Counting bad apples:

Codling moth in the core of Apple Country

Netting Bulletin

Rogers Mesa

Organic Agriculture Research Station

Colorado State University

Ben Bentele

IF you stood on Grandview Mesa in the month of August, & looked out across the valley to the base of Redlands, you'd see a small quilt of green & white shifting in the wind. It's October now, the colors are changing, & the quilt has almost vanished. What you saw there on Rogers Mesa - were three orchards with nets on top of their apple trees. Fishers of fruit. Shepherds of pears. Protectors from wormy apples.

Codling Moth has held the reins of the Western Colorado apple industry for a century now. It is a history of acquired resistance to insecticides. Organic apple production requires more spraying than any other crop here. This leads some to say *"Organic Apples are an oxymoron."* Of course, nets are plastic - certainly not ideal from a sustainability standpoint. But remember, codling moth developed its first worldwide insecticidal resistance just an hour away in the Grand Valley. Turns out moths could tolerate arsenate better than humans could.

I've heard it said: spraying every 10 days used to work. No longer - even a 7 day program struggles to control worms. The only organic spray program on the mesa maintaining below 15% damage is CYD-X every 5 nights on less than 5 acres. This program is impractical for a large orchard. But with 50 -60-70% wormy apples, what is a practical solution?

Nets are drastic. But they work. "But what else changes?" you ask me. "What happens when moths hatch under the net? What about aphids? & why is there tin foil down their orchard rows?"

I hope this bulletin addresses more than just the economics. This is not a sales pitch. I am impartial to the data & keen to tell a story if it's told to me.

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There is only one packing shed left - I never saw the days of apple lorries lined up in Delta. We are on the brink of so many pressures here in Western Colorado: the climate changes, the population shifts. As such, nets aren't just a financial investment. They are a commitment to future fruit growing. We may have to chop those old standard Romes eventually. But don't let it be because of worms.

We need not spend our lives counting bad apples.

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Project Introduction

This project began in 2020 under the auspices of a CDA specialty crops block grant. Albeit, not the easiest year for community research. Five orchards agreed to be surveyed, all on Rogers Mesa. They are representative of orchards in the broader North Fork. A brief description of their Integrated Pest Management programs for Codling Moth (CM IPM):

Ela Family Farms

- Weekly CYD-X spray
- Full Application of Entrust spread out between 1st & 2nd generation.
- Largest orchard in this study: 80 mixed use acres (apple /peach /plum /cherry / grapes /vegetables)

Mesa Crest Orchards

- Difficulty controlling CM with CYD-X in 2020
- Netted in 2021 (about 7 acres)
- ½ application of Entrust in first generation
- No CYD-X

Topp Fruits

- 5 acres apples
- Entrust every 10 days (Full rate)
- Mineral oil every 5 during spring
- CYD-X every 5 days rest of season
- Jug Traps
- Scraped & banded trees in 2019

Honey Crisp Orchard (HCO)

- Netted since 2019
- No sprays for netted trees as of 2021
- Nematodes used as biocontrol 2019 & 2020
- Cide Trak Mating Disruption

Organic Agriculture Research Station (OARS)

