Crop regulation on different apple cultivars with transpiration inhibitors

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Abstract

In organic apple growing in South Tyrol, yield control is commonly achieved by removing buds and flowers with mechanical thinning machines and/or lime sulphur sprays. To allow for thinning also later in the season, trials with shading nets have been carried out over several years. By shading trees with close-meshed nets before June fruit drop, photosynthesis in leaves can be drastically reduced. Notwithstanding the good trial results, the method is not used in the field, because shading trees with nets is labour-intensive and expensive. During the last years we therefore tested different substances as alternatives to shading nets. First promising results were obtained with different oily substances. However, based on our current knowledge, negative side effects such as leaf burn and fruit russeting, can not be excluded. In this experiment, the paraffin oil-based product UFO (Ultra Fine Oil) was applied on different apple cultivars and its thinning efficacy and the side effects were recorded. There have been promising results in thinning, but the differences between the varieties were large. It is therefore clear, that the treatments have to be decided individually for each apple cultivar.

Keywords apple, June drop, thinning, transpiration inhibitors

Introduction

Yield control is an essential practice in apple growing to obtain consistent and high-quality yields. In integrated farming systems, growers rely primarily on synthetic plant growth regulators. Depending on their active substance and application rate, these products may be applied also very late in the season (Südtiroler Beratungsring für Obst- und Weinbau, 2011). As a consequence, fruit set can be estimated accurately and unnecessary manual thinning can be avoided. These products are not allowed in organic farming. Thinning in organic orchards in South Tyrol is done at flowering by using mechanical thinning machines (Strimmer *et al*., 1997; Kelderer *et al*., 2009; Weibel & Walther, 2003) and/or by applying lime sulphur sprays (Kelderer *et al*., 2006). Methods, which allow for thinning later in the season, have been tested for several years. Promising results, that is a drastical reduction of the net photosynthesis of apple trees, were obtained by using close-meshed shading nets (75 – 90% sunlight reduction), and highest efficacy was achieved by shading trees at fruit size up to 10 – 15 mm (Byers *et al*., 1985; Kelderer *et al.,* 2008; McArtney *et al.,* 2004; Musacchi & Corelli Grappadelli, 1994; Stadler *et al*., 2005; Widmer *et al*., 2008). However, the method is not used in the field, because shading nets are very expensive and opening and closing nets for short periods of time is labour-intensive.

Different substances have already been tested as alternatives to shading nets. A partial success was achieved with applications of bentonite sprays, but at harvest visible remains of the substance were still present around the calyx and stalk end of fruits, which thus became unmarketable (Prantl *et al*., 2004). It is known from literature that oily substances can inhibit transpiration in leaves, close stomata, and thus affect photosynthesis. In 2008 and 2009 different oily substances such as pine oil-, paraffin oil-, soybean oil- and canola oil-based products have been applied and compared (Kelderer, 2010). Our recent trials aimed at evaluating the thinning efficacy and possible negative side effects of the paraffin

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oil-based product UFO (Ultra Fine Oil; distributor: Intrachem Bio Italia S.p.A., Grassobbio, Italy) on the main apple varieties cultivated in South Tyrol.

Material and Methods

Trial design:

The trials were conducted in 2010 and 2011 in different apple orchards under integrated management, at the Research Centre Laimburg (Pfatten, South Tyrol, Italy) and in Latsch

(Venosta Valley, South Tyrol, Italy). Both study orchards are located in the valley floor. Laimburg is situated at 220 m, and Latsch at 780 m above sea level. A randomised block design with 4 replications per treatment was used, and assessments were made on 5 trees per plot, uniform in growth, size, and number of flowers. All paraffin oil-based treatments were applied with a motorized sprayer for experimental trials from WAIBL (transverse current blower). A detailed description of the study orchards, the tested treatments, and the timing of the applications is provided in Table 1 and 2.

