Cultivar-specific adaptation of crop load regulation with transpiration inhibitors on the cultivars 'Gala', 'Braeburn' and 'Kanzi'®

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Abstract

The use of transpiration inhibitors to increase June fruit drop has become a common practice in organic fruit growing areas in South Tyrol. However, open questions concerning the management of this thinning technique exist, and there is still potential for improvement. On some cultivars, for example 'Gala', the thinning efficacy of transpiration inhibitors can be considered adequate, and no major phytotoxic symptoms on leaves and fruits are observed. On other cultivars, instead, for example 'Braeburn' and 'Kanzi'®, the fruit thinning effect sometimes is too high, and considerable leaf burn may occur. In addition, the thinning action is not always optimal, because its extent varies depending on crown height. The trials conducted in 2014 and 2015 on the cultivars 'Gala', 'Braeburn' *and 'Kanzi'® showed that a reduction in the thinning efficacy and in the occurrence of phytotoxic symptoms on leaves can be obtained by omitting lime sulphur treatments during the period, in which paraffin oils are commonly applied for fruit thinning. Furthermore, more effective and uniform thinning throughout the entire crown height can be achieved by directing sprays to specific crown zones, for example to the top crown zone.*

Keywords: Paraffin oil, crop load regulation, June fruit drop, thinning, transpiration inhibitors, apple, organic farming

Introduction

The use of transpiration inhibitors for fruit thinning has become a common practice in organic fruit growing in South Tyrol (Südtiroler Beratungsring für Obst- und Weinbau, 2015). Efforts are made to use this method on all cultivars, commonly grown in the area. The studies conducted up to now, however, showed that the thinning action of thinning treatments may vary depending on several factors (Kelderer *et al.*, 2014), such as climatic conditions, crop growth stage (Kelderer *et al.*, 2008), applied product(s) or product mixtures, applied rates, tree shading (Byers *et al.*, 1985; McArtnay *et al.*, 2004; Stadler *et al.*, 2005; Kelderer *et al.*, 2008), and finally also crop selectivity of the applied product(s) on the different apple cultivars (Kelderer *et al.*, 2012). In order to support growers in selecting the most appropriate thinning strategy, it is important to investigate the influence of these different factors on the most commonly grown apple cultivars, and to develop application strategies for each cultivar. For this reason, several treatments applied at different rates, treatment combinations with lime sulphur, and tree shading strategies with hail netting systems have been tested on the main apple cultivars, and the obtained results enabled us to establish a susceptibility chart for these cultivars (Kelderer *et al.*, 2014). In addition, these studies evidenced also an increased thinning action of paraffin oil-based treatments in the lower crown part, in which fruit set is generally already lower than in the upper crown part (Kelderer *et al.*, 2014). This may result in undesired, not uniform fruit set within the tree canopy.

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The trials conducted in 2014 and 2015 were conducted on the cultivars ‘Gala’, ‘Braeburn’ and ‘Kanzi’® because of their different susceptibility to paraffin oil-based treatments. The trials aimed at harmonizing the thinning action of the paraffin oil-based treatments and at reducing phytotoxic effects.

Material and Methods

The trials were carried out in apple orchards under integrated management practices at the Research Centre Laimburg (Pfatten, South Tyrol, Italy). All study orchards were located in the Etschtal (Etsch valley) at 220 m above sea level. Details concerning the study orchards are provided in Table 1. Details on climatic conditions can be found at http://www.laimburg.com/de/meteorologie.asp.

Table 1: Cultivar, year of planting, planting distance (= row distance x plant distance within rows in m), and rootstock present in the study orchards in 2014 and 2015.

Year	Cultivar	Year of planting	Planting distance (m)	Rootstock
2014	Gala	2010	3.4 x 0.8	M9
	Kanzi®	2007	3.0 x 0.8	M9
	Braeburn	2008	3.15 x 0.75	M9
2015	Gala	2011	3.2 x 0.8	M9
	Kanzi®	2007	3.0 x 0.8	M9
	Braeburn	2008	3.15 x 0.75	M9

The different treatments (see Table 2 for details) were compared by using a randomized complete block design with 4 replicates of 5 trees each. Trees were uniform in growth and flowering intensity (tree height: approx. 3 m). All treatments were applied by using a motorized plot sprayer for experimental trials from WAIBL (Meran, Italy) (transverse current blower) and a spray volume of 500 l per ha and meter crown height.

