Transplant steam treatment & miticides for cyclamen mite control in strawberry

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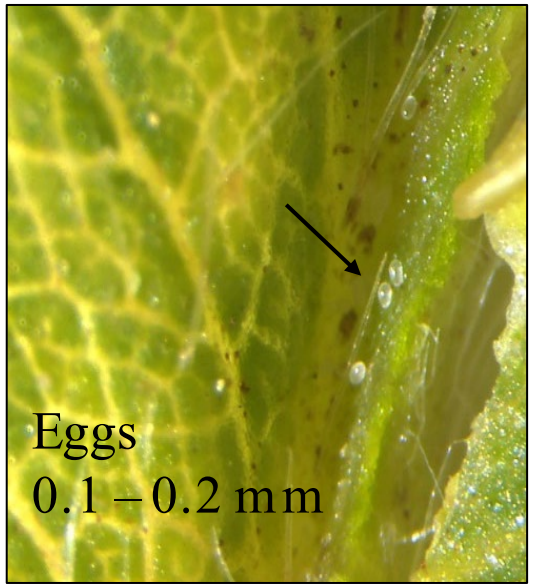
Cyclamen mite is difficult to sample



Remove fully-wrapped leaves from the crown

Separate leaves into leaflets

Uncurl the leaflets and use a hand lens OR pin leaflets open on styrofoam under a microscope

Look for mites:

- on the top surface of the leaflet
- at base of the leaflet
- along the primary vein/main leaflet fold

Cyclamen mite is difficult to sample

Newly expanded leaves with wrinkling and irregular folding and discoloration of veins

Shortened petioles = stunted appearance

New leaves are discoloured, small and do not expand properly

Cyclamen mite is difficult to control

- Deregistration of endosulfan (Thiodan, Thionex) in Canada & USA in 2016
- Agri-Mek®SC (abamectin) is the only registered miticide for cyclamen mite on strawberry

  2 applications/season

  REI: 12h PHI: 3d

  Toxic to bees; avoid application during bloom

  Translaminar in plants
- Predatory mites are an option
  - Suppression of cyclamen mite with Neoseiulus cucumeris in QC (Patenaude et al. 2020)
    - Released 500-1000 N. cucumeris per m^2 every 1-2 weeks June – August

Research on cyclamen mite control options

Pre-plant tools

Cyclamen mite can be easily transmitted on planting material

Steam treatment

Biopesticide transplant dips

Cultivar selection

Controlled atmosphere temperature treatments

For propagation material

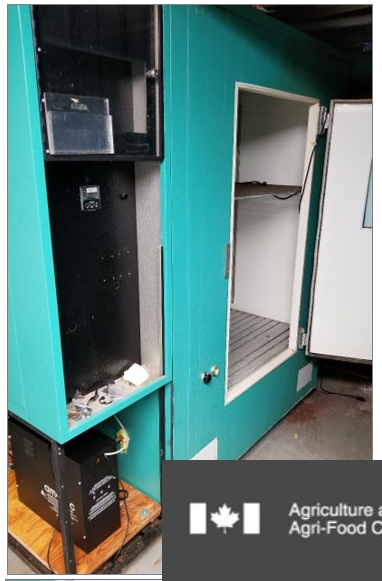
Post-plant tools

Conventional miticides

Biopesticide foliar sprays

UV-C treatment

Transplant steam treatment for strawberries



Converted growth chamber (Conviron) 1.12 m^3 (39.6 ft^3)

AMEREC steam generator (Model AK4.5) (220 V)

Residential Steam Bath Generator (amerec.com)

Water supply connected to a water softener

Steam from copper pipe (3 mm/1/8" holes) on the floor

Wire shelf with two fans (10 cm diameter)

Temperature monitored with HOBO®data loggers

More details:
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Plantsauna

The Plantsauna sterilizes plant material using precise temperature-controlled steam. The Plantsauna is a heat treatment used before planting to eradicate pests, diseases, and fungi.

https://moleda.nl/products/plantsauna/

Transplant steam treatment for strawberries

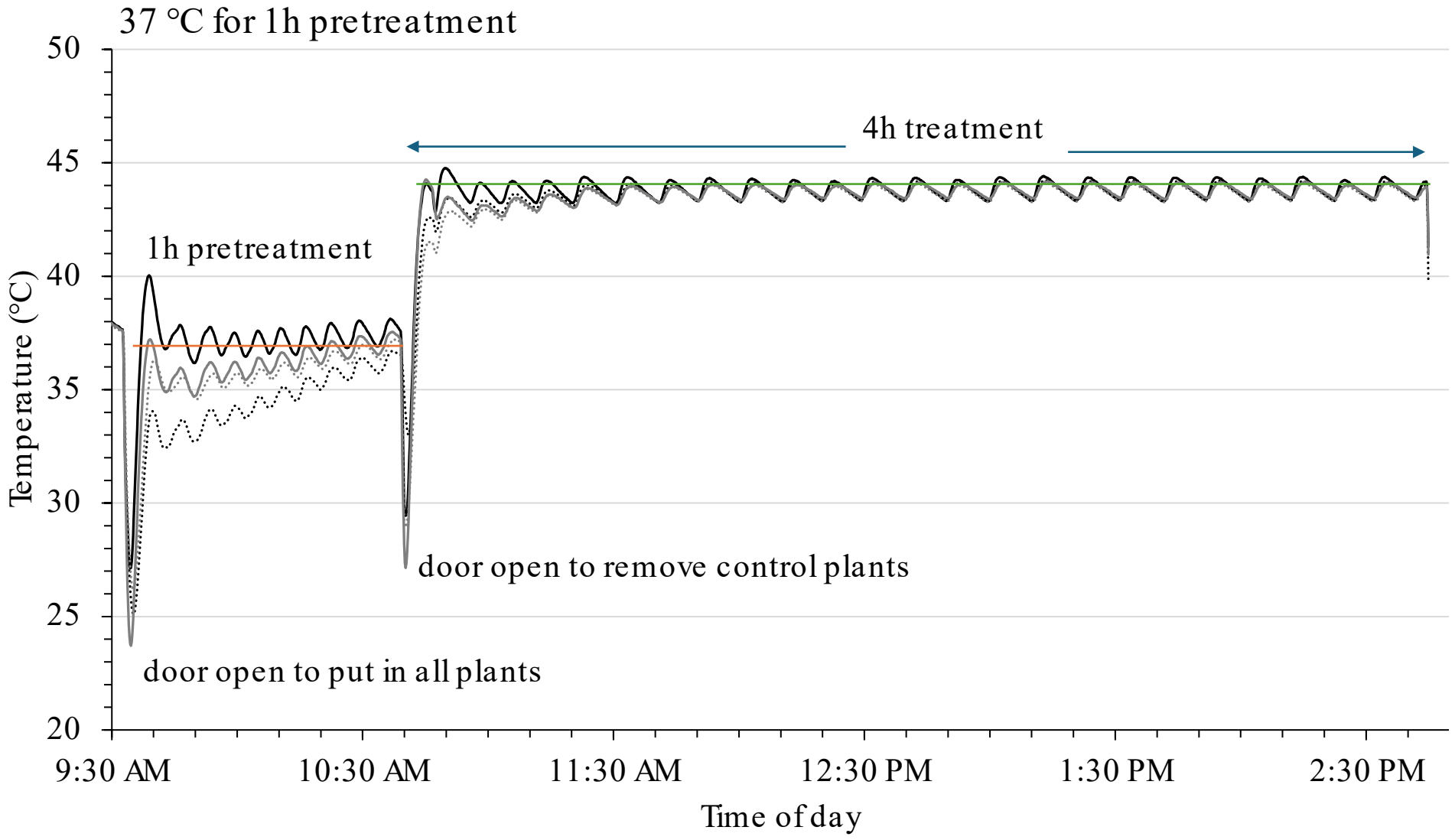

Bare-root on trays


Tips in crates


Bare-root in crates


Plugs in bins

Transplant steam treatment for strawberries



average:
43.68 °C

98.88%
relative
humidity

Steam treatment is effective against strawberry diseases &nematodes

44 °C for 4 h is recommended for:

Diseases: Phytophthora cactorum, Colletotrichum acutatum, Botrytis cinerea, Podosphaera aphanis, Xanthomonus fragariae (Baggio et al. 2021; Gahatraj et al. 2023; Stensvand et al. 2023; Wang et al. 2017)

Nematodes: Aphelenchoides besseyi, Meloidogyne hapla, Pratylenchus penetrans (Khanal et al. 2020)

Heated and humidified air is advantageous compared to hot water or dry heat

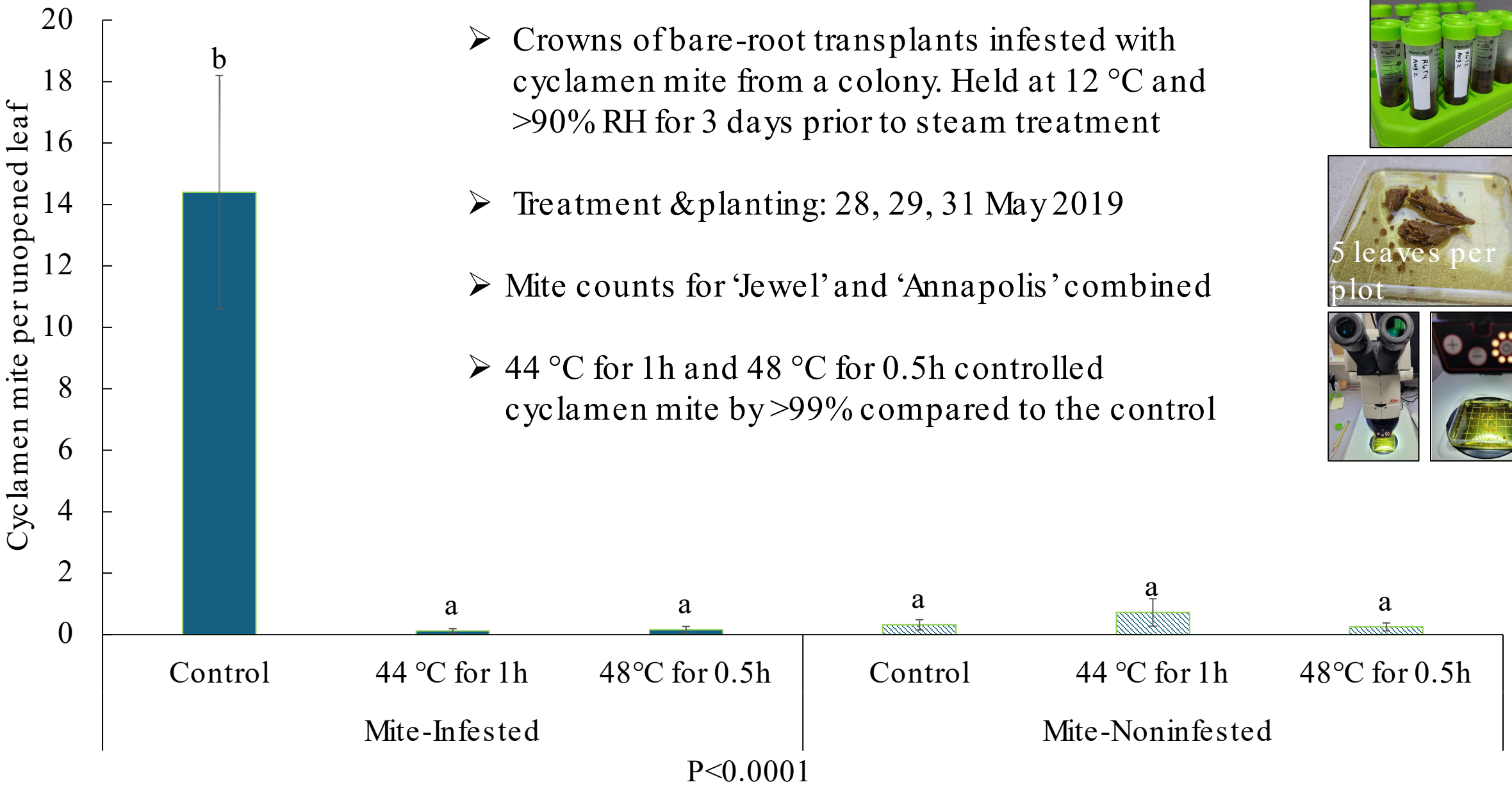
1) No cross-contamination of pathogens in water
2) Fewer adverse effects on strawberry plants, particularly cultivars sensitive to heat
3) Easier to use on a large, commercial scale

Is steam treatment effective against mites?

48 °C for 2 h eliminated twospotted spider mite, but 44 °C was not effective (Renkema et al. 2020)

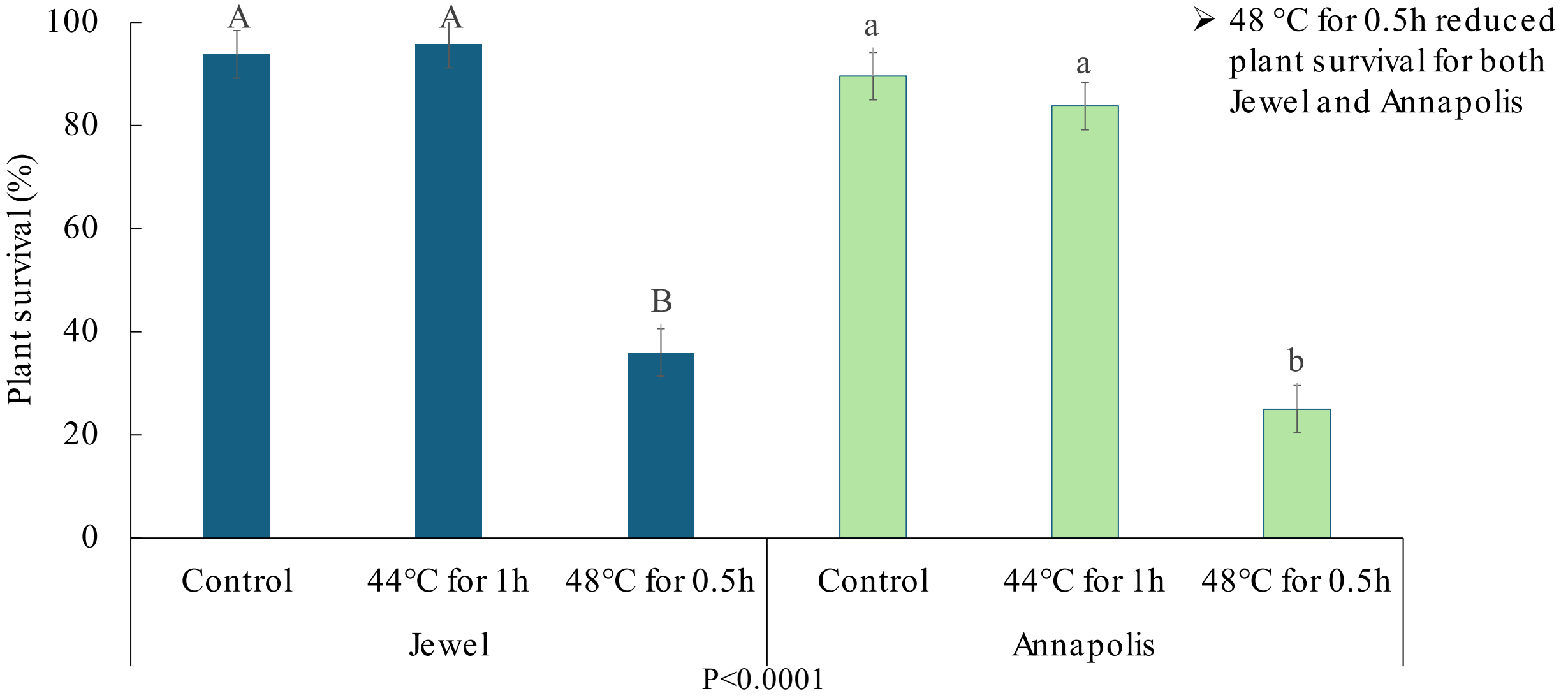
44 °C for 2 h eliminated cyclamen mite (all stages) in lab tests in Norway (Johansen et al. 2022)

1) Cyclamen mite – 4 July (5 weeks-after-planting)



- Crowns of bare-root transplants infested with cyclamen mite from a colony. Held at 12 °C and >90% RH for 3 days prior to steam treatment
- Treatment &planting: 28, 29, 31 May 2019
- Mite counts for 'Jewel' and 'Annapolis' combined
- 44 °C for 1h and 48 °C for 0.5h controlled cyclamen mite by >99% compared to the control

1) Cyclamen mite – Plant survival on 23 August (3 months-after-planting)