In 2011, all experimental plots were treated also with lime sulphur before and after bloom in order to assess for potential negative side effects (phytotoxicity) caused by the application of lime sulphur and paraffin oil in combination. In organic agriculture, lime sulphur is the most applied plant protection product after flowering. It must therefore be considered, that part of the thinning effect observed in this experiment might have been due to the application of lime sulphur.

Table 1: Description of the 2010- and 2011-study orchards (cultivars, rootstock, year of planting and planting density).

Year	Cultivar/Clone	Rootstock	Planting Year	Planting density
2010	Pinova	M9	2000	0,8 × 3,2 m
	Golden Delicious/Klon B	M9	1993	0,7 × 3,5 m
	Braeburn	M9	1998	0,9 × 3,2 m
	Red Delicious/Red Chief	M9	2000	0,7 × 3 m
	Pink Lady	M9	2001	0,8 × 3,15 m
	Gala/Royal Gala	M9	1997	0,8 × 3,5 m
	Fuji/Kiku	M9	2004	1 × 3,25 m
2011	Pinova	M9	2000	0,8 × 3,2 m
	Gala/Royal Gala	M9	1997	3,5 x 0,8
	Golden Delicious/Klon B	M9	1993	3,5 x0,7
	Fuji/Kiku	M9	2004	3,25 x 1
	Pink Lady/Crips Pink	M9	2001	3,15 x 0,8
	Red Delicious/Red Chief	M9	1997	3,2 x 0,9
	Braeburn	M9	1998	3,2 x 0,9
	Kanzi	M9	2008	3,0 x 0,8
	Granny Smith	M9	2009	3,2 x 0,8

Table 2: Tested treatments

Year	Cultivar	Treatment	Trade name	Producer/ distributor	Applied rate	No. Applications	Phenological stage/Fruit size (mm)
2010	Pinova	Paraffin oil	UFO	Intrachem Bio Italia	1,5 l/hl	2×	15 mm
		Untreated control	-	-	-	-	-
	Golden Del.	Metamitron		Experimental product	350 ml/hl	1×	15 mm
	all other cultivars + Golden Del.	Paraffin oil	UFO	Intrachem Bio Italia	1,5 l/hl	2×	15 mm
		Paraffin oil	UFO	Intrachem Bio Italia	1 l/hl	3×	15 mm
		Untreated control	-	-	-	-	-
2011	Pinova	Paraffin oil	UFO	Intrachem Bio Italia	1,5 l/hl	2×	15 mm
		Untreated control					
	all other cultivars	Paraffin oil	UFO	Intrachem Bio Italia	1,5 l/hl	2×	15 mm
		6-Benzyladenine+Naphthaleneacetic acid+Surfactant	Brancher Dirado+ Dirager	Agrimport, Gobbi, Sipcam	100 ml + 10 ml + 100 ml	1×	15 mm
		Untreated control	-	-	-	-	-

Assessments:

Thinning: to assess for the thinning efficacy of the different treatments, in each plot, after June fruit drop, the number of fruits was counted on 100 randomly selected flower clusters (henceforth FC) per tree. To take into consideration also the position of the flowers on the tree, 40 FC were selected in the upper third of the tree, and 60 in the lower part of the tree, uniformly distributed within the outer and inner part of the tree canopy. Counts were made using Fankhauser's method (Fankhauser *et al.*, 1979): after June fruit drop, the number of fruits was counted on all FC present on entire branch sections. The number of fruits per 100 FC was then inferred by calculating the mean value of the assessed data.

Fruit russeting: to assess for fruit russeting, in each plot, at harvest, fruits were checked for symptoms of fruit russeting and classified according to a scale ranging from 0 to 10, with 0 = fruit with no russeting symptoms, 1 = fruit with russeting symptoms at stalk cavity, 2 = fruit with 10-20% fruit area affected by fruit russeting, and so on. Based on this the percentage of russeted fruit surface was calculated.

Flower formation: in 2010, to assess for possible side effects of the different treatments on flower formation the next season, the percentage of flowers on the sprouted buds was determined the following year in spring.