In 2014 also the effect of hail netting on the thinning efficacy of the treatments was evaluated. Trees were covered with hail net at fruit size up to 15 mm (BBCH 71-72), and the hail net was left in the orchards up to harvest. The hail net used was black hail net type Uility pro 2,5 from Tenax (Salerno, Italy) with a mesh size of 8 x 3 mm.

Tree top applications with paraffin oil were conducted by directing the spray to the crown zone at above approx. 170 cm tree height. Lime sulphur applications were made in alternation (before and after) with paraffin oil applications.

Table 2: Treatments (tested products, applied rates, number and timing of applications) tested in the trials conducted on the cultivars ‘Gala’, ‘Braeburn’ and ‘Kanzi’® in 2014 and 2015.

Year	cultivar	N°	treatment	trade name	Producer/ distributor	applied rate l/100l	N. of applications		phenological stage fruit size
							entire tree	tree top	
2014	Gala, Braeburn, Kanzi	1	paraffin oil	Eko Oil Spray	Adama	1.5	1x		15mm
		2	paraffin oil	Eko Oil Spray	Adama	1.5		2x	15mm
		3	paraffin oil	Eko Oil Spray	Adama	1		2x	15mm
		4	paraffin oil lime sulphur	Eko Oil Spray Polisulfuro di Calcio	Adama Polisenio	1 1	3x	2x	
		5	paraffin oil lime sulphur hailnet	Eko Oil Spray Polisulfuro di Calcio Utility Pro 2,5	Adama Polisenio Tenax	1 1	3x	2x	15mm
		6	untreated control	-	-	-	-	-	15mm
2015	Kanzi, Braeburn	1	paraffin oil lime sulphur	Eko Oil Spray Polisulfuro di Calcio	Adama Polisenio	1 1	3x	2x	15 mm
		2	parrafin oil lime sulphur	Eko Oil Spray Polisulfuro di Calcio	Adama Polisenio	0,5 1	3x	2x	15mm
		3	parrafin oil lime sulphur	Eko Oil Spray Polisulfuro di Calcio	Adama Polisenio	1 1	3x	2x	20 mm
		4	paraffin oil lime sulphur	Eko Oil Spray Polisulfuro di Calcio	Adama Polisenio	0,5 1	3x	2x	20 mm
		5	paraffin oil lime sulphur	Eko Oil Spray Polisulfuro di Calcio	Adama Polisenio	0,5 / 1 1	1x 3x	1x	20 mm
		6	paraffin oil	Eko Oil Spray	Adama	0,5 / 1	1x	1x	20 mm
		7	paraffin oil lime sulphur	Eko Oil Spray Polisulfuro di Calcio	Adama Polisenio	1 1	3x	2x	25 mm
		8	paraffin oil lime sulphur	Eko Oil Spray Polisulfuro di Calcio	Adama Polisenio	0,5 1	3x	2x	25mm
		9	untreated control	-	-	-	-	-	-
	Gala	1	paraffin oil lime sulphur	Eko Oil Spray Polisulfuro di Calcio	Adama Polisenio	1 1	1 x 3x		15mm
		2	paraffin oil lime sulphur	Eko Oil Spray Polisulfuro di Calcio	Adama Polisenio	1 1	3x	2x	15 mm
		3	paraffin oil lime sulphur	Eko Oil Spray Polisulfuro di Calcio	Adama Polisenio	0,5 / 1 1	1x 3x	1x	15 mm
		4	paraffin oil	Eko Oil Spray	Adama	0,5 / 1	1x	1x	20 mm
		5	untreated control	-	-	-	-	-	-

Assessments:

Thinning effect: after June fruit drop, 100 flower clusters per tree were selected, and the number of set fruits was counted. To take into consideration also the position of the flower clusters within the tree, 40 flower cluster were selected within the upper third of the tree (top crown part), and 60 within the lower part of the tree (bottom crown part), uniformly distributed within the outer and inner part of the tree crown. Counts were made using Fankhauser’s method (Fankhauser *et al.*, 1979): the number of fruits was counted on all flower clusters present on entire branch sections. The number of fruits per 100 flower clusters was then inferred by calculating the mean value of the assessed data. The thinning effect of each tested treatment was determined by calculating the difference between the number of fruits/100 flower clusters on untreated control trees and the number of fruits/100 flower clusters on treated trees. Percent thinning efficacy (% TE) in the bottom and top crown part was then calculated using Abbott’s formula.

