Hail Netting for Apples: Study Results (2021-2022)

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Apple is one of the most popular fruit crops grown in Minnesota and maintains high consumer demand for fresh fruit sales and agritourism at orchards around the state. Apple trees grown on a high-density trellis system have proven to be an economical production option for growers. In this system, growers typically rely on insecticides to minimize the risk of pest-related fruit losses.

Hail Netting

Hail netting has been used since the 2000s by fruit growers globally to protect various fruit crops from hail damage. According to the National Weather Service, Minnesota averaged 262 hailstorms per year between 2012 and 2022. In 2022, Minnesota ranked 3rd in the nation for hail events/year. In this report, only hailstorms with hail stones of >1" in diameter were recorded. In the 2023 survey of Minnesota apple growers, 29% of responding growers said they had experienced crop losses due to hail the previous year.

In apples, hail netting has been documented to protect fruit from nearly total crop loss. The netting intercepts the hailstones before they can contact the fruit. Across the U.S. apple industry, hail netting has increasingly been adopted as an alternative to hail insurance, which may not pay out the total value of crop losses. Most hail netting products have a fine mesh size, typically around 1/10" x ¼".

Hail netting has gained popularity in pome fruit orchards worldwide to exclude and protect against insect pests. Most hail netting products, if applied during bloom, would limit pollinator presence due to the small mesh size.

Image 1: Single-row DrapeNet hail netting over high density, trellised SweeTango trees (top), mesh size (bottom).

Hail netting should be applied in the spring, immediately after petal fall. At that point, netting will not impact any activity of pollinators in the orchard.

In the case of single-row netting (shown above), it would not be feasible to apply netting during bloom and place honeybee hives inside of the netting as the netting is zip-tied under the tree canopy and does not extend to the soil surface.

Hail Net Field Trials

Field trials were conducted at both of Pine Tree Apple Orchard's locations: in White Bear Lake (Washington Co.) and in Preston (Fillmore Co.) MN. The study was conducted on high-density trellis plantings of SweeTango™ apple. Trees in White Bear Lake plots were planted in 2015 on G-11 rootstock and Preston plots were planted in 2009 on B-9 rootstock. Trials were set up to compare efficacy of the netting to the effect of an IPM-based insecticide spray program. To do this, there were several experimental blocks with 4 treatments: 1) Netted with spray 2) Non-netted with spray 3) Netted without spray 4) Non-netted without spray.

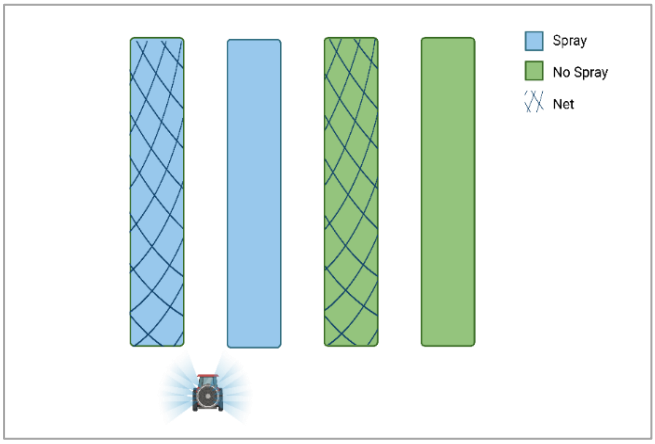

Image 2: Diagram of an experimental block, with four rows adjacent rows. Each row was a different treatment where insect traps were installed.

There were three applications of insecticide in both 2021 and 2022 targeting insect pests of interest (post-bloom). The products used were Rimon (novaluron) for codling moth and Assail (acetamiprid) for apple maggot. Rimon was applied once at petal fall in both 2021 and 2022, and Assail was applied twice for apple maggot, once in July and once in August of both years. No applications were made targeting red-banded leafroller.

Image 3: An un-netted row (left) beside a netted row in one of the experimental blocks.

The netting used in our on-farm trials was DrapeNet® USA (Prosser, WA) 6 X 1.8 mm white netting, which is approved for organic certification and valued annually at $308/acre using an assumed 10-year depreciation with no salvage value. Netting was applied and removed after harvest using a NetWizz (Prosser, WA) applicator. The NetWizz was attached to the back of a tractor which allowed the netting to unroll and drape over a single row of trees. The NetWizz was valued new at $18,000 and annualized for this study at $11.67/acre over 20 years with a 10% salvage value. All high-density trellis trees were pruned to 18 inches or less of the trellis wire to make this system conducive to machine application of hail netting. Netting was secured to the base of trees using zip ties every 5-6 ft. Zip ties were valued at $0.01 each or $11.14/acre. The netting remained on the trees until harvest, covering the trees throughout fruit development.