Leaf drop: we also made visual assessments on leaf drop. To establish leaf drop incidence, a scale ranging from 0 to 5 such as the following was used: 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 on shoots.

Yield and fruit weight: at harvest, all fruits present on the 5 sample trees within each plot were harvested, and fruit yield (kg/tree) and fruit weight (g) were assessed, using a sorting machine from AWETA.

The number of fruits/100 FC, fruit weight (g), yield (kg/tree), percentage of russeted fruit surface and percentage of flower buds in the following season were compared across treatments using 1-way ANOVAs followed by Student-Newman-Keuls' test for posthoc comparisons of means ($P<0.05$). To improve homoschedasticity, data expressed in percentages were arcsin(radq(x/100))-transformed. All analyses were performed with the statistics programme PASW 17.

Results

Table 3: Trial results 2010. Assessments after June fruit drop for no. fruits/100 FC, on 17th of May for leaf drop, and before harvest for fruit russeting.

Treatment	No. Fruits/100 FC		Leaf drop	% Fruit russeting	
Gala 1.5l×2	132.5	a	1	10.6	a
Gala 1l×3	126.0	a	2	11.1	a
Gala Control	169.7	b	0	10.9	a
Fuji 1.5l×2	100.0	a	1	14,1	b
Fuji 1l×3	106.0	ab	1	9.0	a
Fuji Control	117.4	b	0	6.4	a
Pink 1.5l×2	129.1	a	0	1.2	a
Pink 1l×3	128.4	a	1	2.0	a
Pink Control	139.7	a	0	2.1	a
Red Del. 1.5l×2	101.3	a	1	0.2	a
Red Del. 1l×3	107.1	a	2	0.4	a
Red Del. Control	148.0	b	0	0.2	a
Braeburn 1.5l×2	72.3	a	2	3.3	a
Braeburn 1l×3	69.9	a	2	3.6	a
Braeburn Control	92.1	b	0	2.8	a
Golden 1.5l×2	101.3	ab	4	34.0	b
Golden 1l×3	107.7	b	3	30.3	b
Golden Metamitron	91.0	a	0	24.6	a
Golden Control	150.6	c	0	23.8	a
Pinova 1.5l×2	66.8	a	-	0.1	
Pinova Control	122.9	b	-	1.4	

In the first trial year (2010), the paraffin oil-based product UFO was tested on different apple cultivars at two different application rates and timing: in one treatment UFO was sprayed twice at 1.5 l/100 l, while in the other treatment UFO was applied three times at 1.0 l/100 l. On the cultivar Golden Delicious, also the conventional thinning product Metamitron was tested (one application at 350 ml/100 l).

A statistically significant thinning effect was achieved with UFO on all cultivars except Pink Lady (Table 3). On Gala, Red Delicious, Golden Delicious and Braeburn, the number of fruits/100 flower clusters was significantly lower in both UFO-based treatments than in the untreated control. On the cultivar Fuji, instead, only 2 applications of UFO at 1.5 l/100 l achieved a significant thinning effect in comparison to the untreated control, while 3 applications of UFO at 1.0 l/100 l differed significantly neither from the other UFO-based treatment nor from the untreated control. On the cultivar Golden Delicious, also the chemical reference treatment Metamitron was tested: the standard showed highest efficacy in thinning, but a slightly lower, though statistically comparable thinning effect was recorded for UFO applied twice at 1.5 l/100 l. On the cultivar Pinova, only one UFO-based treatment was tested (2 applications at 1.5 l/100 l), and also in this case a significant thinning effect in comparison to the untreated control was obtained.

Leaf drop was estimated visually according to a scale ranging from 0 (= no leaf drop) to 5 (=high leaf drop of rosette leaves and light-medium leaf drop on shoots). In the UFO-treated plots, leaf drop was recorded on all cultivars, while no leaf drop was observed in untreated control plots (Table 3). Leaf drop values ranged between 1 and 2, and were thus relatively low on all cultivars except Golden Delicious, where high leaf drop was observed (3 and 4).