Phytotoxicity on leaves: phytotoxicity on leaves (leaf burn resulting in leaf drop) was assessed visually by using a scale a scale ranging from 0 to 5 with 0 = no leaf drop, 1 = light drop of rosette leaves, 2 = medium drop of rosette leaves, 3 = medium drop of rosette leaves and first symptoms of leaf drop on shoots, 4 = high drop of rosette leaves and light-medium leaf drop on shoots, and 5 = high drop of rosette leaves and medium-high drop of leaves on shoots. The assessment on the leaves was performed 1 month after the application of the paraffin oil, the assessment on the fruits on harvest.

In each trial, the assessed data were compared across treatments using 1-way ANOVAs, followed by Tukey's test ($P<0.05$) for post-hoc comparisons of means. All analyses were performed using the software IBM SPSS Statistics.

Results

Year 2014

Thinning effect:

As already observed in previous studies, also in our trials the thinning efficacy of the different treatments varied among apple cultivars. However, it was not possible to statistically compare the effect of cultivar on thinning across treatments, because the cultivars were not arranged in a randomized block design.

The cultivar 'Gala' was the least susceptible cultivar, with mean percent thinning efficacy of the tested treatments ranging from 18 to 43 % (mean: 29 %) in the bottom crown part and from 30 to 60 % (mean: 44 %) in the top crown part (Table 3). On the cultivars 'Kanzi'® and 'Braeburn', instead, thinning efficacy values of all treatments were generally much higher in both the bottom and top crown part (Table 3): on 'Braeburn' the thinning efficacy of the tested treatments varied between 22 and 62 % (mean: 37 %) in the bottom crown part and between 61 and 73 % (mean: 67 %) in the top crown part, while on 'Kanzi'® it ranged from 26 to 69 % (mean: 48 %) in the bottom crown part and from 40 to 82 % (mean: 62 %) in the top crown part. On all cultivars, treatment applications to the top crown part alone resulted in a reduced thinning action in the bottom crown part in comparison to treatment applications to the entire tree. Furthermore, on all cultivars, the thinning efficacy of alternated applications of paraffin oil and lime sulphur was generally, though not always significantly higher than that of paraffin oil only. Finally, on all cultivars except 'Gala', hail netting resulted in increased thinning efficacy in the bottom crown part, while no statistically significant differences in thinning efficacy among treatments with and without hail net emerged for the top crown part.

Table 3: Percentage of thinning efficacy (TE) of the tested treatments in the bottom and top crown part on the cultivars 'Gala', 'Braeburn' and 'Kanzi'® in 2014.

position	Treatments	GALA		BRAEBURN		KANZI®	
		% TE	stat.	% TE	stat.	% TE	stat.
bottom	EOS 1,5l 1x complete tree	42,7	c	61,9	c	66,8	bc
	EOS 1,5l 2x top	27,4	ab	30,7	ab	25,6	a
	EOS 1l 2x top	17,9	a	27,2	a	29,5	a
	EOS 1l 2x top - LS 1l 3x	28,7	ab	21,6	a	49,7	b
	EOS 1l 2x top - LS 1l 3x - net	29,2	b	41,7	b	69,2	c
top	EOS 1,5l 1x complete tree	30,4	a	60,9	a	54,3	a
	EOS 1,5l 2x top	48,5	b	72,9	a	49,0	a
	EOS 1l 2x top	31,0	a	69,2	a	39,7	a
	EOS 1l 2x top - LS 1l 3x	50,7	b	66,8	a	81,1	b
	EOS 1l 2x top - LS 1l 3x - net	60,3	b	66,9	a	81,6	b

EOS = Eco Oil Spray, SK = lime sulphur, % TE = mean percentage of Thinning efficacy

Phytotoxicity:

None of the tested treatments caused phytotoxic effects on fruits (fruit burn or russetting) on any of the cultivars. Phytotoxic symptoms, instead, were observed on leaves, and symptoms varied from light yellowing or bleaching effects (chlorosis) and necrotic spots of different extent up to heavy leaf drop, especially on rosette leaves. On the cultivar 'Gala', phytotoxicity was scored 1.5 in Treatment n. 1, 1 in Treatment n. 2, 4 and 5, 0.5 in Treatment n. 3, and 0 in Treatment n. 6 (untreated control). On the cultivar 'Braeburn', phytotoxicity (scale: 0-5) was 3 in Treatment n. 1 and 2, 2 in Treatment n. 3, 4 and 5, and 0 in Treatment n. 6 (untreated control). On the cultivar 'Kanzi'® phytotoxicity amounted to 4 in Treatment n. 4 and 5, 3 in Treatment n. 1 and 2, 1 in Treatment n. 3, and 0 in Treatment n. 6 (untreated control).

