Impact and Management of Thrips in Alaska Peony Production
Final Report

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Summary

The objectives of this project were to document the biology and the impact of thrips on peonies in Alaska and to determine if management systems such as cut flower fumigation would be necessary for quality fresh cut flowers especially for foreign markets. We monitored thrips populations at the UAF Georgeson Botanical Garden, Fairbanks and on two grower farms, one in Willow, and a second in Kenai, Alaska. Additionally, we collected flowers at all stages of flower opening to identify when thrips enter the flowers, their location in the buds, which cultivars are most attractive to the thrips, and to make recommendations on management.

Thrips infest peony buds (lay eggs on the surface of flowers) as early as stage 1 when there is no petal color showing and the buds are green and totally enclosed in the calyx and bracts. The initial settling preference of thrips is independent of flower color or the presence of pollen. Thrips primarily overwinter at the edges of fields with smaller numbers overwintering within the fields. Aerial sticky traps indicate two and a partial generations per season in the Kenai and one and a partial generations in Fairbanks. Four to five different species of thrips were identified, including western flower thrips. Monitoring with yellow sticky cards by growers should begin in late April and continue through bloom time. Use overturned traps to identify "hot spots" for emergence. Possible management systems including insecticides and biocontrols are discussed. Thrips definitely are present at the cutting stage on all colors of flowers. Fumigation may be required depending on the buyers. Finally, we conducted an extensive literature review of thrips biology and management for use by growers and to support future research.

Activities Performed

Thrips Biology

Thrips* belong to the family Thysanoptera. Thrips hatch from an egg and develop through two actively feeding larval stages and two non-feeding stages (prepupa and pupa). In any one growing season, a thrips can complete a full or partial life cycle.

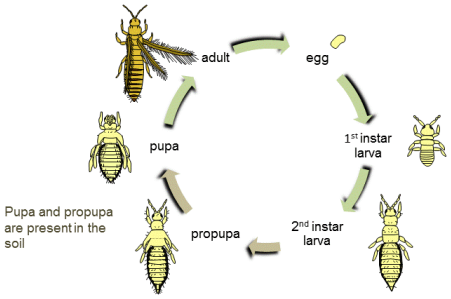

Fig 1. Thrips life cycle. (agric.wa.gov.au)

* The term, "thrips" is correct for both singular and plural. Thrip is an incorrect term.

Eggs are whitish and kidney shaped, and pest thrips insert them into plant tissue (Fig. 2), so they are very difficult to locate. In peonies they can be found at the base of the inner side of the petal where the tissue is thicker. They may also be found in green peony tissue since immatures were observed between bracts and sepals, before buds begin to open. Eggs hatch to an active feeding stage, a larva (Fig. 2), which molts into a second larval feeding stage. They may drop to the soil to pass through 2 non-feeding pupal stages: the propupa (Fig. 4) and pupa (Fig. 5), or pass through their entire life cycle in peony blooms before molting into adults.

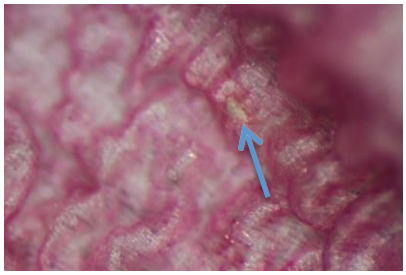

Fig 2. Thrips egg inserted into peony petal.

Adults have fringed wings but are weak fliers (Fig. 7). They can also be carried by wind or storm fronts. Adults cause damage by piercing plant tissue and sucking juices using a needle-like mandible. Thrips also transmit viruses to peonies.

Fig. 3. There are two larval thrips stages. They both are minute and actively feed.

Fig. 4. The propupa has antennae that protrude forward and undeveloped wings.

Fig. 5. Thrips pupa stage has antenna swept backwards with undeveloped wings.

Fig. 6. Adult thrips with fringed wings visible.

Peony morphology and thrips

In stage 1, the peony bud is very firm and the petals are tightly overlapping (Fig. 7). Although minute and flat, even thrips cannot penetrate a stage 1 bud. However, they can lay eggs on the outside of the bud in protected locations and the immature thrips will enter the bloom as the bud opens. Petals of *cabbage-head* peonies do not overlap in the center of the top of the bloom, which might allow earlier entry into these buds, but further observations are needed for verification.

Fig 7. Stage one tightly closed bud.

Goal 1. Monitoring thrips populations at 3 locations

Performance measures: **Emergence traps and aerial sticky cards**

Aerial sticky cards were placed in peony fields; interior Alaska– UAF Georgeson Botanical Garden (64.8589^0 N, 147.8356^0 W); South central – Giggly Roots Farm, Willow and Kenai Peninsula – Echo Lake Farm, Soldotna (60.4867^0 N, 6151.0753^0 W) on 17 and 18 May, 2015. Growers were provided instructions on maintenance of traps and return of cards. With sticky cards, we monitored thrips movement for 2 months, between 29 May and 24 July at the Georgeson Botanical Garden and 18 May to 31 July at Echo Lake Farm. Sticky cards at Giggly Roots Farm were reported lost in a windstorm.

