

Crop regulation in organic grown apples – results of different trials on three different sites

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Abstract

Over a period of five years (2009-2013) different thinning methods and compounds were evaluated at three different sites within the BÖLN project "Increasing crop safety and optimizing of crop loading of organic grown pome fruit" (FKZ 06OE197). Just a small extract of all results will be presented here. The trials were carried out in Weinsberg with the cultivars 'Opal' and 'Pinova', in Klein-Altendorf with the cultivar 'Gala' and in Jork with the cultivars 'Elstar' and 'Braeburn'. Except for these cultivars further cultivars were used in other trials, not described here. The strength of thinning was adapted each year to the intensity of flowering. In different trials thinning by hand was compared to thinning with the Darwin rope thinner, lime sulphur, sunflower lecithin, potassium-bicarbonate (Armicarb[®]) and common salt or combinations of it. Using the Darwin rope thinner alone or in combination with lime sulphur showed the best results. Armicarb[®] showed a very good thinning effect, too, but phytotoxicity on the leaves was observed. It led partly to an overthinning and increased russetting. Lime sulphur, sunflower lecithin and -oil worked partly, as well, but not as good as the other treatments and sometimes not, depending on the year and variety.

Keywords: thinning, apples, organic, rope thinner, lime sulphur, Armicarb[®], sunflower lecithin, sunflower oil

Introduction

In organically grown apple orchards thinning is an important tool to help the tree to regulate its yields, to achieve a good fruit quality and to avoid alternating bearing. In recent years different methods of thinning were tested (Eis *et al.* 2008, Weibel *et al.* 2008 und 2012). From 2009-2013 at the research project „Increasing of crop safety and optimizing crop load of organically grown pome fruit“ (FuE 2806OE197), funded by the „Bundesprogramm Ökologischer Landbau und andere Formen nachhaltiger Landwirtschaft“ different thinning methods and compounds were evaluated at three different sites (LVWO Weinsberg, DLR Rheinpfalz and ÖON Jork): Darwin rope thinner solo or in combination with lime sulphur or common salt, lime sulphur, Armicarb[®], sunflower oil and sunflower lecithin. As scab fungicide against scab only a reduced amount of lime sulphur (23.68 l/ha) can be used in Germany since 2012 (plant-protection registration). The question was, if this reduced amount is sufficient for thinning effects or if it should be combined with other thinning measurements. One of the most important topics of these trials was, by which thinning treatments the effort for thinning by hand is clearly reduced, which is a high cost factor for the organic fruit growers.

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Material and Methods

The trial at **site Weinsberg** was carried out on an organic apple orchard at the fruit experimental station of LVWO Weinsberg from 2009-2013. Every year the same trees of the varieties 'Pinova' (planted 2003) and 'Opal' (planted 2005) at a spacing of 1.2 m x 3.5 m (crown height 2.3 m) were observed (10 trees per treatment, each tree was counted as replication). In spring the number of blossom clusters per tree was counted before application of treatment, the level was uniform, when the treatments started. In the following year the trees showed the reaction on the thinning treatments of the year before. Depending on the setting of blossoms the treatments were adjusted every year, so in case of bad disruption of alternating bearing (like in spring 2012) it happened that no blossom thinning was necessary.

In May/June all trees of all treatments were thinned by hand (first time before June-drop), except for the untreated control, and were adjusted to an average amount of about 90 ('Opal') - 120 ('Pinova') apples per tree. The number of apples removed by hand was counted and time saving for thinning by hand was computed under the presumption that removing one apple per tree needs one hour per ha (2500 trees/ha). This calculation is based on data of measuring of real working effort for thinning by hand, described by Weber (1997).

