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1-Naphthaleneacetic acid and 6-benzyladenine thinning of a common slender spindle 'Jonagold'/M.9 apple orchard. I: Dose effects and spray distribution in the crowns

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SUMMARY
To find the most appropriate rates of application of plant growth regulator (PGR) thinning-agents for a common slender spindle apple (*Malus* × *domestica* Borkh.) orchard, different volumes of dilute 1-naphthaleneacetic acid (NAA) and 6-benzyladenine (BA) were sprayed ha^{-1}. Mature 'Jonagold'/M.9 trees, 3.0 – 3.5 m high and 1.2 – 1.5 m wide, planted in a single row system with 3,030 trees ha^{-1}, were used. Significant thinning was observed in the case of dilute sprays of NAA at 10 mg l^{-1}, or BA at 100 mg l^{-1}, to run-off, using 2,000 l ha^{-1} or 1,500 l ha^{-1}; while 1,000 l ha^{-1} did not result in sufficient thinning. Thinning using smaller volumes (250, 500, or 750 l ha^{-1}) was also significant if the concentration of PGR thinner was proportionally higher (i.e., based on the 1,500 l ha^{-1} application rate of more dilute sprays of NAA at 10 mg l^{-1} or BA at 100 mg l^{-1}). Spray distribution measurements in the crowns showed better spray deposits when higher water volumes (i.e., more dilute PGR solutions) were sprayed at all positions (bottom, middle, or top) of the canopy. At 2,000 l ha^{-1}, 54 – 72% coverage of the leaf area was observed; but, at 250 l ha^{-1}, coverage was only 10 – 21%. The lower 30% of the canopy was covered poorly when smaller volumes of water (250, 500, or 1,000 l ha^{-1}) were applied. When 1,500 l ha^{-1} was sprayed, good coverage of the lower and upper surfaces of the leaves occurred, and no differences in canopy positions were measured. It was concluded that 1,500 l ha^{-1} (i.e., dilute PGR) spraying was the most appropriate volume to use when calculating the dose of NAA or BA to be applied ha^{-1} to common (3.0 – 3.5 m-high) mature slender spindle apple orchards on M.9 rootstock. This study was part of the ISAFRUIT Smartfruit Project, aimed at improving existing methods for apple crop regulation with more precise use of PGR thinning agents and with minimum impact on the environment.

Most pesticide labels used in orchards recommend the practice of high volume spraying to "run-off" (i.e., to achieve the foliage "drip point") at a fixed concentration. It has been argued that, under such conditions, overdosing is minimised because any excess spray is not retained and coverage is complete and uniform. Recently, with the modern trend towards more environmentally-friendly and efficient machine spraying methods, low-volume spraying under conditions well below "run-off" is performed, while the application rate (i.e., the dose) is expressed as the mass or volume of chemical product per unit ground area (ha^{-1}). In practice, pesticide labels do not generally give instructions on how spray applications should be adjusted for varying tree size and/or canopy density, and many fruit growers do not adapt the water volume and/or dose per unit area to the current orchard situation. To calculate the appropriate rate of pesticide to use per orchard area, different methods of dose expression such as "tree row volume" or "tree area density" have been developed, but these are not frequently used in European orchards. However, a broad range of water volumes is used when pesticides are applied to fruit trees. The chemical rates and volumes used in the majority of New Zealand apple orchards are derived from an arbitrary, standard application rate of 2,000 l ha^{-1}, but very high volumes, up to 6,000 l ha^{-1}, have been used in Australia to achieve fruit thinning on mature apple trees (Manktelow and Praat, 1997; Oakford *et al.,* 1994). Some European countries are using the, now-standard, 500 l water m^{-1} of tree crown height in order to calculate the pesticide dose rate ha^{-1} (Lešnik *et al.,* 2006).