- Netted 2021
- Full application of Entrust 1st gen, no CYD-X

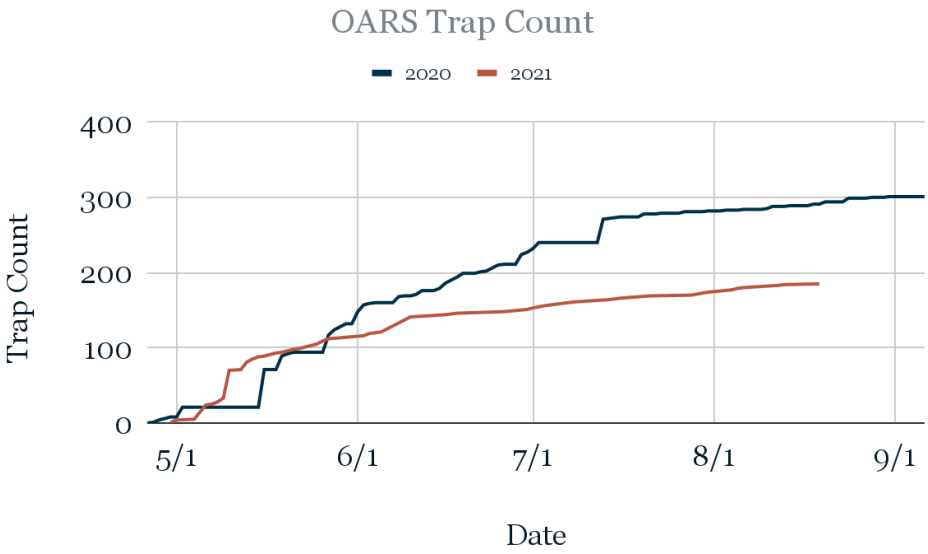
Osito Orchard

- Conventional pesticides in 2020
- Transitioning to organic in 2021
- 3/4 Entrust, CYD-X every 7 days

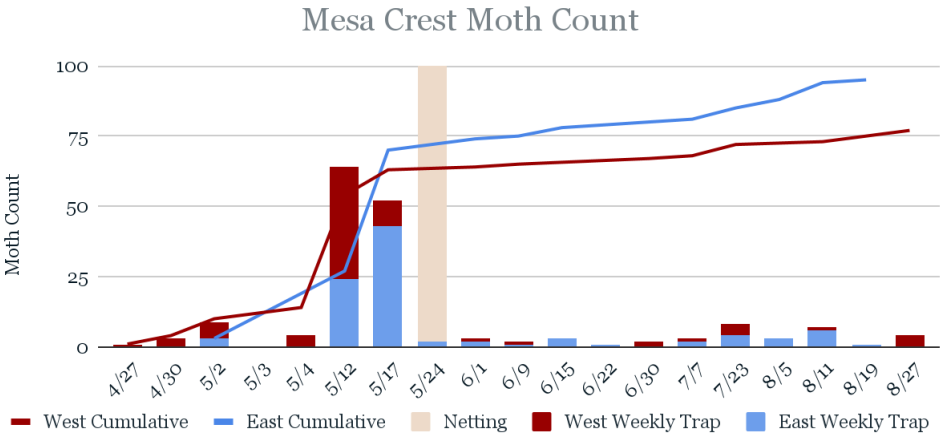
Data

Codling Moth Trap Counts

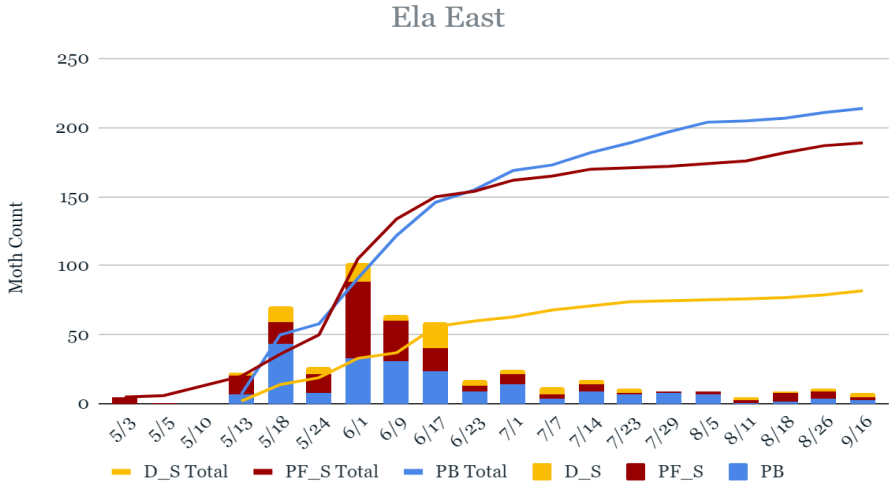
The following graph compares the trap count at OARS for 2020 & 2021. We use the standard combo lure in delta traps placed in the top ⅓ of a tree canopy. In 2020, the whole orchard was un-netted. In order to see the effect of netting on population, in 2021, a single trap was placed in an unnetted row, while all other rows were netted. The population growth can be described as a logarithmic function. As you can see in the chart, in 2021, the population grew 1.5 times slower as compared to 2020.



