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Short communication

Mechanical flower thinning improves fruit quality of apples and promotes consistent bearing

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ABSTRACT

A novel device is presented for mechanical blossom thinning with first test trials in the US on seven-year-old apple [*Malus domestica* (Borkh.)] 'Buckeye Gala' near Yakima, WA, USA. Trees were mechanically blossom-thinned with the novel string thinning device, developed by Damerow et al. (2007), at 260 or 360 rpm rotor speeds and a 2.5 km h^{-1} vehicle speed to improve fruit quality, reduce hand and chemical thinning and to prevent or overcome alternate bearing; manually thinned trees served as controls in a replicated, randomized block trial. The strongest mechanical thinning treatment (360 rpm, 2.5 km h^{-1}) had a positive effect on apple fruit size (75 mm versus 72 mm in the hand-thinned control), firmness 9.0 kg cm^{-2} versus 8.9 kg cm^{-2}, advanced ripening i.e. starch breakdown, sweetness 12.3-12.8 °Brix versus 11.9 °Brix in the control, contained the largest malic acid content 0.43% versus 0.37% in the control and more red blush, i.e. fruit coloration. The sugar:acid ratio was maintained particularly after the strongest 360 rpm mechanical thinning (29:1) and resembled that of the chemical thinning and the hand-thinned control (32:1), since fruit with higher sugar content also contained more malic acid. The best return bloom was achieved by the conventional chemical standard (105%), followed by the strongest mechanical thinning (92% with 360 rpm) then the combination of mechanical and chemical thinning (85%) compared to much lower values in the control (69%), showing the efficacy of blossom thinning to overcome alternate bearing.

1. Introduction

Fruit trees bear an abundance of flowers, which they cannot support through to fruit maturation; only about 7% of flowers are necessary, e.g. in apple for a commercially profitable harvest (Untiedt and Blanke, 2001). Thus, thinning is a prerequisite in fruit crops (i) to achieve high quality fruit with sufficient size and coloration for class I marketing (Blanke, 2007, 2008) including taste as sugar and firmness, (ii) to reduce labor-intense hand blossom and/or green fruit thinning, and (iii) to overcome alternate bearing (change of low and high yielding years) by providing regular moderate yields (McArtney et al., 1996). Mechanical blossom thinning is a new environmentally friendly technology and an alternative to the standard chemical blossom thinning, which is limited by a decreasing number of effective registered, i.e. approved chemical compounds with their success very dependent on weather conditions, variety, flowering dynamics and tree age (Wertheim, 2000). Any chemicals to be used for thinning in the future are to be registered under the EG 91/414 Annex 1 for European approval. Hence, a new device was engineered by Damerow and Blanke in 2006–2007 for mechanical flower thinning at the University of Bonn, Germany (Damerow et al., 2007) to overcome these shortcomings of chemical thinning.

2. Materials and methods

2.1. Engineering device

The mechanical thinning device comprises three adjustable horizontal rotors with vertically rotating brushes (supplement 1) that are able to remove an adjustable amount of flowers by centrifugal force (Damerow et al., 2007). The horizontal rotors are attached to a vertical axis based on a platform located on the front hydraulic three-point hitch of a tractor, autonomous vehicle or OTR (Over The Row).

2.2. Orchard layout and mechanical thinning

Seven-year-old 'Buckeye Gala' apple trees at a spacing of 1.2 m × 3.7 m were selected for the thinning trials. The trees were

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slender spindles on 'NIC29' rootstock and mechanically thinned on 3 May 2009 during full bloom in the Yakima valley, Washington State, USA. The following treatments were applied: mechanical thinning at 260 rpm or 360 rpm rotor speed both at 2.5 km h^{-1} tractor speed; the lower rotor speed was also combined with a chemical post bloom thinning (BA as Maxcel and Carbaryl as Sevin), the higher rotor speed (360 rpm) with an additional hand thinning based on fruit spacing. They were tested against a conventional chemical standard, consisting of lime sulphur and Crocker's fish oil (both sprayed at 2% at 20% and 80% bloom on 28 April and 1 May 2009), and a post bloom thinning with BA (Maxcel) at 9.4 L ha^{-1} and Carbaryl (Sevin) at 3.51 L ha^{-1} at the 10 mm fruitlet stage. Trees of the same cultivar, which were hand-thinned to ca. one fruit per 10 cm in July 2009, served as a control.

2.3. Assessment of fruit set, thinning efficacy, fruit quality and return bloom

In order to measure the success of the thinning trials, eight horizontal sample branches per plot were marked before the thinning was performed; four of them (numbers 1, 2, 5 and 6) on the west side of the row, the other four (numbers 3, 4, 7 and 8) on the east side. The branches were of similar length and circumference and representative of the block. Marked branches 1–4 were at a height of about 1.5 m and branches 5–8 about 2 m from the ground (supplement 2). On these sample branches, flower clusters were counted before thinning and the number of fruit set after mechanical or chemical thinning assessed before an expected June drop. Due to absence of a June drop in the Yakima fruit growing region in 2009 as in previous years, apple trees were hand-thinned in mid July 2009. Return bloom was assessed on 19 April 2010 and expressed as a percentage of flower clusters/branch cross-sectional area when compared with the previous year (2009 values = 100%).