Plant growth regulators (PGRs) have traditionally been applied as high volume (i.e., dilute) sprays, but changing trends to low water volume applications could give inconsistent results because of changes in spray delivery to the target, and numerous factors that influence fruit tree responses, such as sensitivity to a narrow range of applied active ingredient (a.i.), plant surface characteristics, and penetration of a.i. (Bukovac *et al.,* 1986). Furthermore, carrier water volume may also play a role within a constant dose of PGR applied. Bukovac (1981) reported that the response to ethephon was higher at low water volumes, while carrier volume had no effect if 1-naphthaleneacetic acid (NAA) or 6-benzyladenine (BA) was being sprayed (Black *et al.,* 1995; Hull *et al.,* 1995).

The aims of this study were: (i) to define the most appropriate water volume with which to apply chemical thinning agents (PGRs) to the most common type of European apple orchard on dwarf M.9 rootstock, with 3,000 trees ha^{-1} trained as a slender spindle with a crown height of 3.0 – 3.5 m; (ii) to test whether NAA or BA could be applied at higher concentrations and therefore

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at lower water carrier volumes; and (iii) to follow spray delivery within the crown when different water volumes were used for thinning. A more rational use of PGR thinning agents, and increasing the yield of top quality fruit fulfil the goals of these ISAFRUIT Smartfruit-related experiments.

MATERIALS AND METHODS

Plant material

Three-years of experiments (in 2005, 2006, and 2007) were conducted in the experimental orchard at Brdo, in continental Slovenia. Mature slender spindle-trained 'Jonagold'/M.9 apple trees, 3.0 – 3.5 m high and 1.2 – 1.5 m wide were planted in a single row system at a spacing of 3.0 m × 1.1 m (3,030 trees ha^{-1}) and were selected for uniformity of size, vigour, and bloom density. At harvest, the numbers of fruits per tree were counted and fruits were weighed. The extent of return bloom was estimated visually in the following Spring using a scale from 1 to 10 (where 1 = no flowers present; and 10 = abundant flowering). Analysis of covariance was undertaken, where the number of flower clusters per tree was used as a covariate, and treatment means were separated by Duncan's test at P = 0.05.

Application of treatments and measurements of spray distribution

A broader description is provided by Stopar *et al.* (2009). In short, three homogeneous trees were selected and sprayed for each treatment. Four repetitions were performed as a randomised block design in two rows. NAA and BA were sprayed on both sides of the experimental trees, at the 9 – 10 mm fruitlet diameter stage, using a tractor and axial fan sprayer. In 2005, 2,000 l water ha^{-1} was defined as the dilute spray volume; but, in 2006 and 2007, the dilute spray volume was set to 1,500 l water ha^{-1}. A smaller water volume was used by changing the nozzle size, and a proportionally higher concentration of a.i. was applied, in order to retain the same overall dose of NAA or BA ha^{-1}. To compare dilute spray applications made by tractor, a knapsack hand-sprayer was also used as a second control treatment to ensure run-off spraying, and approx. 1 l water per tree was used to wet the tree thoroughly. Spray deposition was measured as the "percentage covering area" using water-sensitive paper attached to the lower and upper surfaces of leaves at five positions in the canopies of the experimental trees (Stopar *et al.,* 2009; Figure 1). The NAA water-volume experiment from 2006 was used for canopy leaf coverage measurements.

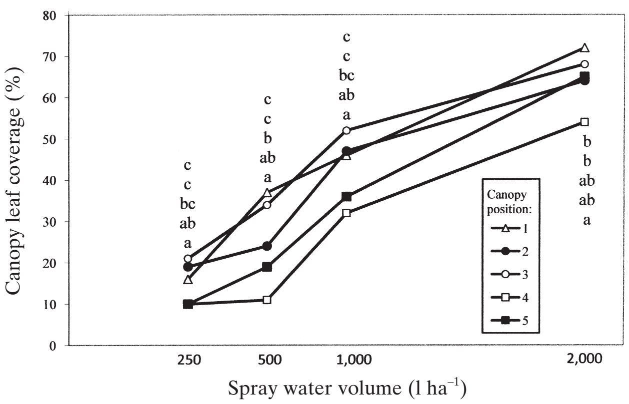

FIG. 1
Leaf area covered by spray deposits, as the average of the upper (adaxial) and lower (abaxial) leaf surface at five canopy positions (1, top; 2, middle internal; 3, middle external; 4, bottom internal; 5, bottom external) when a 250, 500, 1,000, or 2,000 l ha^{-1} spray volume of NAA at various concentrations was applied. The lower-case letters above (or below) the mean values indicate their statistical significance by Duncan's multiple range test at P = 0.05, in the order of canopy position at each spray volume treatment.

