RESULTS OBTAINED ON THE EFFICACY OF 6-BA ALONE, AND IN COMBINATION WITH OTHER THINNING AGENTS FROM DIFFERENT APPLE PRODUCING AREAS OF NORTHERN ITALY

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A B S T R A C T

The thinning efficacy of 6-BA alone, and in combination with other chemicals, relating to fruit size and climate conditions, was investigated in different apple producing areas of Northern Italy. In two different areas of the Emilia-Romagna region (Bologna and Ferrara), 150 ppm of 6-BA alone, and in combination with Carbaryl or NAA, were applied to fruit on 'Galaxy' and 'Fuji' orchards at different phenological stages. In the Piedmont region (Cuneo district area), 150 ppm of 6-BA alone, and in combination with Carbaryl, NAD, or Ethephon, were applied to three cultivars ('Schniga Schnitzer', 'Nagafu 6' and 'Scarlet') at different phenological stages, namely between 12.7 and 14 mm of the king fruit's diameter. During the growing season, and at the time of application, the minimum and maximum temperatures were monitored daily. The number of flower clusters at full bloom, fruitlets at fruit set, and fruit before and after the June drop, were assessed. At harvest, the productive performance, (fruit number, fresh weight and the distribution of fruit in the commercial sized classes), was measured. During the trial performed in the Bologna district area, the biometric, (diameter and length) and the quality parameters, (fresh weight, soluble solid content, flesh firmness and starch), were also

measured at harvest. The thinning efficacy of 6-BA alone, and in combination with other chemicals, appeared to relate more to king fruit size than to climate conditions. Moreover, 6-BA alone induced similar thinning efficacy, comparable to that of "Standard thinning" methods, on 'Gala' and 'Fuji', when king fruit diameter and climate conditions were appropriate. The efficacy of the compounds tested alone, and in combination with other chemicals, with the exception of Carbaryl, produced results which were more dependent upon the time of application rather than the climatic conditions.

Key words: abscission, phenological stage, temperature, *Malus*

INTRODUCTION

Chemical thinning is an established orchard management technique which is used mainly to reduce crop load and improve fruit quality (Costa, 1981). Excessive crop loads not only increase the proportion of small fruit on the tree, but also adversely affect important fruit quality traits, including color, sugar content, and storage life (Wertheim, 1997). Inadequate thinning can reduce return bloom and yield in the following year.

The effects of a particular chemical thinner are highly variable, differing not only from year to year, but also from week to week. Among the factors affecting the thinning response are: dose, fruitlet diameter, amount of sunlight, temperature, and relative humidity.

In the United States, apple growers are generally advised to apply chemical thinning agents when daytime high temperatures are expected to be between 21°C and 26°C, for the coming four days (Robinson and Lakso, 2004).

The EUFRIN (European Fruit Research Institutes Network) working group on Fruit Chemical Thinning formulated a new experimental protocol for the evaluation of thinning agents. The criteria concerning the time of application of the chemical thinners refer not only to fruit diameter, but also to the minimum temperatures expected during the trial period.

The aim of this study was to gather further data on the correlation between environmental conditions; particularly temperature, fruit dimensions and chemical thinners efficacy, on 'Gala'- and 'Fuji'- derived cultivars in Northern Italy. A pluriennial trial, with BA alone, and in combination with other chemical thinners in different geographical areas, was carried out.

MATERIAL AND METHODS

The trials were carried out in 2005 at three different locations. These were the Bologna and the Ferrara districts of the Emilia-Romagna region and the Cuneo district of the Piedmont region.

The dosage and application schedule used in this study are presented in Table 1.

Table 1. The chemical thinners, doses, and application time of the trials performed in the different apple producing areas of Northern Italy, where Bo = Bologna, Fe = Ferrara, Cn = Cuneo; Control = unthinned trees. In the Bo and Fe trials: St. thinning = Carbaryl + NAA + 0.1% of mineral oil. In the Cn trials, 0.1% of mineral oil was added to each spray, St. Thinning = Carbaryl + 0.1% mineral oil and OF = open flowers

Trial	Concentration [ppm]	KFO [mm]	Cultivar
Control	-	-	Galaxy (Bo)
6-BA (MaxCel)	150	12	Galaxy (Bo)
6-BA (LG 187)	150	12	Galaxy (Bo)
6-BA + NAA (LG 183)	150 + 10	12	Galaxy (Bo)
6-BA (MaxCel) + Carbaryl	150 + 237	12	Galaxy (Bo)
St. thinning	237 + 10	12	Galaxy (Bo)
Control	-	-	Fuji (Bo)
6-BA (MaxCel)	150	>14	Fuji (Bo)
6-BA (LG 187)	150	>14	Fuji (Bo)
Control	-	-	Fuji (Fe)
6-BA (MaxCel)	150	12	Fuji (Fe)
6-BA (MaxCel) + Carbaryl	150 + 237	12	Fuji (Fe)
6-BA (MaxCel) + 2x Carbaryl	150 + 474	12	Fuji (Fe)
St. thinning	237 + 10	12	Fuji (Fe)
St. thinning	400	13.2	S. Schnitzer (Cn)
6-BA (MaxCel) + NAD	50 + 150	petal fall + 13.2	S. Schnitzer (Cn)
6-BA (Brancher) + NAD	50 + 150	petal fall + 13.2	S. Schnitzer (Cn)
St. thinning	400	13.8	Nagafu 6 (Cn)
6-BA (MaxCel)	150	13.8	Nagafu 6 (Cn)
St. thinning	400	12.7	Nagafu 6 (Cn)
6-BA (Brancher)	150	12.7	Nagafu 6 (Cn)
6-BA (MaxCel) + ethephon	100 + 150	1% OF + 12.7	Nagafu 6 (Cn)
St. thinning	400	14	Scarlet (Cn)
6-BA (Brancher) + Carbaryl	150 + 250	14	Scarlet (Cn)
6-BA (Brancher) + ethephon	100 + 100	5% OF + 14	Scarlet (Cn)

