SSC : Starch	-0.257 n.s.	-0.456*

Note: n.s., *, **, *** nonsignificant or significant at P≤0.05,0.01 and 0.001, respectively

The principal component analysis of basic quality parameters (FW, TA, SSC/TA, RI and colour) showed that the first two principal components (PC) are significant (i.e. with eigenvalue higher than 1) and that they comprise 72.4 % of variability. PC1 (43.94 % variability) is mostly composed of TA, SSC/TA and RI, and PC2 (28.50 % variability) is mostly composed of FW and colour (Table 4).

With PC1 and PC2 it is possible to achieve good separation of fruits depending on the thinning method (Fig. 1).

Table 4. Eigenvectors of PC1 and PC2 for hand and chemically thinned fruits of 'Golden Delicious cl. B' apple

Fruit characteristic	PC1 (43.94 %)	PC2 (28.50 %)
Fruit weight	0.0326	-0.703
TA	0.601	-.005
SSC/TA	-0.625	0.114
RI	0.493	0.110
Hue	0.062	0.694

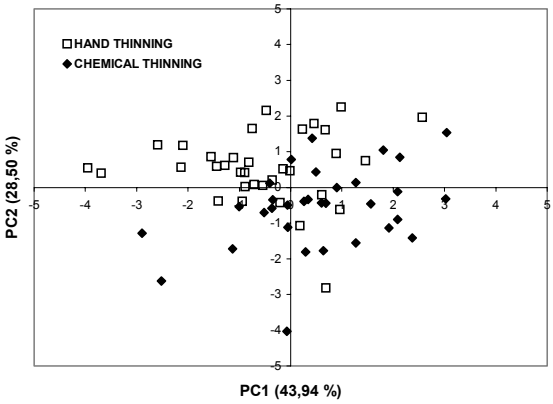

Figure 1. Principal component analysis of hand and chemically thinned fruits of 'Golden Delicious cl. B' apple

Conclusion

The described results show that the thinning methods significantly affect maturity dynamics and fruit quality of apple. It is also possible that some very important nutritional fruit characteristics (vitamin content etc.) could be affected by chemical thinning. Therefore, this issue should receive much more scientific attention to find optimal thinning strategies that will have booth good thinning effect and positive effect on fruit quality.

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