RESULTS AND DISCUSSION

An NAA fruit thinning experiment in 2005 was used to establish the overall (preliminary) volume of water required to thin a common, mature slender spindle apple/M.9 orchard having a canopy height of 3.0 – 3.5 m. Previous experiments had shown that application of 10 mg l^{-1} NAA to run-off successfully thinned 'Jonagold'/M.9, an easy-to-thin apple cultivar (Stopar, 2000). In the present trial, the greatest final reduction in fruit number (approx. 37%) occurred when 10 mg l^{-1} NAA was sprayed to run-off using a knapsack sprayer (with 64 fruit per tree; 30 fruit per 100 clusters), compared to the crop load on control, unthinned trees (102 fruit per tree; 47 fruit per 100 clusters; Table I). Similar fruit thinning results were obtained following the application of 10 mg l^{-1} NAA at 2,000 l water ha^{-1} using a tractor and axial fan sprayer, where an excessive (drip point) spray solution was observed on the leaves. When the same dose of NAA was delivered to 'Jonagold'/M.9 crowns using 1,000 l water ha^{-1} (i.e., 20 mg l^{-1} NAA), some, but not significant, thinning was observed (88 fruit per tree; 43 fruit per 100 clusters; Table I). Also, and in the same range, no significant reduction in fruit numbers occurred when the water volume was reduced further to 500 l ha^{-1} or 250 l ha^{-1}, with a constant NAA delivery dose to the tree. Most authors state that more concentrated applications of NAA do not change its thinning efficiency when different water volumes are used (Camilo and Palladini, 2000). The high average fruit weight on control trees (198 g) indicated that thinning was not essential, which could be the reason for the insignificance at thinning when concentrated PGR sprays were used. When 10 mg l^{-1} NAA was distributed over the canopy with 1,000 l ha^{-1} water (i.e., half the dose of NAA compared to 2,000 l ha^{-1} at 10 mg l^{-1} NAA), slight but significant thinning occurred (83 fruit per tree; 39 fruit per 100 clusters). Considering that 10 mg l^{-1} or 20 mg l^{-1} NAA sprayed at 1,000 l ha^{-1} thinned trees only slightly, while the application of 10 mg l^{-1} NAA at 2,000 l ha^{-1} significantly reduced final fruit numbers, but that drift (run-off) was also observed, leads us to the conclusion that the appropriate volume of water for determining the dose of PGR ha^{-1} for this size of tree should be between 1,000 l ha^{-1} and 2,000 l ha^{-1}, when 10 mg l^{-1} NAA was being sprayed.

Using water-sensitive paper, the same water volume trial showed the distribution of spray solution at five different locations in the canopy when using standard tractor and axial-fan, whole-tree spraying. The averages of the upper and lower leaf surface areas covered were measured (Figure 1). In general, more coverage was achieved at all positions in the canopy using higher volume spraying. For example, leaf coverage at 2,000 l

TABLE I
Number of flower clusters at the start of the experiment, final fruit numbers, mean fruit weights, and return bloom in 'Jonagold'/M.9 apple trees in the water-volume application experiment in 2005