Table 1: Thinning treatments at Weinsberg, 'Pinova' 2011 - 2013

No	Treatment	Application 2011	Application 2012	Application 2013
1	Untreated control	-	-	-
2	Thinning by hand (1)	26.05. + 21.07.11	24.05./23.07.12	03.06./01.07./13.08.13
3	Rope thinner (1) BBCH 57	220 U/min, 6 km/h 10.04.11	180 U/min, 8 km/h 13.04.12	220 U/min, 6 km/h 26.04.13
4	Rope thinner (1) BBCH 59	220 U/min, 6 km/h 14.04.11	-	220 U/min, 6 km/h 30.04.13
5	Rope thinner (1) BBCH 64-65	220 U/min, 6 km/h 16.04.11	180 U/min, 8 km/h 27.04.12	220 U/min, 6 km/h 05.05.13
6	Lime sulphur	3 x 30 l/ha 13./18./20.04.11	-	3 x 24 l/ha 03./06./08.05.13
7	Additional pruning, BBCH 56-57 (removed bl.cl./tree)	06.04.11 (Ø 86 bl.cl.)	-	19.04.13 (Ø 177 bl.cl.)
8	Thinning by hand (2)	26.05. + 21.07.11	24.05./23.07.12	03.06./01.07./13.08.13
9	Rope thinner (2) BBCH 64-65	220 U/min, 6 km/h 16.04.11	180 U/min, 6 km/h 27.04.12	220 U/min, 6 km/h 05.05.13
10	Rope thinner (2) + lime sulphur	220 U/min, 6 km/h 16.04.11 + 1 x 25 l/ha 20.04.11	-	200 U/min, 6 km/h 05.05.13 + 1 x 24 l/ha, 08.05.13
11	Sunflower oil + Rimulgan	3 x 25 l/ha + 2.4 l/ha 13./16./20.04.11	-	3 x 25 l/ha + 2.5 l/ha 03./06./08.05.13
13	Lime sulphur with reduced nozzles ¹			3 x 24 l/ha 03./06./08.05.13
14	Armicarb®			2 x 15 kg/ha, 03./08.05.13
15	Sunflower lecithin			2 x 3 kg/ha, 03./06.05.13
16	Sunflower lecithin + lime sul- phur with reduced nozzles			2 x 3 kg/ha, 03./06.05.13 + 1 x 24 l/ha, 08.05.13*

¹ at tunnel sprayer instead of 16 nozzles only 12 nozzles were used, 10 bar instead 9 bar, only 640 l/ha, so only part of the canopy is treated according to 30 l lime sulphur/ha, but in total per ha only 24 l are used.

Lime sulphur, Armicarb[®], sunflower oil and sunflower lecithin were applied with a tunnel sprayer using a spraying volume of 800 l water per ha (except for tr. no. 13 and lime sulphur spraying at tr. no.16). Additional pruning to regular pruning in winter was done to reduce the number of blossom clusters at BBCH-stage 56-57 (green-red bud) by removing single branches with lots of blossom-clusters. Darwin Rope thinner was used at different flower stages (table 1), rotations/minute and velocity were chosen depending on the setting of blossoms. At harvest number, weight, size and colour of fruits were determined, as well as intensity of russetting and infestation with fungi and pests (e. g. sooty blotch). In winter the length of the one-year-old branches was evaluated, counting them per tree and dividing in length classes (< 5 cm, 5-10 cm, 10-20 cm, 20-35 cm, 35-50 cm, > 50 cm).

Table 2: Thinning treatments at Weinsberg, 'Opal' 2009 - 2013

Treatment	Application / Dosage / Date				
	2009	2010	2011	2012	2013
Untreated control	-	-	-	-	-
Thinning by hand	10.06.09	04.06.10	not necessary	23.05.12 23.07.12	04.06./05.07./ 08.08.13
Lime sulphur	3 x 25 l/ha* 16./20./24.04.09	1 x 25 l/ha 29.04.10	3 x 25 l/ha 11./13./16.04.11	1 x 24 l/ha 27.04.12	3 x 24 l/ha 01./03./06.05.13
Armicarb [®]				1 x 15 kg/ha 27.04.12	2 x 15 kg/ha 01./06.05.13
Sunflowerlecithin				1 x 2.5 kg/ha 27.04.12	2 x 2.5 kg/ha 01.0/6.05.13

* additional 1.5 l/ha Bioblattmehltaumittel (soybean lecithin)

Another trial at **Klein-Altendorf** in the variety 'Gala' (3.45 m x 1.00 m) was carried out in the organic orchard of the DLR Rheinpfalz. Besides the use of the Darwin rope thinner, the effect of lime sulphur with different application rates and the addition of common salt were tested. Furthermore in 2013 the product Armicarb[®] was used (table 3). The tested treatments have been repeated four times with five to seven trees per testing plot. Three trees per testing plot have been evaluated. In April blossom clusters were counted and after the treatments during blossom the trees have been adjusted to an amount of 90 (2011) or 100 (2013) apples/tree at end of May or begin of June (before June drop). The number of apples removed by hand was counted and time saving for thinning by hand was computed under the presumption that removing one apple per tree needs one hour per ha (2500 trees/ha). At harvest yield (kg) and the amount of fruits/tree were recorded. More details about sorting of size and colour are described in the final research report.