Georgeson Botanical Garden

Emergence traps

Thrips movement and cultivar preference was studied at the Georgeson Botanical Garden in Fairbanks, AK, between 29 May and 24 July using aerial sticky cards, and two types of emergence traps. The purpose of traps was to pinpoint exact time of thrips emergence in the Fairbanks peony-growing region and to determine if thrips primarily overwinter inside or outside of peony fields.

Two types of emergence traps were used: 1) **closed boxes, 22 May** - soil samples were collected from various weedy borders and from inside the peony field and placed into individual plastic shoeboxes (Fig 8). Yellow sticky cards were affixed to the inside of the plastic lids and boxes placed in a protected area out of the sun. 2) **Overturned traps, 26 May** - overturned plastic shoeboxes were positioned in weedy borders and inside the peony field with sticky cards attached to the inside of the box tops.

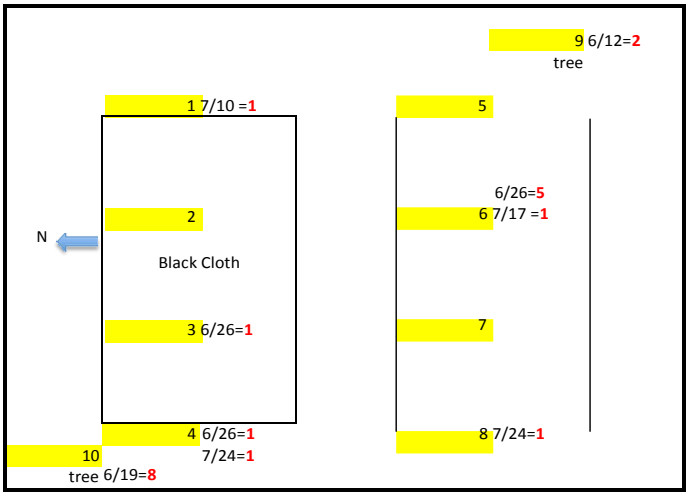

Fig. 8. Georgeson emergence trap locations closed boxes and overturned traps 5/24 – 7/24.

Closed box soil samples captured a single thrips the week of June 19. **Overturned boxes** captured seven thrips from boxes positioned inside the field and of those, only 1 came from the field with weed-barrier cloth. Four thrips emerged on the western border of the field and 10 thrips emerged from 2 overturned boxes positioned near two separate trees on the eastern and western sides of the plot (2, 8 respectively). Thrips peaked simultaneously in both the aerial sticky cards and field boxes the week of 19 June (Figs. 9 & 10).

Closed box soil samples were collected from depths of up to 3 inches, which unfortunately was too shallow to reach thrips, which overwinter at depths of 4" to 24" (Franssen & Huisman 1958). Overturned traps consisting of overturned plastic boxes however, successfully measured thrips emergence and are recommended for future studies.

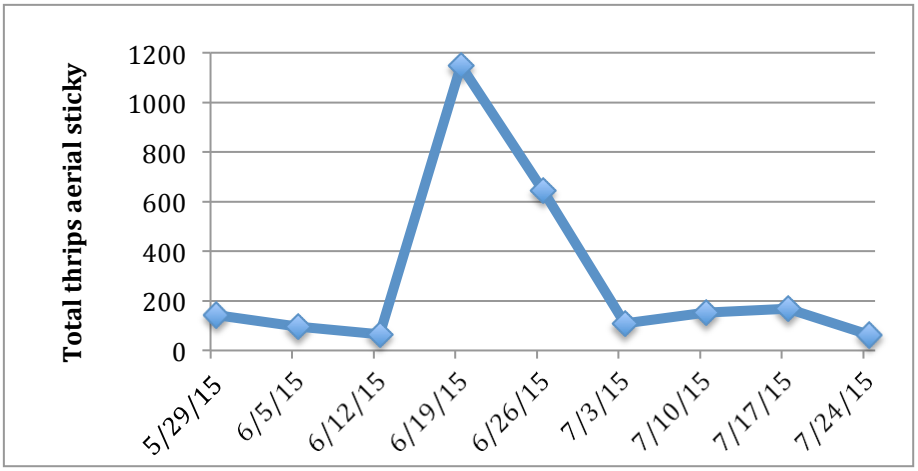

Fig. 9. Thrips flight period indicated by aerial sticky cards at the Georgeson Botanical Garden, UAF, Fairbanks, AK.

