Hail Netting of Apple Orchards—Australian Experience

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A severe hailstorm can destroy an apple crop in minutes, and in the hail-prone apple producing regions of eastern Australia increasing numbers of orchardists are using hail netting for the protection of fruit and trees. Hail netting allows these regions to meet the fruit quality and fruit volume expectations of markets and guarantees a consistent apple supply from year to year.

To offset the high establishment costs, orchard productivity under hail netting must be maximized through the production of high yields of premium quality fruit and efficiency in tree management. There has been a reluctance by some orchardists to incur the expense of hail net installation until convinced that detrimental effects on orchard productivity do not occur.

Over the past 7 years in Australia, trials conducted on commercial apple orchards in Queensland (Stanthorpe 28°37'S), New South Wales (Orange 33°19'S) and Victoria (Drouin 38°08'S) have measured the effect of hail netting on orchard climate, how apple trees respond to the environment beneath netting (tree growth, yield, fruit quality) and evaluated tree management strategies (pruning, thinning, pollination, irrigation) appropriate to apple trees grown under hail netting. Varieties included Royal Gala, Hi Early Red Delicious, Red Fuji (Nagafu 2), Granny Smith and Pink Lady.

Hail netting is an investment in orchard productivity.

ORCHARD CLIMATE UNDER HAIL NETTING

Climatic measurements were taken within identical commercial blocks of apple trees (same date of planting, variety, rootstock, tree density, soil, tree management) where hail netting had been erected over part of the orchard block and the remainder left uncovered. Block size was a minimum of 1 hectare (2.5 acres), but usually much larger. Sites were carefully selected to avoid local topographical effects on microclimate.

Two automatic weather stations (AWS) were used simultaneously, one weather station within trees under the hail netting and the other weather station within uncovered trees. The sensors used with each weather station were 10 PAR (photosynthetically active radiation) cosine-corrected silicon cell radiation sensors (light meters), four air temperature sensors (± 0.1°C accuracy), a relative humidity (capacitance) sensor protected by a sintered bronze filter, and an anemometer (3 cup). Readings were logged at 6-minute intervals, 24 hours a day. For each AWS, three light meters were positioned above the tree. For trees under netting, these light meters were positioned 50 cm below the hail netting.

The semi-protected environment beneath hail netting is most obviously characterized by lower light levels. All sites in Queensland, New South Wales and Victoria consistently showed that hail netting can cause:

- Reductions in sunlight levels (PAR) of 12 to 27% (dependent on net type, mesh size and color).
- Increased humidity of up to 10 to 15%.
- Up to 50% lower windspeed compared to outside netting.
- Slight reduction in daytime temperatures by 1 to 3°C (34 to 37°F) on warm to hot days.
- Little effect on nighttime temperatures and does not offer frost protection.

Although hail netting can reduce sunlight levels by up to 25% or more, the tree canopy itself can reduce sunlight levels by over 95%. Similarly, cloud cover and seasonal changes in solar radiation levels also dramatically affect incident sunlight levels. In mid-April, which coincides with the harvest of mid- to late-season apple varieties, light levels on overcast wet days are extremely low regardless of the presence of netting.

Readings from a temperature sensor with its sensory tip exposed to radiation and wind were up to 4 to 6°C (39 to 43°F) higher than temperature readings taken from sensors inside a Stevenson Screen. Perceived cooler temperatures under netting are due to reduced radiant heat (from lower sunlight levels) rather than a change in air temperature.

Higher humidity under net increases the leaf wetness period after either rainfall or spraying. The incidence of apple scab (*Venturia inaequalis*) under hail netting in Queensland is generally not greater than on trees outside net, however recent seasons have been dry. Nevertheless, the Apple Scab Warning Service provided to Queensland apple growers is based on leaf wetness and weather information obtained from automatic weather stations positioned within commercial apple orchards under hail netting.

The higher humidity and reduced wind under hail netting increase spray efficacy through a twofold effect: 1) slower drying times that permit improved chemical absorption by

TABLE 1

Apple tree response to hail netting compared to similar adjacent trees not covered by netting.