The 'Buckeye Gala' apples were harvested on 25 August 2009 and were assessed for their fruit quality. Starch breakdown was determined with iodine staining, firmness using a GÜSS FTA GS-14 firmness tester (Bioworks Inc., KS, USA) with a 1 cm^2 plunger. All fruit from the trees under investigation were harvested, weighed for yield determination on a per tree basis, and pooled. One hundred apples randomly chosen thereof, viz. of each treatment, were color-graded and categorized into classes Premium, 2nd grade, 3rd grade or culls, as of the US-American guidelines for the fruit industry.

A sub-sample of twenty fruit (from the 100 original fruit sample) was juiced and used to determine the fruit acidity by titration against 0.1 mol L^{-1} KOH in a DL 50 Graphix titrator (Mettler Toledo GmbH, Germany) and soluble sugars in °Brix, using a digital PR-32 refractometer (Atago Co. Ltd., Japan).

2.4. Integrated coefficient of thinning (ICT)

Since rotor speed (which determines the centrifugal force) and vehicle speed induce opposing effects in the thinning motion, i.e. flower removal and potential tree damage, the integrated coefficient of thinning (ICT) (Solomakhin and Blanke, 2010) is used here to describe the overall impact on both parameters and to develop critical threshold values to aid future decision-making processes.

$$\mathrm{ICT} = \frac{m \times s^2}{\mathrm{FS} \times v \times r} \tag{1}$$

where FS is the fruit set (%), m is mass of a rope in the brush (0.003 kg), s is rotor speed (rpm), r is radius, i.e. length of a rope in the brush (0.3 m), and v is the vehicle speed or velocity (km h^{-1}).

2.5. Experimental design and statistical analysis

The six treatments comprised four mechanical, one chemical and one hand-thinning (control). The trial was set up in a randomized block design in a commercial orchard, with four repetitions of each treatment block in order to overcome errors and border row effects and allow proper statistical analysis. Each block consisted of 12 trees with data collected from the inner eight trees of each of the four blocks as repetition – thus, the complete trial consisted of 288 apple trees.

Analyses of variance were conducted using IBM SPSS Statistics 19 statistical software (IBM, Armonk, NY, USA). The separation of means was completed using Tukey's test at the 5% level and statistical significance was based on arcsine data transformations for all ratings based on percentages.

3. Results

3.1. Efficacy of mechanical flower thinning, fruit set and effects on fruit size and yield

The goal of this study was to remove an average of ca. 1–2 flowers per flower cluster during bloom in May in order to achieve marketable fruit size of high quality in terms of firmness, taste and apple fruit coloration at harvest in August with a perspective of a commercially profitable yield the year after.

All thinning treatments were effective in terms of removing excess flowers, judged by the fruit set given as fruits per 100 flower clusters (Table 1, column 4). The best thinning efficacy in apple was obtained when combining four chemicals, followed by the solely mechanical application at both rotor speeds (Table 1). The faster rotor speeds of 360 rpm removed the targeted ca. 1–2 flower-s per cluster and thinned more effectively than the lower rotation speed of 260 rpm.

Table 1
Effect of mechanical thinning on fruit set in cv. 'Buckeye Gala' apple trees and ICT at a constant vehicle speed of 2.5 km h^{-1}.

Type of thinning	ICT index	Fruit set [fruits/branch cross-sectional area][a]	Fruit set [fruits/100 flower clusters][a]	Fruit size Gala [mm]	Yield [kg/tree]	Return bloom (%)[b]	Return bloom/CSA[b]
Chemical thinning	n.a.	3.6 b[*]	57 b	75.4 a	18.2 b	105 ns	4.8 ns
Mech. thinning (260 rpm)	4.4	4.2 ab	61 b	73.7 c	22.4 ab	82	4.9
Mech. thinning (360 rpm)	8.3	4.0 ab	62 b	74.7 bc	18.1 b	92	5.0
Mech. thinning (260 rpm) + chemical thinning	4.3	4.2 ab	64 b	74.9 ab	20.6 ab	85	4.8
Mech. thinning (360 rpm) + hand thinning	6.9	5.4 ab	75 ab	74.7 bc	22.3 ab	82	4.9
Control (hand thinning)	n.a.	5.7 a	92 a	72.4 d	26.0 a	69	4.1

[a] After mechanical thinning.
[b] In 2010, expressed as percentage of blossom clusters per branch cross-sectional area (CSA) of the respective branch (100% in 2009).
[*] Mean separation by Tukey's test ($p \leq 0.05$). Means followed by different letters within the same column are significantly different; n.a., not applicable; ns, not significant.