Treatment [Volume applied; (NAA concentration)]	Flower clusters (No./tree)	Final fruit no (No./tree)	Final fruit no (No./100 clusters)	Mean fruit weight (g)	Return bloom (1–10)**
Control, (no thinning)	237 a*	102 d	47 d	198 a	1.5 a
To run-off, NAA (10 mg l^{-1})	210 a	64 a	30 a	246 b	2.8 b
2,000 l ha^{-1}, NAA (10 mg l^{-1})	206 a	69 ab	34 ab	221 ab	2.2 ab
1,000 l ha^{-1}, NAA (20 mg l^{-1})	219 a	88 cd	43 cd	210 a	2.1 ab
500 l ha^{-1}, NAA (40 mg l^{-1})	216 a	92 cd	44 cd	202 a	2.3 ab
250 l ha^{-1}, NAA (80 mg l^{-1})	217 a	88 cd	42 cd	221 ab	1.7 a
1,000 l ha^{-1}, NAA (10 mg l^{-1})	209 a	83 bc	39 bc	218 ab	2.0 ab

*Mean separation within each column was by Duncan's multiple range test (P = 0.05). Values followed by different lower-case letters were significantly different.
**Estimation of flowering in the next season was on a scale from 1 – 10, where 1 = no flower clusters; 10 = very dense flowering.
NAA, 1-naphthaleneacetic acid.

ha^{-1} ranged from 54 – 72%; but, at 250 l ha^{-1}, it was only 10 – 21%. When 250 l, 500 l, or 1,000 l water ha^{-1} was used, significantly smaller leaf canopy coverage was observed at both the lower canopy positions (4, internal, near the trunk; and 5, external, near the spray lane), compared to leaves in the middle of the canopy (position 2, internal; and position 3, external), or at the top of the canopy (position 1), which received nearly twice as much coverage. Black *et al.* (1995) also observed that approx. 70% less spray was captured at the bottom of an apple tree canopy compared to the middle and top positions when different water volumes were applied. Crabtree and Bukovac (1980) and Knoche *et al.* (1998) found that the performance of the growth regulators NAA, GA_3, or daminozide was related to their effects at the interface area between the droplets and the leaf surface. Thus covering-area should be an important parameter when the action of thinning agents is being considered. In our experiments, improved thinning was also observed using higher water volumes (i.e., when better leaf area coverage occurred).

From previous experiments, it could be determined that the appropriate volume of water for (dilute) application of 10 mg l^{-1} NAA to thin a common, mature slender spindle 'Jonagold'/M.9-type of orchard, probably lay between 1,000 l ha^{-1} and 2,000 l ha^{-1}. To test if 1,500 l ha^{-1} (as a dilute spray) was suitable to use for determining the amount of thinning agent (a.i.) ha^{-1}, additional experiments were done using 10 mg l^{-1} NAA or 100 mg l^{-1} BA (Table II). NAA at 10 mg l^{-1}, and at various carrier volume applications, significantly reduced the final fruit number at harvest, from 276 fruit per tree (no thinned-control) to 207 fruit per tree (at run-off spraying with a knapsack sprayer), or 217 fruit per tree (at 2,000 l ha^{-1}), or 186 fruit per tree (at 1,500 l ha^{-1}). The smallest reduction in fruit number (to 220 fruit per tree) occurred when 1,000 l ha^{-1} of 10 mg l^{-1} NAA was used. Relative thinning, expressed as fruit number per 100 flower clusters, was significant only when run-off, 2,000 l ha^{-1}, or 1,500 l ha^{-1} spraying was applied; but not in the case of 1,000 l ha^{-1} spraying.

Combining these data, we concluded that 1,500 l ha^{-1} was necessary to thin 3.0 – 3.5 m-high 'Jonagold'/M.9 trees reliably using 10 mg l^{-1} NAA. If the water volume was reduced to 750 l ha^{-1}, 500 l ha^{-1}, or 250 l ha^{-1} and, at the same time, the concentration of NAA was increased proportionally to 20 mg l^{-1}, 30 mg l^{-1}, or 60 mg l^{-1}, respectively (i.e., maintaining an overall dose equivalent to 10 mg l^{-1} NAA when sprayed at 1,500 l ha^{-1}), then the intensity of thinning was not changed. Other researchers have reported similar thinning efficiencies when a constant dose of NAA was applied at different spray volumes (Black *et al.,* 1995; Camilo and Palladini, 2000). The application of NAA in a lower volume of water may