The trials in Bologna were carried out in two orchards belonging to the Experimental Farm of the University of Bologna. One orchard was planted with the 'Galaxy' variety, the other with 'Fuji'/M9. In both orchards, the trees were four years old and were planted at a density of 3,300 trees per hectare.

In Ferrara, the trials were carried out in a commercial orchard planted with the variety 'Fuji'/M9. The trees

were six years old and were planted at a density of 2,800 trees per hectare.

In Cuneo, the trials were carried out in three orchards. The first was planted with 'Schniga Schnitzer'/M9. The trees were four years old and planted at a density of 2,300 trees per hectare. The second was planted with 'Nagafu 6'/M9. The trees were ten-years old and were planted at a density of 1,785 trees per hectare. The third was planted with 'Scarlet' and 'Pajam 2'. The trees were four years old and planted at a density of 2,500 trees per hectare.

Data recorded included the number of blossom clusters per tree, the number of fruitlets per tree at fruit set, and the number of fruit per tree at harvest time. This data also included the trunk cross-sectional area (TCSA), which was calculated from the trunk diameter.

The abscission rate was calculated according to the following formula:

$$A = (F_s - F_h)/F_s \cdot 100\%$$

where: A represents the abscission rate, F_s represents the number of fruitlets at fruit set, and F_h represents the number of fruit at harvest.

The following data was also recorded at harvest time: yield per tree, mean fruit weight, diameter, length, ratio of length to diameter, and soluble solids content. The starch content and fruit firmness were also measured.

All data were tistically evaluated using analysis of variance, followed by means separation using Duncan's multiple-range t-test at $P \leq 0.05$. All calculations were performed using the SAS software package (SAS Institute, Cary, NC, USA).

RESULTS

Trials at Bologna

The minimum and maximum daily temperatures during the fruit growing season at Bologna are presented in Figure 1A.

The 'Galaxy' trees were treated on May 9, when the fruitlets were 12 mm in diameter. The mean daily temperature, three days prior to spraying, was 18°C. The mean daily temperature on the day of spraying, was 18°C. During the first four days after spraying, the mean daily temperature fell to 16°C.

The 'Fuji' trees were treated on May 16, when the fruitlets were 14 mm in diameter. On the day of spraying, the mean daily temperature was 18°C, and remained at about that level over the following few days.

Highly uniform trees were selected for this study (Tab. 2).

The abscission rate with the 'Galaxy' variety, with 6-BA alone, and in combination with Carbaryl or NAA, was generally higher than in the control trees, and either comparable to, or higher than, that with "Standard thinning" (Tab. 2).

Considering the productive performance, all the chemical thinners, except MaxCel, significantly increased fruit weight (Tab. 3).

With MaxCel alone, and in combination with Carbaryl, yield was significantly lower than the control trees, but comparable to that with "Standard thinning" (Tab. 3).