Table 3: Thinning treatments and date of treatments, 'Gala', Klein-Altendorf 2011 and 2013

Treatment	Application /Dosage	Date of treatment
thinning by hand	---	07.-09.06.2011 / 19.06.2013
lime sulphur	3 x 24 l/ha	14./19./26.04.2011 08./13./17.05.2013
lime sulphur	3 x 30 l/ha	14./19./26.04.2011 08./13./17.05.2013
2011: lime sulphur + common salt 2013: Armicarb [®]	2011: 3 x 24 l/ha + 5 kg/ha 2013: 2 x 15 kg/ha	14./19./26.04.2011 08./13.05.2013
Darwin rope thinner + lime sulphur	see treatment 2 + 7	see treatment 2 + 7
Darwin rope thinner + lime sulphur	see treatment 3 + 7	see treatment 3 + 7
Darwin rope thinner	200 U/min, 8 km/h	14.04.2011 /08.05.2013

The trial at site **Jork** was carried out in an organic orchard with the varieties '**Elstar**' and '**Braeburn**' at the ESTEBURG Fruit Research and Advisory Centre (Jork). Different thinning methods like thinning by hand, lime sulphur (1000 l water/ha), potassium bicarbonate (Armicarb®) or mechanical thinning by Darwin rope thinner were compared over the years 2012 – 2013 (table 4). Due to a large variety of flowering intensity in the '**Elstar**'-orchard, the trial was repeated **every year with new sample trees**. Only trees with high flowering rate were chosen over the years to assess the fundamental effect of every thinning method. The variants were repeated four times with ten trees per repetition. Three trees per repetition were chosen for evaluation. In the '**Braeburn**'-orchard the same trees were evaluated every year. The treatments have been replicated five times with ten trees per testing plot. In spring the intensity of flowering per tree was rated by notes from one to nine (6=optimal). In opposite to Weinsberg and Ahrweiler the trees weren't thinned by hand after the treatments during blossom. Only the trees of the variant "thinning by hand" have been adjusted to an average amount of 100-110 apples per tree after June drop. Fruits were harvested on two ('Elstar') or three ('Braeburn') picking dates every year.

Table 4: Thinning treatments at Jork, 'Elstar' and 'Braeburn' 2012-2013

Treatment	Application / Dosage	Date 2012	Date 2013
untreated control			
thinning by hand	after June drop	11.07.12	16.07.13
lime sulphur (A)	3 x 30 l/ha	04.05./07.05./11.05.12	17.05./21.05./23.05.13
lime sulphur (B)	3 x 24 l/ha	04.05./07.05./11.05.12	17.05./21.05./23.05.13
Armicarb®	2 x 10 kg/ha	04.05./08.05.12	17.05./23.05.13
rope thinner BBCH 59-60 (A)	220 U/min, 8 km/h	02.05.12	13.05.13
rope thinner BBCH 59-60 (B)	240 U/min, 8 km/h	02.05.12	13.05.13
rope thinner (A) + lime sulphur (B)	220 U/min, 8 km/h + 3 x 24 l/ha	02.05.12 04.05./07.05./11.05.12	13.05.13 17.05./21.05./23.05.13

Results

In **Weinsberg** with the cultivar '**Pinova**' (table 5, striking data were marked grey) flower setting in 2011 and 2013 was very high and in 2012 only moderate due to normal alternation. All thinning treatments during blossom 2011 improved the flowering setting in 2012 (about 100 blossom clusters more/tree). Because of frost damage of about 80 % at mid of April 2012 only three variants with the rope thinner (No 3, 5, 9) were treated that year. Depending on level of flower setting in 2012 the flowering setting in spring 2013 was a little bit lower in treatments No. 4, 5, 6 than in untreated control and hand thinning variant, but still on a high level.