TABLE II
Number of flower clusters at the start of the experiment, final fruit numbers, mean fruit weights, and return bloom in 'Jonagold'/M.9 apple trees after the water-volume experiments in 2006 (NAA) and 2007 (BA)

Treatment [Volume applied; (PGR concentration)]	Flower clusters (No./tree)	Final fruit no (No./tree)	Final fruit no (No./100 clusters)	Mean fruit weight (g)	Return bloom (1–10)**
2006					
Control, (no thinning)	217 ab*	276 c	132 c	105 a	2.7 a
To run-off, NAA (10 mg l^{-1})	221 ab	207 ab	102 ab	133 bc	5.0 abc
2,000 l ha^{-1}, NAA (10 mg l^{-1})	214 ab	217 ab	109 ab	144 c	3.6 ab
1,500 l ha^{-1}, NAA (10 mg l^{-1})	172 a	186 ab	93 a	127 abc	5.7 bc
1,000 l ha^{-1}, NAA (10 mg l^{-1})	289 b	220 ab	121 bc	127 abc	3.7 ab
750 l ha^{-1}, NAA (20 mg l^{-1})	224 ab	199 ab	92 a	118 ab	6.8 c
500 l ha^{-1}, NAA (30 mg l^{-1})	235 ab	172 a	90 a	124 abc	4.5 abc
250 l ha^{-1}, NAA (60 mg l^{-1})	246 ab	214 ab	114 abc	115 ab	5.9 bc
2007					
Control, (no thinning)	430 a	247 b	84 b	150 a	3.5 ab
To run-off, BA (100 mg l^{-1})	356 a	171 a	56 a	177 a	5.4 b
2,000 l ha^{-1}, BA (100 mg l^{-1})	404 a	193 a	64 a	164 a	4.6 ab
1,500 l ha^{-1}, BA (100 mg l^{-1})	319 a	204 a	69 a	162 a	4.8 ab
1,000 l ha^{-1}, BA (100 mg l^{-1})	305 a	225 ab	83 b	154 a	3.0 a
750 l ha^{-1}, BA (200 mg l^{-1})	308 a	199 a	74 ab	168 a	3.6 ab
500 l ha^{-1}, BA (300 mg l^{-1})	354 a	193 a	63 a	161 a	4.0 ab
250 l ha^{-1}, BA (600 mg l^{-1})	310 a	205 a	65 a	158 a	3.8 ab

*Mean separation within each column was by Duncan's multiple range test (P = 0.05). Values followed by different lower-case letters were significantly different.
**Estimation of flowering in the next season was on a scale from 1 – 10, where 1 = no flower clusters; 10 = very dense blooming.
NAA, 1-naphthaleneacetic acid; BA, 6-benzyladinine