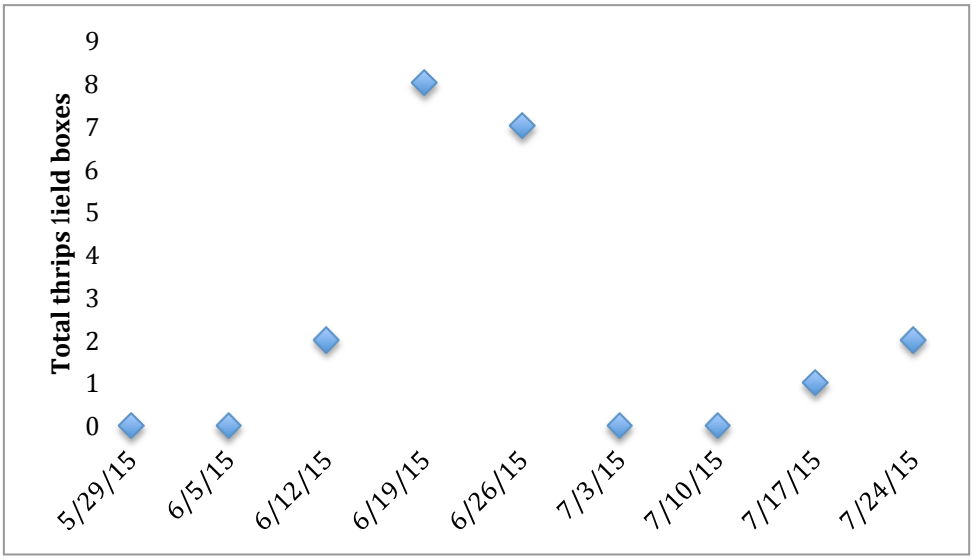

Fig. 10. Field box emergence dates for thrips at the Georgeson Botanical Garden, UAF, Fairbanks, AK.

Aerial sticky cards

Aerial sticky cards captured 2,591 thrips, while boxes collected only 21 thrips (Fig. 9). Thrips had already begun to emerge prior to placement of the first aerial sticky cards on 29 May, which suggests trap placement should occur no later than late April to 1 May to ensure success. Setting them out too early increases likelihood of debris sticking to the cards.

Aerial sticky card catches indicate a single and a partial second thrips generation/year occurs in the Fairbanks area, beginning early to mid-May and peaking 1 month later in mid-June (Fig. 10). Compared with earlier studies performed by ARS scientist, Dr. Alberto Pantoja in 2010 and 2009, thrips peak flight period in 2015 occurred approximately 2 weeks earlier than the 30 June flight period in 2010 but coincided with approximately the same peak flight of 15 June in 2009. The 2-week variation in emergence dates in the 2 consecutive years underscores the effects extended winter conditions may have on thrips emergence.

Trapping summary

Although the numbers of emergence traps were few (10 closed box, 10 overturned), the information suggests the following trends:

- Thrips overwinter both inside and outside the field, especially in soil near trees.
- Thrips numbers were higher in plots without weed barrier cloth, which suggests use of weed barrier can reduce chances of thrips overwintering in the field but cannot prevent infestation from thrips flying in from weedy borders.
- A single thrips generation plus a partial second generation occurs in Fairbanks.
- Overturned style boxes are more effective in measuring thrips emergence than closed boxes.

Aerial Sticky Cards - Cultivar preference studies

Aerial sticky cards were placed within rows of forty-five different cultivars at the Georgeson Botanical Garden between 6/30 and 7/10 (Fig 11). Although earlier observations seemed to indicate that thrips prefer light colored flowers, peonies of various colors including several dark colors were also infested (Table 1). This is because color is not a factor when thrips initially move into fields from overwintering sites. See results section, Goal 4.