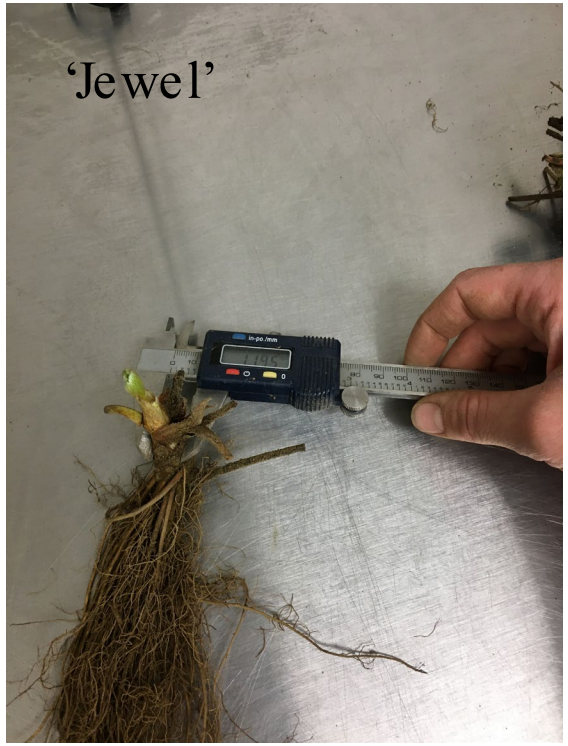


- 48 °C for 0.5h reduced plant survival for both Jewel and Annapolis

Experiment 2, 2021-2022

Erica Pate, OMAFA berry specialist, U Guelph MSc student

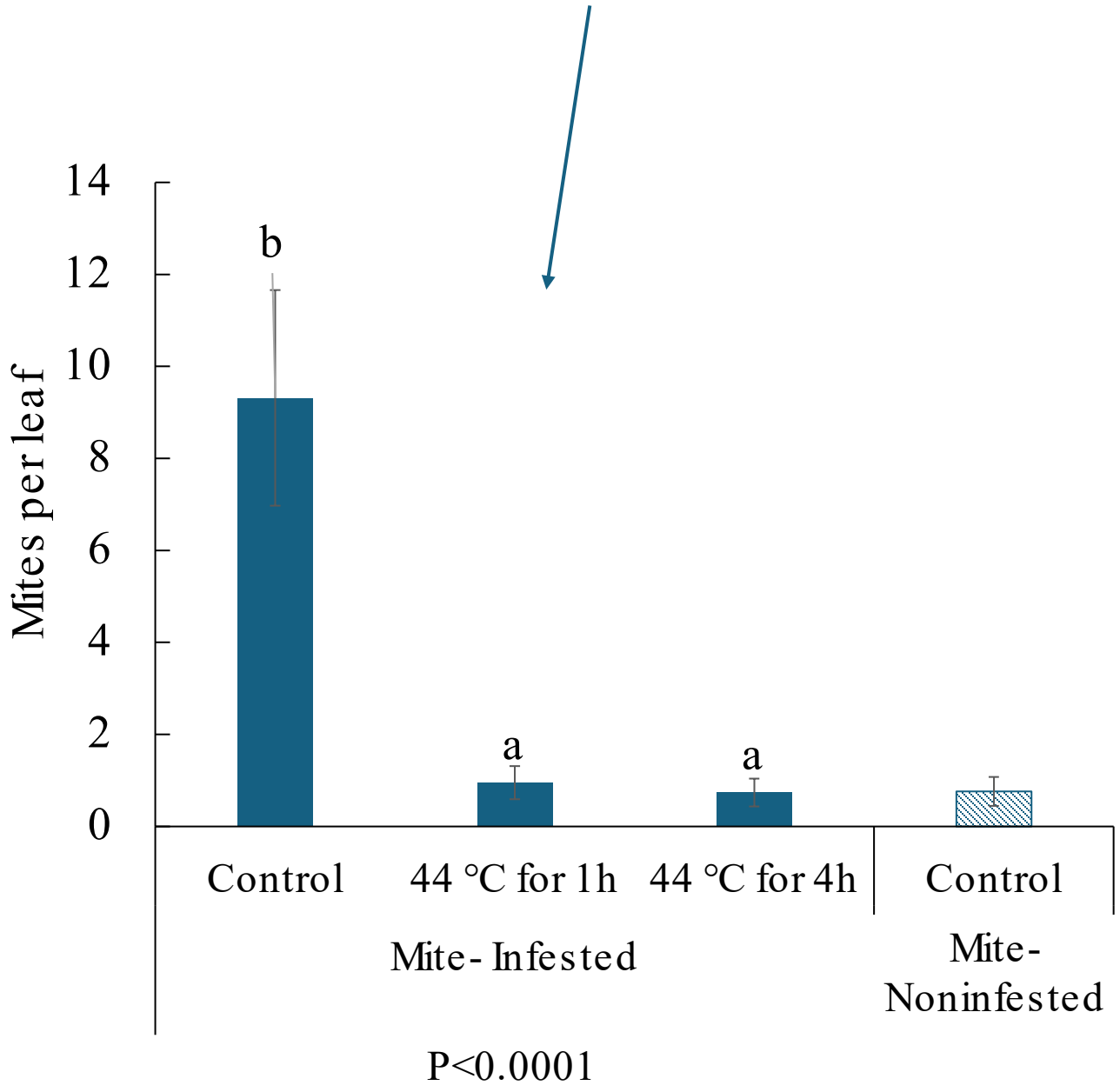
- Are there differences in cyclamen mite survival between 44 °C for 1 or 4h?
- Is transplant crown size an important factor for survival?

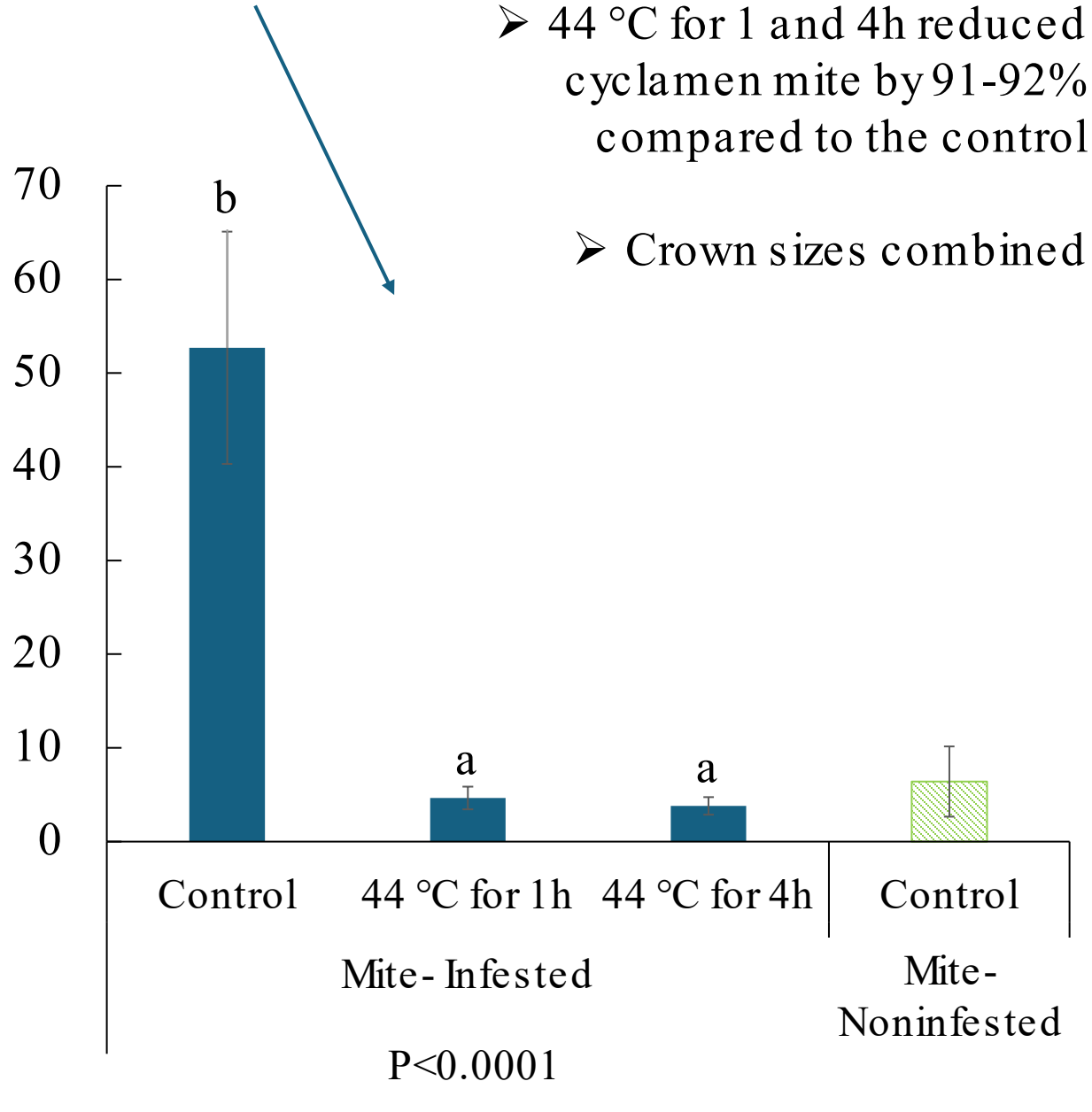


Small (6-8mm) (1/4-1/3")

Large (10-13mm) (2/5-1/2")

2) Cyclamen mite – 8 Sep 2021 (3 months-after-planting) & 15 July 2022 (13 months-after-planting)





- 44 °C for 1 and 4h reduced cyclamen mite by 91-92% compared to the control
- Crown sizes combined

Small crowns

Control

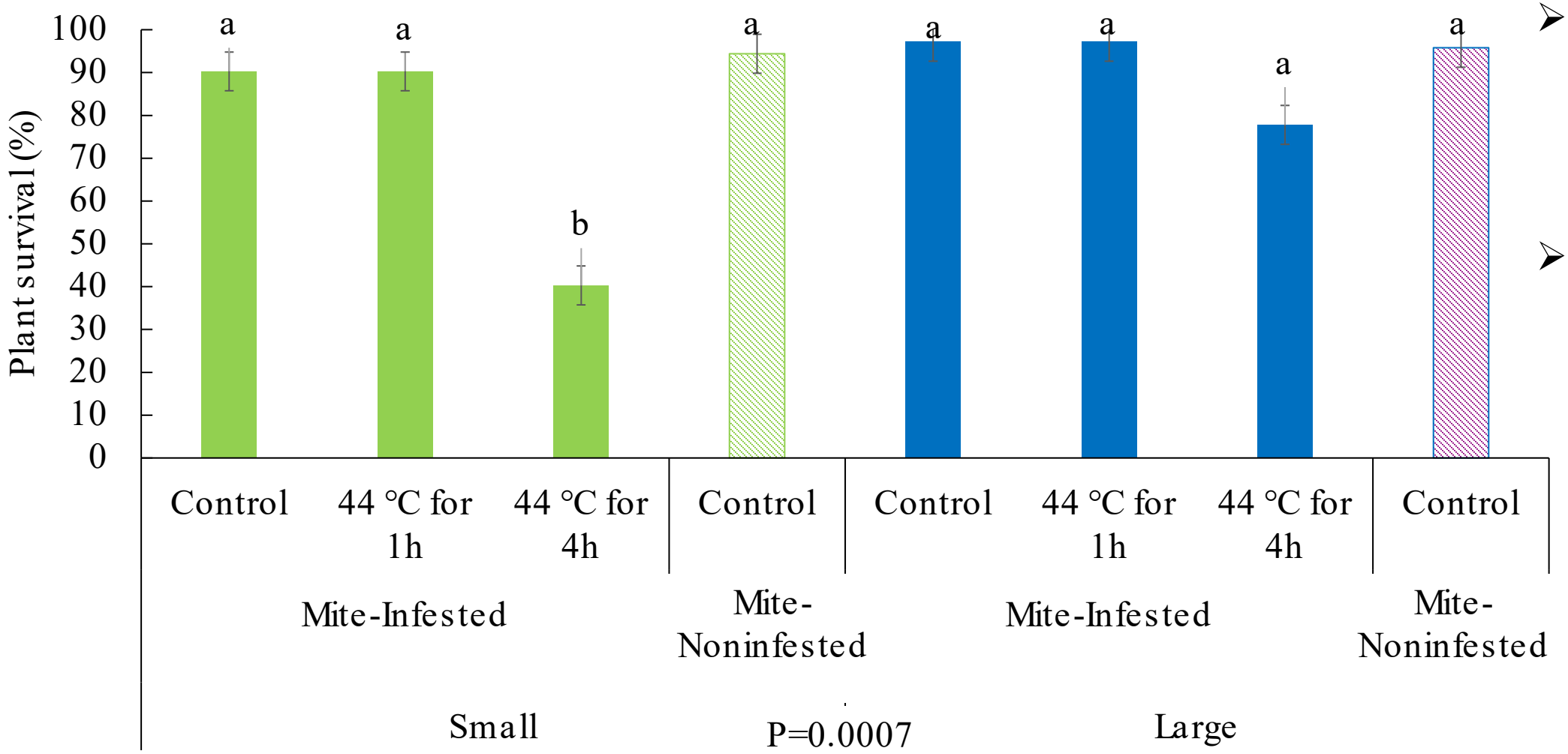
44 °C for 4 h

Large crowns

Control

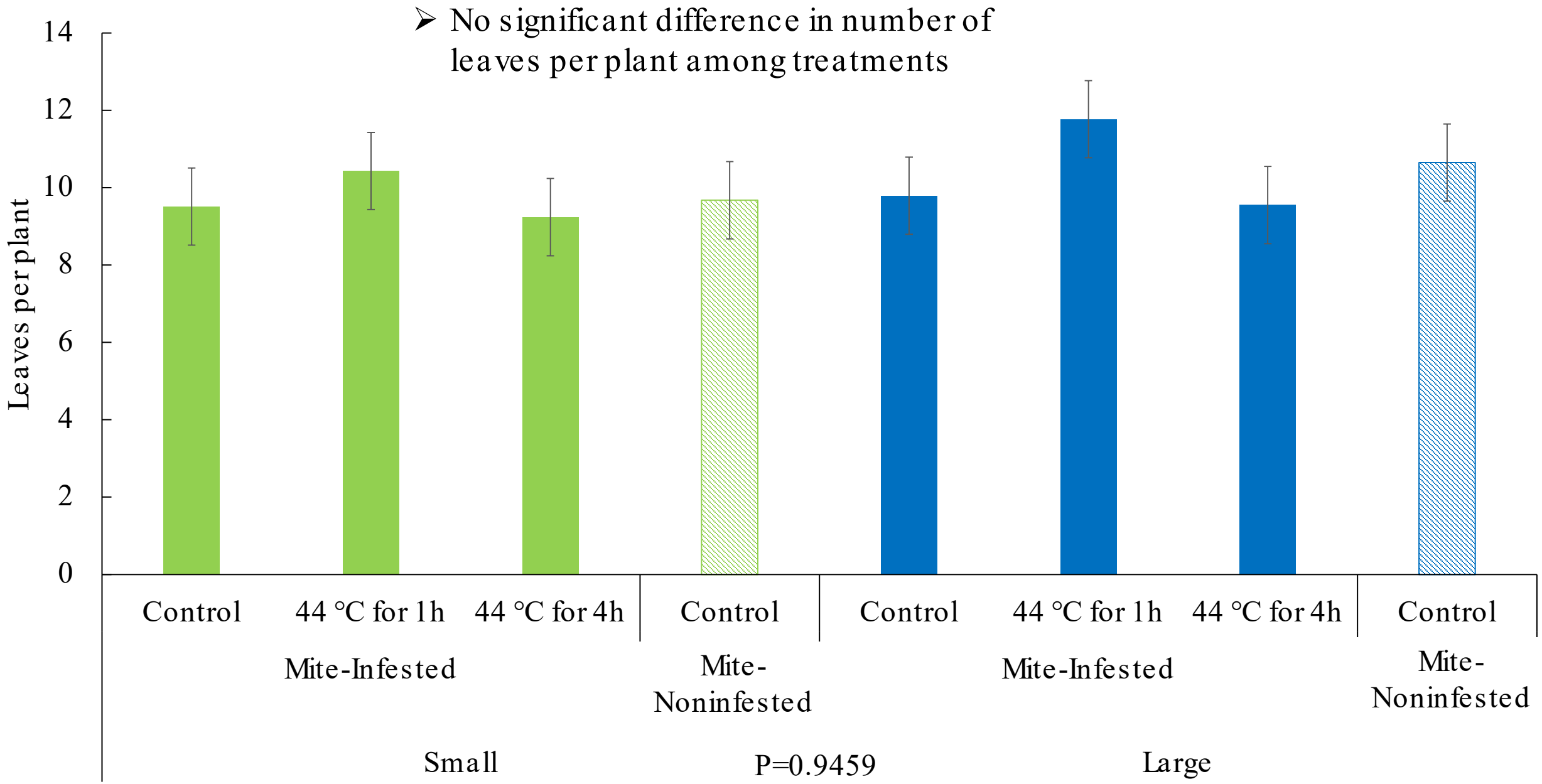
44 °C for 1 h

2) Cyclamen mite – plant survival on 10 August (8 weeks-after-planting)

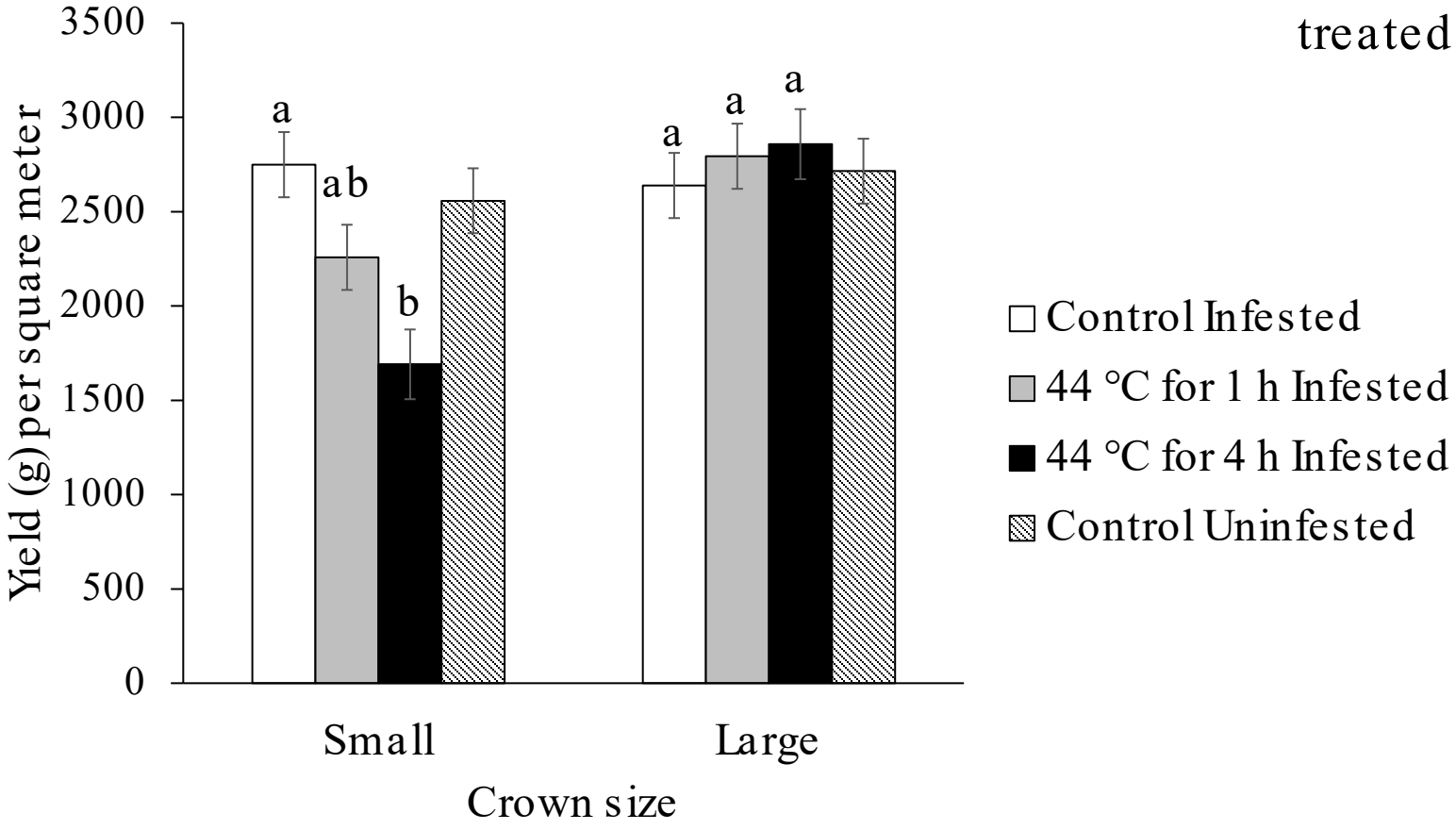


- Survival of plants with small crowns reduced to 40% after 44 °C for 4h
- No effects on survival of plants with large or small crowns after 44 °C for 1h