Table 4: Trial results 2010. Assessments at harvest for fruit weight (g) and yield (kg/tree), the following year in April for the percentage of flower buds.

Treatment	Yield (kg/tree)		Fruit weight (g)		% Flower buds	
Gala 1.5l×2	15.6	b	120.8	b	2.9	a
Gala 1l×3	12.3	a	124.9	b	7.3	b
Gala Control	17.6	b	108.1	a	2.8	a
Fuji 1.5l×2	30.0	a	135.5	a	0.0	a
Fuji 1l×3	29.9	a	135.5	a	0.0	a
Fuji Control	30.8	a	128.6	a	0.0	a
Pink 1.5l×2	30.1	a	143.9	b	27.5	b
Pink 1l×3	30.5	a	140.6	ab	27.0	b
Pink Control	32.9	a	135.5	a	16.0	a
Red Del. 1.5l×2	16.8	a	136.1	b	2.9	a
Red Del. 1l×3	17.6	a	145.7	c	8.7	a
Red Del. Control	18.1	a	121.6	a	5.8	a
Braeburn 1.5l×2	27.5	a	150.3	b	37.8	b
Braeburn 1l×3	26.0	a	158.4	c	51.5	c
Braeburn Control	37.9	b	123.7	a	10.0	a
Golden 1.5l×2	21.2	a	159.2	b	13.5	b
Golden 1l×3	22.2	a	171.7	c	8.9	b
Golden Metamitron	22.4	a	185.0	d	15.1	b
Golden Control	30.6	b	128.6	a	1.5	a
Pinova 1.5l×2	-		-		75.5	b
Pinova Control	-		-		68.0	a

Increased fruit russeting in the UFO-based treatments was registered only on the cultivars Fuji and Golden Delicious: on Fuji, the fruit surface affected by russeting was significantly higher for UFO applied twice at 1.5 l/100 l UFO (14.1%) than for UFO applied 3 times at

1.0 l/100 l (9.0%) and the untreated control (6.4%). On Golden Delicious, both UFO-based treatments showed significantly more russeted fruit surface (34.0 and 30.3%) than the Metamitron-based treatment (24.6%) and the untreated control (23.8%) (Table 3).

Statistically significant differences among treatments in yield emerged only on three cultivars (Table 4). On the cultivar Gala, yield was significantly lower in the plots treated with 3×1.0 l/100 l UFO (12.3 kg/tree) than in those treated with 2×1.5 l/100 l UFO (15.6 kg/tree) and in untreated control plots (17.6 kg/tree). On the cultivars Braeburn and Golden Delicious, instead, yield was significantly lower in both UFO-based treatments (respectively 27.5 and 26.0, and 21.2 and 22.2 kg/tree) than in the untreated control (respectively 37.9 and 30.6 kg/tree). Furthermore, on Golden Delicious, yield in the UFO-based treatments was statistically comparable to that in the reference treatment Metamitron (22.4 kg/tree).

A significant effect on fruit weight was recorded on almost all cultivars (Table 4). On the cultivar Gala, mean fruit weight was significantly higher in UFO-treated plots (120.8 and 124.9 g) than in untreated control plots (108.1 g). On the cultivar Pink Lady, fruit weight was highest for 2×1.5 l/100 ml UFO (143.9 g), intermediate for 3×1.0 l/100 l UFO (140.6 g), and lowest for the untreated control (135.5 g). On the cultivars Red Delicious and Braeburn, instead, fruit weight was significantly higher for 3×1.0 l/100 l UFO (145.7 and 158.4 g) than for 2×1.5 l/100 l UFO (136.1 and 150.3 g) and finally for the untreated control (121.6 and 123.7 g). On the cultivar Golden Delicious, the plots treated with Metamitron showed highest fruit weight (185.0 g), followed by those treated with 3×1.0 l/100 l UFO (171.7 g), those treated with 2x1.5 l/100 l UFO (159.2 g), and by untreated control plots (128.6 g).