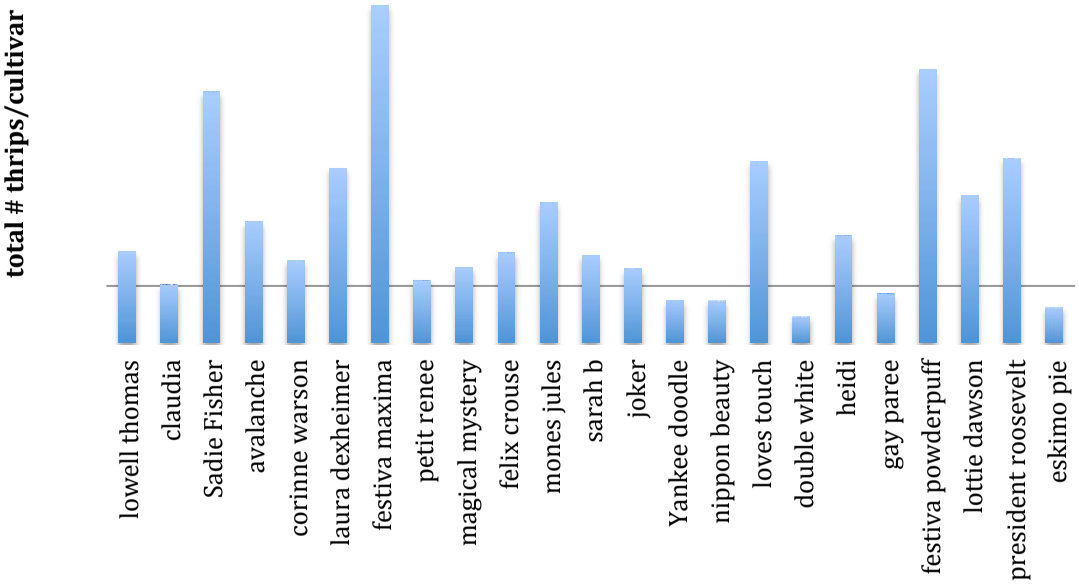

Fig 11. Total thrips from aerial sticky cards within cultivars, Georgeson Botanical Garden. Collected 6/30/15 to 7/10/15.

Table 1. Cultivar color and % infested at Georgeson Botanical Garden, Fairbanks, AK.

	Buds			
Cultivar	**Infested**	**not infested**	**% infested**	**color**
Avalanche	32	20	61.5	white
Ann Cousins	2	28	6.7	white
Avis Varner	6	25	19.4	Dk. pink
Bartzella	0	13	0	Yellow
Best Man	5	41	10.9	Dk. pink
Bridal Icing	5	15	25	White
Cheddar Supreme	9	17	34.6	Dk. pink
Claudia	14	22	38.9	Dk. pink
Corinne Werson	34	26	56.7	Dk. pink
Double White	42	22	65.6	White
Eskimo Pie	7	5	58.3	White
Felix Crousse	8	22	26.7	Dk. pink
Festiva Maxima	30	36	45.5	White
Festiva Powder Puff	21	42	33.3	White/Lt. pink
Fragrant Pink Improved	2	50	3.8	pink
Gay Paree	2	14	12.5	Dk. Pink/white center
Glory Hallelujah	7	57	10.9	md. pink
Heidi	19	11	63.3	md. pink
Helen Hayes	10	32	23.8	Dk. pink
Hermione	4	42	8.7	Lt. pink
Irwin Altman	6	62	8.8	Dk. pink
Joker	19	7	73.1	Md. pink
Julia Rose	7	9	43.8	Md. pink
La Lorraine	5	43	10.4	Lt. pink
Largo	7	53	11.7	Med. pink
Leslie Peck	17	39	30.4	Med. Pink yel. center
Lady Kate	2	36	5.3	Lt. pink
Lora Dexheimer	13	48	21.3	Dk. pink
Love's Touch	20	47	29.9	Lt. pink
Lowell Thomas	49	37	57	Dk. pink
Mary Jo Legare	2	28	6.7	Dk. pink
Magical Mystery Tour	6	30	16.7	Yellow
Mons. Jules Elie	16	28	36.4	Med. pink

	Buds			
Cultivar	**Infested**	**Cultivar**	**Infested**	**Cultivar**
Nippon Beauty	39	21	65	Dk. red
Orlando Roberts	4	48	7.6	Red
Petite Renee	22	46	32.4	Med. pink
Pres. Roosevelt	14	18	43.8	Dk. pink
Pres. Taft	18	44	29	Lt. pink
Sadie Fisher's Peony	56	16	77.8	White
Shirley Temple	0	58	0	Lt. pink
Sarah Bernhardt	22	48	31.4	Lt. pink
Singing in the Rain	0	7	0	Yellow
Sitka	10	42	19	Med. Pink
Smith Family Yellow	1	11	8.3	Yellow
Yankoo Doodle Dandy	1	9	10	Dk. pink

Yellow highlight indicates top two- percent infested cultivars.

Influence of daylight hours and temperature on generations

Total daylight was calculated for collecting dates in Fairbanks. Numbers of thrips collected from aerial sticky traps were plotted alongside total minutes of daylight/day (Fig. 12). Predictably, thrips numbers increase with increasing light and warmth (Fig. 13). Peony growers in the Fairbanks region should use yellow sticky cards to monitor thrips flight period beginning late April to early May depending on snow cover and ability to get into the fields. Overturned traps can provide information on overwintering sites and should be placed at the same time as aerial sticky cards.