Cumulative codling moth trap counts for 2020 & 2021



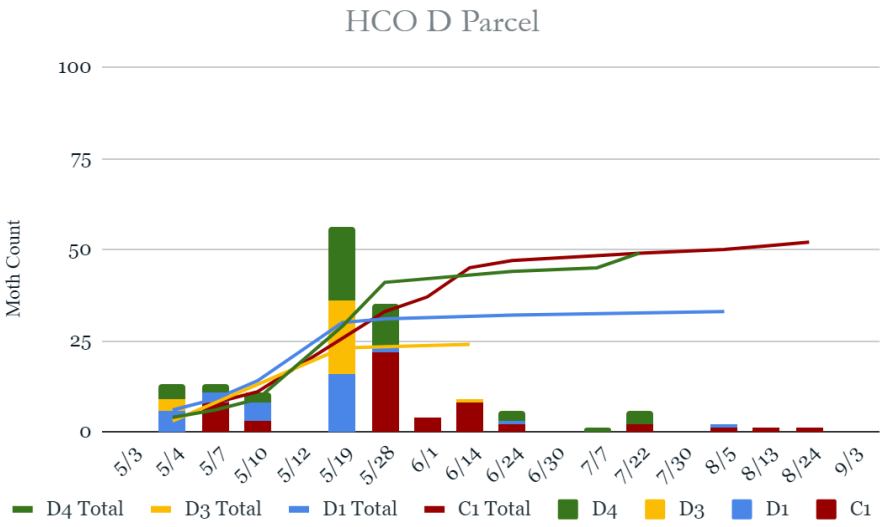
You can see the effect of netting on population growth more clearly in the above figure. Every row was netted at this orchard (Mesa Crest). Nets were installed between 5/17 & 5/24. They drastically changed the nature of population growth in late May. Had there been no nets, modelling would predict 100 trapped moths by June. Instead, the whole season trap count was <100 moths. Compare this to a nearby unnetted orchard in the bottom figure: peak first generation activity was observed around June 1 & has a smoother gaussian tail here than in the netted orchard. Lines represent the cumulative growth, whereas bars show the weekly trap count for 3 trap locations in the Eastern Parcel of Ela Family Farms.



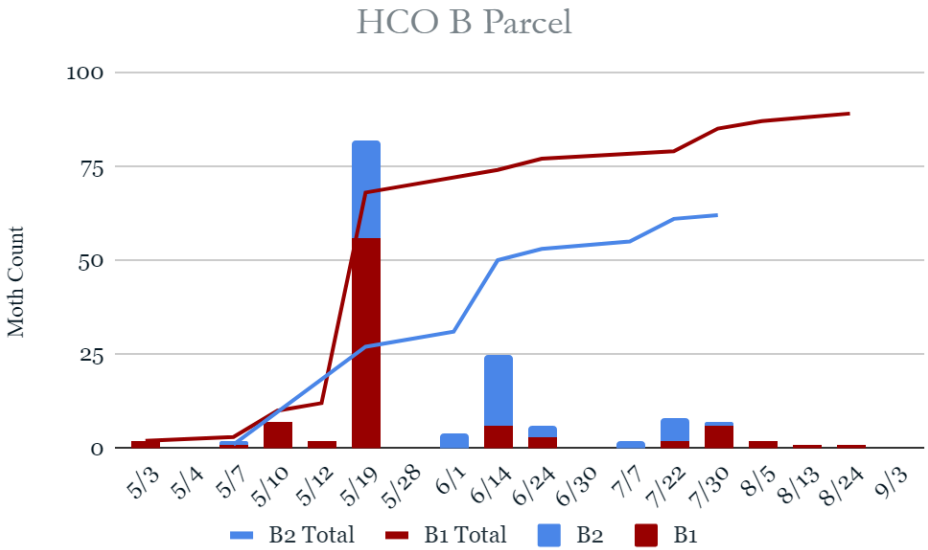
Initially we were concerned that we needed to trap differently. Traps were installed inside the nets, however no moths were ever trapped. Obviously there were moths around. But if a moth cannot access a pheromone trap, it likely cannot find a mate either. So even if moths can get inside a net, the chance of fertile oviposition is very low.