2) Cyclamen mite – leaves per plant on 10 August (2 months-after-planting)



2) Cyclamen mite – yield per 1 m^2 per plot June-July 2022



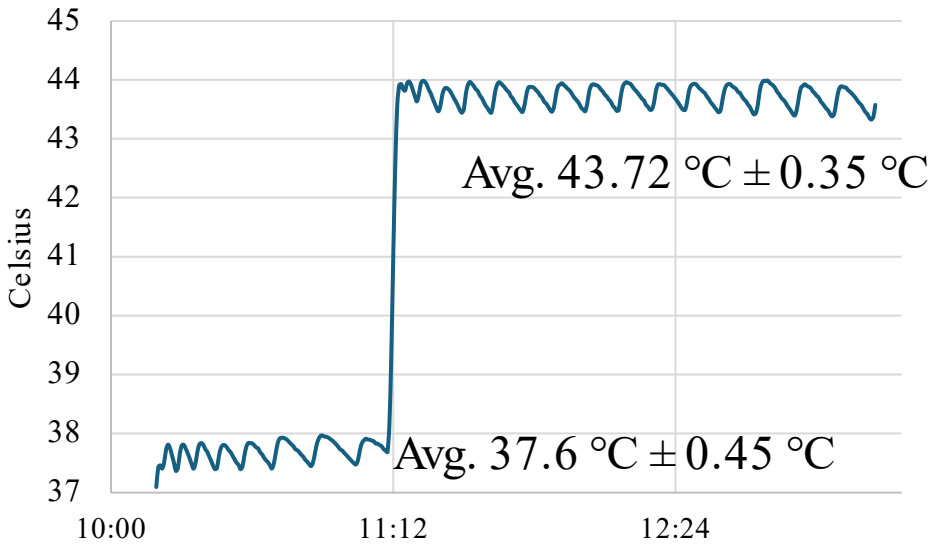
- Lower yield with small crowns treated at 44 °C for 4h

3) Cultivar steam treatment experiment 2022

What is the effect of steam treatment on common, short-day, bare-root cultivars?

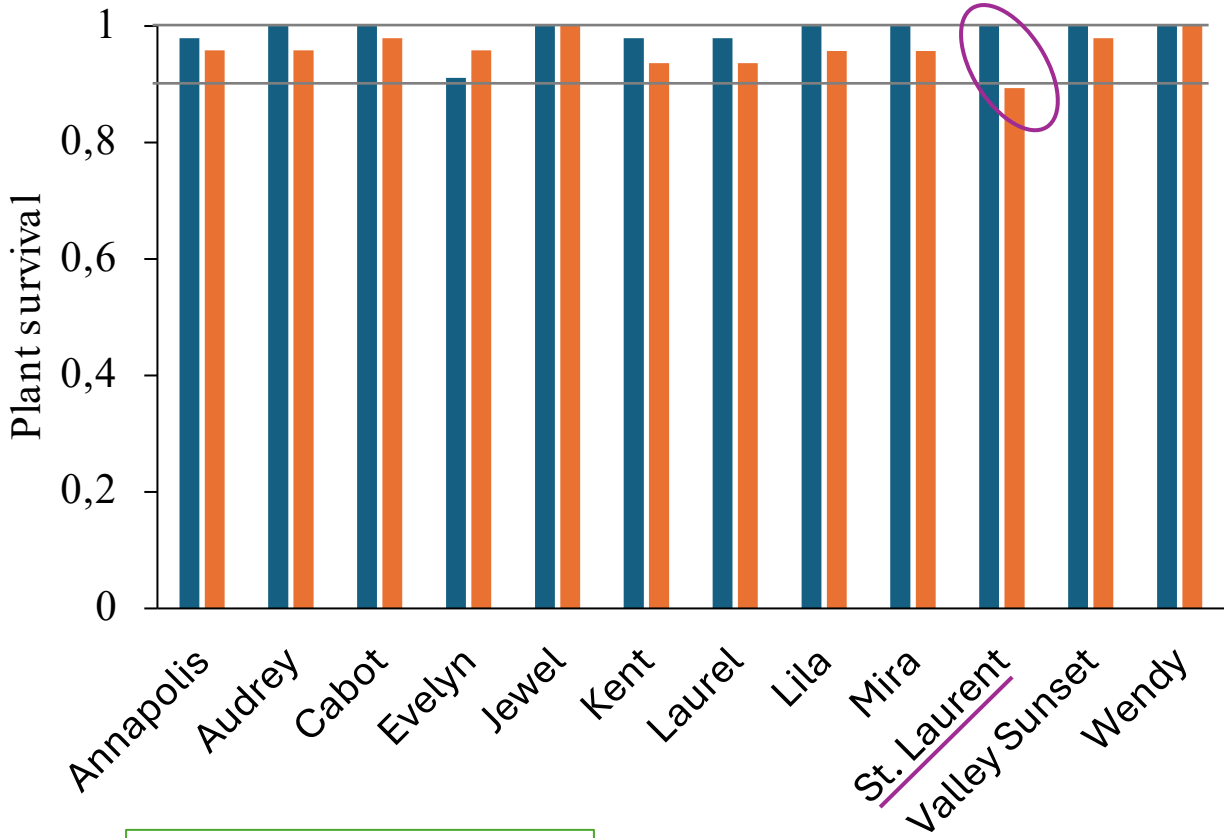
12 Cultivars	Steam	Nursery
Evelyn	No	1
Evelyn	Yes	1
St.Laurent	No	1
St.Laurent	Yes	1
Annapolis	No	2
Annapolis	Yes	2
Cabot	No	2
Cabot	Yes	2
Jewel	No	2
Jewel	Yes	2
Kent	No	2
Kent	Yes	2
ValleySunset	No	2
ValleySunset	Yes	2
Wendy	No	2
Wendy	Yes	2
Audrey	No	3
Audrey	Yes	3
Laurel	No	3
Laurel	Yes	3
Lila	No	3
Lila	Yes	3
Mira	No	3
Mira	Yes	3

- Steam treated &planted 24 May in AAFC research plots in Jordan, Ontario
- Randomized complete block design with 4 replications, 12 plants per plot



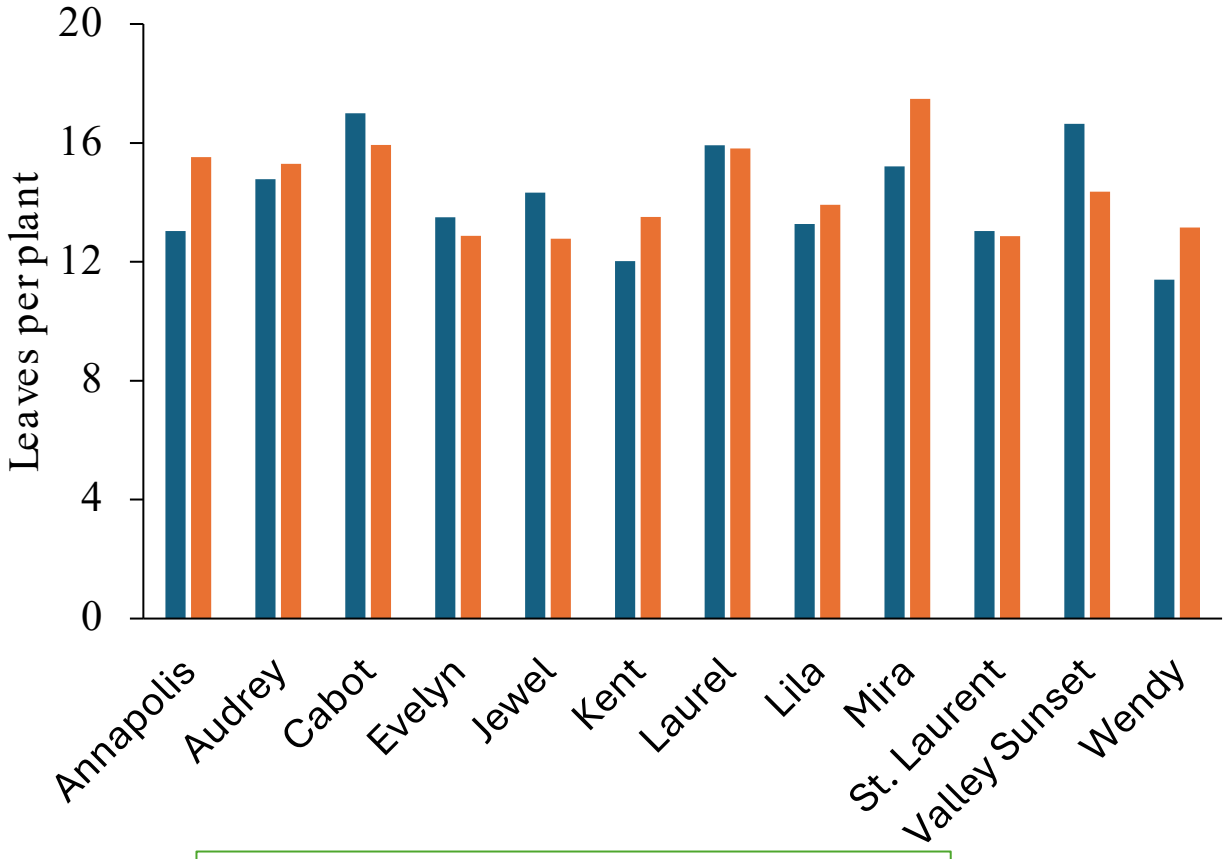
3) Cultivar steam treatment – plant survival & growth

June 8 (15 days-after-planting)



Control = 98.7%
44 °C for 2h = 95.9%
P = 0.006

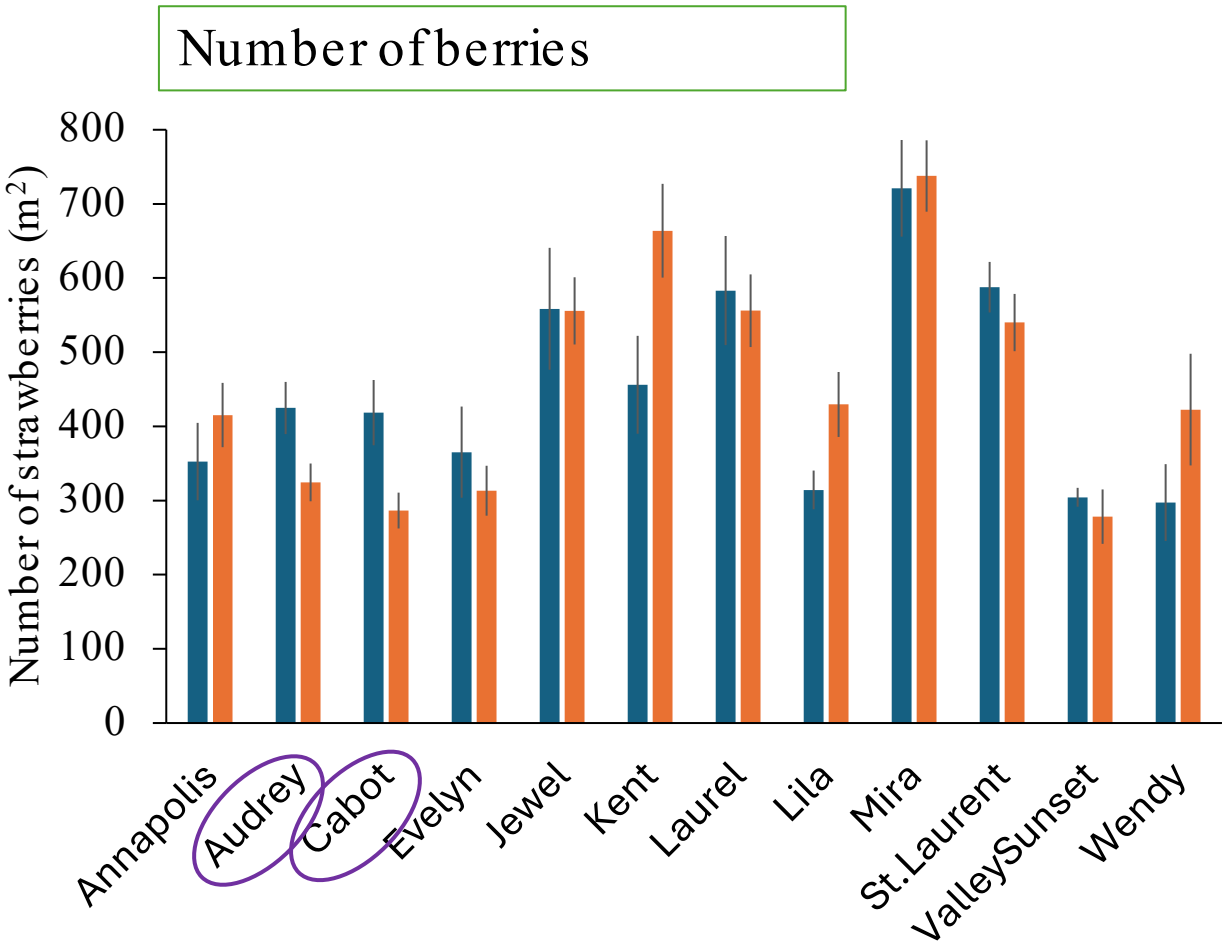
Leaves per plant July 21

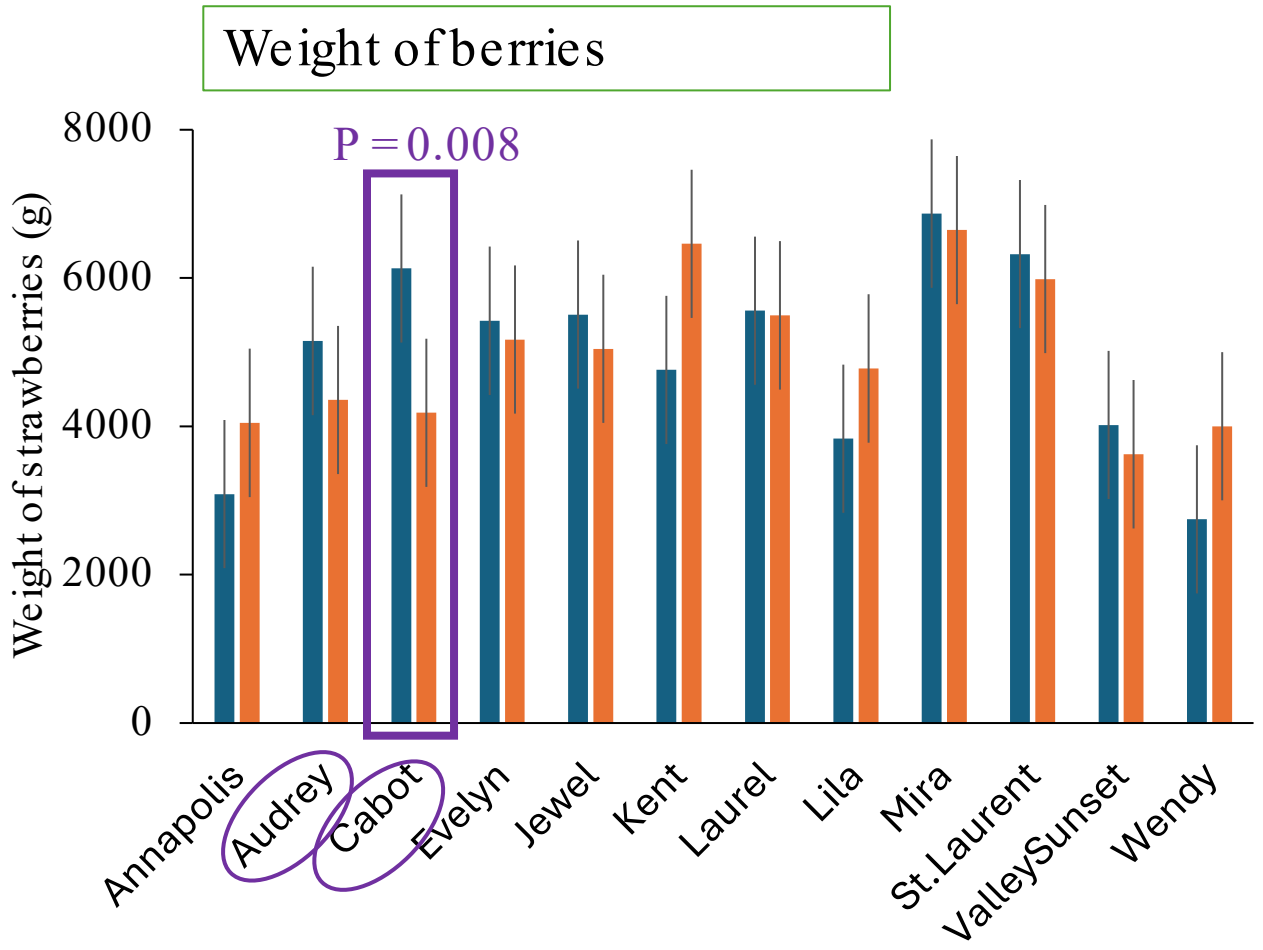


Control
44 °C for 2h

Steam treatment P = 0.575
Cultivar P = 0.003
Steam treatment * cultivar P = 0.651