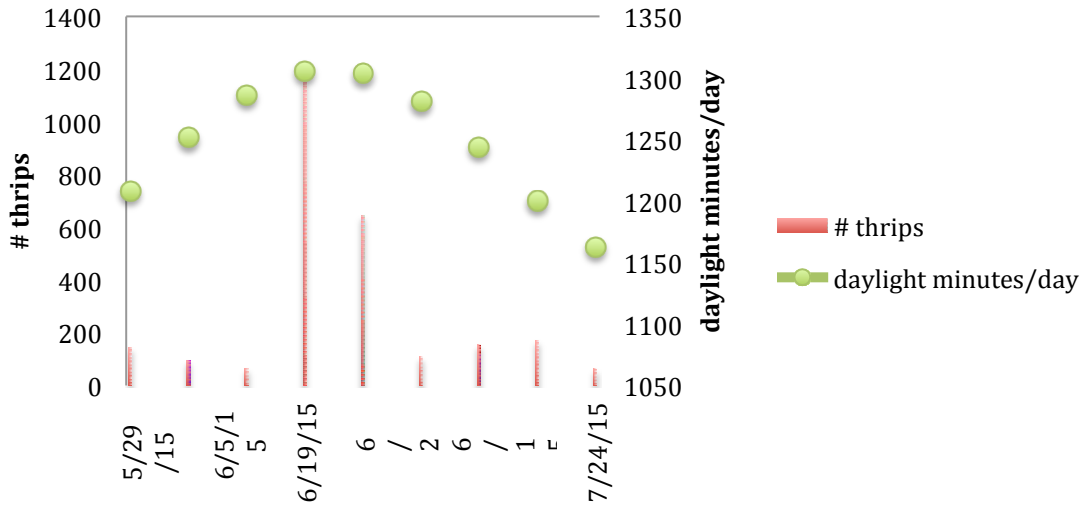

Fig 12. Aerial thrips catches with total daylight hours/day at Georgeson Botanical Garden, UAF, Fairbanks, AK.

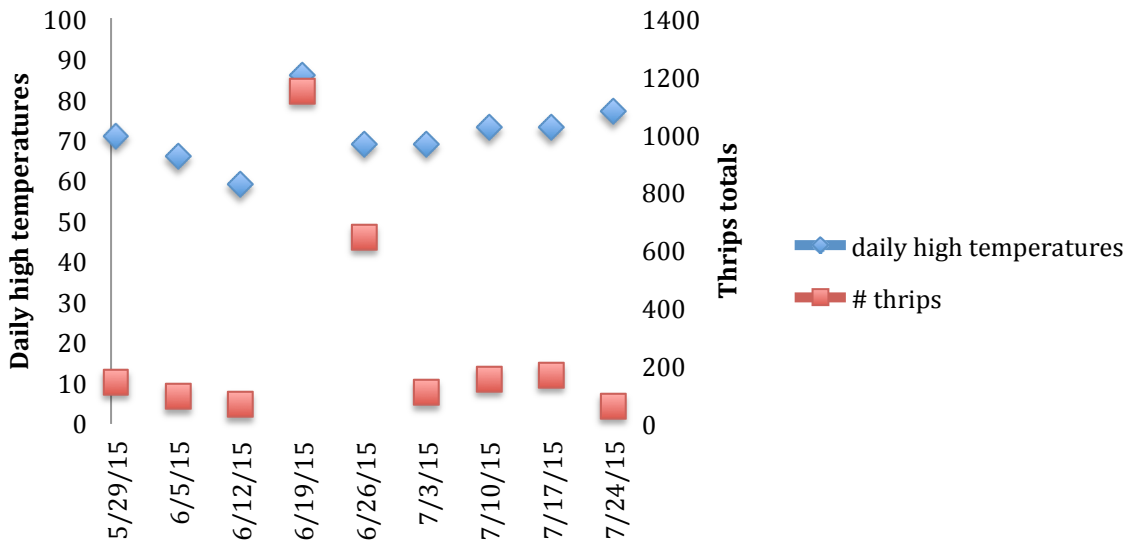

Fig 13. Total aerial thrips catches plotted with daily high temperatures, Georgeson Botanical Garden, UAF. Fairbanks, AK.

Echo Lake May 18 – August 27

On the Kenai Peninsula, a multiple variety peony field was divided into 4 quadrants (Fig. 14) to track movement of thrips using aerial sticky cards and emergence traps. Soil samples for the closed box emergence traps were taken on 18 May in Soldotna, AK from field borders and from inside the field, with and without weed-barrier cloth. Overturned traps were not used since they weren't added to the protocol until the Georgeson Botanical Garden site. The closed box soil samples were not successful in trapping any thrips. In the future overturned traps will exclusively be used as emergence traps for thrips studies.

Quadrant 1 Total 268 F25 B243	**Quadrant 2** Total 224 F14 B210
Quadrant 4 Total 99 F20 B79	**Quadrant 3** Total 133 F28 B105

Fig. 14. Echo Lake quadrants with total thrips collected in the field (F) and borders (B) in Soldotna, AK.