Therefore, a clear trend in susceptibility among cultivars emerged, with 'Kanzi'® being the most susceptible cultivar, followed by 'Braeburn', and 'Gala' being the least susceptible cultivar. On the cultivar 'Kanzi'®, phytotoxic symptoms on leaves were especially severe in those treatments, in which paraffin oil was used in alternation with lime sulphur, while on the cultivar 'Braeburn' high application rates of paraffin oil appeared to be responsible of the strongest phytotoxic effects.

Year 2015

Thinning effect:

On the cultivar 'Gala', a uniform and strong thinning efficacy was achieved in both the bottom and top crown part (mean: respectively 45 and 41 %) with one single application of paraffin oil to the entire tree in combination with lime sulphur applications (Treatment n. 1; Table 4). A similar thinning efficacy in the top crown part was obtained with 2 applications of paraffin oil to the top crown part in combination with lime sulphur applications (Treatment n. 2), but the thinning efficacy of this treatment in the bottom crown part was extremely low (mean: 6 %). An optimal thinning efficacy was observed for Treatment n. 3, consisting of 1 application of paraffin oil at a low rate (0.5 l/hl) to the entire tree, followed by 1 application of paraffin oil to the top crown part at 1.0 l/hl, always in combination with lime sulphur applications. In fact, mean thinning efficacy amounted 36 % in the top crown part and to 22 % in the bottom part. When the same paraffin oil-based applications were made without combining them with lime sulphur applications (Treatment n. 4), thinning efficacy values were slightly though not significantly lower. In general, applications onto the tree top resulted in higher thinning efficacy values in the top crown part than in the bottom crown part (ratio bottom/top: 1/2.7).

On the cultivars 'Braeburn' and 'Kanzi'®, the reduction in the application rate of paraffin oil resulted in a decrease in thinning efficacy, irrespective of timing of applications except on the cultivar 'Kanzi'® for applications conducted at fruit size 20 mm (Table 4). In this case, considerable differences in the thinning efficacy of the high and low rate of paraffin oil emerged neither in the bottom nor in top crown part. Furthermore, on this cultivar, a lower thinning efficacy was obtained, when treatments were made at fruit size 15 mm. Applying the paraffin oil-based treatments in alternation with lime sulphur resulted in a general increase in thinning efficacy on both 'Braeburn' and 'Kanzi'®, and on 'Kanzi'®, at fruit size 20 mm, efficacy values were more than doubled. At fruit size 25 mm, instead, the thinning action was much lower than at fruit size 20 and 15 mm.

Table 4: Percentage of thinning efficacy (TE) of the tested treatments in the bottom and top crown part on the cultivars 'Gala', 'Braeburn' and 'Kanzi'® in 2015.

position	Treatments	GALA		BRAEBURN		KANZI	
		% TE	stat.	% TE	stat.	% TE	stat.
bottom	**EOS 1l 1x complete tree - LS 1l 3x - 15mm**	45,1	c	-	-	-	-
	EOS 1l 2x top - LS 1l 3x - 15mm	6,4	a	23,2	a	61,6	cd
	EOS 0,5l 1x complete tree + 1l 1x top - LS 1l 3x - 15mm	22,2	b	-	-	-	-
	EOS 0,5l 1x complete tree + 1l 1x top - 15mm	10,8	ab	-	-	-	-
	EOS 0,5l 2x top - LS 1l 3x - 15mm	-	-	13,9	a	49,8	bc
	EOS 1l 2x top - LS 1l 3x - 20mm	-	-	28,4	ab	58,2	cd
	EOS 0,5l 2x top - LS 1l 3x - 20mm	-	-	14,3	a	58,9	cd
	EOS 0,5l 1x complete tree + 1l 1x top - LS 1l 3x - 20mm	-	-	41,5	b	76,6	d
	EOS 0,5l 1x complete tree + 1l 1x top - 20mm	-	-	12,6	a	33,5	ab
	EOS 1l 2x top - LS 1l 3x - 25mm	-	-	25,3	ab	19,3	a
	EOS 0,5l 2x top - LS 1l 3x - 25mm	-	-	19,7	a	21,9	a
top	**EOS 1l 1x complete tree - LS 1l 3x - 15mm**	40,9	a	-	-	-	-
	EOS 1l 2x top - LS 1l 3x - 15mm	40,2	a	30,2	ab	77,1	d
	EOS 0,5l 1x complete tree + 1l 1x top - LS 1l 3x - 15mm	35,6	a	-	-	-	-
	EOS 0,5l 1x complete tree + 1l 1x top - 15mm	31,0	a	-	-	-	-
	EOS 0,5l 2x top - LS 1l 3x - 15mm	-	-	24,4	a	42,9	bc
	EOS 1l 2x top - LS 1l 3x - 20mm	-	-	47,4	bc	61,7	cd
	EOS 0,5l 2x top - LS 1l 3x - 20mm	-	-	32,8	ab	61,9	cd
	EOS 0,5l 1x complete tree + 1l 1x top - LS 1l 3x - 20mm	-	-	52,9	c	55,8	cd
	EOS 0,5l 1x complete tree + 1l 1x top - 20mm	-	-	29,7	ab	20,0	ab
	EOS 1l 2x top - LS 1l 3x - 25mm	-	-	33,9	abc	18,9	ab
	EOS 0,5l 2x top - LS 1l 3x - 25mm	-	-	14,2	a	10,1	a