Tree Growth – magnitude of response is dependent on tree vigor		
Shoot Numbers	-	Greater
Shoot Lengths	-	Longer
Leaf Size	-	Larger
Yield, Fruit Quality		
Fruit Set	-	Reduced, fewer multiple clusters
Yield	-	Variable effect, dependent on tree vigor, pollination
Fruit Size	-	Smaller on overvigorous trees
	-	Similar or larger on dwarf to semi-dwarf trees, where vigor is under control
Color	-	Variable effect, dependent on fruit position and tree vigor
Soluble solids	-	Reduced
Sunburn, windrub	-	Reduced
Russet	-	Reduced
Bird damage	-	Reduced or eliminated

leaves and 2) facilitating timely spray applications under windy conditions that would otherwise prevent the spraying of trees outside net due to spray drift.

TREE RESPONSE TO HAIL NETTING

The response of apple trees to hail netting is primarily determined by tree vigor (Table 1). Hail net most noticeably affects the tree growth, yield, fruit size and fruit color on vigorous trees that would have shading problems regardless of the presence of netting. Reduced fruit size and increased shoot growth occurred on vigorous trees under hail netting at Stanthorpe, Orange and Drouin. Conversely, fruit size was increased on trees where vigor was under control. The effect of hail netting on tree growth is minor on smaller trees where vigor is under control, e.g., apples on dwarf rootstocks.

Fruit set was always lower on trees under netting, with fewer multiple clusters. In Queensland there is a tendency for some orchardists to totally abstain from chemical thinning under net. At all trial sites, less follow-up hand thinning was required on trees under net. This permits potential cost savings through reducing the annual level of fruitlet thinning required, provided tree vigor is controlled and fruit size is maintained. Fruit size on vigorous trees under hail netting is reduced if inappropriate pruning strategies are used that encourage excessive shoot growth.

Hail net can affect the fruit color of red varieties, dependent on tree vigor and the location of apples within the tree canopy. Overvigorous trees with excessive shoot growth shade fruit within the canopy and produce a higher proportion of poorly colored fruit. By contrast, where tree vigor is well controlled, the color of Hi Early apples on trees under black netting at Orange was consistently better than the color of fruit from uncovered trees (Table 2). Similarly, Red Fuji (Nagafu 2) fruit from trees under netting at Stanthorpe had superior color to apples from adjacent uncovered trees (Table 2).

The incidence of fruit windrub, russet (Table 3) and sunburn (Table 4) is reduced by hail netting. The high incidence of sunburnt fruit at Stanthorpe in 1998 (36% of Red Fuji fruit numbers affected) is typical, with white netting reducing the sunburn incidence to 8% of fruit numbers (Table 4). It is particularly noteworthy that the skin finish of Fuji (Nagafu 2) apples grown under hail netting at Stanthorpe is improved, with reduced russet (Table 3) and smoother skin with improved color (Table 2). An additional benefit of hail netting is the reduction or elimination of bird damage to fruit, achieved with hail net structures that are fully skirted to the ground.

The delayed maturity of apples under black netting is used on some orchards in Queensland to facilitate the harvesting of blocks at optimum maturity for both the fresh market and for medium or long-term storage. Refractometer readings at Drouin (Victoria), showed Granny Smith fruits under hail netting were of 0.7 to 1.5% lower total soluble solids (TSS) than apples harvested from adjacent uncovered trees. Consistent effects of hail netting on TSS have, however, been difficult to quantify. Fruit size and the location of apples within the tree canopy can both confound any effect of hail netting on sugar content and make it difficult to directly attribute differences in fruit TSS to hail netting. Additionally, the harvest of fruit at some trial sites at or past optimum maturity for the fresh market minimizes potential large differences in soluble solids that may be evident at earlier harvest dates.

TREE MANAGEMENT UNDER HAIL NETTING

The management of apple trees under hail netting must aim to :

- Control tree vigor.
- Maintain good light distribution throughout the canopy.
- Maximize fruit yield and quality.

Pruning/Crop Load

The shoot growth on vigorous trees under hail netting is greater than on identically pruned comparable trees outside net (Table 5). Many of the orchards in Australia that were initially covered with hail netting consisted of large, vigorous trees, and these will produce smaller apples than comparable trees outside net if additional available water is directed into shoot rather than fruit growth.

This effect on fruit size can be reversed through judicious pruning and tree management. Pruning treatments used on vigorous apple trees in Queensland, New South Wales and Victoria have compared various combinations of chunk (heavy) dormant pruning (WIN Ch), standard (lighter) dormant pruning (WIN St), no (0) pruning, chunk summer pruning

TABLE 2

Fruit quality (fruit color as % of fruit numbers) in the open and under hail netting.