Overwintering and Generations

A sticky card was placed on each quadrant border and centered within each field quadrant. There were 2x the number of border sticky cards than within-field sticky cards. Cards were changed weekly. A total of 88 aerial sticky cards were analyzed. Total thrips collected from border sticky cards was 637 while 87 thrips were collected within the field. To compare activity, the total number of thrips trapped in border sticky cards was divided in half, 318.5. A 3.7 fold difference in thrips activity was observed between the field and borders, suggesting that while most thrips overwinter outside the field, some also overwinter in the fields. Weed barrier was used in that field but not exclusively. As previously mentioned use of weed barrier may reduce thrips overwintering in the field but not prevent infestation from surrounding areas.

Differences between thrips totals in each of the quadrant borders suggests some possess more favorable overwintering sites. Borders of quadrants 1 and 2 had uncultivated areas on two sides while quadrants 3 and 4 had a single uncultivated border as well as bordering the cultivated peony field to the south. Presence of weedy borders results in greater numbers of thrips so controlling border weeds could reduce thrips, but may not be humanly possible. Using emergence traps can help growers pinpoint areas with high numbers of overwintering thrips. Thrips adults are weak fliers and wind direction may also play a role in dispersal.

Sticky cards identified 2-3 peaks in thrips activity in Soldotna representing two and a partial summer generations in the Kenai Peninsula (Figs. 15 &16), mid-June and mid-July.

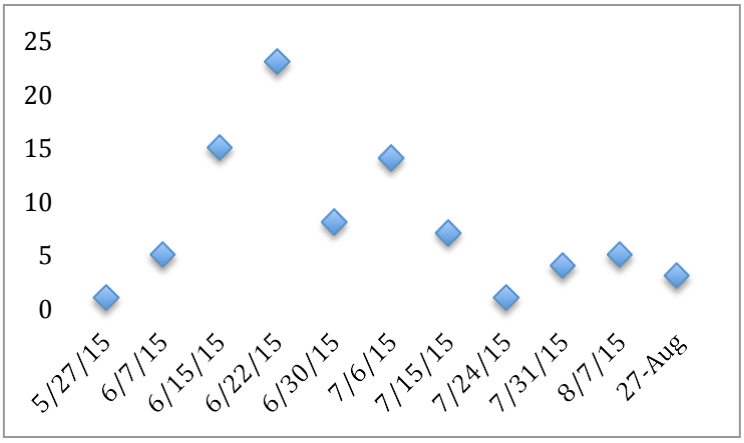

Fig. 15. Echo Lake aerial sticky cards

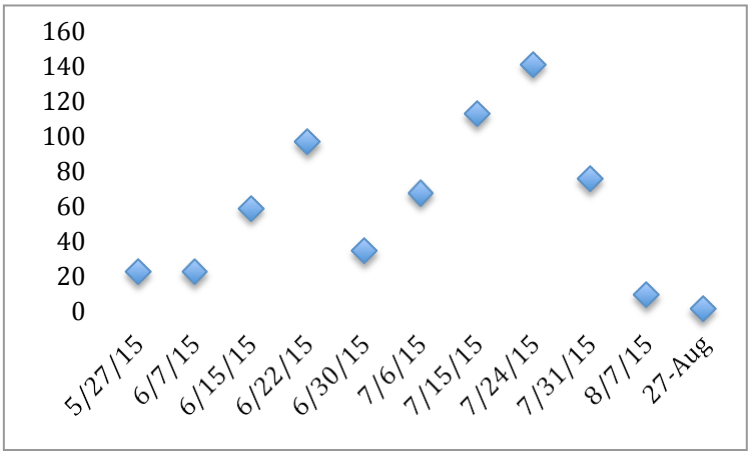

Fig. 16. Echo Lake Farm aerial sticky cards field borders.

Thrips Peony Phenology

Bud stage was recorded along with sticky cards at Echo Lake Farm. Records indicate overwintering adults begin to move into the field in mid-May when peony plants are just 3-4 inches tall with no buds present. However by mid-June stage 1 peony buds were recorded, coinciding with the first peak flight or 1st generation of thrips. The first summer generation occurs before the buds show color and therefore initial distribution is independent of color. These data concur with that of the Georgeson Botanical Garden, where thrips were discovered first infesting exteriors of stage 1 buds. Once thrips infest a peony bud, they lay eggs and move in as their numbers increase and the buds open.

The 2nd peak flight occurs mid-July when buds are at stages 3 and 4. Depending on cultivar, harvest occurs between bud stages 1.5 - 4.5. Harvest period at Echo Lake began prior to and continued during the highest thrips numbers (Figs. 17 & 18), which occurred during the 2nd flight period in mid-July.