Looking at the treatments **No 1 to 7** time for thinning by hand after treatment was depending on the number of blossom clusters, the treatment itself and the weather conditions during bloom (frost). In 2011 an average level of 193 h/ha over all variants was measured, in 2012 only 52 h/ha and in 2013 561 h/ha were necessary. Most time was saved by the rope thinner (No 3-5) in 2011 and 2013, not for no. 4 in 2012 (blossom setting was higher), while lime sulphur did not save time in 2011 and 2013. Additional pruning in 2011 did not weaken the alternate bearing, but in 2013 color and average fruit weight were improved. The untreated control had the highest amount of too small and too green apples every year. All three rope thinner variants (No 3-5) had high proportions of

marketable yield, while at lime sulphur (No 6) only in 2011 the amount of well colored fruits was higher than in the hand thinning parcel. Vegetative growth was moderately increased for rope thinner treatments No. 3+4 in 2011 and 2013, in 2012 only for No. 3 (more branches/tree in classes < 5 cm and 10-20 cm). At the last flower setting was more homogenous over the years compared to the other variants for treatment 5 (rope thinner BBCH 64-65), while the tested dosages of lime sulphur were too low for a sufficient thinning of such high flower settings, the flowering season 2014 will show very interesting differences in flower setting depending on blossom thinning in 2013.

Table 5: Blossom clusters/tree, time for thinning by hand, yield (kg/tree) and average fruit weight (g) at different treatments at Weinsberg, 'Pinova' (2400 trees/ha), 2011-2013

No Treatment		Data 2011 – 2012 - 2013			
		Blossom cl./tree	thinning by hand (h/ha)	yield (kg/tree)	Ø fruit weight (g)
1	Untreated control	552 - 113 -596	-	29.87- 4.88-33.80	131-139- 88
2	Thinning by hand (1)	520 - 203- 521	198 – 49 - 713	21.31-10.82-27.63	156-153-121
3	Rope thinner (1) BBCH 57	595 - 203- 506	143 – 47 - 412	20.80-13.01-24.48	163-165-126
4	Rope thinner (1) BBCH 59	644 - 198 -469	134 – 59 - 396	24.85-10.61-23.08	158-136-127
5	Rope thinner (1) BBCH 64-65	381 - 272 -461	92 – 103 - 388	18.56-14.37-21.33	162-142-125
6	lime sulphur	506 - 198 -432	226 – 46 - 660	21.00- 9.79-24.02	163-162-134
7	additional pruning	444 - 126 -709	364 – 6 - 795	22.51- 4.98-26.20	156-123-133
8	Thinning by hand (2)	418 - 243 -547	208 – 128 - 740	21.80-14.21-29.12	147-143-121
9	Rope thinner (2) BBCH 64-65	417 - 344 -488	62 – 158 - 394	15.71-16.27-22.79	176-158-123
10	Rope thinner (2) BBCH 64-65 + lime sulphur	468 - 249 -494	56 – 87 - 299	18.59-16.60-21.76	163-150-133
11	Sunflower oil / Rimulgan	417 - 171 -560	194 – 42 - 590	17.89-12.09-23.34	196-157-118
Year 2013					
8	Thinning by hand (2)	547	740	29.12	121
6	Lime sulphur	432	660	24.02	134
12	Lime sulphur with reduced nozzles	594	789	26.35	122
13	Armcarb®	542	532	22.00	118
14	Sunflower lecithin	543	548	24.90	124
15	Sunflower lecithin + lime sulphur with reduced nozzles	552	580	25.21	123

Looking at the treatments **No 8 to 11** variants with combination of rope thinner (No 9) and lime sulphur (No 10) did not show as much alternate bearing as the variants thinning by hand 2 (No 8) and sunflower oil+Rimulgan (No 11). In 2011 rope thinner variant No. 9 saved 146 h/ha time in comparison to thinning by hand, but the yield was a little bit too low (only 15.71 kg/tree). The potential of time saving was 346 h/ha for treatment No. 9 and 441 h/ha for No.10 in comparison to thinning by hand in 2013. The combination of rope thinner and lime sulphur (No. 10) improved average fruit weight (especially in 2013) and the proportion of well colored fruits in every year.