3) Cultivar steam treatment harvest in 1 m^2 per plot in 2023





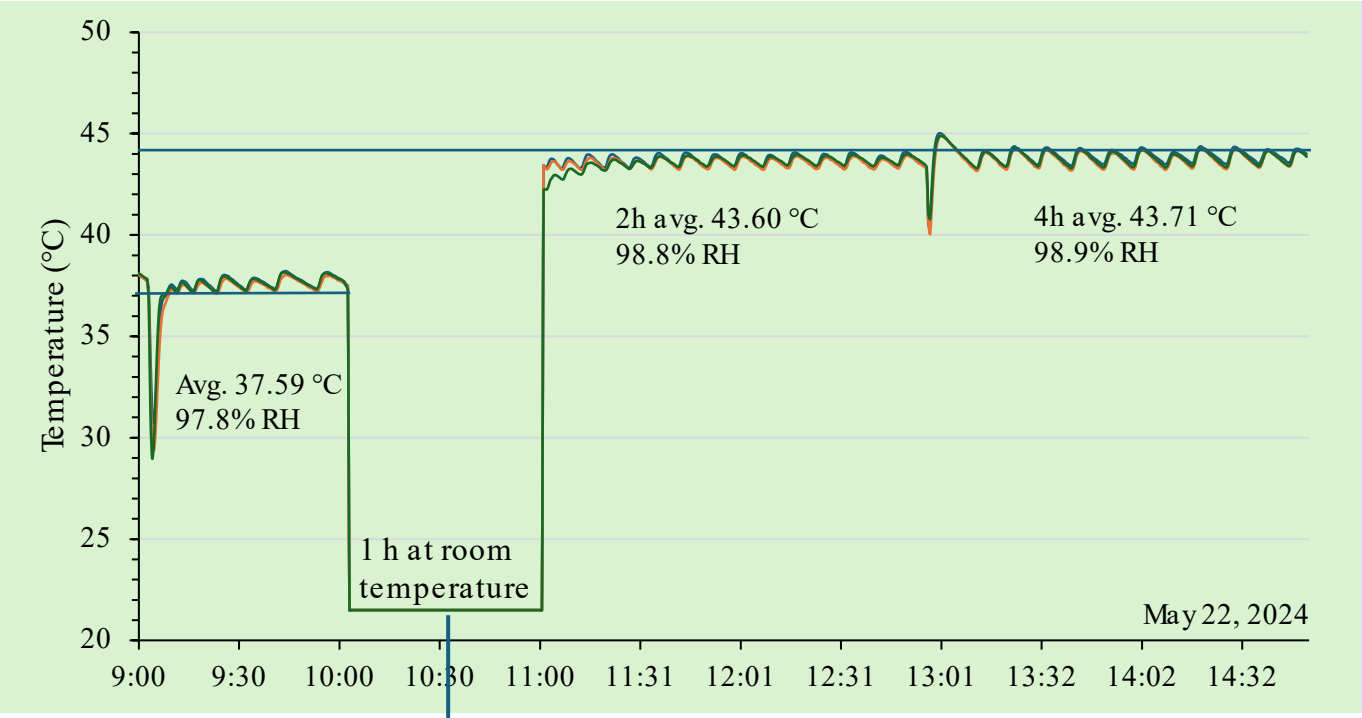
Steam treatment P = 0.569
Cultivar P < 0.0001
Steam treatment * cultivar P = 0.0457

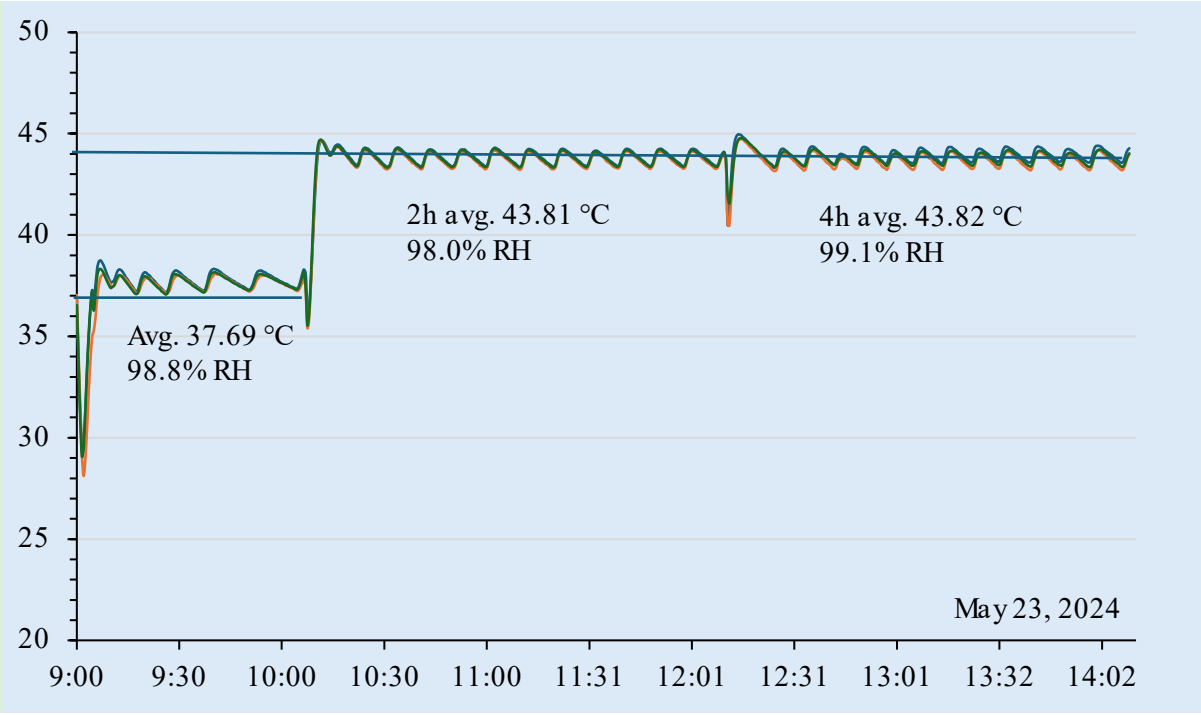
Control
44 °C for 2h

Steam treatment P = 0.876
Cultivar P < 0.0001
Steam treatment * cultivar P = 0.0438

4) Cultivar steam treatment: part 2

- A 1 h "rest period" can improve plant tolerance to heat





4) Cultivar steam treatment: part 2 2024

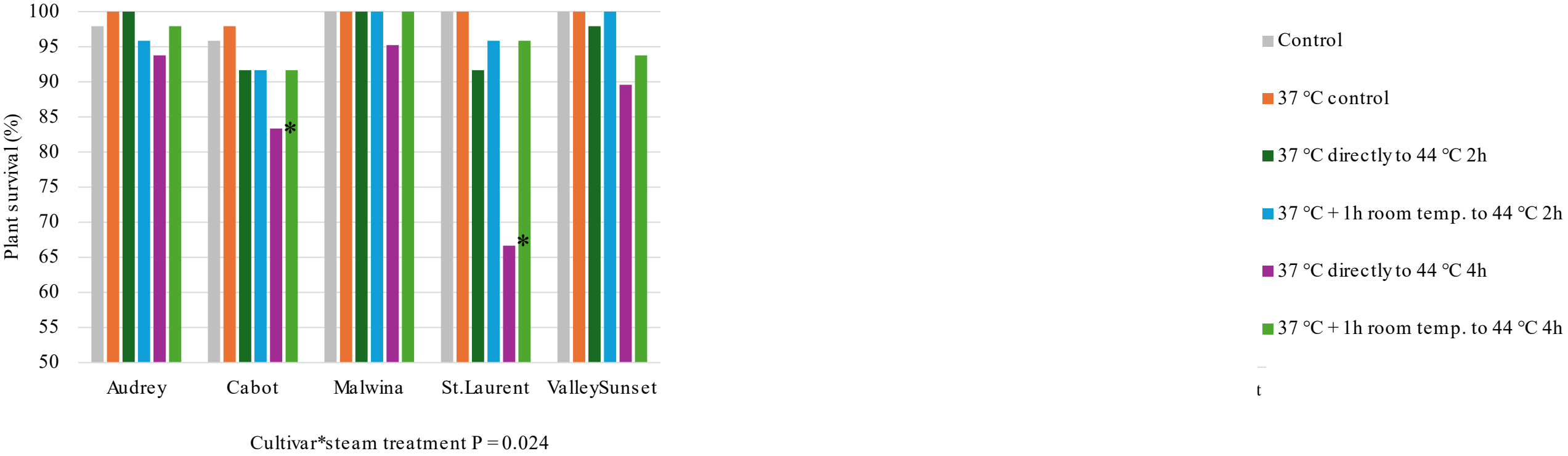
Cultivar	Steam Condition	Treatment Date	Planting Date
Audrey	Control (no steam)	-	23-May
	37 °C control	23-May	23-May
Nursery 1	37 °C directly to 44 °C for 2h	23-May	23-May
	37 °C directly to 44 °C for 4h	23-May	23-May
	37 °C + 1 h room temp to 44 °C for 2h	22-May	22-May
	37 °C + 1 h room temp to 44 °C for 4h	22-May	22-May
Cabot	Control (no steam)	-	23-May
	37 °C control	23-May	23-May
Nursery 1	37 °C directly to 44 °C for 2h	23-May	23-May
	37 °C directly to 44 °C for 4h	23-May	23-May
	37 °C + 1 h room temp to 44 °C for 2h	22-May	22-May
	37 °C + 1 h room temp to 44 °C for 4h	22-May	22-May
Malwina	Control (no steam)	-	23-May
	37 °C control	23-May	23-May
Nursery 2	37 °C directly to 44 °C for 2h	23-May	23-May
	37 °C directly to 44 °C for 4h	23-May	23-May
	37 °C + 1 h room temp to 44 °C for 2h	22-May	22-May
	37 °C + 1 h room temp to 44 °C for 4h	22-May	22-May
St. Laurent	Control (no steam)	-	23-May
	37 °C control	23-May	23-May
Nursery 3	37 °C directly to 44 °C for 2h	23-May	23-May
	37 °C directly to 44 °C for 4h	23-May	23-May
	37 °C + 1 h room temp to 44 °C for 2h	22-May	22-May
	37 °C + 1 h room temp to 44 °C for 4h	22-May	22-May
Valley Sunset	Control (no steam)	-	23-May
	37 °C control	23-May	23-May
Nursery 2	37 °C directly to 44 °C for 2h	23-May	23-May
	37 °C directly to 44 °C for 4h	23-May	23-May
	37 °C + 1 h room temp to 44 °C for 2h	22-May	22-May
	37 °C + 1 h room temp to 44 °C for 4h	22-May	22-May

- Planted in AAFC research plots in Jordan, Ontario
- Randomized complete block design with 4 replications, 12 plants per plot

4) Cultivar steam treatment: plant survival

6 June (2 weeks-after-planting)

29 plants were not categorized



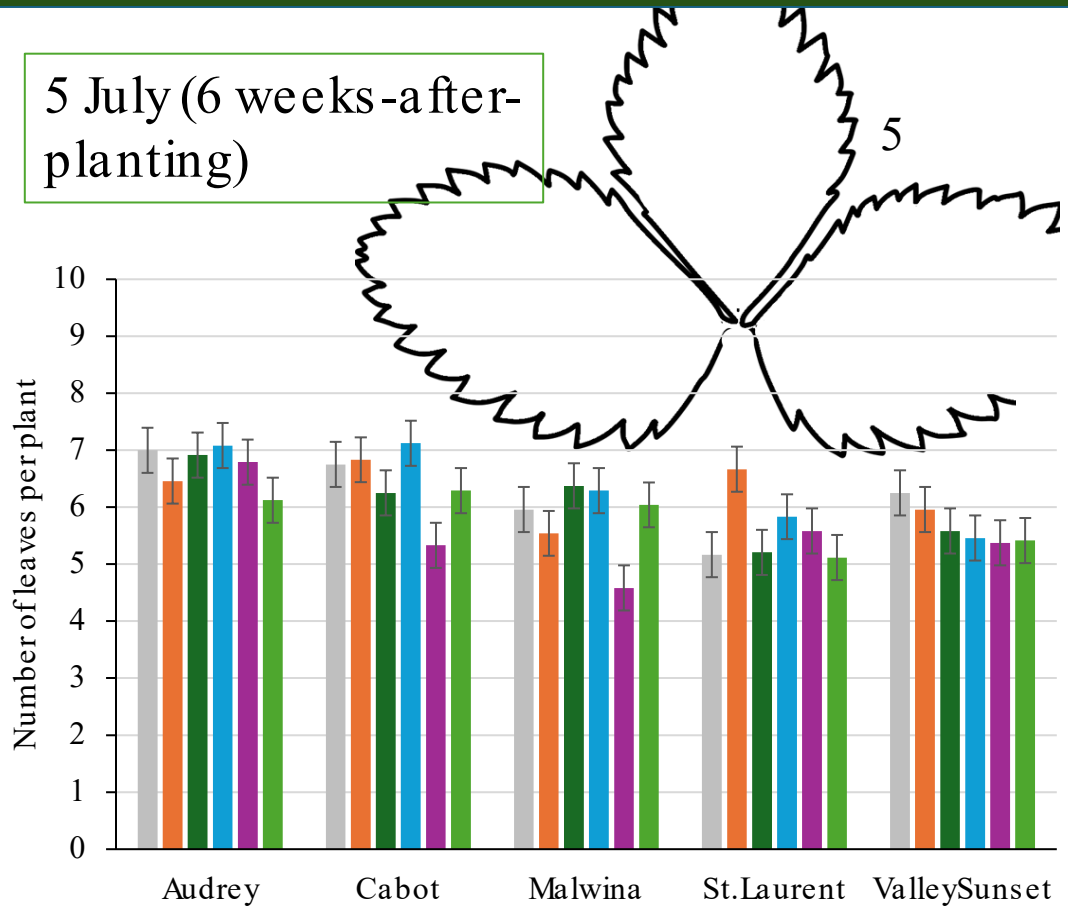
Cultivar*steam treatment P = 0.024

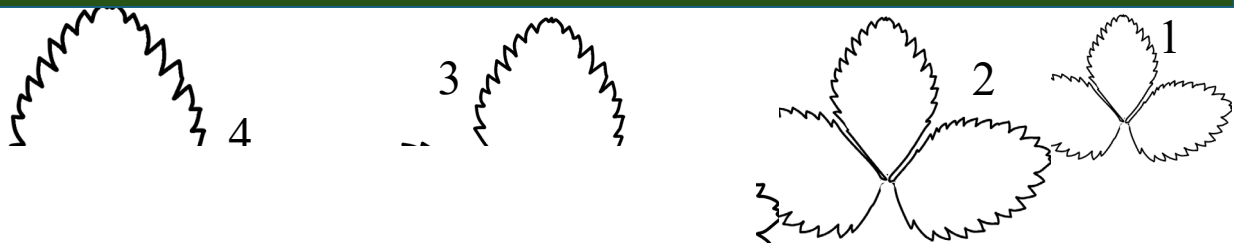
A 1 h rest period before 44 °C for 4 h improves plant survival for Cabot, St. Laurent, Malwina

A 1 h rest period before 44 °C for 2 h does not improve plant survival

4) Cultivar steam treatment: plant growth

5 July (6 weeks-after-planting)





Control
37 C
37 °C directly to 44 °C 2h
37 °C + 1h room temp. to 44 °C 2h
37 °C directly to 44 °C 4h
37 °C + 1h room temp. to 44 °C 4h

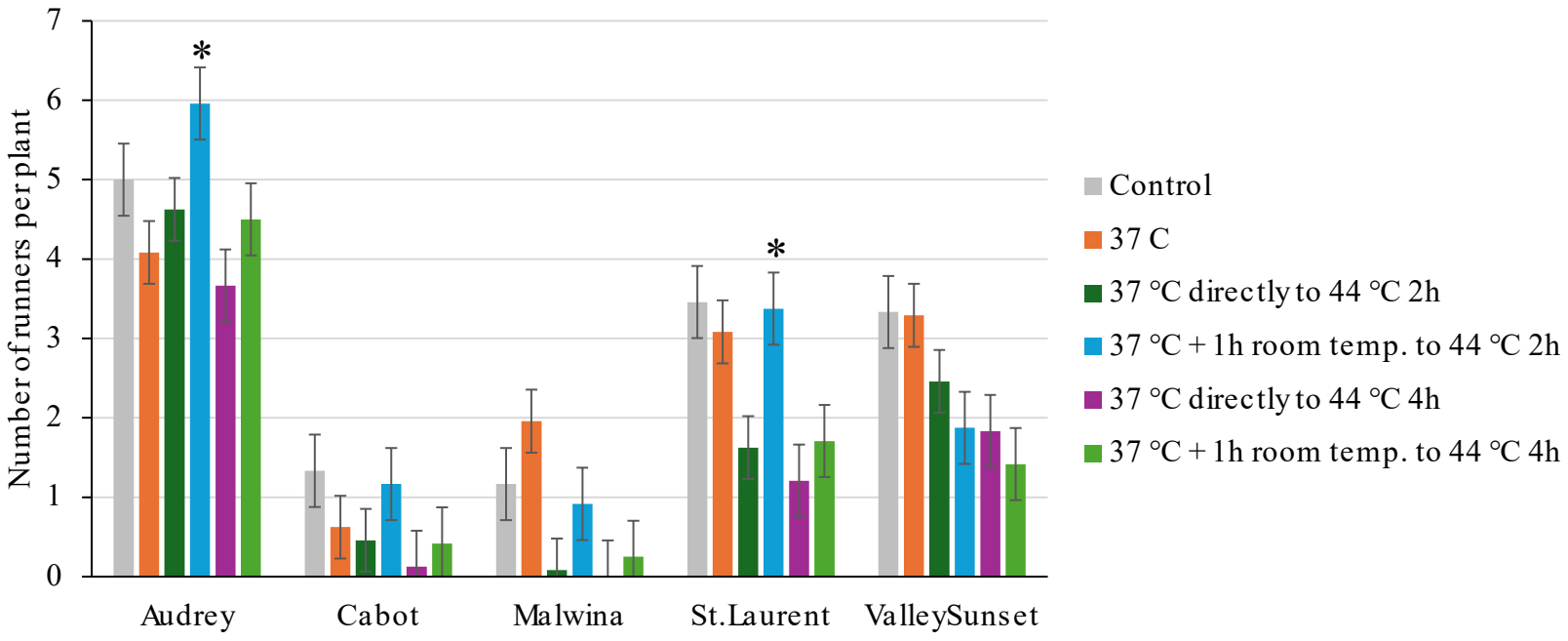
Cultivar P < 0.0001
Steam treatment P = 0.008
Cultivar*steam treatment P = 0.087