Is the effect the same for a larger netted orchard? It is not quite as drastic in the two parcels from HCO orchard on the following page. Both parcels were netted in late May, however there are more nearby unnetted habitats: newly grafted trees & neighboring apple orchards. Moth activity nearly vanished at Mesa Crests after nets; whereas, at >5 traps per week during June, moth activity is still concerning at HCO. There is more second generation activity at HCO than at Mesa Crest as well. However, if left unnetted, we predict the trap counts would have continued to climb till June 1 at >20 moths per week. This is certainly a substantial improvement.

Damage counts will be discussed in the next section - though I will note here that the high trap counts from parcel B & D did impact packout in a couple rows. Overall though, these do not change the total packout percentages considerably. This teaches us that monitoring continues to be important after netting. Regions of high trap counts in the spring should be top priorities for early thinning.



Lines represent cumulative trap counts
Stacked bars show the weekly traps for each parcel
Netting was installed by June 1st



Damage counts

Damage counts were surveyed in the field as well as at processing facilities. Both measurements agree on <2% codling moth damage at harvest for netted orchards. On a row to row basis, hot spots of ~15% damage were observed at OARS & HCO. However, this damage was contained to single rows. HCO typically does 2 rounds of thinning: a traditional early summer thinning & a codling moth damage thin in early August. This makes data collection complicated. We only did the initial traditional thinning at OARS, and so this data is easier to relate.

I sorted about half of the honeycrisp harvest at OARS (10 rows) with specific attention to hotspot rows. Drops are difficult to assess, but I attempted to account for CM drops in the following numbers.

The two hot spot rows had an average 9.4% CM damage out of 3269 apples counted.

Three low damage rows had an average of 1.2% damage out of a total 5136 apples.

Visually, the other 5 rows resembled the <2% damage rows. It's very time consuming to count every apple in an orchard - so packing shed data is far more useful for sure statistics. Mesa Crest did no thinning this year, & yet had 1.7% CM damage for the entire gala packout (10% total

culls). Compare that to 2020, when most of their bins were in excess of 70% culls. The bulk of the 2020 harvest was sent to the juicery because it isn't economical to sort at that cull %. And so, for 2021, there were 17 times as many marketable apples than 2020. (Yet only 1.6 as many apples picked in 2021 as 2020.)

For the Cameo harvest at OARS, there were only 10 CM damaged apples out of a harvest of 3.5 bins. Netted Fuji data from Mesa Crest will be added to this report once processed.

As part of this grant, we had hoped to test the acquired resistance of CM to the granulovirus used in CYD-X & Virosoft. Samples have been sitting at Purdue for a year now & we still haven't heard back. However, there are a couple of local anecdotes worth sharing. If there was resistance, a shift from Virosoft to CYD-X should have translated to a shift in apple damage. No shift was noticed though (this was before the current grant's survey).

& yet, I've heard the same story across our region: CM becomes much harder to control if an orchard went unsprayed during a year with near total crop loss from a frost. This is exactly the sort of event that breeds pesticide resistance into a population.

Economics

The first thing on most people's mind is return on investment. So, here are some quick numbers:

- $4000 an acre for netting
- $18000 for a netting machine
- Typical total cull % after netting = <10%

On 1 acre, the calculation for the first year profitability of nets can be simplified to the following formula:

Profit with nets = $T^*(P_F - P_c) \times (\%_c - \%_N) - \$4000$

Where:

T = Total Harvest (in lbs)
P_F = Fancy Price
P_c = Cull Price

$\%_c$ = No nets Cull %
$\%_N$ = Nets Cull %

Even in the first year, without a crew experienced with nets, it is easy to reduce total culls to 10% of a harvest regardless of prior codling moth damage. So take for example an orchard with 70% culls prior to netting. Reduce that to 10% with nets. For local galas, a grower can get $1 a pound for wholesale Fancy & $.22 cents to juice the culls. Plug all that in:

(1-.22) x (.7-.1) = .468

To break even on this acre, we need a profit of $4000 to pay off the nets

So, solve for T:

T = 4000 ÷ .468

=8457 pounds

or

11 bins of apples.

Thus, this grower only needs to pick 11 bins to pay off the nets on that acre. A modest pick for Galas. Of course the profitability changes for an orchard with less moth damage:

If you had 25% culls prior to netting, but had the same price structure, you would need to pick 43 bins to pay off that acre of netting.