Looking at the treatments **No 8, 6 and 12 to 15** (table 5, year 2013), the very high number of blossom clusters led to a very high work intensity for thinning despite a higher fruit fall in June. Taking into account the number of blossom clusters per tree, all treatments saved time for thinning by hand, except of lime sulphur (No 6), while lime sulphur with reduced nozzles (No 12) only showed a minimal effect. Best thinning variant in 2013 was Armicarb[®] (No 13, saving time: 208 h/ha), followed by sunflower lecithin (No 14, saving time: 192 h/ha). In 2013 despite the high work intensity, the number of fruits per tree was still high, especially with thinning by hand (2) with 241 fruits/tree and 29 kg. Accordingly low was the fruit weight (between 118 and 134 g). The variants sunflowerlecithin (No 14), Armicarb[®] (No 13) and lime sulphur with reduced nozzles (No 12) had the highest amount of marketable apples (average of 11.6 kg/tree), but at the variant Armicarb[®] (No 13) fruits were smaller while at lime sulphur (No 6) fruit weight was highest because number of fruits per tree (179) was not as high compared to the other variants (over 200).

At cultivar 'Opal' (table 6) damage by strong late frost in May 2011 caused very low yields and led in all variants to a high number of flowers in 2012. At mid of April 2012 again a frost occurred (frost damage of about 40 % at the variety 'Opal'), therefore all spraying variants were only applied once. Lime sulphur led always to a good flower setting in the following year. Armicarb[®] and sunflower lecithin had a similar effect after blossom thinning in 2012 with clearly increased blossom setting in 2013. The unthinned control showed high bi-annual bearing in the years 2009-2013, more fluctuations than in all thinned variants.

Table 6: Blossom clusters/tree, time for thinning by hand (2009-2013), yield (kg/tree) and average fruit weight (g) for different treatments at Weinsberg, 'Opal' (2400 trees/ha).

Treatment	Bl. clusters/tree			Data 2009-2010-2011		
	2009	2010	2011	time for thinning by hand (h/ha)	yield (kg/tree)	Ø fruit weight (g)
Untreated control	252	45	524	0 - 0 - 0	19.53 - 5.32 - 5.58	105 - 145 - 157
Thinning by hand	228	95	460	114 - 12 - 0	12.80 - 11.22 - 4.75	147 - 142 - 154
Lime sulphur	219	200	297	49 - 27 - 0	12.38 - 13.48 - 3.66	139 - 125 - 143
Treatment	Bl. clusters/tree		Data 2012-2013			
	2012	2013	time for thinning by hand (h/ha)	yield (kg/tree)	Ø fruit weight (g)	
Untreated control	436	205	0	24.82 - 24.51	96 - 85	
Thinning by hand	403	352	216 - 207	13.44 - 19.30	123 - 112	
Lime sulphur	332	392	134 - 171	10.14 - 18.22	114 - 97	
Armicarb [®]	457	390	183 - 151	13.23 - 18.49	125 - 103	
Sunflower lecithin	450	424	208 - 250	12.37 - 21.02	121 - 100	

In 2009, 2012 and 2013 the use of lime sulphur reduced the effort for thinning by hand afterwards. Respecting the number of blossom clusters per tree in 2012 and 2013 Armicarb[®] showed good results, between 33 and 56 h/ha*year could be saved. Only in 2012 with sunflower lecithin 8 h/ha were saved, the flower setting in spring 2013 was surprisingly high (219 blossom clusters/tree more the untreated control and 72 blossom clusters more than thinning by hand). but there was no thinning effect during blossom seen in 2013. In both years fruits of the Armicarb[®] variant and of sunflower lecithin-variant were

at least covered with sooty blotch, but in 2013 russetting was increased for Armicarb and lime sulphur (about 23 % less fruits with low russetting than thinning by hand). In 2009, 2012 and 2013 the not thinned control had absolutely the highest yield, but in return also a very high number of too green apples with low fruit weight.

Klein-Altendorf

2011: At the cultivar 'Gala' the use of lime sulphur (3 x 24 l/ha) showed with 19 h/ha (12 %) the least time reduction for thinning by hand (table 7), but the highest flower setting in the following year 2012. A concentration of 3 x 30 l/ha or a combination of 3 x 24 l/ha plus common salt achieved a time saving of 40 h/ha (25 %) or 56 h/ha (35 %) towards thinning by hand. The best result was achieved with a combination of Darwin rope thinner and lime sulphur. In those treatments only 11 or 15 apples had to be removed by hand. This corresponds to a reduction of working time of 93 % or 91 %. Using only mechanical thinning the time saving amounts to 77 h/ha (48 %).