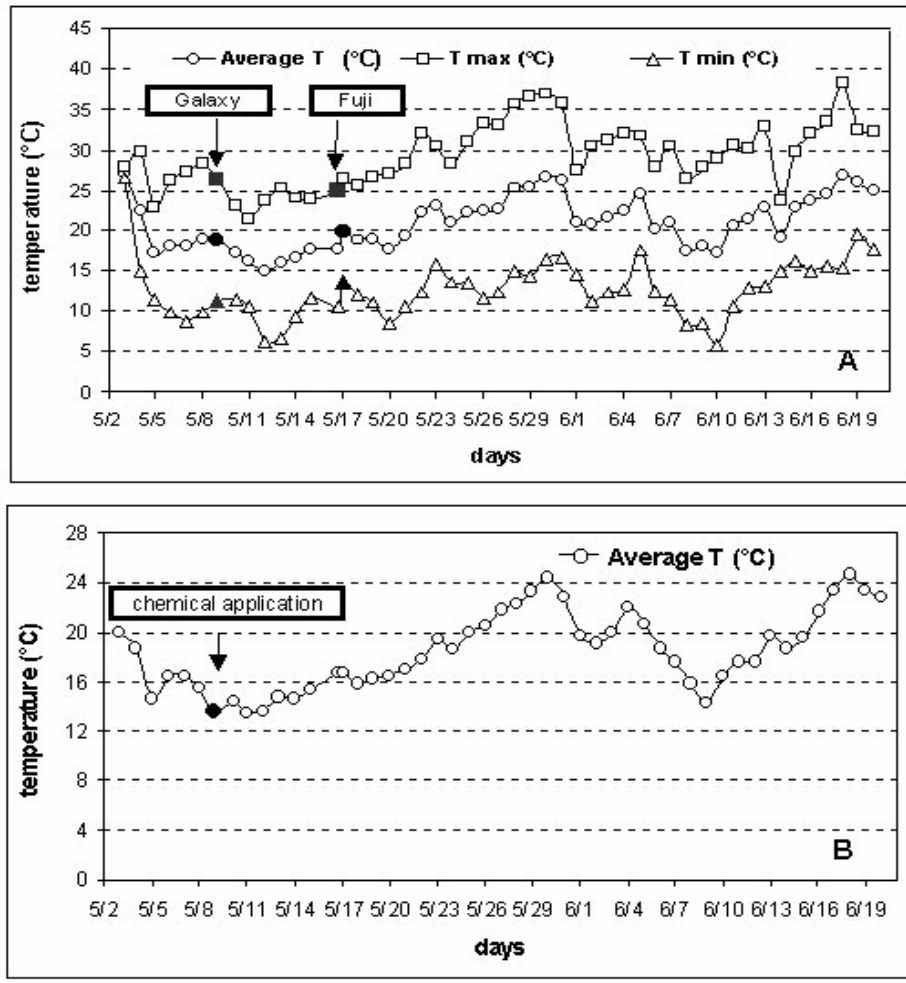

Figure 1. Daily minimum, maximum, and average temperatures, recorded on 'Galaxy' and 'Fuji' apple orchards in the Bologna and Ferrara district areas, (A) and (B) respectively, during the fruit growing season

A better productive performance was obtained with 6-BA alone (LG 187) and in combination with NAA (LG 183). Neither application decreased yield, which was similar to that obtained in the control trees.

The L/D ratio was significantly increased with the use of 6-BA alone, (LG 187), and with MaxCel, in combination with Carbaryl (Tab. 3).

The soluble solid contents were significantly higher in the chemically thinned fruit than in control (Tab. 3).

Table 2. The number of flower clusters, fruit at fruit set and harvest, and percentage of chemical abscission on 'Gala' apple trees (cv 'Galaxy'), as affected by 6-BA alone, and in combination with Carbaryl or NAA. Control = unthinned trees; St. thinning = Carbaryl + NAA + mineral oil. The different letters indicate significant differences at $P \leq 0.05$ (Duncan's t-test)

	TCSA	Flower cluster		Fruit at fruit set		Fruit at harvest		Chemical abscission
	[cm^2]	[no./cm^2]	[no./tree]	[no./cm^2]	[no./tree]	[no./cm^2]	[no./tree]	[% on fruit set]
Control	12.5 a	17.1 a	214 a	22.4 a	280 a	10.6 a	133 a	53 b
6-BA (MaxCel)	14.1 a	16.6 a	234 a	23.5 a	331 a	7.5 c	106 c	68 a
6-BA (LG 187)	13.2 a	15.5 a	205 a	21.7 a	287 a	8.3 b	110 b	62 a
6-BA + NAA (LG 183)	12.6 a	17.3 a	218 a	24.4 a	306 a	10.5 a	132 a	57 ab
6-BA (MaxCel) + Carbaryl	13.4 a	12.3 b	165 b	19.4 a	260 a	7.0 c	94 c	64 a
St. thinning	12.9 a	16.7 a	215 a	21.1 a	272 a	8.9 b	115 b	58 a

Table 3. The productive and biometric parameters, and soluble solid content (SSC) of fruit on 'Galaxy' trees, as affected by 6-BA alone, and in combination with Carbaryl or NAA. Control = unthinned trees; St. thinning = Carbaryl + NAA + mineral oil. The different letters represent significances using Duncan's multiple range t-test at $P \leq 0.05$

	Yield [kg/tree]	Fruit number [no./tree]	Fruit weight [g]	Diameter [mm]	Length [mm]	L/D	SSC [°Brix]
Control	16.2 a	133 a	121 b	70.7 ab	63.0 b	0.89 b	11.6 c
6-BA (MaxCel)	13.7 b	106 b	132 ab	71.4 a	64.0 b	0.90 ab	12.0 b
6-BA (LG 187)	16.2 a	110 b	147 a	71.9 a	66.6 a	0.93 a	12.2 a
6-BA + NAA (LG 183)	18.5 a	132 a	141 a	70.2 b	62.2 b	0.89 b	12.3 a
6-BA (MaxCel) + Carbaryl	13.1 b	94 b	137 a	72.1 a	66.0 a	0.92 a	12.3 a
St. thinning	14.4 ab	106 b	136 a	71.5 a	64.0 b	0.90 ab	12.3 ab