No rest period before 44 °C for 4 h reduces leaf growth compared to controls

A 1 h rest period before 44 °C for 2 h or 4h results in increased leaf size compared to no rest period

4) Cultivar steam treatment: runners

26 July (9 weeks-after-planting)



Cultivar $P < 0.0001$
Steam treatment $P < 0.0001$
Cultivar*steam treatment $P = 0.015$

A 1 h rest period before 44 °C for 2 h resulted in more runners in Audrey and St. Laurent than no rest period

Conclusions – bareroot, short-day transplants

- 44 °C for 1h, 2h, 4h eliminates almost all cyclamen mite
  - Should reach or slightly exceed 44 °C on average
- Small crowns tolerate direct to 44 °C for 1h
- Cultivars tolerate direct to 44 °C for 2h
  - Minor negative effects on a few cultivars
- Most cultivars benefit from a 1h rest period before 44 °C for 4h

Steam treatment effects on other strawberry plant-types

1. Spring-planted, day-neutral 'Albion' plug plants, on-farm, Niagara region ON, 2023

2. Short-day 'Yambu' trayplants (250 cc) for table-top, runner-production at Ferme Onesime Pouliot, Île d'Orléans QC, 2023

3. Spring planted, bare-root 'Albion' in trays (March in hoophouse moved to field in May) for runner production at Fenwick Berry Farms, Niagara ON, 2024

   - No negative effects of 44 °C for 2h or 4h on plant survival or growth. More but smaller tips from plants treated for 4 h compared to control

4. 'Albion' tips before pinning in July, Tigchelaar Berry Farms, Niagara region ON, 2024

   - No negative effects of 44 °C for 4h on tip survival or plant growth

5. 'Albion' plugs (124 cc) at 44 for 4h in early September for Neopestilotiopsis spp. control at AAFC research plots, Niagara region ON, 2024

   - 80-90% of the steam-treated plugs did not survive

Steam treatment effects on ‘Albion’ plugs

Day-neutral ‘Albion’ plugs (135 cc) at Tigchelaar Berry Farms in Jordan Station, ON

Cold stored (-1.8 °C) from Oct. 28, 2022

Thawed at 12 °C on May 9, 2023

Steam treated at 44 °C for 4 h and planted on May 10, 2023

No cyclamen mite added to plants prior to steam treatment

Plot = ~30 plants (4 rows, 16” spacing)

4 replications

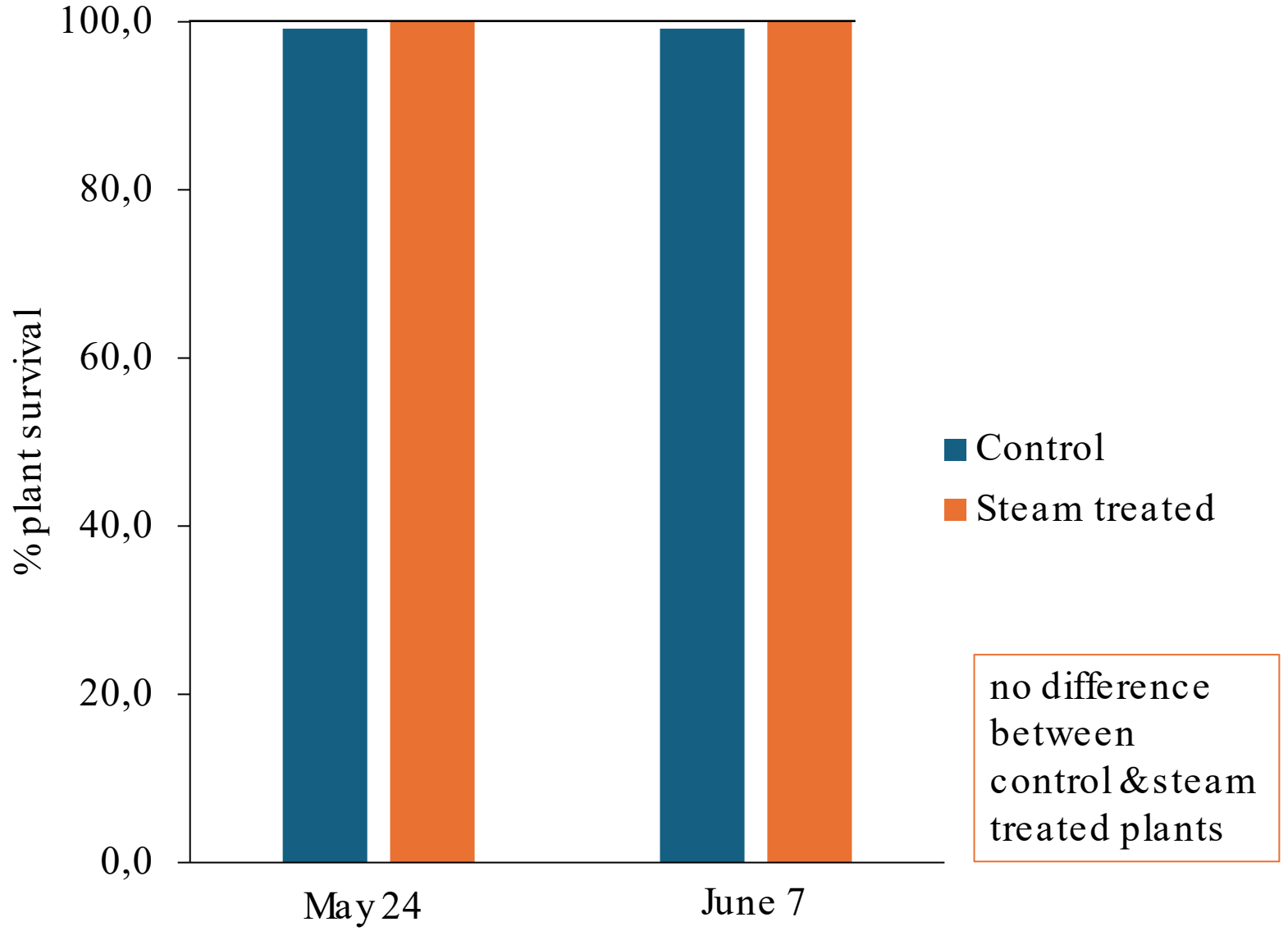
Steam treated

May 24

Control

Plant survival

Assessed all plants in each plot

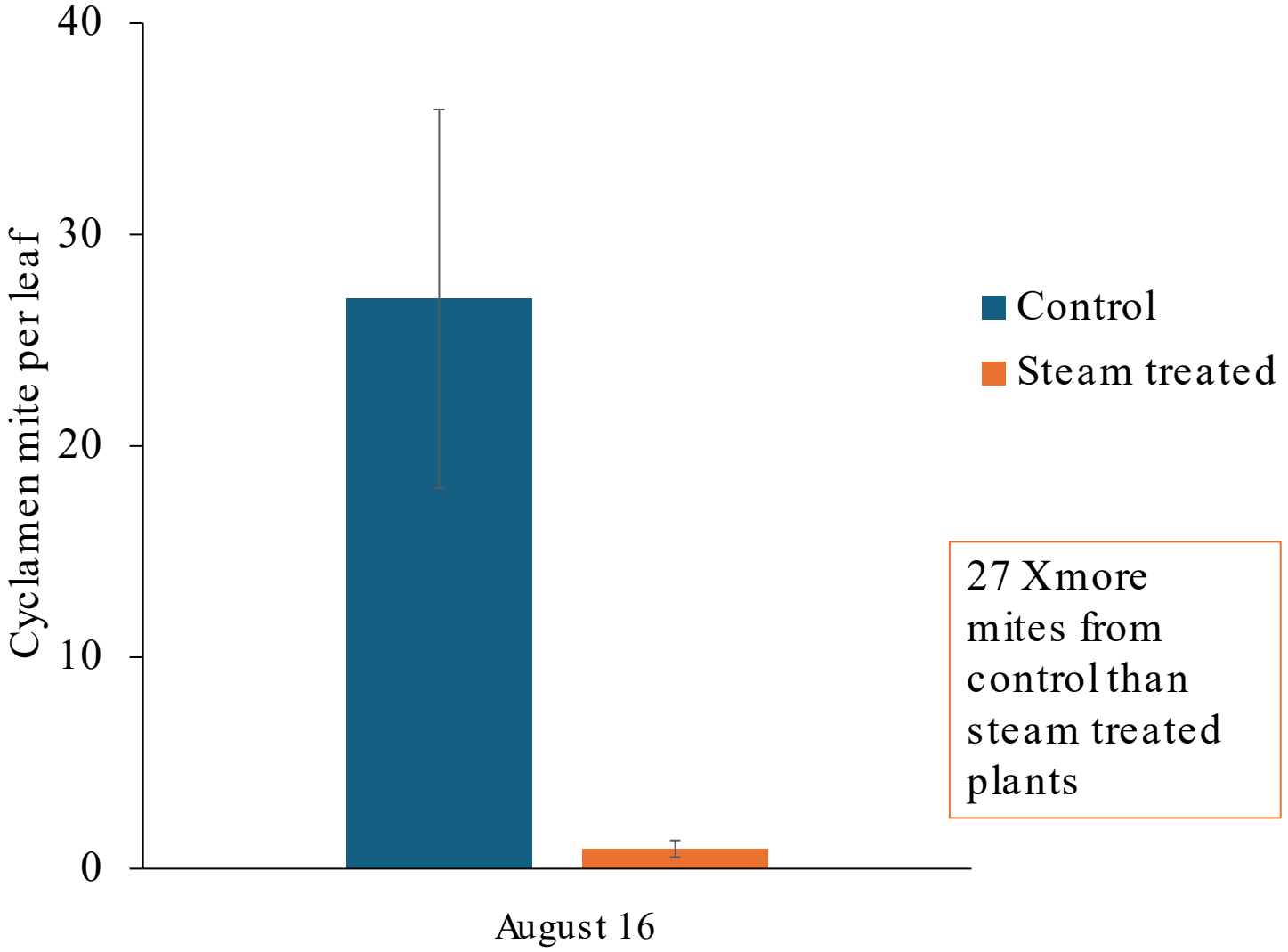


Cyclamen mite per leaf

Sampled 1 newest leaf from 8 plants per plot

Soaked, triple-rinsed and washed samples

Counted cyclamen mite at 20X magnification

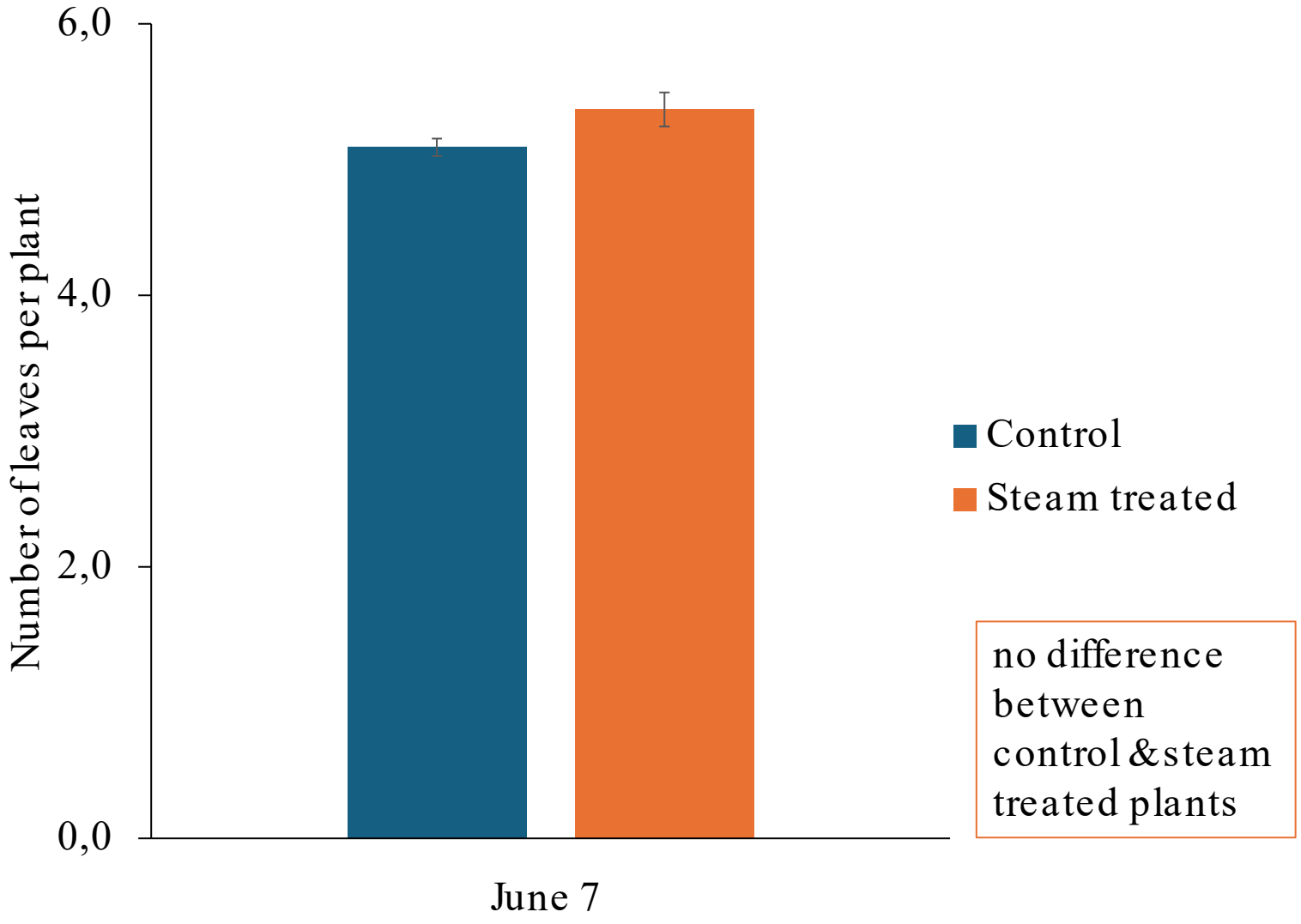


t = 2.9; df = 6; P = 0.027

Plant growth

-leaves per plant

Counted all fully-expanded green leaves on all plants in each plot



t = 2.0; df = 6; P = 0.095

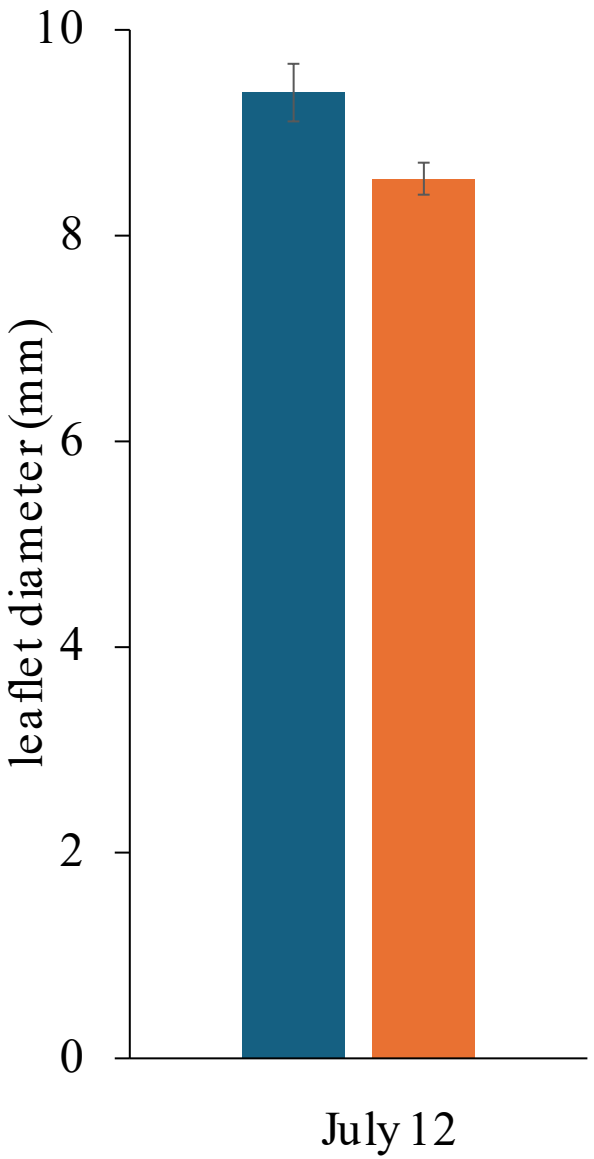
Plant growth

-leaf size

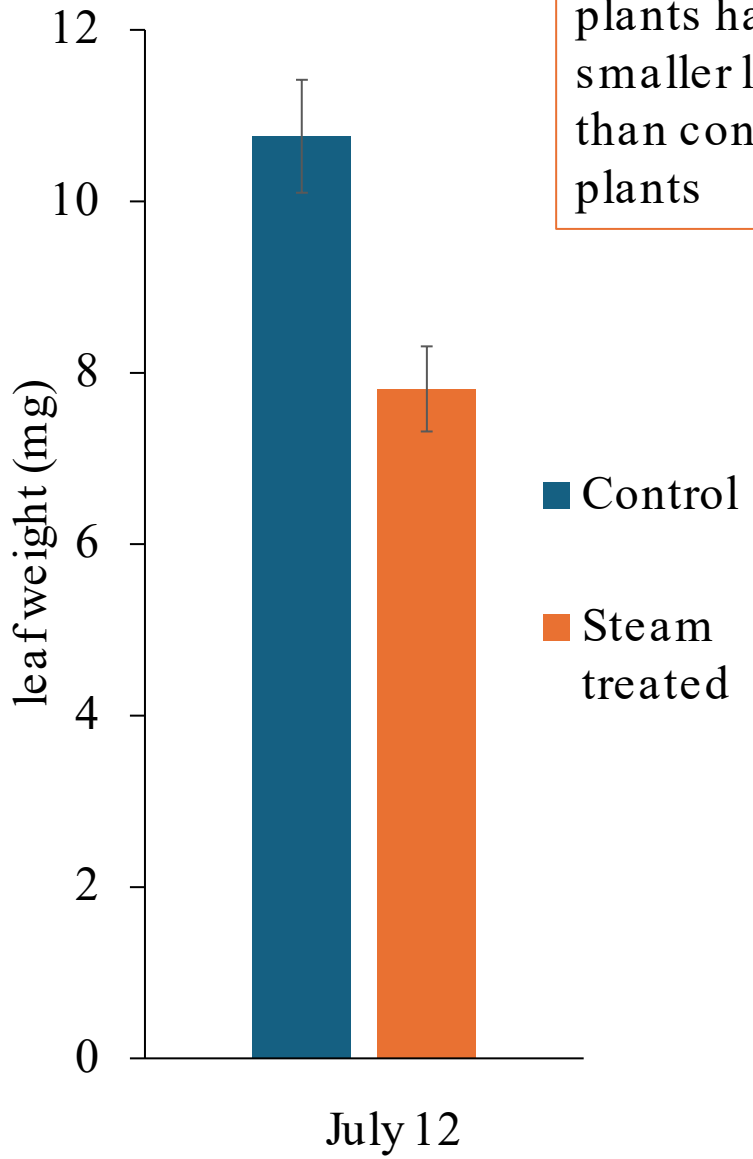
Sampled 2 new leaves per plant from 4 plants per plot