	1996 Hi Early (NSW)		1999 Hi Early (NSW)		1998 Red Fuji (Qld)	
Color (rating)^Z	**Open**	**Net**	**Open**	**Net**	**Open**	**Net**
Excellent (4,5)	59	67	42	50	39	57
Satisfactory (3)	32	27	34	32	47	31
Poor (1,2)	9	6	24	18	14	12
Sample size	**(11,000 apples)**		**(51,000 apples)**		**(6,000 apples)**	

^{Z}Fruit color visually rated (1 to 5).

TABLE 3

Fruit quality (russet incidence as % of fruit numbers) in the open and under hail netting.

	1998 Red Fuji (Qld)		1997 Hi Early (NSW)		1997 Granny Smith (Vic)	
Russet	**Open**	**Net**	**Open**	**Net**	**Open**	**Net**
Severe	19	5	6.1	1.2	3.7	0.8
Moderate	21	13	n/a^Z	n/a	n/a	n/a
Slight	31	45	n/a	n/a	n/a	n/a
0	29	37	n/a	n/a	n/a	n/a
Sample size	**(11,000 apples)**		**(2,000 apples)**		**(13,000 apples)**	

^{Z}n/a=not assessed.

TABLE 4

Fruit quality (sunburn incidence as % of fruit numbers) in the open and under hail netting.

	1996 Hi Early (NSW)		1997 Granny Smith (Vic)		1998 Red Fuji (Qld)	
Sunburn	**Open**	**Net**	**Open**	**Net**	**Open**	**Net**
Severe			9.2	0.8		
Moderate + severe	7.8	0.7	21.1	6.4	36.0	8.0
Sample size	**(8,000 apples)**		**(13,000 apples)**		**(11,200 apples)**	

TABLE 5

The effect of pruning vigorous trees in the open and under hail netting on shoot numbers >1 meter long in Orange, New South Wales.

	1999		2000	
Pruning^Z	**Under net**	**Open**	**Under net**	**Open**
WIN Chunk	27 a^Y	12 b	49 a	21 b
No pruning	13 b	0 c	19 b	6 c
SUM Chunk	8 b	0 c	22 b	6 c

^{Z}WIN Chunk is chunk (heavy) pruning in winter, SUM Chunk is chunk (heavy) pruning in summer.
^{Y}Means in a column followed by the same letter are not significantly different (p=0.05).

(SUM Ch) and standard (lighter) summer pruning (SUM St), in combination with light, medium and heavy crop loads.

Heavy chunk winter pruning, whether done over 1 or 2 years, cannot be recommended as a pruning strategy for overvigorous trees under hail net, as it encouraged excessive regrowth which in turn reduced yields in subsequent years (Tables 6 and 7). No pruning in one year followed in the next year by light dormant pruning and/or summer pruning effectively slowed tree growth. High crop loads reduced regrowth but also reduced average fruit size.

Excessive shoot growth caused by WIN Ch pruning at Orange in 1998 led to a very dense, crowded canopy that shaded developing fruit buds and reduced yields to just 17.9 kg per tree in March 2000 (Table 7). In this particular experiment the trees were not hand thinned, hence Table 7 shows the effect of pruning treatments on yield and productivity without the confounding effect of adjusted crop load.

In a pruning experiment where crop load was standardized, heavy chunk pruning significantly reduced fruit size (Table 6, March 1997). The excessive regrowth caused by heavy WIN Ch pruning in turn reduced flower production, fruit set and yields in the following season (Table 6, March 1998). This established a severe biennial bearing pattern with low yields in the off year. Fruit size differences between pruning treatments in March 1998 were primarily due to crop load.

Overvigorous trees left unpruned (0 prune) and unthinned for one season appeared unsightly, with minimal regrowth and spindly overcropped branches bent over with heavy crops of apples. Standard dormant pruning of these trees in the subsequent season tidied up their appearance but, more importantly, generated sufficient younger renewal wood without excessive debilitating regrowth to upset tree growth, balance and productivity. With no pruning followed by minimal pruning, the trees spurred up and weakened (despite their high vigor), and the cropping zone was pushed to outer and upper parts of the tree which were relatively well-illuminated zones producing large fruit. The sacrifice of some of the crop in the year the trees were left unpruned saw tree balance and productivity improved in subsequent years without the biennial bearing habit and excessive vigor that occurred with heavy dormant chunk pruning.