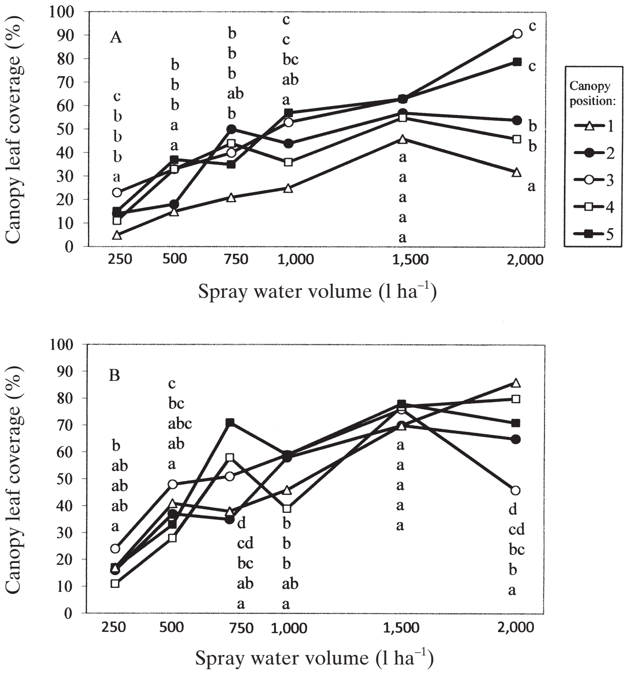

FIG. 2
Spray coverage areas using water-sensitive paper placed on the upper (adaxial; Panel A) or lower (abaxial; Panel B) surfaces of leaves at five canopy positions (1, top; 2, middle internal; 3, middle external; 4, bottom internal; 5, bottom external) when a 250, 500, 750, 1,000, 1,500, or 2,000 l ha^{-1} spray volume of NAA at various concentrations was applied. The lower-case letters above (or below) the mean values indicate their statistical significance by Duncan's multiple range test at $P = 0.05$, in the order of canopy position at each spray volume treatment.

be possible, if the dose of NAA ha^{-1} to 3.0 – 3.5 m-high slender spindle apple trees stayed constant and was calculated based on a 1,500 l ha^{-1} (dilute) application of 10 mg l^{-1} NAA (i.e., using a dose of 15 g NAA ha^{-1}).

Similar results were obtained from the BA experiment. BA (at 100 mg l^{-1}) was applied as a dilute spray to the same 'Jonagold'/M.9 apple trees to produce reductions in fruit set on this easy-to-thin cultivar (Stopar, 2000). BA at 100 mg l^{-1}, applied to run-off with a knapsack sprayer, or with a tractor and axial fan sprayer adjusted to 2,000 l ha^{-1}, or 1,500 l ha^{-1}, significantly reduced the final numbers of fruit per tree from 247 (control) to 171, 193, or 204 fruit, respectively (Table II). Spraying at 1,000 l ha^{-1} did not significantly reduce the final fruit number (i.e., 225 fruit per tree). Similar results could be deduced from the number of fruits retained at harvest per 100 flower clusters. If the dose (amount) of BA applied at 1,500 l ha^{-1} was kept constant while the water volume was reduced to 750 l ha^{-1}, 500 l ha^{-1}, or 250 l ha^{-1}, the reduction in final fruit numbers stayed at the same level as with 1,500 l ha^{-1} spraying (i.e., using 150 g BA ha^{-1}).

Few reports could be found regarding the thinning of apple trees using high concentrations of BA and low volumes of water. Official recommendations for thinning apple trees using BA focus on the use of dilute sprays with a sufficient amount of water to ensure complete tree coverage. Basak *et al.* (2006) cited a stronger response to BA thinning when higher water volumes were sprayed, but Bound *et al.* (1997) mentioned thinning 'Delicious' apple trees with low volumes of BA spray. We have shown that apple thinning with BA at a low water volumes works when the dose (i.e., g ha^{-1}) of BA was based on 1,500 l ha^{-1} of dilute BA spray, and the size of the trees was considered.

The NAA-water volume experiment was also used to measure the leaf areas covered by spray solution. When 2,000, 1,500, 1,000, 750, 500, or 250 l ha^{-1} was used, the area covered by the spray was measured on water-sensitive paper placed on the upper and lower surfaces of the leaves at five different positions in the canopy (Figure 2A, B). Water-sensitive paper on both the upper and lower surfaces of leaves received better coverage in the case of spraying higher water volumes. A broad range of coverage areas was observed between canopy positions at both low water volumes (250 l ha^{-1}), from 5 – 23% covering; and at high volumes (2,000 l ha^{-1}), from 30 – 90% coverage. The upper surfaces of the leaves at the top of the canopy (position 1) were not well covered at any spray volume, while both external positions in the middle and at the bottom of the canopy, next to the spray lane, received better coverage on the upper leaf surfaces than at other positions for most spray volumes (Figure 2A). Bukovac *et al.* (1986) also found that the highest deposit of spray occurred at the periphery of the canopy, next to the spray lane, at 1 – 2 m above ground level, when 100 – 400 l ha^{-1} was applied to peach trees. An irregular delivery of spray was seen on the lower surfaces of leaves at each position and for each water volume (Figure 2B). Crabtree and Bukovac (1980) found that ethylene production was induced more when NAA was applied to the lower surface of sour cherry leaves compared to the upper leaf surface, suggesting that the lower leaf surface played a more important role in the uptake of NAA. However, after the application of 1,500 l ha^{-1}, good leaf coverage and no differences between positions in the canopy could be found on the upper or lower leaf surfaces in our experiments. Thus, a sufficient and uniform response to PGRs could be anticipated on whole trees if 1,500 l ha^{-1} was used as the spray volume. From this point of view, 1,500 l ha^{-1} should also be an appropriate volume from which to calculate the dose of NAA or BA (in g ha^{-1}) for this size and shape of tree.