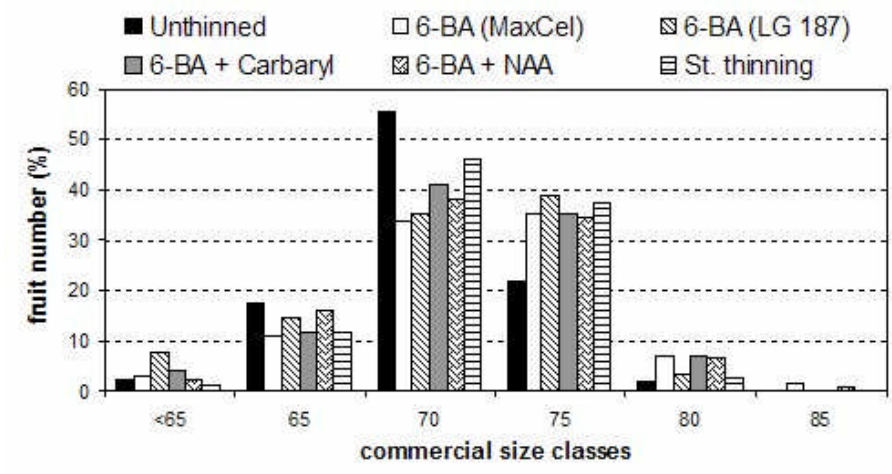

Figure 2. Commercial size classes of 'Galaxy' fruit as affected by 6-BA alone from two different commercial sources, (MaxCel from Valent Biosciences and LG 187 from l.gobbi), and in combination with Carbaryl or NAA

There were no significant differences in either flesh firmness or starch content between the treated fruit and those of the controls (data not shown).

The proportion of marketable fruit was higher in the treated trees than those of the controls (Fig. 2).

Two commercial formulations of 6-BA were tested at Bologna: MaxCel (Valent Biosciences) and LG 187 (l. gobbi). When applied to 'Fuji' trees, at 14 mm fruit diameter, no significant differences in the abscission rate, yield, or fruit quality were found between the two formulations (data not shown).

Trials at Ferrara

The minimum and maximum daily temperatures during the fruit growing season at Ferrara are presented in Figure 1B.

The 'Fuji' trees were treated on May 9, when the fruitlets were 12 mm in diameter. The trees were treated with 6-BA, (MaxCel from Valent Biosciences), alone, and in combination with Carbaryl. The temperatures at this time were relatively cold. During the three days prior to spraying, mean daily temperatures did not exceed 16°C. During the three days after spraying, mean daily temperatures dropped to as low as 13°C.

The abscission rate was higher in the trees treated with 6-BA, in combination with Carbaryl, than those of the controlled orchards, but comparable to that with "Standard thinning" (Tab. 4).

Table 4. The number of flower clusters, number of fruit at fruit set and at harvest, and percentage of chemical abscission on apple trees (cv 'Fuji'), as affected by 6-BA alone, and in combination with different concentrations of Carbaryl. Control = unthinned trees. St. thinning = Carbaryl + NAA + mineral oil. Different letters indicate significant differences at $P \leq 0.05$ (Duncan's t-test)

	TCSA	Flower cluster		Fruit at fruit set		Fruit at harvest		Chemical abscission
	[cm^2]	[no./cm^2]	[no./tree]	[no./cm^2]	[no./tree]	[no./cm^2]	[no./tree]	[% on fruit set]
Control	24.2 a	9.9 a	240 a	23.0 a	557 a	12.9 a	312 a	44 c
6-BA (MaxCel)	23.1 a	10.0 a	232 a	23.1 a	533 a	12.8 a	266 a	50 bc
6-BA (MaxCel) + Carbaryl	22.9 a	10.7 a	244 a	25.6 a	585 a	9.9 bc	226 bc	61 a
6-BA (MaxCel) + 2x Carbaryl	20.8 a	10.6 a	221 a	26.6 a	553 a	10.5 ab	243 ab	56 ab
St. thinning	22.2 a	8.9 a	197 a	20.9 a	465 a	8.7 c	194 c	58 ab

Table 5. The productive parameters of 'Fuji' trees, as affected by 6-BA alone, and in combination with different concentrations of Carbaryl. Control = unthinned trees. St. thinning = Carbaryl + NAA + mineral oil. Different letters represent significant results from Duncan's multiple range t-test at $P \leq 0.05$

	Yield [kg/tree]	Fruit number [no./tree]	Fruit weight [g]
Control	40.6 a	312 a	130.4 b
6-BA (MaxCel)	38.0 a	266 a	150.2 ab
6-BA (MaxCel) + Carbaryl	35.9 ab	226 bc	159.0 a
6-BA (MaxCel) + 2x Carbaryl	39.2 a	243 ab	161.3 a
St. thinning	31.8 b	194 c	164.2 a

With 6-BA alone, there were no significant differences in the abscission rate between the treated, the control, and the "Standard thinning" trees.

All of the treatments increased fruit weight, especially 6-BA + Carbaryl and "Standard thinning" (Tab. 5).

"Standard thinning" significantly decreased yield. However 6-BA alone, and in combination with Carbaryl did not (Tab. 5).