A pruning x crop load strategy for vigorous trees under hail netting should aim for a balance between tree vigor (ideally <150 meters shoot growth annually; all shoots <75 cm; 2.5 ft), crop load, fruit size and biennial bearing (0 or slight). On mature 15-year-old Hi Early Red Delicious trees in Queensland and New South Wales this was achieved with a crop load of 400 to 500 fruit/tree (3.0 to 3.5 apples/cm^2 TCA) and a pruning strategy of 0 or light winter pruning, followed by light or chunk summer pruning. This pruning strategy done over two seasons at Orange, New South Wales, maintained yields at 95 to 105 kg/tree (Tables 6 and 7) while minimizing excessive shoot growth.

With lower evapotranspiration and improved water relations under hail netting, judicious pruning and crop load strategies can ensure larger fruit size under net, even on vigorous trees (Table 8). In the relatively dry Australian environment, it is essential that any increases in available water as a consequence of hail netting are used to maximum efficiency and are directed to and utilized by developing fruitlets rather than in the production of excessive shoot growth.

Dormant pruning cuts on overvigorous trees under hail netting must be minimized to restrict regrowth. Mistakes in tree pruning are exacerbated under hail netting. Large shading effects in the tree are due to vigorous leaf canopy and not the hail netting itself, although on vigorous trees netting may contribute to excessive shoot growth and classic shading response symptoms.

Irrigation

Soil moisture levels tend to decline more slowly under hail net (Fig. 1). This is primarily due to lower evapotranspiration (Middleton and McWaters, 1996) and offers the potential for improved water use efficiency and targeted reductions in irrigation to control tree vigor.

The schematic representation in Figure 1 is based on EnviroSCAN soil moisture measurements that were continuously made at four depths (10 cm, 20 cm, 40 cm, 70 cm) and illustrates the different rates of change in soil moisture content beneath 3-year-old Royal Gala trees under and outside white hail netting over a 2-week period in 1998/99.

Chemical Thinning

The consistently lower fruit set of trees under hail net offers a potentially significant advantage in reduced thinning costs. Hi Early Red Delicious trees under hail net at Orange were not spray thinned in 1999/2000, whereas adjacent uncovered trees received two sprays (NAA and Cylex). In previous years the trees under net received two chemical thinning sprays and required minimal follow-up hand thinning, while trees outside the net received three chemical thinning sprays and required significant follow-up hand thinning.

TABLE 8

The effect of hail netting and crop load on the average fruit weight (April 1999) of Granny Smith apple trees at Drouin, Victoria.

	Average fruit weight (g)	
Crop load (fruit/cm^2 TCA)	Under net	Open (uncovered)
2.6	177	162
3.7	161	147
4.2	152	133

TABLE 6

The yield and average fruit size in 1997 and 1998 of Hi Early Delicious trees under black hail netting (Orange, New South Wales) as influenced by pruning.

Pruning[Z]		March 1997			March 1998		
1996-97	1997-98	Yield (kg/tree)	Fruit no./tree	Av. fruit wt. (g)	Yield (kg/tree)	Fruit no./tree	Av. fruit wt. (g)
1. WIN Ch	WIN Ch	90.1	665	135.5 a[Y]	44.6 a	277 a	160.4 a
2. WIN St	0	99.1	667	148.6 b	104.9 b	788 b	133.1 b
3. WIN St	SUM St	95.3	616	154.7 b	103.2 b	768 b	134.4 b
		NS[X]	NS				

[Z]See text for explanation of pruning treatments.
[Y]Means in a column followed by the same letter are not significantly different (p = 0.05).
[X]NS=not significant.

TABLE 7

The yield and average fruit size in 1999 and 2000 of vigorous Hi Early Delicious trees under black hail netting (Orange, New South Wales) as influenced by pruning.

Pruning[Z]		March 1999			March 2000		
1996-97	1999-00	Yield (kg/tree)	Fruit no./tree	Av. fruit wt. (g)	Yield (kg/tree)	Fruit no./tree	Av. fruit wt. (g)
1. WIN Ch	WIN St	78.5 a[Y]	634 a	123.9 a	17.9 a	115 a	155.7 a
2. 0	WIN St	108.3 b	951 b	113.8 b	47.8 b	335 b	142.7 b
3. SUM Ch	WIN St	102.4 b	882 b	116.1 b	59.1 b	424 b	139.4 b

[Z]See text for explanation of pruning treatments.
[Y]Means in a column followed by the same letter are not significantly different (p = 0.05).