Table 7: Number of blossom clusters/tree, amount of apples removed by hand, time saving h/ha and % and yield data, 'Gala', Klein-Altendorf 2011 and 2013

Treatment	2011/2012/2013	Data 2011 / 2013				
	number of blossom clusters/tree	Amount of apples removed by hand	Time saving (h/ha) *	Yield (kg/tree)	Amount of fruits per tree	Ø fruit weight (g)
thinning by hand	545 – 86 - 229	161 / 149	---	14.7 / 20,7	97 / 144	151 / 144
lime sulphur (3 x 24 l/ha)	541 – 126 - 188	143 / 79	19 / 70	13.4 / 18,9	89 / 125	151 / 150
lime sulphur (3 x 30 l/ha)	532 – 122 - 192	122 / 64	40 / 85	14.5 / 18,1	97 / 129	149 / 140
2011: lime sulphur (3 x 24 l/ha) + common salt 2013: 2 x 15 kg Armicarb®	559 – 106 - 218	105 / 5	56 / 144	14.4 / 7,3	104 / 44	139 / 166
rope thinner + lime sulphur (3 x 24 l/ha)	536 – 113 - 210	15 / 19	146 / 130	11.9 / 13.6	77 / 89	154 / 152
rope thinner + lime sulphur (3 x 30 l/ha)	539 – 100 - 226	11 / 20	151 / 128	11.9 / 13.9	77 / 89	155 / 155
rope thinner	419 – 91 - 247	84 / 73	77 / 76	13.2 / 17.1	90 / 118	147 / 145

* Presumption: thinning one apple per tree needs one hour per ha (2500 trees/ha)

2013: As in 2011 the treatment with lime sulphur (3 x 24 l/ha) achieved with 70 h/ha (47 %) the lowest time saving. An increasing of the application rate to 3 x 30 l/ha reduced the remaining time for thinning by hand up to 85 h/ha (57 %). The sole mechanical treatment led to a reduction of 76 h/ha (51 %). Additional applications with lime sulphur increased the time saving for thinning by hand up to 130 h/ha (87 %). The product Armicarb® (2 x 15 kg/ha) achieved in 2013 the highest thinning effect. Only an average amount of five fruits still had to be removed. Even before thinning by hand the number of apples per tree was lower than the target number of 100. The treatments in the variety 'Gala' with Armicarb® led to an obvious overthinning of the trees (at harvest only 44 apples and

7.3 kg/tree, only one third of treatment thinning by hand) and an increased russetting of the fruits at harvest (observation, but not evaluated in detail).

In both years the combination of rope thinner and lime sulphur led to a lower yield (2011: 11.9 kg / 2013: 13.6 kg and 13.9 kg) and to less fruits per tree at time of harvest (2011: 77/ 2013: 89). This was combined with a higher average fruit weight of 153.8 g and 154.6 g (2011) or 152.3 g and 155.3 g (2013). In the other treatments the results of yield were close together with 13.2 kg to 14.5 kg in 2011 and 17.1 kg to 18.9 kg in 2013. Just the product Armicarb[®] caused an overthinning of the trees and a much lower yield of only 7.3 kg/tree. The low number of fruits resulted in the highest average fruit weight of 165.6 g.

Jork

At **Jork** the influence of every thinning method was assessed from 2012 to 2013 by means of flowering intensity in the following year, yield and fruit quality. The mechanical thinning (BBCH 59-60) caused an average **yield reduction** of 30 – 40 % over the years at the variety 'Elstar' (table 8). Yields from 8.2 – 13.8 kg/tree could be reached with an increasing fruit size of 3.0–3.5 mm towards untreated control. From 2012 to 2013 a yield reduction of 20-28 % (except for 2013) was observed when thinning with lime sulphur. This treatment achieved yields about 10.0 – 14.5 kg/tree. The lower dosage of 24 l/ha showed a comparable effect like the previous dosage of 30 l/ha. In 2012 the combination of mechanical thinning and applications with lime sulphur led into a reduction of yield of 25% and to an increase of fruit size about 2.2 mm. On the other hand this double treatment caused a yield reduction of 43.7 % towards untreated control in the year 2013. Spraying two times with Armicarb[®] at full bloom showed different thinning effects in the years. Compared to untreated control the yield was halved by using Armicarb[®] in 2012 (overthinning), while in the year 2013 the yield was only reduced about 16.4 %. The weather conditions during and after the applications were important for these results. Thinning by hand showed a possible yield reduction of 10.2 % – 36.2 %, an increase of fruit size (+ 2.6 mm) could be observed in the year 2012.