Measured diameter of each middle leaflet

Dried (60 °C for 48 h) & weighed all leaves



t = 2.6; df = 6; P = 0.04



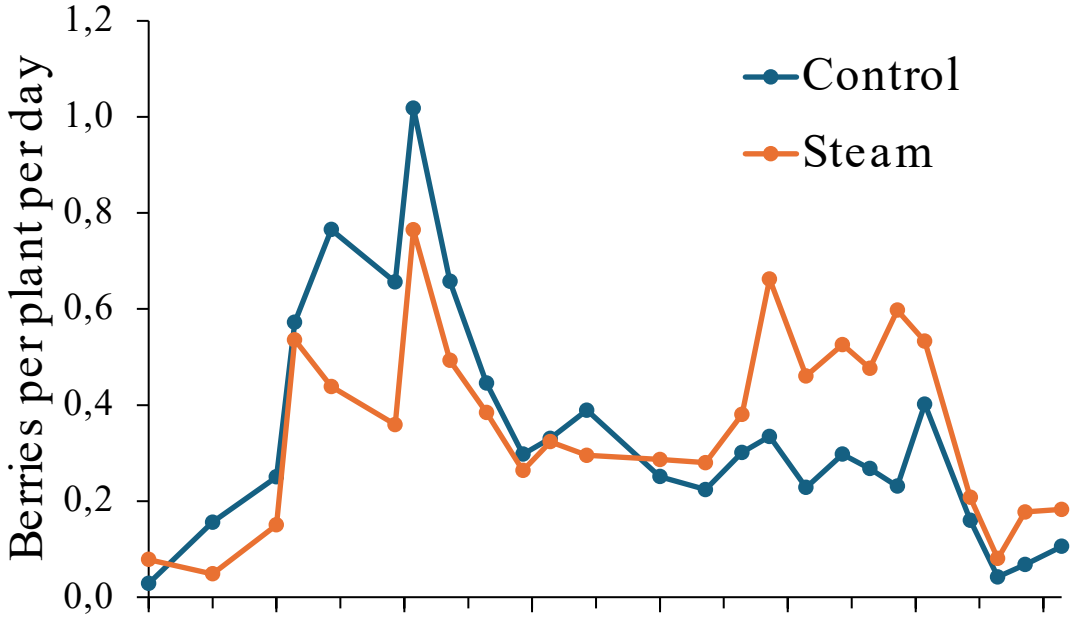
t = 3.6; df = 6; P = 0.011

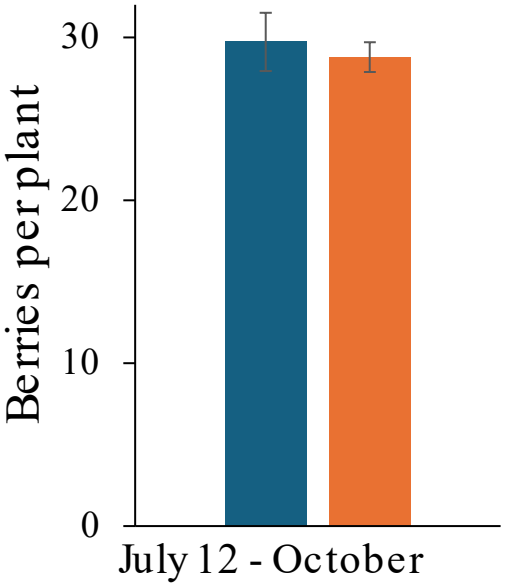
Steam treated plants had smaller leaves than control plants

Yield

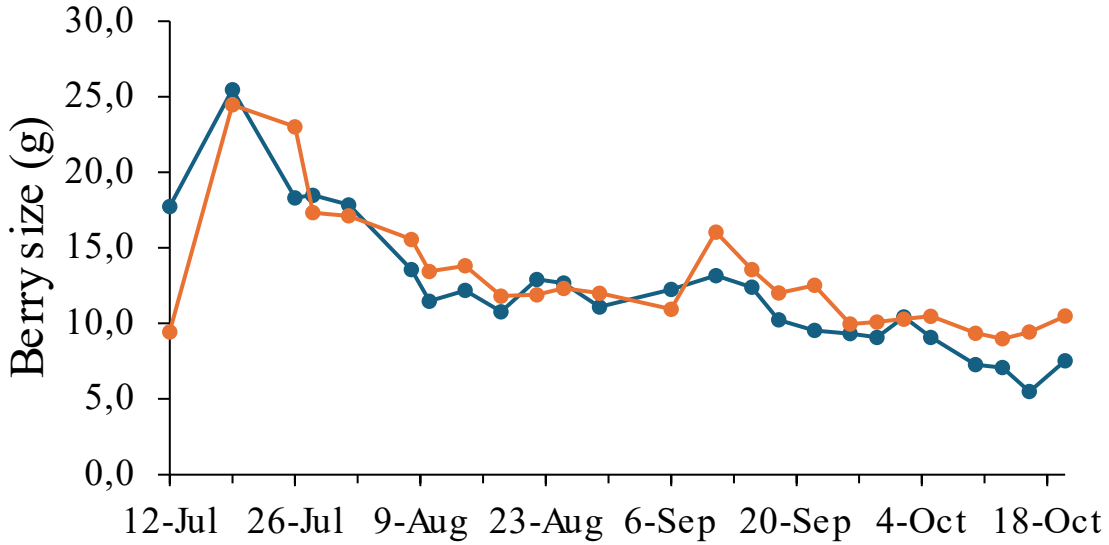
-number & size of strawberries

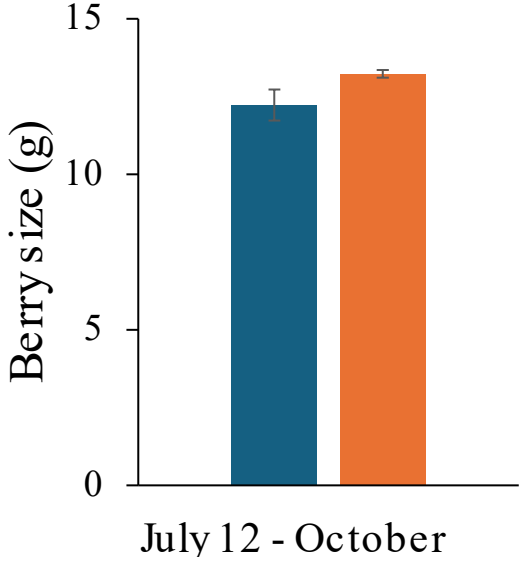
All ripe strawberries per plot picked every 3-5 days, counted and weighed





t = 0.5; df = 6; P = 0.659





t = 1.9; df = 6; P = 0.099

Short-day ‘Yambu’ trayplants (250 cc) for table-top, runner-production at Ferme Onesime Pouliot on Île d’Orléans, QC

Plants cold-stored (-1 °C) on Nov 10, 2022

No cyclamen mite added to plants prior to steam treatment

May 28:

Pre-treated 37 °C for 1h

Ambient temperature for 1h

Steam treated at 44 °C for 2h

Planted in coconut coir substrate

Plot = 1m trough = 12 plants

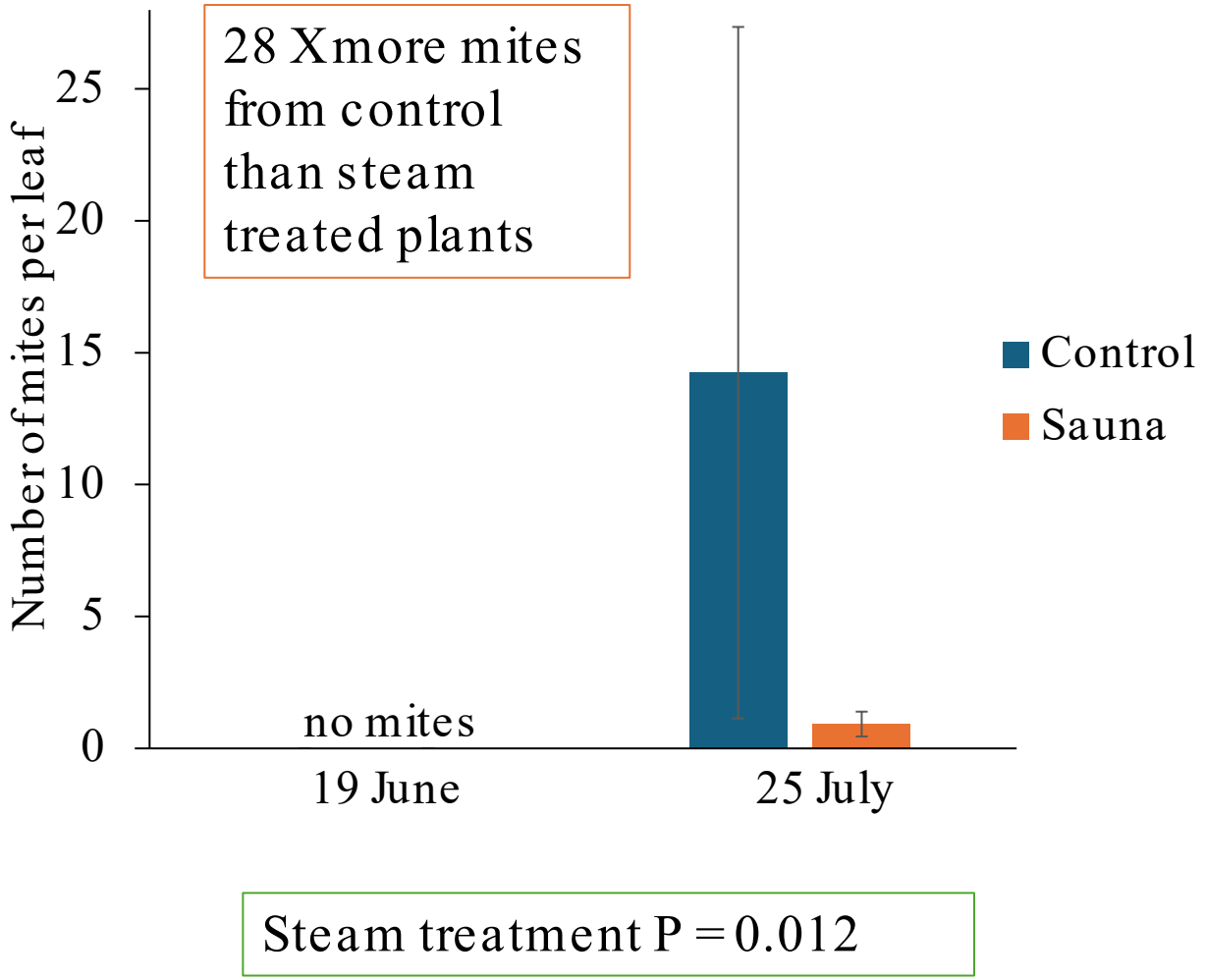
8 replications

May 28

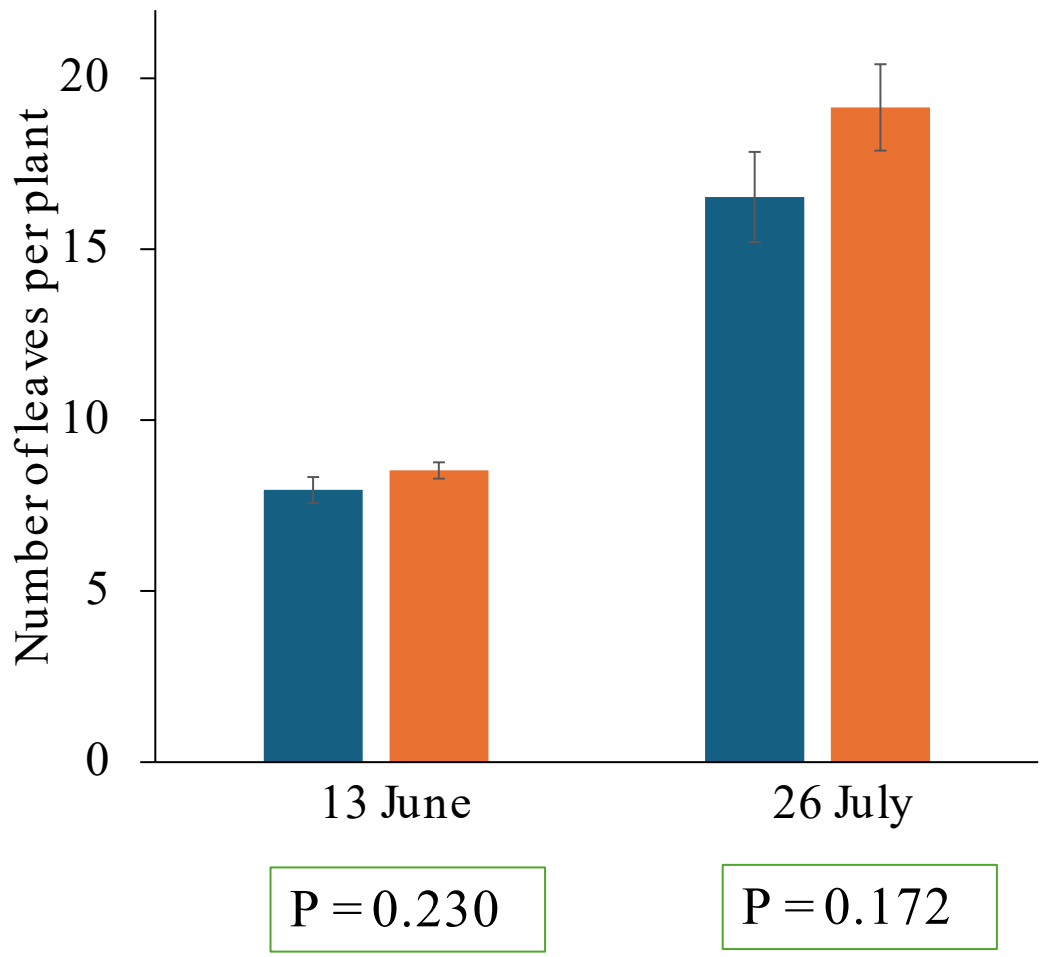
Steam treated

Control

Plant sauna effects on 'Yambu' plugs



Steam treatment P = 0.012



P = 0.230

P = 0.172

Research on cyclamen mite control options

Pre-plant tools

Cyclamen mite can be easily transmitted on planting material

Steam treatment

Biopesticide transplant dips

Cultivar selection

Controlled atmosphere temperature treatments

For propagation material

Post-plant tools

Conventional miticides

Biopesticide foliar sprays

UV-C treatment

Miticides: Magister®SC registered in strawberry in Canada in 2023

- Active ingredient: fenazaquin (Group 21A) 205g/L
- Strawberry: 1 day pre-harvest interval (PHI) and 12 h re-entry interval (REI)
- Do not apply during bloom
- 1 application per year
- 1.75 – 2.34 L/ha in at least 500 L of water/ha
- Tetranychus spp: two-spotted spider mite, McDaniel spider mite, Pacific spider mite
- Is Magister effective against cyclamen mite?