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REFERENCES

BASAK, A., HOLOWNICKI, R. and SWIECHOWSKI, W. (2006). Spraying techniques and the efficiency of thinning agents. I. Spray volume and concentration in relation to crown size. *Acta Horticulturae,* **727,** 389–396.

BLACK, B. L., BUKOVAC, M. J. and HULL, J. (1995). Effect of spray volume and time of NAA application on fruit size and cropping of Redchief 'Delicious' apple. *Scientia Horticulturae,* **64,** 253–264.

BOUND, S. A., OAKFORD, M. J. and JONES, K. M. (1997). Reducing spray volumes and dosages on conventional airblast orchard sprayer using low volume nozzle systems. *Australian Journal of Experimental Agriculture,* **37,** 591–597.

BUKOVAC, M. J. (1981). Performance of daminozide and ethephon when applied in low-volume spray to sour cherry. *Acta Horticulturae,* **120,** 25–29.

BUKOVAC, M. J., REICHARD, D. L. and WHITMOYER, R. E. (1986). The spray application process: central for the efficient use of growth regulators in tree fruits. *Acta Horticulturae,* **179,** 33–45.

CAMILO, A. P. and PALLADINI, L. A. (2000). Effect of fruit thinners at different volumes on 'Gala' apple tree. *Pesquisa Agropecuaria Brasileria,* **35,** 2191–2195.

CRABTREE, G. D. and BUKOVAC, M. J. (1980). Studies of low volume application of plant growth substances. Part 1: Ethylene production induced by 1-naphthylacetic acid, as a means of evaluating spray parameters. *Pesticide Science,* **11,** 43–52.

HULL, J., BUKOVAC, M. J. and BLACK, B. L. (1995). Effect of concentration and time of Accel application on cropping of selected cultivars. *HortScience,* **30,** 765.

KNOCHE, M., BUKOVAC, M. J., NAKAGAWA, S. and CRABTREE, G. D. (1998). Spray application factors and plant growth regulator performance. I. Bioassays and biological response. *Pesticide Science,* **54,** 168–178.

LEŠNIK, M., MATIS, G. and MIKLAVC, J. (2006). Škropilna tehnika in uspeh zatiranja jablanovega škrlupa. *Sad,* **2,** 3–7.

MANKTELOW, D. W. L. and PRAAT, J. P. (1997). The tree row volume spraying system and its potential use in New Zealand. *Proceedings of the Fifth New Zealand Plant Protection Conference.* Canterbury, New Zealand. (O'Callaghan, M., Ed.). 119–124.

OAKFORD, M. J., JONES, K. M., BOUND, S. A., COVEN, I. E. and GRAHAM, B. R. (1994). Comparison of the biological effectiveness of controlled droplet application sprayers and high-volume sprayers in thinning apple trees. *Journal of Horticultural Science,* **69,** 213–218.

STOPAR, M. (2000). Comparision of the most frequently used apple thinning compounds for the thinning of 'Jonagold', 'Elstar' and 'Golden Delicious' apples. *Research Reports, Biotechnical Faculty, University of Ljubljana, Agriculture,* **75,** 89–94.

STOPAR, M., LESKOŠEK, G. and SIMONČIČ, A. (2009). 1-Naphthaleneacetic acid and 6-benzyladenine thinning of a common slender spindle 'Jonagold'/M.9 apple orchard. II. Partial tree spraying. *Journal of Horticultural Science & Biotechnology,* **ISAFRUIT Special Issue.**