Table 8: Intensity of flowering (1-9), total yield (kg/tree) and fruit size (mm) of 'Elstar', Jork 2012-2013, (Tukey-test $\alpha = 0.05$)

Treatment	2012				2013		
	Bloom 2012	Bloom 2013	Yield [kg/tree]	Fruit size [mm]	Bloom 2013	Yield [kg/tree]	Fruit size [mm]
Untreated control	6.0	4.9	19.9 a	72.1	6.0	12.8 ab	73.8
Thinning by hand	5.9	5.0	12.7 ab	74.7	6.2	11.5 ab	73.2
Lime sulphur (3x30 l/ha)	6.0	5.5	14.5 ab	74.3	6.3	14.1 a	73.9
Lime sulphur (3x24 l/ha)	6.0	5.1	14.0 ab	73.5	6.4	10.0 ab	73.2
Armicarb [®]	5.8	5.1	8.8 b	76.7	6.0	10.7 ab	75.2
Rope thinner BBCH 59-60 (A)	6.0	5.0	12.1 ab	75.4	6.2	8.5 ab	76.5
Rope thinner BBCH 59-60 (B)	5.9	4.9	13.8 ab	75.8	6.1	8.2 ab	76.9
Rope thinner + lime sulphur	5.9	5.5	14.8 ab	74.3	6.4	7.2 b	75.6

Over the years a reduction of biennial bearing was shown after mechanical thinning (BBCH 59-60) and treatment with lime sulphur (table 8). In 2013 the intensity of flowering was given with constant notes of five at both variants. But also the use of Armicarb® and the combination of mechanical thinning and lime sulphur reached a moderate intensity of flowering in the following year.

Mechanical thinning may stimulate vegetative tree growth. This effect was assessed by counting and measuring new shoots in summer (pruning) and January/February the following year. The trees of untreated control showed a vegetative growth of 21 m/tree over the years. Using the rope thinner on BBCH 59-60 with 220-240 U/min led into an increase of vegetative growth with 26 m/tree.

The trees of the variety 'Braeburn' showed an optimal intensity of flowering (note 6-7) every year. All thinning treatments were able to reduce the yield, but they reached different results in the years (table 9). The mechanical thinning (BBCH 59-60) caused an average yield reduction of 14 % - 28 %, with an increasing fruit size of 2.0–3.0 mm towards untreated control. By using lime sulphur three-times during full bloom the yield was reduced about 25 % in 2012 and merely diminished about 7 % in the year 2013. An increase of fruit size (+ 1.8 mm) could only be observed in 2012. The dosage of 24 l/ha showed a lower effect than the previous dosage of 30 l/ha. The combination of mechanical thinning and lime sulphur led into a yield reduction of 29.6 % in 2012 and of 16.1 % in 2013. In spite of these fluctuating results this treatment showed the biggest and heaviest fruits every year. In the year 2012 two treatments with Armicarb® at full bloom were able to reduce the yield only about 6 %, but caused a clearly increase of fruit size (+ 4.2 mm) and fruit weight. In 2013 the yield reduction was given with 11.7 % and the fruit size showed a plus of 1.9 mm.