Miticide and biopesticide testing summary

'Jewel' planted May 2019 in small plots. Transplants infested with cyclamen mite
2019 products applied: 28 June &3 July (biopesticides) 28 June (miticides)
2020 products applied: 18 &25 Aug (biopesticides) 19 Aug (miticides)

2019 Product	2019 efficacy rating	2020 yield & damage	2020 Product	2020 efficacy rating	2021 yield & damage
Agri-Mek SC +Agral 90	-	-	Agri-Mek SC +Agral 90	+++	++
Magister SC +Agral 90	++	+	Magister SC +Agral 90	+++	++
Grandevo	-	-	Magister SC + Vegol	+++	++
Venerate/EcoTrol	+	-	Magister SC + Agral 90	+++	++
Bb Protec	-	-	**Botanigard ES**	+	-
EcoTrol	-	-	JMS Stylet Oil	-	-
Vegol*	-	-	Vegol*	-	-
Agral 90 (0.25%)	-	-	Agral 90 (0.25%)	-	-
Water	-	-	Water	-	-

+++ almost no surviving mites/much greater yield ++ effective but some mites surviving/moderately improved yield

+ minor mortality/slightly increased yield - not effective, no mortality, no yield increase *Registered for cyclamen mite in strawberry

Conventional miticides tested

Product	Active ingredient	IRAC Group	Registered in strawberry (CA)	Pests	PHI	Max. Apps/Year
Agri-Mek SC	abamectin	6	Yes	Spider mite, cyclamen mite	3 days	2
Magister SC	fenazaquin	21A	Yes (Jan 2023)	Spider mite	1 day	1
Nexter SC	pyridaben	21A	Yes	Spider mite	10 days	2
Pylon	chlorfenapyr	13	No (GH ornamentals, fruiting veg)	Spider mite, cyclamen mite	0 days (fruiting veg)	1
Oberon	spiromesifen	23	Yes	Spider mite	3 days	3

Two greenhouse experiments with potted plants – winter 2021 and 2022

One field experiment in research plots – August 2022 to June 2023

Miticides in the greenhouse – winter 2021 and 2022

Products applied (2 mL per plant) at label rates to the crowns and new leaves

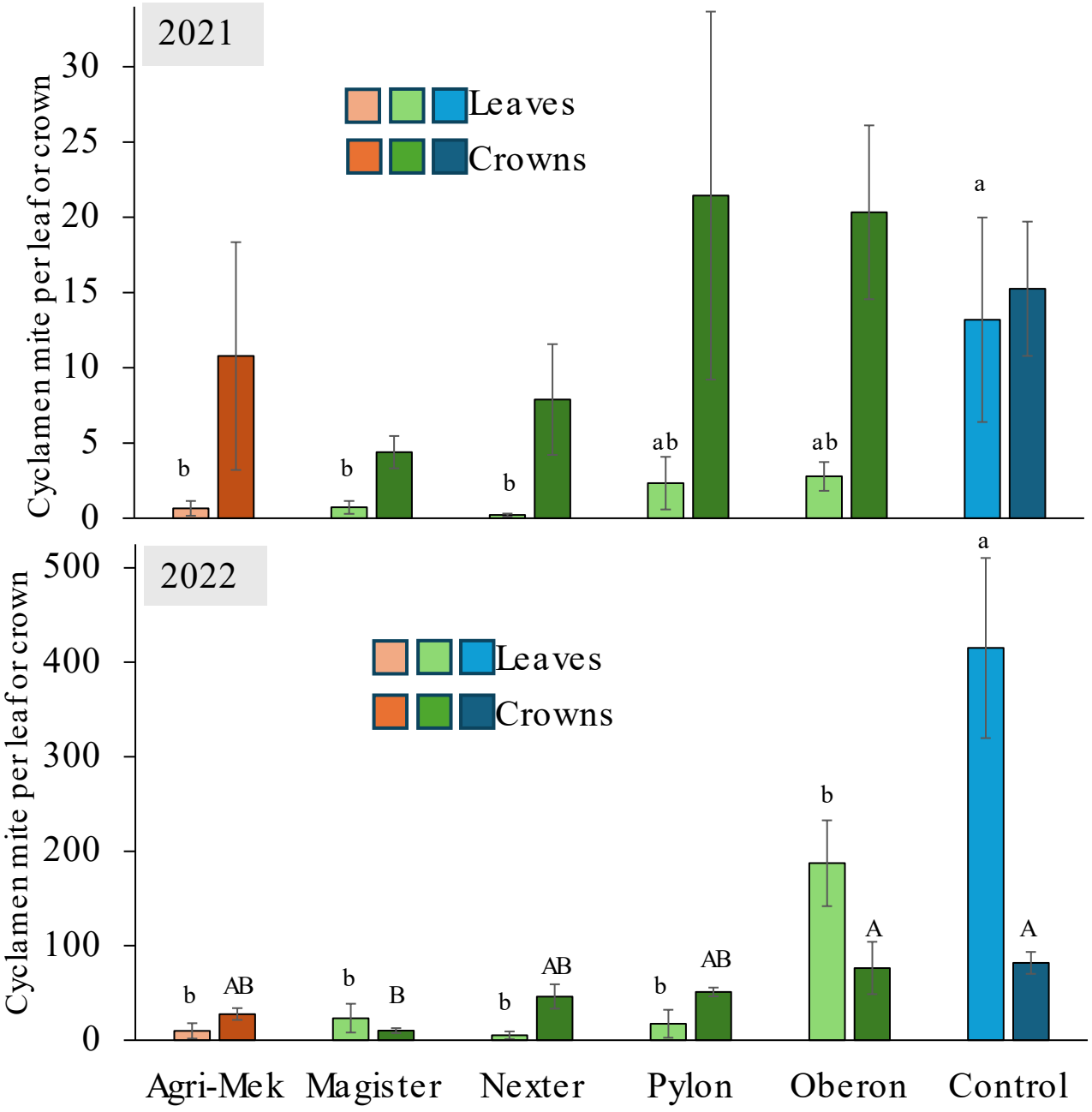
Single or double crown 'Brilliance' 2021

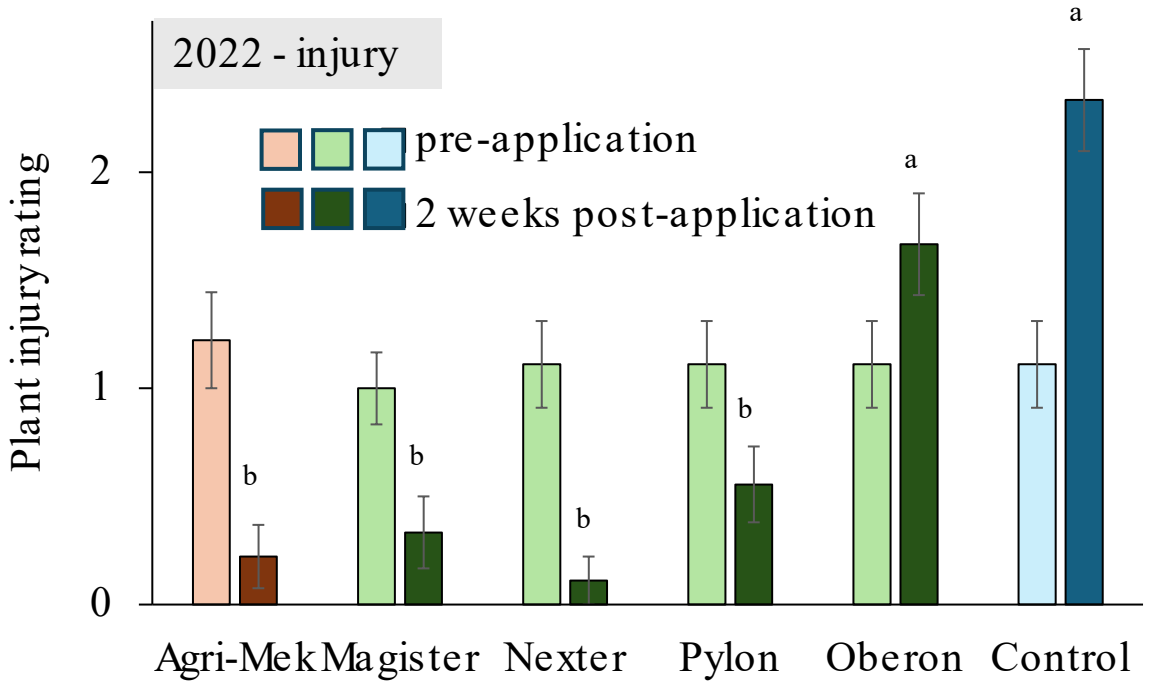
Single or double crown 'Jewel' 2022

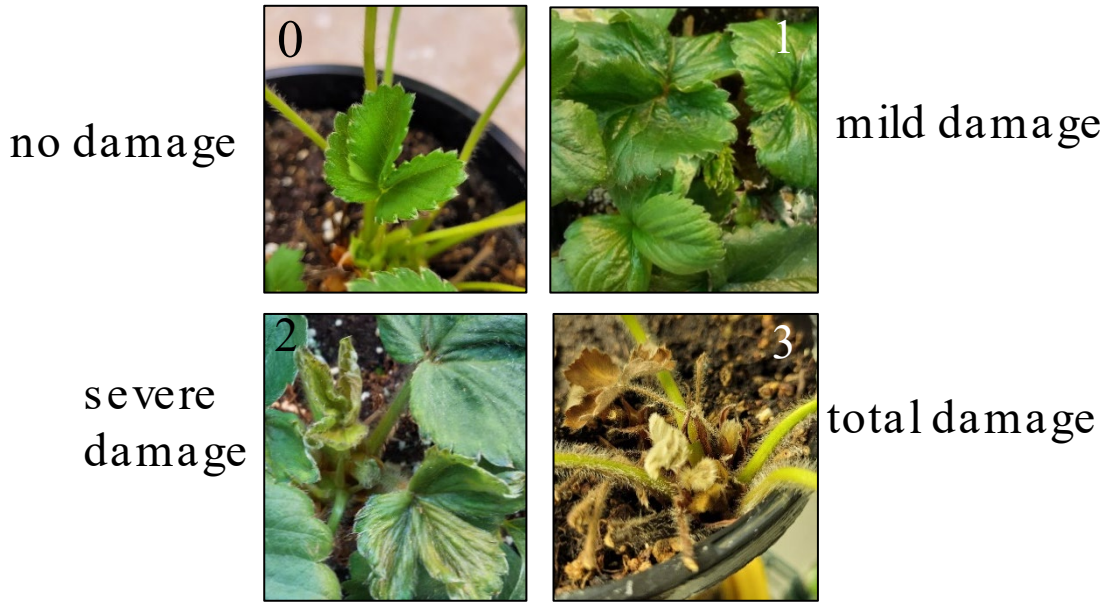
1. Infested plants with cyclamen mite from lab colony
2. Waited 3 weeks 2021, 4 weeks 2022
3. Rated plant injury (2022 only)
4. Applied miticides
   Mar 10, 2021 & Mar 4, 2022
5. Destructively sampled plants 2 weeks after application
   New leaves and crowns separately
6. Counted mites in ethanol

Micro-applicator (air brush)

Miticides in the greenhouse – 2 weeks post-application







Miticides in the field - 2022

Plots (12 'Jewel') planted in spring 2021 (for biopesticide transplant dip experiment)

Plots mowed 25 July 2022

Plots sprayed 2 August 2022

Backpack CO_2 sprayer with hand-held, double-nozzle wand

Miticides at label rates at 2L per plot (~1000L/ha = 107 gal/A)