For flower formation (% flower buds on sprouted buds) the following spring, significant differences among treatments emerged on all cultivars except Fuji and Red Delicious (Table 4). On the cultivar Gala, the percentage of flower buds was significantly higher for 3 applications of UFO at 1.0 l/100 l UFO (7.3%) than for 2 applications of UFO at 1.5 l/100 l (2.9%) and for the untreated control (2.8%), with the latter two treatments not differing significantly one from the other. On the cultivar Pink Lady, the percentage of flower buds was significantly higher for both UFO-based treatments (27.5 and 27.0%) than for the untreated control (16.0%). On the cultivar Braeburn, the percentage of flower buds was highest for the treatment 3x1.0 l/100 l UFO (51.5%), intermediate for the treatment 2x1.5 l/100 l UFO (37.8%), and lowest for the untreated control (10.0%). On the cultivar Golden Delicious, the Metamitron- and UFO-based treatments (15.1, 13.5 and 8.9%) showed significantly more flower buds than the untreated control (1.5%). On the cultivar Pinova, significantly more flower buds were formed in the UFO-based treatment (75.5%) than in the untreated control (68.0%).

In the second trial year (2011), the thinning efficacy of the paraffin oil-based product UFO was tested in comparison to the reference product Brancher Dirado (Benzyladenin) applied in tank mixture with the adjuvant Dirager (henceforth B+D treatment; distributors in Italy: Agrimport, Gobbi, and Sipcam).

On the cultivar Golden Delicious, both the UFO and the B+D treatment (73.0 and 78.4 fruits/100FC) showed a significant and comparable thinning effect in comparison to the untreated control (129.1 fruits/100 FC) (Table 5).

Table 5: Trial results 2011. Assessments after June fruit drop for no. fruits/100 FC, on 13th of May for leaf drop, and on 5th of August for fruit russeting.

Treatment	No. Fruits/100 FC		Leaf drop	% Fruit russeting	
Golden Del. UFO	73.0	a	3	13.3	a
Golden Del. B + D	78.4	a	0	10.6	a
Golden Del. Control	129.1	b	0	9.5	a
Pink Lady UFO	33.6	a	1	no fruit russeting has been recorded	
Pink Lady B + D	72.5	b	0		
Pink Lady Control	158.6	c	0		
Braeburn UFO	23.3	a	3		
Braeburn B + D	53.3	b	0		
Braeburn Control	96.7	c	0		
Fuji UFO	47.7	a	2	5.7	a
Fuji B + D	60.9	b	0	3.3	a
Fuji Control	103.2	c	0	4.3	a
Gala UFO	57.9	a	2	no fruit russeting has been recorded	
Gala B + D	74.7	b	0		
Gala Del. Control	98.7	c	0		
Granny Smith UFO	21.4	a	1	4.7	b
Granny Smith B + D	27.8	b	0	1.4	a
Granny Smith Control	29.4	b	0	1.0	a
Red Del. UFO	16.3	a	4	no fruit russeting has been recorded	
Red Del. B + D	47.3	b	0		
Red Del. Control	69.0	c	0		
Kanzi UFO	2.5	a	5		
Kanzi B + D	23.1	b	0		
Kanzi Control	34.0	c	0		
Pinova UFO	61.8	a	-		
Pinova Control	73.3	b	-		

On the cultivars Pink Lady, Braeburn, Fuji, Gala, Red Delicious, and Kanzi, instead, the thinning effect was significantly higher for the UFO treatment than for the B+D treatment, which still significantly reduced the number of fruits/100 FC in comparison to the untreated control. On the cultivar Granny Smith, only the UFO treatment resulted in a significant reduction of fruit set (21.4 versus 27.8 fruits/100 FC for the B+D treatment and 29.4 fruits/100 FC for the untreated control). Also on the variety Pinova, the UFO treatment resulted in a significant thinning effect (61.8 fruits/100 FC) in comparison to the control (73.3 fruits/100 FC).