The calculation changes if you are considering a larger acreage & wish to buy your own netting machine. As well, there are local orchards with their own processing facilities where the cull price is different.

On 10 acres, with 60% culls & .36 cents a pound for culls:

T=10*(4000/(.64 x .5)+18000

=

382 bins on 10 acres
Pays off the whole package.

This is a simplification of course. I've ignored labor costs & the price of pesticides & hail insurance policies. But the thing is, if you switch to nets, all of these factors are in your favor. We sprayed no Virosoft or CYD-X this year & had below 2% codling moth damage on most of our rows. Another orchard in the project only sprayed half the rate of Entrust, no CYD-X & also had below 2% damage. Pesticides are expensive, & tractors need maintenance. We also had a serious hail event, & by mid July, 100% our unnetted control row was cull grade or worse.

Hail netting has been in use in the Cedaredge area for several decades now. Though hail nets only cover the tops of the trees, it's important to note their experience.

Mountain Spirits removed their hail netting. Wooly aphid pressure increased under the nets & the apples wouldn't color correctly. This was detrimental to the point of un-marketable apples & serious tree damage. Taking the nets off immediately relieved aphid pressure. Now, it is possible to remove the nets a week or two before harvest for coloration. We did that on Rogers Mesa this year & at least for galas & honeycrisp we had no coloration issues.

There is a research paper from the Czech Republic[1] warning against the use of nets in temperate climates. Essentially, the more cloudy days you have, the worse these issues will be. There are still growers in Cedaredge who use hail netting, but it is important to say that nets are not appropriate for every climate.

Points of Concern

Deer

We have a resident family of deer that like to bed down in the apple alleys. Whether antlers or otherwise, they ripped several large (<10ft) tears in the netting.

Birds

Birds often get trapped in the nets.

Aphids

Aphid's predators are also excluded from the apple tree - thus allowing for outbreaks of aphids. Ladybugs were still seen under the nets associated with aphid colonies. They must find a way in through gaps. I did not observe Lacewing or Syrphid flies.

Rosy Aphid

There was a rosy aphid flare up before the July heat. It resolved without any grower mitigation. Damage was not deemed economically impactful. Never was a full tree infested. The trees easily recovered.

Wooly Aphids

Specific concern for late vigorous varieties (fuji / cameo). A month after the nets were removed, (early October) an infested block of Galas had recovered.

The economic impact remains to be seen. The worst I've seen: 5 neighboring trees which senesced early due to near 100% branch infestation. They will be monitored next year.

Mineral Oil

Part of the aphid population increase may also be due to less oil spraying. Oil was only sprayed once a month with foliar nutrients this year rather than once a week last year. This reduction may have subsequent benefits to tree health, as oil clogs stomata & can impair translocation of nutrients within the phloem.[2]

Other Environmental pressures (Bitterpit / splitting)

If an orchard block has historically had bitterpit or splitting issues it makes less economical sense to net them. These will persist with netting. However, nets may have a minor effect on calcium uptake due to increased water retention. So nets could slightly ameliorate both of these issues. Requires further research.

Dropping apples

If you take the nets off at harvest time, you risk knocking / dropping a significant amount of apples in the process. Two words of advice: don't yank.

Netting lifespan

An untrained crew will tear holes in the nets. Shoots growing through the nets will cause holes during removal. Minor holes can be patched with zip ties. Major holes need to be repaired with the sewing machine. Holes in the nets are not obviously associated with moth damage. DrapeNets claims a 10 year lifespan.

Mating Disruption

Anecdotally, it is important to install mating disruption in the spring if you have neighboring moth pressure (HCO). This decreases first generation damage before the nets are installed. I assume it also compounds the disorienting effect of nets on mating. We didn't use it at OARS this year & see no reason to next year on our small acreage.

Thinning

Thinning is more time consuming under the nets. But thinning is a great way to handle first generation damage. It may be possible to thin with the nets by limiting pollinator access. We hope to study this next year.

Shipping Costs

The current price of nets has much more to do with shipping expenses (from China) than it does with manufacturing costs. If you are on the fence & can wait another year - it may be worth waiting for shipping costs to settle down again.