Chemical thinning of trees under hail net can induce greater fruitlet drop than on uncovered trees, and care should be taken to avoid overthinning. The fruit set (December 2000) following a full bloom NAA spray and a carbaryl spray 3 weeks after full bloom applied to Hi Early Red Delicious (Orange, New South Wales) was always lower on trees under net than on uncovered (open) trees (Fig. 2).

Bee counts showed similar bee activity under and outside net. The greater shedding of fruitlets from trees under net as blossom density increased is most likely due to direct competition between developing fruitlets and reduced bud strength as influenced by light levels and other factors during their initiation and development the previous season. Physiological studies (photosynthesis, source:sink relations) are required to confirm this.

FIGURE 1

Adjusted schematic representation of soil moisture content (mm) beneath Royal Gala apple trees protected by white hail net (Net), and adjacent uncovered (Open) Royal Gala trees.

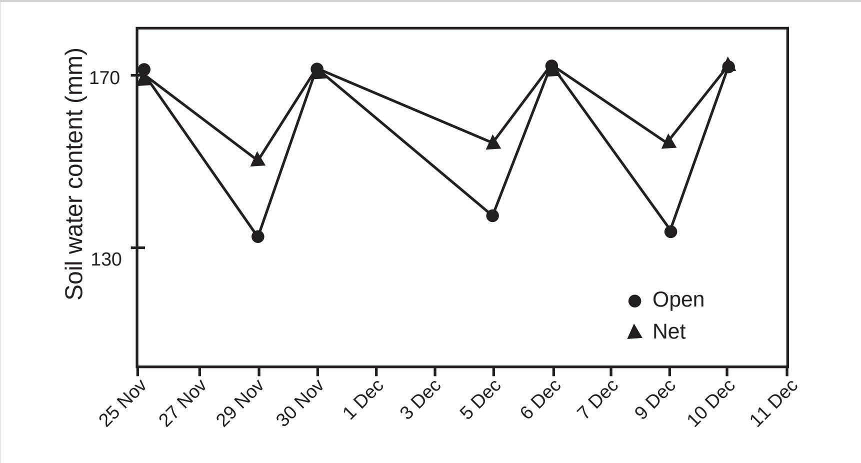

FIGURE 2

The effect of hail netting on the fruit set of Hi Early Delicious trees following chemical thinning (10 ppm NAA at full bloom; 200 mls/100 L carbaryl at 3 weeks after full bloom).

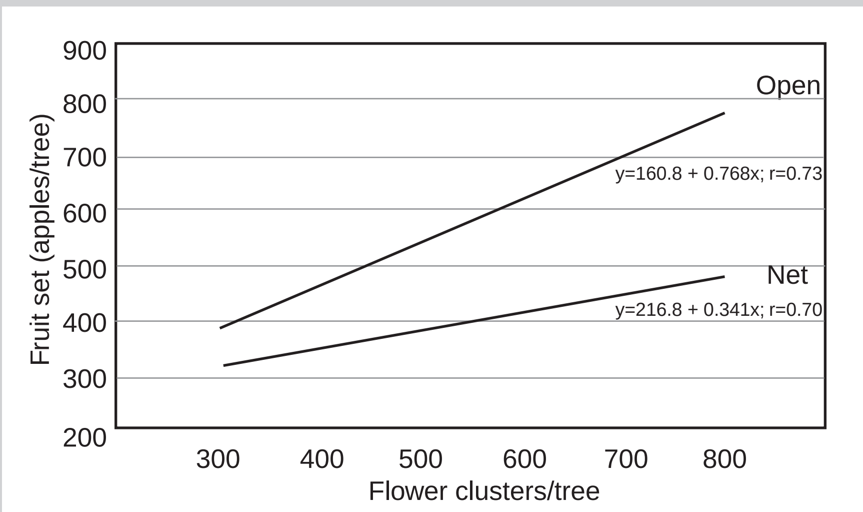

TABLE 9

Expected profitability of hail netting at Stanthorpe (Queensland).