The highest temperatures, 84^0 F occurred mid June during the 2015 Soldotna peony harvest, with the highest average daily temperature reaching 68.5^0 F (20.28^0 C) on 17 June. Between 21-23 June, peak daylight hours reach 19. Combined, long daylight and high temperatures promote rapid development and precede a rise in thrips numbers. Between 77^0 F and 87^0 F, generation time for western flower thrips takes approximately 11 days in California but effects of long daylight in Alaska may decrease generation time. Thrips populations reached their peak in July when high temperatures stabilized between 55^0 F and 73^0 F. By 21 July, light drops below 18 hours shortly before nighttime temperatures also begin to drop. Thrips, like all insects, are affected by photoperiod and temperature. As long days increase during the Alaskan summer, so do thrips populations but light dropping near 18 hours combined with dropping nighttime lows, result in big changes to the thrips populations after 15 July (18h: 13m). At that time, thrips numbers (trap catches on yellow sticky cards) plunged 2.2 fold from 176 to 79, followed by a second drop 8.3 fold to fourteen by 31 July (17h 4m) and finally to only four thrips by 7 August.

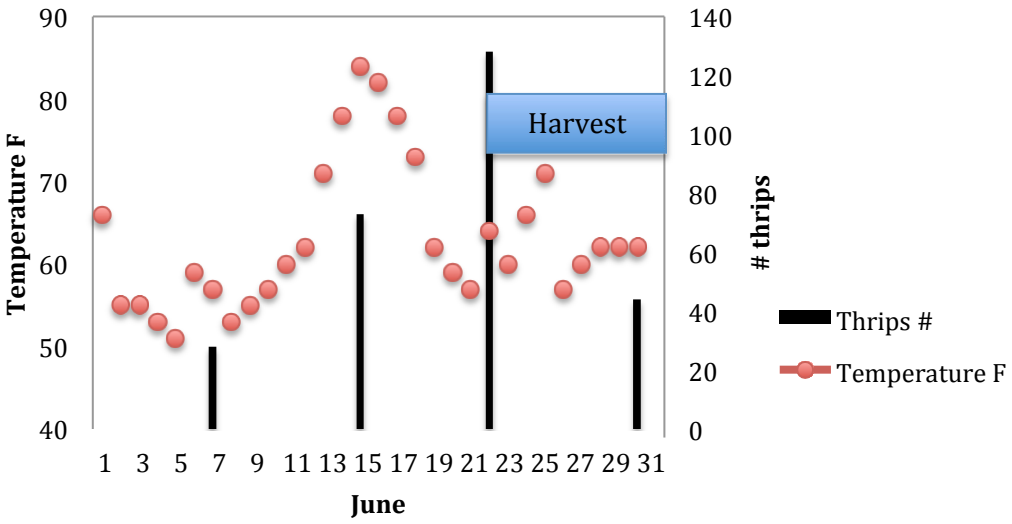

Fig. 17. Total number of thrips plotted with daily high temperatures in June at Echo Lake Peony farm, Soldotna, AK.

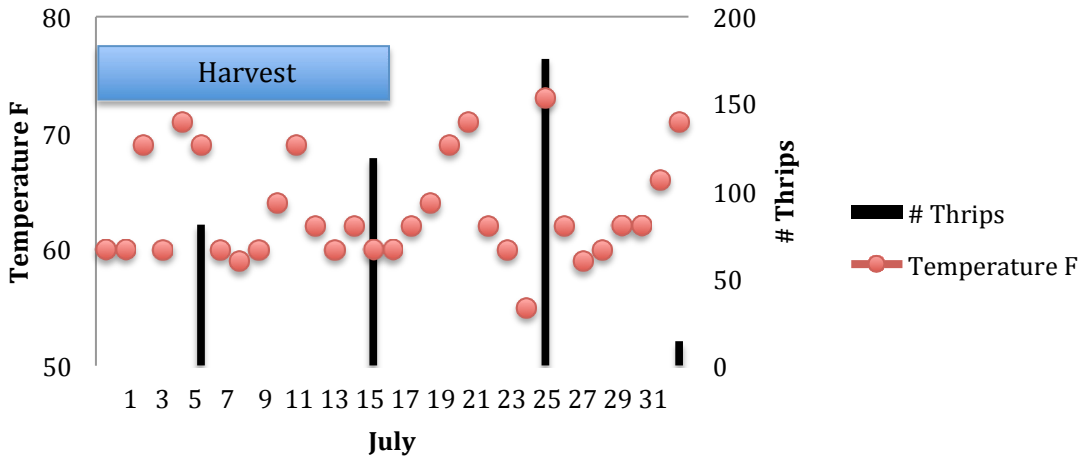

Fig. 18. Total number of thrips plotted with daily high temperatures in July at Echo Lake Peonies in Soldatna, AK.

Multiple cultivars

Besides daylength and temperatures, additional factors assist thrips populations to flourish in peony fields. Growers tend to grow multiple cultivars with varying bud maturity, stimulating thrips populations by providing a continuous source of susceptible buds. Poor sanitation practices, failing to deadhead, allow thrips populations to build to maximum levels unchecked.