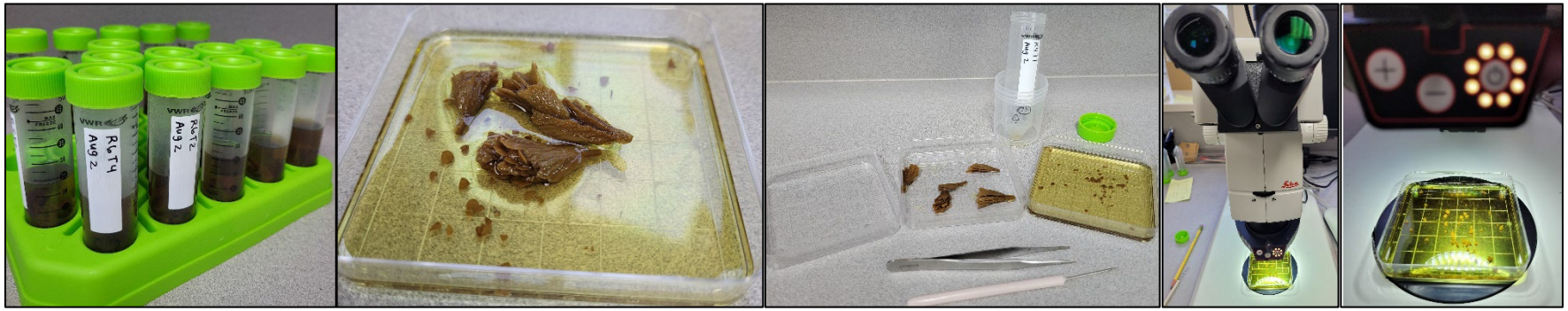
Five leaves per plot collected

2 August (pre-spray)

16 August (2 weeks post-spray)

13 September (6 weeks post-spray)

8 June 2023

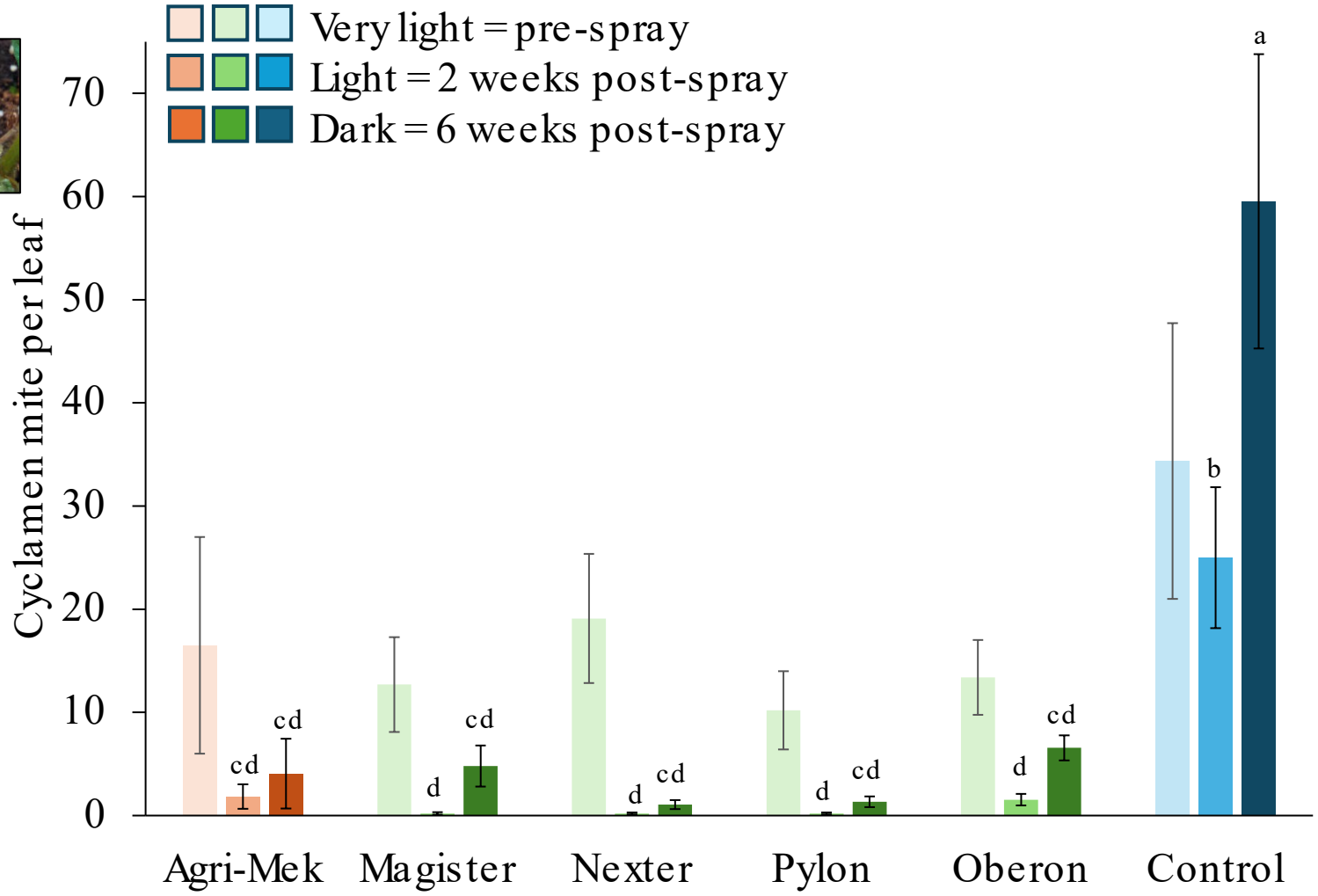


Plots harvested 14 June – 4 July 2023

Strawberries weighed, graded and counted

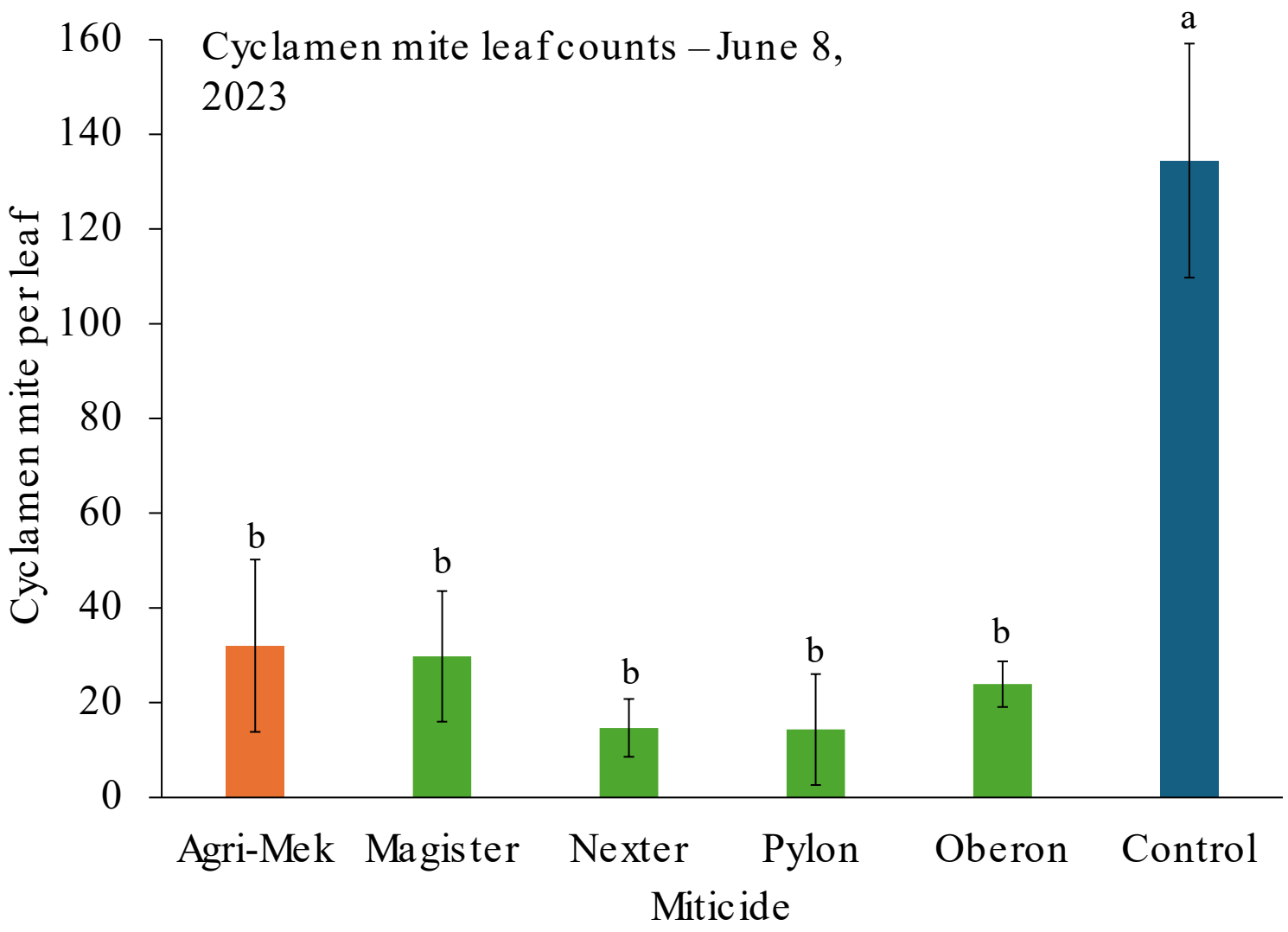
Miticides in the field - 2022

Cyclamen mite leaf counts



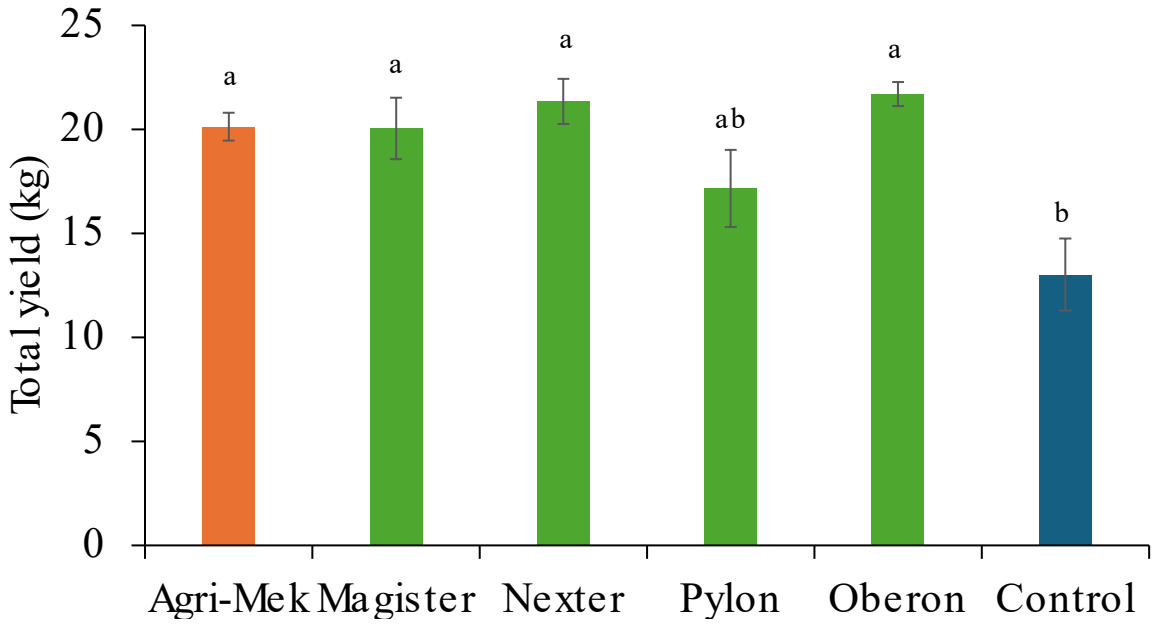
- All products resulted in low cyclamen mite numbers compared to the control
- Oberon resulted in better control compared to GH
  - Rainfall?
  - Aug 3-9: 21.2mm
- Pylon provided excellent control
  - Only registered in GH crops
  - Toxic to pollinators
- Nexter resulted in the fewest mites
- Magister = Agri-Mek

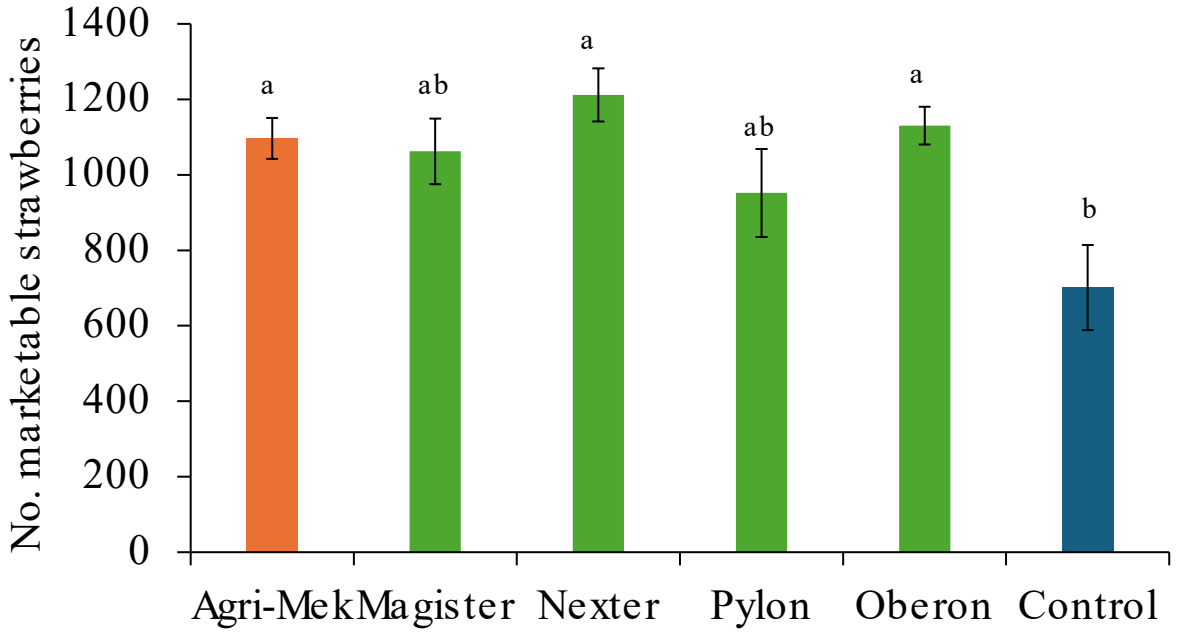
Miticides in the field – 2023

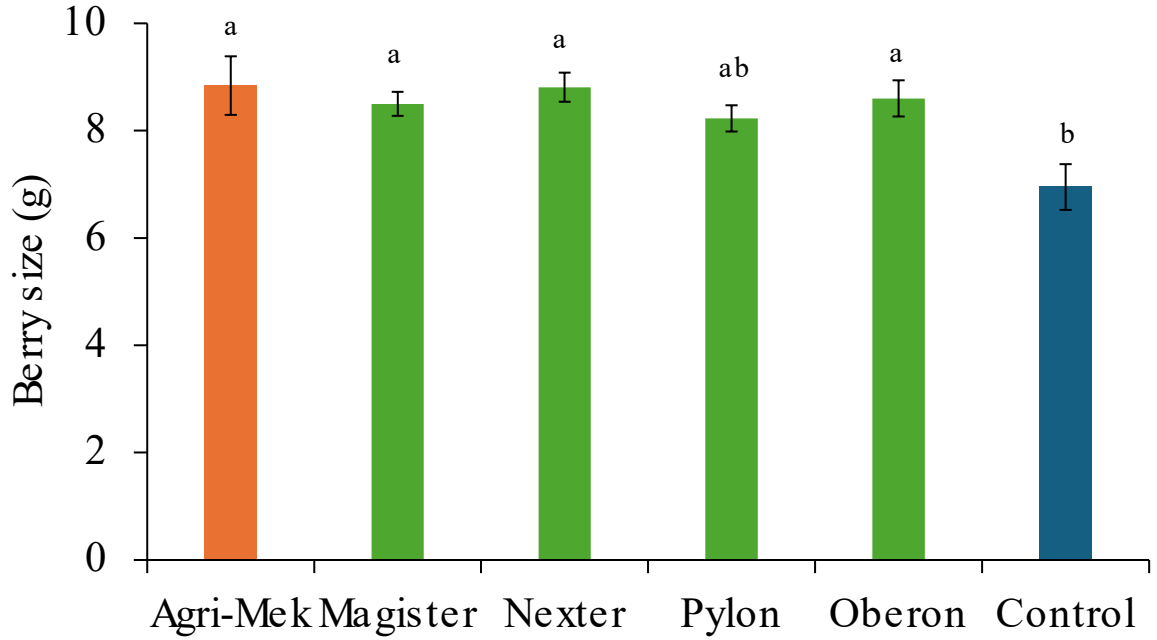


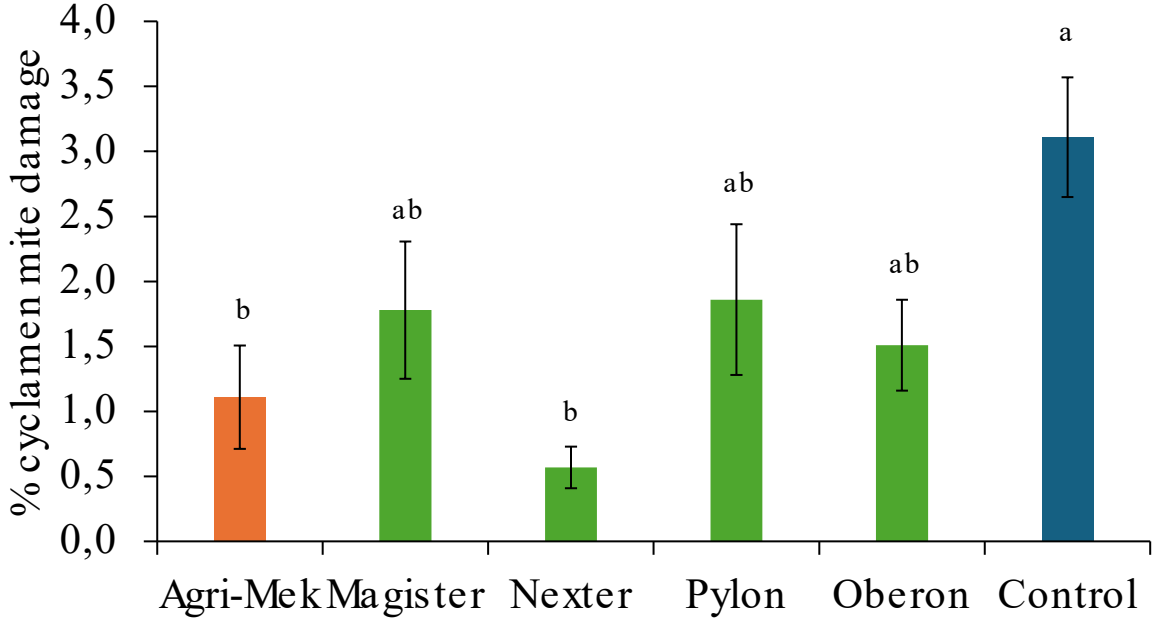
- All products had fewer cyclamen mite compared to the control
- 15-30 mites per leaf is above nominal threshold values

Miticides in the field – 2023 Yield (June 14 – July 4)

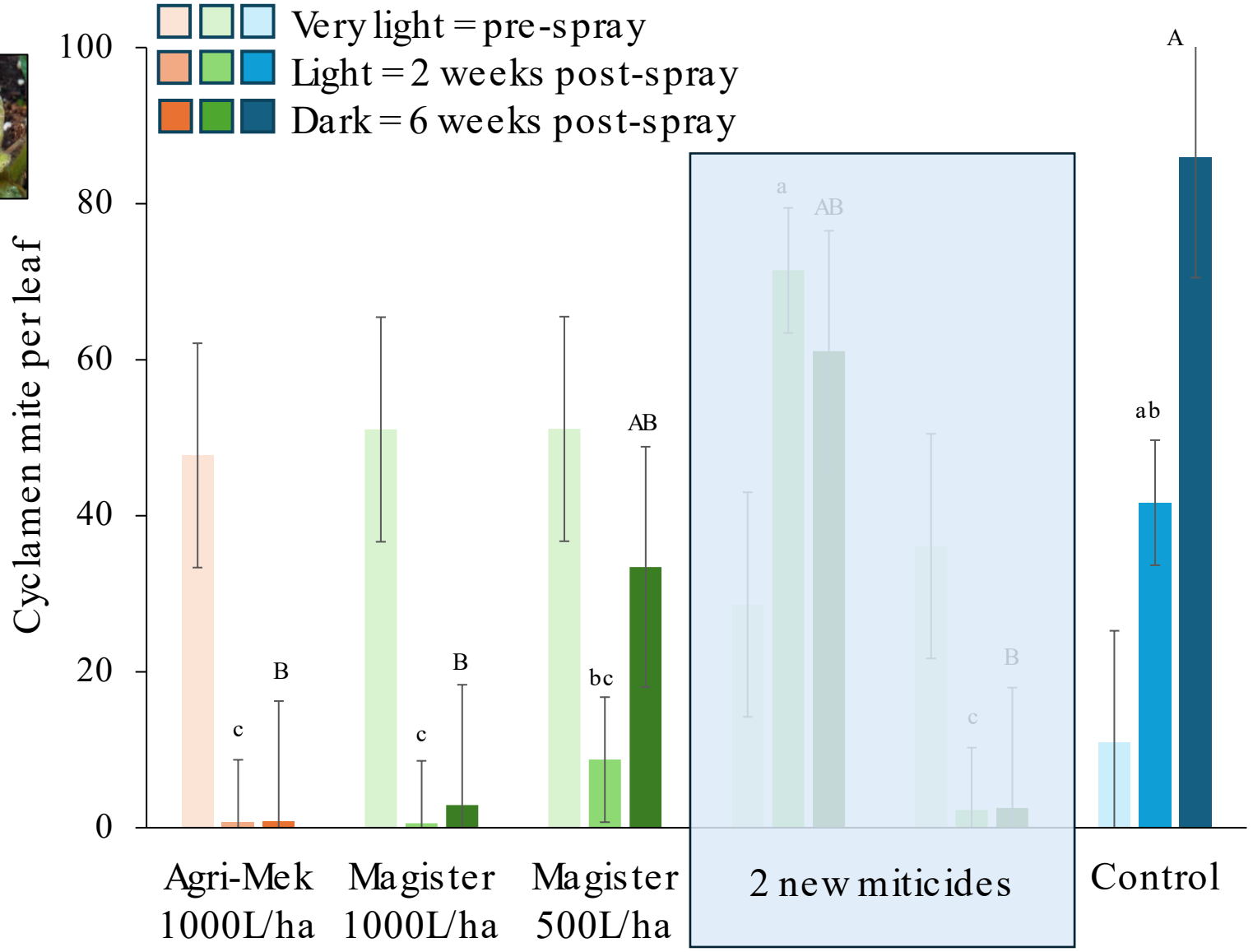








Miticides in the field – spray volume & Magister



- Magister = Agri-Mek applied at 1000 L/ha
- Magister applied at 500 L/ha was not as effective
  - Magister is not reaching mites in the crowns
- Apply Magister twice at 500 L/ha?
- Apply Magister at an intermediate water volume? 750 L/ha?
- Effects at lower cyclamen mite numbers?
  - 40-50 mites per leaf is high

Active ingredient	Product name(s)	IRAC Group	Zalom et al. 2009	Fountain et al. 2010		Labanowska 2006		Labanowska et al. 2015
			Lab	Season 1	Season 2	Season 1	Season 2	Multiple seasons
pyridaben	Sanmite, (Nexter)	21A						+++
spiromesifen	Oberon	23	++	-				
fenpyroximate	Fujimite, Sequel, (Portal)	21A	+++	+	++			
bifenazate	Floramite, Acramite	20D	+	-	-	+/+	+/+	
tebufenpyrad	Masai	21A		+/++	++/+++			
acequinocyl	Kanemite	20B	++	+				
etoxazole	Zeal, Borneo	10B	+		+++			
spirotetramat	Movento	23						++
propargite	Omite	12C				+++	++	
amitraz	Mitac	19				++	++	
spiridoclofen	Envidor	23				++	+/+	
milbemectin	Mesa	6	++++					

++++ highly effective, almost no surviving mites +++ effective but some mites surviving ++ some mite mortality (~50%)

+ minor amount of mortality - not effective, no mortality bold = with surfactant

Cyclamen mite management conclusions

Pre-plant tools

Cyclamen mite can be easily transmitted on planting material

Steam treatment

- Highly effective against cyclamen mite
- 44 °C
  - 1 or 2h if the main target is cyclamen mite
  - 4 h with a 1h rest period for disease control

Post-plant tools

Conventional miticides

- Agri-Mek, Magister, Nexter, Oberon
  - Label expansion for Magister to include cyclamen mite

- Apply ~1 week after mowing in matted-row strawberry
- Use at least 500 L/ha
- Use a non-ionic surfactant

Cyclamen mite management: new project

Sustainable Canadian Agricultural Partnership

Competitive. Innovative. Resilient.

AgriScience Projects

Title 'Developing pest management strategies for field, greenhouse, and vertically farmed strawberries'

Ontario Berries

Years 2024-2028

Lead Applicant Berry Growers of Ontario (Victoria Buma)

Contributors L'APFFQ, Koppert Canada, Sollum Tech.

Project leads Justin Renkema, Rose Labbe (AAFC Harrow)

Collaborators Valérie Fournier, Martine Dorais (U Laval), Stéphanie Tellier (MAPAQ), Erica Pate, Cara McCreary (OMAFA)

Partners Tigchelaar Berry Farms (Niagara, ON), Ferme Onesime Pouliot (L'Île d'Orléans QC), Ferme d'Hiver (Vaudreil-Dorion QC)

Objectives for cyclamen mite:

1. Continue optimizing steam treatment protocols
   - On-farm demonstration trials

2. Continue optimizing miticide application strategies
   - On-farm demonstration trials

3. Develop sampling strategies for molecular detection

4. Determine an integrated approach
   - Steam treatment + biological control +/- miticides

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Erica Pate – U of Guelph

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Valérie Fournier – U Laval
Erica Pate – OMAFRA
Stephanie Tellier – MAPAQ

Co-operators

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