Variety	Average price (Aust. $/ case)	Packout (% without net / % with net)	Expected equivalent annual return ($/ha)	Expec ted IRR (%)	Expected payback period (years)
Average	18.59	78/94	355	10.2	14
Red Delicious	16.02	85/95	-1172	na	na
Granny Smith	19.32	70/95	1621	14.4	10
Fuji	28.51	65/80	3817	20.7	7
Pink Lady	31.26	60/75	4570	24.7	5
Royal Gala	28.53	70/85	4125	21.0	8

Optimal crop load of the trees in this experiment was 400 to 500 apples. Trees with 300 flower clusters (1500 flowers) had little need for chemical thinning, and under net there was some overthinning of these trees. At 800 flower clusters (4000 flowers per tree) it is evident that the chemical thinning of the trees under net produced an optimal crop load, whereas the same chemical thinning of uncovered trees required the removal of a further 250 to 350 fruitlets per tree in follow-up hand thinning for optimal crop load to be achieved. At 300 flower clusters per tree the grower normally would not have chemically thinned the trees under net.

Some orchardists are hesitant to chemically thin trees of high-value apple varieties under hail net for fear of overthinning. No chemical thinners should need to be applied to trees under net of low blossom density, however there is potential for chemical thinning to minimize or eliminate the need for follow-up hand thinning on medium to heavy flowering trees under net.

Hail Net Structures

The structures that support hail netting may be either gabled (peaked) or flat. Gabled structures are designed to allow the hail to fall down their sloping surfaces and onto the ground between the tree rows, whereas flat structures allow hail to accumulate on the top of the net. The seams of flat hail netting are above the tree rows, so the weight of ice causes the net above the alleyways to be pulled down. As the ice melts the net returns to its original position, although some re-tensioning may be required. In areas with winter snow, netting is temporarily rolled up and then unfurled at the start of the season, usually at or after flowering. Black, grey and white nets have all been used in apple orchards. Mesh types vary but are now commonly interwoven with microfilaments that reduce aperture size to 5 mm or less.

Many hail net structures are fully skirted and completely enclosed down to or almost down to ground level. Such enclosures eliminate bird damage to fruit and protect the fruit on trees growing at the edge of the block from wind-driven hail.

Bee Activity

To ensure adequate cross-pollination and fruit set of apple trees under hail netting, four key points in the management of bees should be considered. These and other aspects of bee management are discussed in more detail by Middleton et al. (2000a, b).

Place hives under the netting. It is essential to place hives under hail netting to achieve good pollination. Generally bees are less inclined to fly into orchard blocks covered by hail netting than into blocks of uncovered trees. It is therefore advisable to distribute the hives throughout the netted orchard to ensure an even distribution of foragers.

Bees must be introduced under hail netting once flowering has commenced, usually about 3 to 5% bloom. Introduction of hives before this will only encourage bees to seek alternative nectar and pollen sources outside the netted area. Similarly, any delays in the introduction of hives can adversely affect fruit set.

Adequate gap between the top of the tree and the hail net cover. Adequate space between the top of the trees and the hail net is essential for optimum bee flight. Where there is little or no gap between the tree top and the net, bees are unable to fly freely and an uneven distribution of bees may occur within the block of trees. The bees will then prefer to forage along the rows. This will have a particularly adverse effect on cross-pollination if pollenizer trees are planted in separate rows to the main variety. The problem of obstructing bee flight may be compounded further if the hail netting structure is of peaked (gable) design and the tree tops are growing up into the apex of these peaks.

Bees naturally tend to work along tree rows, however the more protected environment under netting can encourage increased bee foraging across alleyways and between adjacent tree rows. Full advantage should therefore be taken of this beneficial effect of hail netting by ensuring that bee flight in the orchard is not obstructed by trees growing too close to the hail net cover.

Trapped bees. When hives are first introduced to a fully enclosed environment, some of the foraging field bees may become disoriented and trapped in the apex or gables of the netting structure. Trapped bees eventually die and are replaced by younger bees that have acclimatized to the conditions under the hail net. This is generally less of a problem in structures where the net is flat.

Temporary removal of netting during flowering. Temporary removal of netting, or sections of it, during flowering is one means of assisting pollination. Bees are able to fly upward out of the hail net environment and then fly back down to the target trees. If persistent pollination problems occur in a particular block of trees, it may be worth considering ways to temporarily remove some runs of net during the flowering period as well as allow for this facility in the erection of subsequent hail netting support structures.