Trials at Cuneo

The 'Schniga Schnitzer' trees were treated on May 11, when the fruitlets were 13.2 mm in diameter. For several days prior to spraying, the mean daily temperatures had been gradually falling, finally reaching 12°C on the day before spraying. On the day of spraying, however, the mean daily temperature rose to 15°C. During the first five days after spraying, the mean daily temperature remained at around 15°C (Fig. 3A).

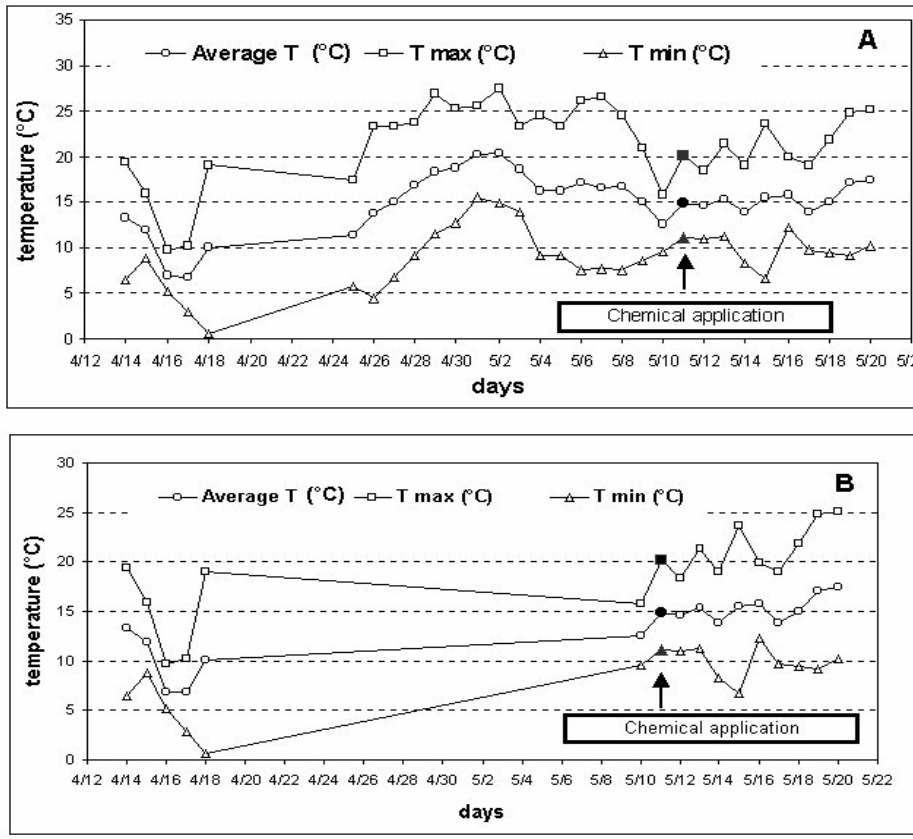

Figure 3. Daily minimum, maximum, and average temperatures of 'Schniga Schnitzer' (A), and 'Nagafu 6' and 'Scarlet' orchards (B), in the Cuneo district area, measured during the fruit growing season

Two commercial formulations of 6-BA were tested at Cuneo: MaxCel (Valent Biosciences) and Brancher (Agrimport). Both were applied in combination with NAD. Brancher + NAD resulted more effective than MaxCel + NAD inducing higher abscission rate and productive performance (yield and fruit quality). There were no significant differences in the amount of marketable fruit among the treatments tested (Tab. 6, 7).

Two groups of 'Nagafu 6' trees were treated in the same orchard on May 12. In the first group the fruitlets were 12.7 mm in diameter. In the second group the fruitlets were 13.8 mm in diameter.

Table 6. Number of flower clusters, fruit at harvest, and percentage of chemical abscission on 'Gala' apple trees (cv 'Schniga Schnitzer'), as affected by 6-BA from two commercial sources in combination with NAD. St. thinning = Carbaryl + mineral oil. Different letters indicate significant differences at P≤0.05 (Duncan's t-test)

	TCSA	Flower cluster		Fruit at harvest		Chemical abscission
	[cm^2]	[no./cm^2]	[no./tree]	[no./cm^2]	[no./tree]	[%]
St. thinning	11.9 a	30.4 a	363 a	12.6 b	150 b	88 a
6-BA (MaxCel) + NAD	11.9 a	25.1 a	300 a	19.0 a	230 a	80 b
6-BA (Brancher) + NAD	11.8 a	27.2 a	322 a	15.9 b	189 b	85 a

Table 7. The productive parameters and marketable amount of fruit on 'Gala' apple trees (cv 'Schniga Schnitzer'), as affected by 6-BA from two commercial sources in combination with NAD. St. thinning = Carbaryl + mineral oil. Different letters indicate significant differences at P≤0.05 (Duncan's t-test)

	Yield [kg/tree]	Fruit [no./tree]	Fruit weight [g]	Marketable >117g [%]	Unmarketable <117g [%]
St. thinning	29 a	150 b	172 a	97 a	3 a
6-BA (MaxCel) + NAD	36 a	230 a	156 a	94 a	6 a
6-BA (Brancher) + NAD	31 a	189 b	163 a	96 a	4 a

The temperature conditions for both groups were the same. The mean daily temperatures had been steadily increasing over the few days prior to spraying. On the day of spraying, and thereafter the mean daily temperature was 15°C (Fig. 3B).