Table 9: Intensity of flowering (1-9), total yield (kg/tree) and fruit size (mm) of 'Braeburn', Jork 2012-2013, (Tukey-test $\alpha = 0.05$)

Treatment	2012			2013		
	Bloom 2012	Yield [kg/tree]	Fruit size [mm]	Bloom 2013	Yield [kg/tree]	Fruit size [mm]
Untreated control	6.5	19.6 a	70.7	6.2	13.7 a	69.4
Thinning by hand	6.4	13.7 a	72.9	6.7	12.2 a	69.9
Lime sulphur (3x30 l/ha)	6.5	13.8 a	72.3	7.0	12.6 a	69.9
Lime sulphur (3x24 l/ha)	6.5	15.5 a	72.7	6.8	12.7 a	70.3
Armicarb®	6.5	18.3 a	74.9	6.7	12.1 a	71.3
Rope thinner BBCH 59-60 (A)	6.2	16.2 a	72.5	6.1	9.8 a	71.3
Rope thinner BBCH 59-60 (B)	6.3	16.8 a	73.9	6.6	10.9 a	71.6
Rope thinner + lime sulphur	6.0	13.8 a	74.9	7.1	11.5 a	72.5

Discussion

The decision, which strategy for flower thinning should be chosen, depends on different factors: site and in general weather conditions during blossom, cultivar, the number of blossom clusters and occurrence of wild bees and honey-bees in the orchard, the

available equipment, availability of seasonal workers for thinning by hand or financial aspects.

Depending on the flower setting and the weather conditions especially during bloom the time for thinning by hand may vary very much. At Weinsberg at the variety '**Opal**' between 0 h/ha (frost in 2011) and 216 h/ha (2012) were needed for the variant thinning by hand. Spraying application during bloom reduced the time for thinning by hand. In 2012 and 2013 Armicarb[®] showed a good result, but it was combined with heavy browning of petals, phytotoxicity on leaves and increased russetting of the fruits. This corresponded with the results from Weibel *et al.* (2012) who had satisfying thinning results with an application of 2 times 15 kg Armicarb[®]. Lime sulphur and sunflowerlecithin showed promising results, too. All spraying variants led to a good flower setting in the following year.

At the variety '**Pinova**' all treatments saved time for thinning by hand, except for lime sulphur alone. The tremendous high number of blossom clusters/tree in 2013 led to a very high work intensity in thinning by hand, the numbers of fruits per tree at harvest were still very high. Using the rope thinner (BBCH 57-65) saved about 131 h per year (average of 2011-13) for thinning by hand compared to the treatment thinning by hand. Using the rope thinner plus lime sulphur showed a very good thinning effect and saved about 211 h/ha. This corresponds to the results of the years 2009-2011 (Sinatsch *et al.* 2012), but there lime sulphur showed a good thinning effect in 2009 and 2010. Armicarb[®] and sunflowerlecithin, both tested in 2013, showed a good thinning effect, too. Armicarb[®] did not lead to a higher russetting at '**Pinova**'. The use of the rope thinner led only to a moderately higher vegetative growth at this cultivar.

At the site Klein-Altendorf using lime sulphur (3 x 24 l/ha) at the variety '**Gala**' showed the least time reduction in thinning by hand. A concentration of 3 x 30 l/ha lime sulphur or a combination of 3 x 24 l plus common salt saved more time for thinning by hand. The best variant in time saving was the combination of the Darwin rope thinner plus lime sulphur. In 2013 Armicarb[®] led to a overthinning of the fruit trees.

At Jork during the years mechanical thinning (BBCH 59-60, 220-240 U/min) and lime sulphur showed the best results, regarding the yield, fruit size, weight and colour. At the variety '**Elstar**' a first reduction of biennial bearing was shown after both treatments. Also a stimulation of vegetative tree growth was observed after mechanical thinning with the Darwin rope thinner. The lower dosage of lime sulphur (3 x 24 l/ha) showed a comparable effect like the previous dosage (3 x 30 l/ha) at the variety '**Elstar**'. But at '**Braeburn**' instead a lower effect was observed during the years. By using Armicarb[®] (potassium bicarbonate, 2 x 10 kg/ha) two-times at full bloom a clearly yield reduction could be reached, but the effect was fluctuating over the years and due to weather conditions during spraying overthinning was possible.

Altogether simplified economical calculations depending on the efficacy of the thinning treatments were done in this research project regarding time for thinning by hand (calculated with 9 € per working hour), yield (divided in marketable yield and cider apples), different prices for these two proportions, and time for picking (based on rate of picking of 120 kg/h, 9 €/h). Respecting these factors the conclusion was, that in some single cases, if the yield was too low due to an overthinning during blossom, the advantage of less costs for thinning by hand was not levelled out by income of the yield, than the moderate thinning treatments were judged better, even if they needed more effort to organize the seasonal workers in time.

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