Questions

What happens when moths hatch under the net? How important is it to patch holes in the net? Can moths lay eggs on an apple touching the net?

It depends on the tree architecture. With large vase trees, there is the possibility of a row-localized moth population within the net. In a compact / spindle - there is very little maneuverability for the moths. (Think of moths in your house - they aren't exactly agile).

We left one row unnetted & unsprayed. The moth pressure from that row had an impact on the neighboring netted row to the effect of ~15% moth damage. This row was also torn by deer. Interestingly, moth damage was not correlated with the tears. Rather, damage was primarily on apples touching the net on the side which faced the unnetted row. While it is harder to oviposit successfully on the net, it appears given sufficient pressure, moth damage can still occur from the outside.

Which varieties have coloration issues with netting? Does tree architecture matter?

Spindle / compact trees will benefit from summer pruning. We harvested our open vase honeycrisp & cameos about a week later than last year, but they had no coloration issues. A Washington State survey stated: "41.2% *indicated they observed reduced coloration of fruit under nets whilst* 29.4% *reported no problems with fruit color under netting. About* 29.4% *of surveyed growers were unsure if fruit color was affected by protective netting.*"[3]

How tightly do the nets need to be sealed / cinched?

We had a small crew at OARS to install the nets. Instead of tightening the nets around the base of every tree trunk with zip ties, we used grape netting hooks every other tree. As with the deer tears, a gap in the nets was not obviously correlated with moth damage.

Do the nets impact microsprinkler spray?

Yes. At HCO microsprinklers are left within the nets. At OARS, we dangled the sprinklers beneath the netting so the spray pattern was unchanged. Further research needs to be done next year on what is ideal / economical.

What changes in the climate under the nets?

There is mixed research on general temperature & humidity differences depending on the country of study. However, there is consensus that netting reduces surface temperature & radiation on fruit & leaf. This is the reason for the reduction in sunburn incidence. Also, wind speed is reduced by 40% under the nets. "Protective netting can actually increase the amount of scattered light reaching lower portions of the tree and has the potential to increase net productivity even with overall reductions in light reaching the leaves"[4]

In sum, in desert regions there is too much light - a plant will actually benefit from shading.

Do nets impact the occurrence of other diseases?

There was no difference in fireblight occurrence, but under the nets there was less occurrence of rusts & SBFS symptoms.[5]

Why are there green nets at Honeycrisp Orchard?

There is ongoing research on how netting color affects fruit color & quality. The shading factor changes, but also the ratio of wavelengths to each other changes. I've included bulletins & papers in the references if you wish to read more.

References

Climate under the nets

1

Effect of hail nets and fertilization management on the nutritional status, growth and production of apple trees

5

Impact of exclusion netting row covers on arthropod presence and crop damage to 'Honeycrisp' apple trees in North America: A five-year study

The influence of protective netting on tree physiology and fruit quality of apple: A review

Net Coloration

4

Above and below-ground environmental changes associated with the use of photoselective protective netting to reduce sunburn in apple

3

Washington State University Extension Bulletin

Exploring the Potential use of Photo-Selective Nets for Fruit Growth Regulation in Apple

Reviews

Codling moth exclusion netting: an overview of French and Italian experiences

Apple tree and fruit responses to shade netting

Mineral Oil

2

(PDF) Localization and movement of mineral oil in plants by fluorescence and confocal microscopy

Acknowledgements

As a land-grant university, it behooves us to acknowledge the land on which we live & study.

The ancestors of these mesas were forcibly removed from their homes in the 1880s before any orchards were planted. At that time, Tabeguache was the name of the Ute band who lived here "on the warm side of sun mountain." Tabe or Tava refers to Sun Mountain - Pike's Peak. Currently, they state the name of their people as

Aka'-páa-gharuru Núuchi

The Uncompahgre Utes

To know this word, uncompahgre, is to visit the creeks
& rivers after a monsoon - to see:
"The rocks that make water red."

If acknowledgements were citations, Bryan Braddy would be a widely read scholar. Thanks for all the tips & history; thoughts & walks.

I owe much of these insights to Arturo Jimenez - and am so grateful for his time & generosity to this research.

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Mellisa Franklin

"The apple that Adam ate was Colorado Jonathan and I cannot blame him that he did eat."