In the 12.7 mm group, the abscission rate was higher with 6-BA in combination with ethephon than with 6-BA alone or with "Standard thinning". The mean fruit weight was higher with 6-BA in combination with ethephon than with "Standard thinning". However, the mean fruit weight was lower with 6-BA alone than with "Standard thinning" (Tab. 8 and 9). The proportion of unmarketable fruit was higher with 6-BA alone than with 6-BA in combination with ethephon or "Standard thinning" (Tab. 9).

In the 13.8 mm group, a higher abscission was induced leading to productive performance comparable to that of the "Standard thinning" trees (Tab. 10 and 11).

6-BA in combination with Carbaryl or ethephon was tested on the 'Scarlet' ('Red Delicious') variety.

Applications were performed on May 11, when fruit diameter reached 14 mm. The average temperature was 15°C, which remained stable at spraying time and thereafter (Fig. 3B).

Table 8. The number of flower clusters, fruit at harvest, and percentage of chemical abscission on 'Fuji' apple trees (cv 'Nagafu 6'), as affected by 6-BA alone, and in combination with ethephon. St. thinning = Carbaryl. Note: 0.1% of mineral oil was added to each spray. Different letters indicate significant differences at P≤0.05 (Duncan's t-test)

	TCSA	Flower cluster		Fruit at harvest		Chemical abscission
	[cm^2]	[no./cm^2]	[no./tree]	[no./cm^2]	[no./tree]	[%]
St. thinning	45.2 a	12.8 a	580 a	6.6 b	300 b	90 a
6-BA (Brancher)	51.5 a	12.9 a	666 a	8.1 a	417 a	87 b
6-BA (MaxCel) + ethephon	50.0 a	12.6 a	630 a	5.7 b	290 b	91 a

Table 9. The productive parameters and marketable amount of fruit on 'Fuji' apple trees (cv 'Nagafu 6'), as affected by 6-BA alone, and in combination with ethephon. St. thinning = Carbaryl. Note: 01% of mineral oil was added to each spray. Different letters indicate significant differences at P≤0.05 (Duncan's t test)

	Yield [kg/tree]	Fruit [no./tree]	Fruit weight [g]	Marketable >120g [%]	Unmarketable <120g [%]
St. thinning	58 a	300 b	193 a	96.8 b	3.2 b
6-BA (Brancher)	63 a	417 a	152 b	83.8 a	16.2 a
6-BA (MaxCel) + ethephon	53 a	290 b	183 a	92.1 b	7.9 b

Table 10. Number of flower clusters, fruit at harvest, and percentage of chemical abscission on 'Fuji' apple trees (cv 'Nagafu 6'), as affected by 6-BA alone. St. thinning = Carbaryl. Note: 01% of mineral oil was added to each spray. Different letters indicate significant differences at P≤0.05 (Duncan's t-test)

	TCSA	Flower cluster		Fruit at harvest		Chemical abscission
	[cm^2]	[no./cm^2]	[no./tree]	[no./cm^2]	[no./tree]	[%]
St. thinning	45.2 a	12.8 a	580 a	6.64 a	300 a	89.7 a
6-BA (MaxCel)	59.3 b	9.6 a	569 a	5.94 a	352 a	87.6 a

Table 11. The productive parameters and marketable amount of fruit on 'Fuji' apple trees (cv 'Nagafu 6'), as affected by 6-BA alone. St. thinning = Carbaryl. Note: 0.1% of mineral oil was added to each spray. Different letters indicate significant differences at P≤0.05 (Duncan's t-test)

	Yield [kg/tree]	Fruit [no./tree]	Fruit weight [g]	Marketable >120g [%]	Unmarketable <120g [%]
St. thinning	58.2 a	300 a	193 a	96 a	3.2 a
6-BA (MaxCel)	64.5 a	352 a	183 a	95 a	5.0 a

Table 12. The number of clusters, fruit at harvest, and the percentage of chemical abscission on 'Red Delicious' apple trees (cv 'Scarlet'), as affected by 6-BA in combination with Carbaryl or ethephon. St. thinning = Carbaryl. Note: 0.1% of mineral oil was added to each spray. The different letters indicate significant differences at P≤0.05 (Duncan's t-test)

	TCSA	Flower cluster		Fruit at harvest		Chemical abscission
	[cm^2]	[no./cm^2]	[no./tree]	[no./cm^2]	[no./tree]	[%]
St. thinning	14.9 a	12.3 a	185 a	4.4 b	66 b	93 a
6-BA (Brancher) + Carbaryl	14.3 a	11.8 a	169 a	4.8 b	69 b	92 a
6-BA (Brancher) + ethephon	15.0 a	11.9 a	179 a	7.8 a	118 a	87 b

Table 13. The productive parameters and marketable amount of fruit on 'Red Delicious' apple trees (cv 'Scarlet'), as affected by 6-BA in combination with Carbaryl or ethephon. St. thinning = Carbaryl. Note: 0.1% of mineral oil was added to each spray. The different letters indicate significant differences at P≤0.05 (Duncan's t-test)

	Yield [kg/tree]	Fruit [no./tree]	Fruit weight [g]
St. thinning	17.8 b	66 b	272 a
6-BA (Brancher) + Carbaryl	17.4 b	69 b	252 a
6-BA (Brancher) + ethephon	26.4 a	118 a	224 b

The fruit abscission induced by 6-BA and Carbaryl was similar to that of the "Standard thinning", while the combination with ethephon induced a significantly lower abscission (Tab. 12).