Temporary net removal is a standard management practice in New South Wales (Batlow and Orange), where hail netting is rolled up over winter to prevent the weight of accumulated snow collapsing the support structure. To facilitate bee activity and cross-pollination it is suggested that either the unfurling of the hail net is delayed until after the end of flowering or, alternatively, only every second run of net is unrolled at or prior to flowering. Growers also need to consider the incidence of spring storms and the risk of hail damage to flowers when implementing these strategies.

Opening the hail net covering during flowering will help to:

- Increase light levels within the netted area and thereby encourage bee activity.
- Facilitate bee access to the trees and allow bees to forage across blocks.
- Reduce the bee numbers trapped in the net.

Economics

A cost-benefit analysis, with a discount rate of 8%, was used to calculate the expected profitability of hail netting in Queensland, New South Wales and Victoria. The profitability criteria calculated were Equivalent Annual Return (EAR) (the annualized Net Present Value), Internal Rate of Return (IRR) and Discounted Payback Period.

The analyses took into consideration the secondary benefits of hail netting, such as reductions in sunburn and bird damage to fruit. For Stanthorpe, Queensland, the analyses were partly based on the probability distribution of hailstorms, and risk analysis was incorporated to account for the uncertainty of hailstorms. The economic analyses are described and discussed in further detail by Whitaker and Middleton (1999).

Using simulations based on the probability distribution for hail events, hail netting at Stanthorpe, Queensland, was profitable for all apple varieties, with the exception of Red Delicious (Table 9). The analyses showed that the profitability of hail netting increases with decreasing cost of hail netting and increasing yield, packout and apple market price. Of these, price was the most influential factor determining the profitability of hail net.

Given the probability distribution of hail events, hail netting in Stanthorpe, Queensland, was profitable for most of the apple varieties analyzed. This was especially so for the higher value varieties (Fuji, Pink Lady and Royal Gala) and where packout under hail netting was high relative to the packout with no hail netting (Granny Smith). For these four varieties hail netting was profitable even with minimal or no losses from hailstorms.

Severe hailstorms not only damage the current crop but can cause structural and bud damage to trees that may reduce or wipe out the apple crop for the subsequent 2 or 3 seasons. One such storm affected parts of the Stanthorpe region in late October 1999 and, depending on damage to the trees, the crop loss can be as high as 200 to 300%. This scenario may make the hail netting of even the lowest price varieties a consideration, as well as prompting growers to consider attaching a dollar value to "peace of mind" and having a good night's sleep.

SUMMARY

Hail netting reduces sunlight levels by up to 25%, however the apple tree canopy itself can reduce sunlight levels by up to 95% or more. It is tree vigor that determines how apple trees respond to netting, and fruit size on vigorous trees under hail netting will be reduced if inappropriate pruning strategies are used that encourage excessive shoot growth.

Orchards protected by hail netting need to rapidly attain and maintain high yields and packouts to recoup the cost of the netting and support structure. High yielding intensive apple orchard systems on dwarf or semi-dwarf rootstocks are particularly suited to protection by hail netting, with high yields of fruit produced in well-illuminated exposed regions of the tree canopy which would otherwise be prone to sunburn without the presence of netting.

Hail netting is an investment in orchard productivity. It is therefore essential to use the beneficial effects of netting to greatest advantage, while at the same time minimize any adverse effects. Reduced fruit sunburn and russet, improved fruit color and skin finish, and the elimination of bird damage are all benefits of hail netting that may make it an economic proposition in districts where the incidence of hailstorms is low.

REFERENCES

Middleton, S.G. and A.D. McWaters. 1996. Hail netting to increase apple orchard productivity. HRDC Final Report. Project AP320. December 1996.

Middleton, S.G., A.D. McWaters and R. Goodman. 2000a. Bee pollination under netting. Part 1. PomeFruit Australia June/July 2000. p. 16, 24.

Middleton, S.G., A.D. McWaters and R. Goodman. 2000b. Bee pollination under netting. Part 2. PomeFruit Australia. August 2000. p. 15.

Whitaker, K. and S.G. Middleton. 1999. The profitability of hail netting in apple orchards. Proceedings 43rd Annual Conference of the Aust. Agricultural & Resource Economic Society. Christchurch, NZ. Jan 1999.

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