Key Insect Apple Pests

Insect Pest Descriptions

Codling moth (*Cydia pomonella*)

- Two generations of adult moths per year in Minnesota
- A major pest of apple and other pome fruits across the world
- Developed resistance to various classes of insecticides, both in Europe and North America
- More info on codling moth

Apple Maggot (*Rhagoletis pomonella*)

- One generation of adult flies per year in Minnesota
- A major pest of apple in North America, native insect in Minnesota and the Northeastern U.S.
- *More info on apple maggot*

Red-banded leafroller (*Argyrotaenia velutinana*)

- One of several leafroller moth species that are native to Minnesota and pests of apple and other fruit crops.
- Does not usually cause much damage to fruit unless populations become very large.
- No action threshold is established for this species.
- More info on red-banded leafroller

Insect Exclusion Study: Methods

Following the application of the hail-netting to netted rows, traps for the three pest species were set up for all treatments. In the netted rows, traps were placed in the trees under the netting. White Trécé PHEROCON wing-style traps with species-specific sex pheromone lures were used to trap codling moth and the red-banded leafroller. Red ball traps baited with an apple essence lure, and covered with a sticky coating, were used to trap apple maggot. Pheromone lures for codling moth and red-banded leafroller were replaced every three weeks.

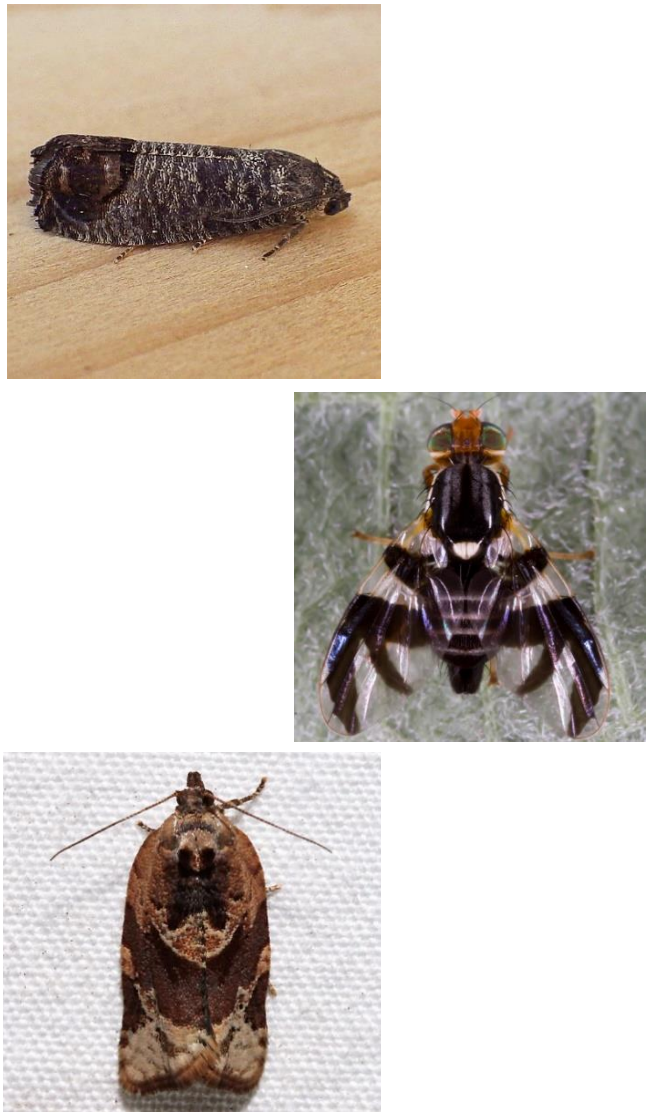

Image 4: Photos of the three insect pest species trapped in this study: codling moth (top), apple maggot (middle), and red-banded leafroller (bottom).

Insect Exclusion Study: Results

Codling moth was reduced by 94% under the netting.

Season-long averages for each experimental block were less than 1 codling moth/trap under the netting, regardless of spray.

Without netting, season-long averages varied between 0.2 to 6 moths/trap. The control group (no net & no spray) resulted in an average trap catch of 1.12 codling moth/trap/week, compared to the netting treatment that significantly reduced trap catch, to 0.76 moths/trap/week ($p < 0.0001$). The application of insecticide did not significantly reduce codling moth trap catch.

Apple maggot was reduced by 96% under the netting.

Without netting or insecticide sprays, traps averaged 1.48 apple maggot/trap/week. By comparison, traps under netting averaged 0.74 apple maggot/trap/week, a significant decrease in trap catch numbers ($p< 0.0001$). Insecticide applications did not significantly reduce the number of apple maggots caught compared to the unsprayed treatments.

Red-banded leafroller was reduced by 56% under the netting.

Without netting or insecticide sprays, an average of 2.69 RBLR/trap/week were caught, compared to the netting treatment with an average of 1.81 RBLR/trap/week. This was again a significant reduction in the number of moths caught ($p < 0.0001$). The season-long average trap catch of red-banded leafroller was 4.2 moths under the netting and 9.6 moths without netting. The insecticide applications did not significantly reduce the number of red-banded leafrollers caught in traps.

Conclusions of Insect Exclusion Study

- Hail netting alone significantly reduced pest pressure for all three of the pest species.
- Insecticide spray did not reduce pest pressure for any of the pest species.
- Hail netting can be used as a tool for protecting apples from both hail and multiple insect pests at once.