With regards to the productive performance, the 6-BA + Carbaryl combination results were similar to the "Standard thinning" values. Trees treated with the 6-BA + ethephon induced significantly higher yield and lower fresh weight as compared to the other treatments (Tab. 13).

These differences were also confirmed by the distribution of fruit in the commercial sized classes. The highest number of fruit treated with 6-BA + ethephon were in the intermediate classes (75/80 and 80/85), while fruit treated with 6-BA + Carbaryl showed a distribution similar to that of fruit harvested from "Standard thinned" trees (Fig. 4).

DISCUSSION

Our results confirm once again that the efficacy of the tested chemical thinners, in particular 6-BA, is highly dependent upon the phenological stage of the fruit. In fact, all the applications performed at 12-13 mm fruit diameter were effective, while later applications were not. Ward and Marini had already concluded in 1999, after having investigated a number of ways to

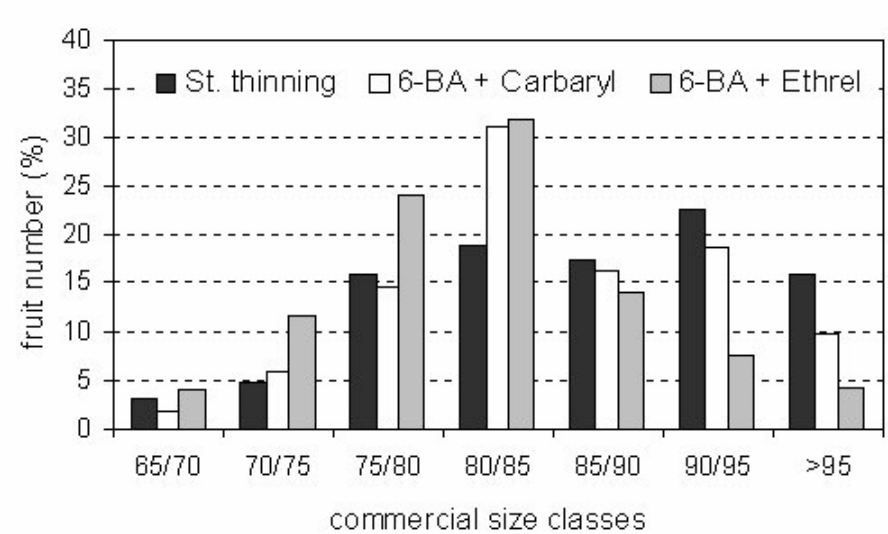

Figure 4. Commercial size classes of 'Scarlet' fruit, as affected by 6-BA (Brancher from Agrimport), and in combination with Carbaryl or ethephon

asses thinner efficacy, that fruit growth measurements were the only accurate and practical way to obtain a good thinner response. Stover et al. (2001) had also observed that the effectiveness of 6-BA and NAA applications to the 'Empire' apple, was influenced more by phenological stages than by moderate differences in temperature.

The climate conditions at the time of application, and thereafter, are of course important factors in affecting the response of the thinners. However, in our experimental conditions, the phenological stage also generally appeared to play the most important role. Earlier applications performed on 'Fuji' at low temperature (14°C), and at 12 mm fruit diameter, were more effective than the sprays performed at 14 mm fruit diameter, when tem peratures reached a level of 18°C, normally considered optimal for the treatments. These results partially contrast to those obtained in Piedmont on the same cultivar, where, surprisingly, the later application (13.8 mm fruit diameter) was more effective than the earlier one (12 mm fruit diameter), performed on the same day and with the same climatic conditions. The differences obtained on 'Fuji' might be related to the condition of the tree. In fact, the length of the blooming period, and as a consequence, the non-uniformity of the flower opening, the fruitlet age or the type of wood carrying the fruitlet, can affect thinner response (Comai and Dorigoni, 2000).

Moreover, the 6-BA/phenological stage related not only to induced abscission, but also to the overall fruit quality. In fact, trees sprayed with 6-BA at the right time of application, yielded fruit of higher quality, in terms of fruit biometric and internal

parameters. The effect of BA on fruit size and on some quality traits, especially with regards to the increase in flesh firmness and soluble solid content, had already been observed in several experiments (Greene et al., 1990; Wertheim, 2000). The recorded increase in soluble solid content may be attributed to stimulation resulting from the import of sorbitol from the leaf, as demonstrated by Yuan and Greene (2000) in a specific experiment carried out with ^{14}C-sorbitol.