EOS = Eco Oil Spray, SK = lime sulphur, % TE = mean percentage of Thinning efficacy

Phytotoxicity:

As in 2014, also in 2015 phytotoxic symptoms were observed on fruits on none of the tested cultivars. Phytotoxic effects, instead, appeared on leaves, and were scored as follows:

- on the cultivar 'Braeburn', 3 in Treatment n. 1, 2.5 in Treatment n. 2 and 4, 2 in Treatment n. 5, 1.5 in Treatment n. 3 and 7, 1 in Treatment n. 8, 0.5 in Treatment n. 6;
- on the cultivar 'Gala', 2 in Treatment n. 1 and 3, 1.5 in Treatment n. 2, 1 in Treatment n. 4;
- on the cultivar 'Kanzi'®, 4.5 in Treatment n. 3, 4 in Treatment n. 1, 3 in Treatment n. 2, 4 and 5, 2.5 in Treatment n. 7, 1.5 in Treatment n. 8, 1 in Treatment n. 6.

Phytotoxicity amounted to 0 in Treatment n.9 (untreated control) on all cultivars.

The combination paraffin oil and lime sulphur resulted in increased phytotoxicity on leaves on all cultivars, with effects being most severe on 'Kanzi'®. On both 'Braeburn' and 'Kanzi'®, leaf burn and drop were less pronounced when treatments were applied at fruit size 25 mm than when applied at fruit size 20 and 15 mm. Reducing the application rate of paraffin oil resulted in a negligible decrease of phytotoxic symptoms.

Discussion

Previous studies (Kelderer *et al.*, 2012, 2014) showed that considerable differences among cultivars in the thinning efficacy of paraffin oil exist. Especially on the cultivars 'Kanzi'® and 'Braeburn' crop load may be excessively reduced, and disproportionate fruit drop can occur in the bottom crown part. The studies conducted in 2014 and 2015 aimed at developing strategies for optimal thinning also on these highly susceptible cultivars. The

cultivar ‘Gala’, which shows an adequate response to paraffin oil-based thinning treatments was used as reference cultivar.

Our studies confirmed what has already been observed previously, that is a strong impact of lime sulphur treatments on the thinning efficacy of paraffin oil-based treatments on the cultivars ‘Braeburn’ and Kanzi®. Furthermore, especially on the cultivar Kanzi®, severe phytotoxic effects on leaves occurred, and resulted in a considerable reduction of the leaf wall area.

Hail netting systems can increase thinning efficacy. However, it should be pointed out that in the trial conducted in 2014, the hail net was placed directly onto the trees. This results in increased tree shading in comparison to that obtained by using conventional hail netting systems.

In 2015, also low application rates of paraffin oil (0.5 l/hl) were tested in order to better adapt applications to each cultivar. Low application rates resulted in reduced thinning efficacy values only on the cultivar ‘Braeburn’, while no clear trend in terms of reduction of phytotoxic symptoms was observed.

By applying the paraffin oil at fruit size 25 mm rather than at fruit size 20 or 15 mm, a decrease in the thinning efficacy and also in phytotoxic effects was registered. However, the observed decrease in phytotoxicity may also be related to changes in climatic conditions

All treatments consisting of tree top applications or applications to the entire tree with additional tree top applications enabled to reduce the thinning efficacy in the bottom crown part and thus to obtain a more uniform crop load throughout the entire tree canopy.

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