Leaf drop was recorded only for the UFO-based treatment, and this on all tested varieties. Highest leaf drop was observed on the cultivars Kanzi (5 = high drop of rosette leaves and on shoots) and Red Delicious (4 = high drop of rosette leaves and light-medium leaf drop on shoots), while the cultivar Pink Lady was the least affected variety (1 = light drop of rosette leaves).

Fruit russeting could be recorded only on the cultivars Golden Delicious, Fuji, and Granny Smith (Table 5). On the cultivars Golden Delicious and Fuji, the percentage of fruit surface affected by russeting did not differ significantly among treatments, while on the cultivar

Granny Smith, the UFO treatment showed a higher percentage of fruit russeting (4.7%) than the B+D treatment (1.4%) and the untreated control (1.0%).

Discussion

In organic apple growing in South Tyrol, yield control is achieved by using mechanical thinning machines and/or lime sulphur sprays during flowering (Südtiroler Beratungsring für Obst- und Weinbau, 2011b). These tools allow for flower thinning. At this crop stage it is already visible how many flowers each tree will bear, but actual fruit set depends also on several additional factors, which can not be predicted at the moment of flower thinning. Frequently, successive steps must be undertaken to assure yield of good quality. In integrated farming systems this is achieved by applying phytohormones. In organic farming, instead, at the moment, the only available tool is manual thinning, which is labour-intensive and expensive.

With the aim of reducing transpiration and net photosynthesis of leaves on treated trees, and thus increasing June fruit drop, the paraffin oil-based product UFO (Ultra Fine Oil) was tested at the research centre Laimburg (South Tyrol, Italy) on different apple varieties in 2010 and 2011. The trials were conducted in different integrated apple orchards (training system: spindle). In 2010, UFO was tested at two different application rates and timing: 2 applications at 1.5 l/100 l and 3 applications at 1.0 l/100 l, respectively. The trials have been conduced in integrated management orchards and it is known, that trees have a different behaviour under integrated and organic conditions. Therefore it would be interesting, to test this experiment also under organic conditions, but it has to be clear, that thinning effects vary significantly between different cultivars, orchards and areas and so there will never be one single thinning application for all apple growing.

In 2010, on all cultivars except Pink Lady, a significant thinning effect of the UFO-based treatments emerged. On the cultivar Golden Delicious, also the synthetic reference product Metamitron was tested. This product showed the highest thinning effect, followed by 2x1.5 l/100 l UFO, 3x1.0 l/100 l UFO, and the untreated control, each treatment differing significantly one from the other. Leaf drop on all cultivars occurred in the UFO-treated plots, but not in the untreated control. However, leaf drop values ranged between 1 and 2, and were thus relatively low. Statistically significant differences among treatments in fruit russeting emerged only on the cultivars Gala and Golden Delicious, with a high percentage of russeted fruit surface in the treatment 2x1.5 l/100l UFO. Significantly lower yield in the UFO-based treatments than in the untreated control was recorded on the cultivars Gala, Braeburn, and Golden Delicious, which is due to the thinning effect of the paraffin oil. Significant differences in fruit weight could be recorded on almost all cultivars. In general, fruit weight was higher in UFO-treated than in untreated control plots, and on the varieties Red Delicious, Braeburn, and Golden Delicious mean fruit weight was highest for 3x1.0 l/100 l UFO, intermediate for 2x1.5 l/100 l UFO, and lowest for the untreated control. Flower bud formation the following spring was generally higher in UFO-treated than in untreated control plots.

In 2011, the paraffin oil-based product UFO was tested in comparison to the integrated phytohormone Brancher Dirado applied in tank mixture with the adjuvant Dirager (B+D treatment) on different apple cultivars. The highest thinning effect was achieved with the UFO-based treatments, followed by the B+D treatment. Leaf drop on all varieties was observed only for the UFO-based treatments. Fruit russeting could be recorded only on the cultivars Golden Delicious, Fuji and Granny Smith, but remained below 15% in all treatments.

It can be concluded that the tested paraffin oil-based product UFO showed a promising thinning potential on all apple cultivars, but, at the moment, the risk of leaf drop and slight fruit russeting can not be excluded.

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