The efficacy of 6-BA, in relation to the different cultivars tested, confirmed the importance of the cultivar. This is in agreement with similar research previously carried out on the efficacy of chemical thinners on different species and cultivars (Wertheim, 1997). For instance, in some 'Red Delicious' selections, which are considered difficult to be thinned (Costa, 1981), a "multiple chemical application strategy" is generally performed in practice. This strategy consists of applying several thinning agents consecutively to the same trees at different phenological stages, in order to reduce the flower/fruitlet load: i.e ethephon at full bloom + 6-BA at 12 mm fruit diameter, and thereafter Carbaryl until fruit diameter reaches 14-15 mm.

As far as the 6-BA formulation trials are concerned, the results were more than interesting. Of all the tested 6-BA preparations, the best performance was obtained with the LG 187 formulation. However it must be emphasized that since one of the objectives was to test the practical reliability of the different thinning strategies, the comparison among the different BA formulations was performed against the standard chemical thinning practice commonly used. The 6-BA formulations were, in some cases, combined with other thinners such as Carbaryl or auxin. When the same chemical combination and 6-BA was tested, the efficacy of 6-BA was arbitrarily estimated and produced comparable results to the effects induced by the other chemicals. Generally, in these sets of trials however, the efficacy of the 6-BA in combination with other chemical thinners did not produce any significant results.

In conclusion, 6-BA alone, and in combination with other chemicals, proved to be an effective fruit apple thinner, thus contributing to the solution of the problem of crop load control for adequate fruit size. Findings also confirmed that 6-BA improved fruit size, even at low induced abscission levels and without reducing the crop load in comparison to controlled orchard trees (Bregoli et al., 2005). This effect might be due to both a stimulation of cytokinesis and an enhancement of the expansion of a larger number of cells.

The efficacy of 6-BA, and of the other chemical thinners, is dependent more upon the time of application than the temperature. However, consideration must be given to other factors: the relative humidity and blooming length, for instance, which play an important role in affecting fruitlet growth uniformity. In order to fine-tune the chemical thinning operation,

and to increase its reliability, these aspects have to be taken into account whilst continuing with all the other cultural practices, such as winter pruning, bud extinction, dormancy breaking agent application, in order to be able to enhance the uniformity of the reproductive buds which will be exposed to the chemical thinning operation.

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WYNIKI BADAŃ SKUTECZNOŚCI 6-BA ZASTOSOWANEJ ODDZIELNIE I W KOMBINACJI Z INNYMI ŚRODKAMI PRZERZEDZAJĄCYMI OWOCE UZYSKANE W RÓŻNYCH REJONACH PRODUKCJI JABŁEK W PÓŁNOCNYCH WŁOSZECH

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S T R E S Z C Z E N I E

W różnych rejonach sadowniczych północnych Włoch badano skuteczność 6-BA zastosowanej oddzielnie i w kombinacji z innymi preparatami w celu przerzedzenia zawiązków owocowych jabłoni, ze szczególnym uwzględnieniem wielkości owoców i warunków klimatycznych. W dwóch różnych rejonach sadowniczych (Bolonia i Ferrara) rejonu Emilia-Romagna zastosowano 6-BA 150 ppm oddzielnie, i w kombinacji z karbarylem lub NAA, na jabłonie odmian 'Galaxy' i 'Fuji' w różnych stadiach fenologicznych owoców. Natomiast w rejonie Piedmont (Cuneo region) zastosowano 6-BA oddzielnie i w kombinacji z karbarylem, NAD lub etefonem na jabłonie odmian 'Schniga Schnitzer', 'Nagafu 6' i 'Scarlet' w różnych stadiach fenologicznych owoców, a mianowicie na owoce królewskie średnicy od 12.7 do 14 mm. W okresie wzrostu owoców i podczas stosowania preparatów, codziennie monitorowano temperaturę minimalną i maksymalną. Określano liczbę kwiatostanów podczas pełni kwitnienia, liczbę zawiązków owocowych w okresie ich zawiązywania oraz liczbę owoców przed i po opadzie czerwcowym. Podczas zbioru określano produktywność drzew za pomocą takich parametrów, jak liczba owoców, przeciętna ich masa i dystrybucja owoców w klasach wielkości o znaczeniu produkcyjnym. W badaniach wykonanych w rejonie Bolonia podczas zbioru oceniano także parametry biometryczne owoców (średnicę i długość) oraz dotyczące ich jakości (świeżą masę, zawartość cukrów, jędrność miąższu i zawartość skrobi).

Stwierdzono, że skuteczność 6-BA po zastosowaniu oddzielnie i w kombinacji z innymi preparatami, bardziej zależała od wielkości owocu królewskiego niż warunków klimatycznych. Ponadto, na jabłoniach odmian 'Gala' i 'Fuji' 6-BA zastosowana oddzielnie, ale na owoce królewskie właściwej wielkości i podczas odpowiednich warunków klimatycznych przerzedzała z podobną skutecznością i porównywalnie do metod przerzedzania stosowanych w badaniach jako standardowe. Skuteczność preparatów stosowanych oddzielnie i w kombinacji z innymi, z wyjątkiem karbarylu, bardziej zależała od czasu ich zastosowania niż warunków klimatycznych.

Słowa kluczowe: opadanie owoców, stadium fenologiczne owoców, temperatura, *Malus*