Hail Netting Impact on Fruit

Within the same experimental blocks that we monitored for insects, the influence of netting on fruit marketability and yield was also evaluated. Samples of fruit from within the experimental blocks were evaluated and rated following SweeTango club variety specifications. Fruit was rated based on: % red skin color, size, deformity, and blemishes. Ratings were assigned as extra fancy (EF), fancy (F), Minneiska (M), utility (U), and cull (C). Between both years, 1350 apples were evaluated at harvest time. For yield data, all apples were harvested and weighed from every row from within each experimental block.

Impacts on Fruit Quality

Proportions of extra fancy, fancy, Minneiska, utility, and cull fruit were compared in each of our treatments. Out of the 1,350 apples that were rated, 269 of these were extra fancy, 278 were fancy, 481 were Minneiska, 140 were utility, and 203 were cull apples. In the control treatment (no spray and no net), 44.3% (150 out of 338 sampled apples) were 1st quality (extra fancy or fancy). Netting alone did not significantly change the proportion of fruit

that were 1st quality in our sample. Netting and spray together increased the proportion of 1st quality apples to 62.5% (210 out of 338 sampled apples).

All the Minneiska apples were then added to the first quality group to determine what proportion of our sample was of fresh market quality (not utility or cull). Out of the total 1350 sampled apples, 1,015 were fresh market quality while 335 were not.

The untreated control treatment had a 76.7% proportion of fresh market quality fruit (259 out of 338 sampled apples). The netting alone did not significantly increase the proportion of fruit that was of fresh market quality. When spray and netting were used together, the proportion of fresh market quality fruit increased to 90.9% (307 out of 338) of our sample.

Image 5: Harvesting apples for the marketability and yield study.

Lastly, all the marketable fruit (extra fancy, fancy, Minneiska, and utility) were compared to the unusable, culled fruit. In total, 1,154 apples of the total sample were marketable while 196 apples were culled. The untreated control treatment had a proportion of 83.1% (281 out of 338) of fruit being marketable. The addition of netting did not significantly influence this proportion. The use of netting and spray together increased the proportion of marketable fruit to 93.1% (315 out of 338) of the sample.

Another important takeaway was that netting does influence the development of red skin color. Other studies have found that netting can delay fruit maturation by up to a week. Lower abundances of red fruit under the netting were observed in this study. There were no meaningful differences in fruit size between our treatments.

Parameter	Description		Rating
Red Skin	% skin surface red in color	>80%	EF
		60-79%	F
		20-60%	M
		<20%	U
Size	Diameter of apple (mm)	>69.5	EF/F
		63.5-69.5	M
		<63.5	U
Russeting	% surface webbed/blotched	<10%	EF
		10-25%	F
		>25%	M
Deformity	Asymmetry/misshapenness	Present	U
Blemishes	Open wound/rotting	Present	C
		Absent	EF/F/M/U
	Closed wound (>9.5 mm)	Present	M/U
		Absent	EF/F
	Closed wound (<9.5 mm)	Present	F/M/U
		Absent	EF

Image 6: Parameters for determining the quality rating of each individual apple that was harvested for marketability data.

Impacts on Yield

No significant differences in yield between treatments were found. Any differences that were observed were attributed to factors outside the variables measured in this study

(i.e. soil type, rootstock, etc.) In general, very low rates of insect damage in our experimental blocks were observed, as pest pressure was relatively low in both years.

Conclusions of Marketability & Yield Study

- Hail netting and insecticide sprays together increased the proportion of fruit that were 1st quality, fresh market quality, and generally marketable (fresh market & utility grade).
- Hail netting does delay the development of the fruit's red skin color; but no major detrimental effects of hail netting were observed in the 2-year study.

Economics of Hail Netting for Insect Pest Management

A partial budget economic analysis comparing the netting treatment and the netting + spray treatment to the spray only treatment was conducted to explore whether hail netting is an economically prudent pest management strategy. The direct costs of the three different systems were compiled and the net only treatment was determined to be financially competitive with the other IPM spray program and the spray + netting system.

Annual Direct Costs ($/acre)	Netting Only	Netting + Spray	Spray Only
Tractor rental	40	101	81
Application equipment	12	22	10
Netting	308	308	0
Insecticides	0	102	102
Tractor fuel	34	85	85
Application & removal labor	134	314	176
Harvest labor	481	496	379
Hail insurance	0	0	471
Total annual direct costs ($/acre)	**1,009**	**1,428**	**1,304**

Hail netting allowed for a significant reduction in overall insecticide applications, thus producing savings in labor and chemical inputs, with no impact on fruit quality or yield. Additional cost savings for the netting system were realized from savings on hail insurance ($471/acre). Total savings for the net treatment compared to the spray treatment ($295/acre) are directly attributable to reduced costs under the assumption that there is no difference in marketable apple yield, quality, or price across treatments.

Growers managing an orchard that is completely (or nearly) netted, may consider reducing insecticide applications for major pests without sacrificing income and, at the same time, garnering the secondary financial benefits associated with crop protection from hail.

Acknowledgements

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