Correct timing of insecticide applications is imperative. Timely early season applications can impact thrips moving into the field, ultimately preventing or suppressing the larger second summer generation in July. Adequate insecticide coverage is easy when buds are in stage 1 since there are no petals present. See discussion under *management*. The second peak generation in Soldotna occured in mid-July when buds reach stage 3 and 4.

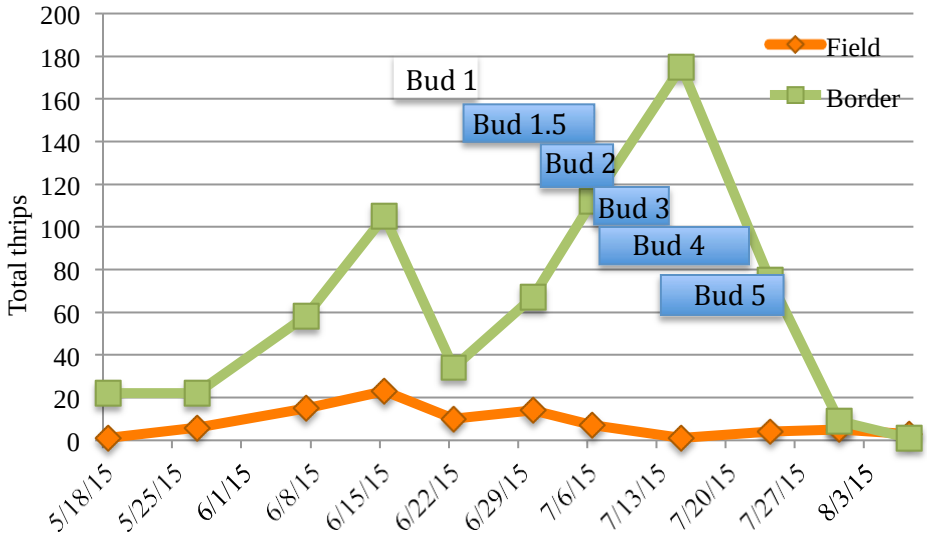

Fig. 19. Bud stage plotted with movement of thrips totals within the field and along borders at Echo Lake Farm, Soldotna, AK.

Thrips Flight Periods Comparison

Comparison in thrips flight periods between Georgeson Botanical Garden, Fairbanks, AK and Echo Lake Farm, Soldotna, AK indicates Echo Lake undergoes 2 generations and a partial 3rd generation during the peony season, while Fairbanks experiences one and a partial 2nd generation (Figs 9, 20). Georgeson Botanical Garden is situated at 64.85^0 N, while Echo Lake Farm is located 60.48^0 N, representing nearly 5 degree difference in latitude. Nevertheless Georgeson's flight peak in 2014, nearly coincided with Echo Lake's first flight peak, 19 June. Depending on occurrence of unseasonal weather conditions, these partial generations could drop back or result in an additional full generation.

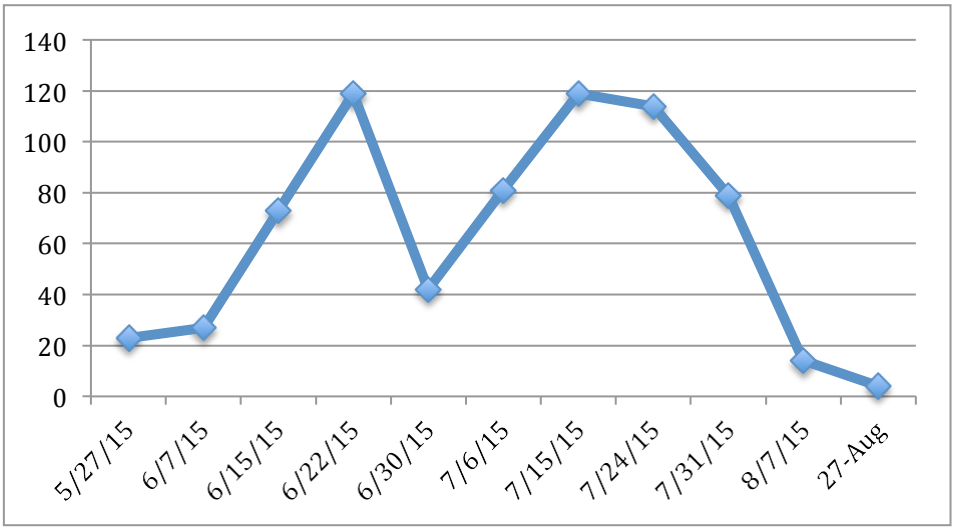

Fig. 20. Thrips flight periods combined field/border sticky cards --- Soldotna

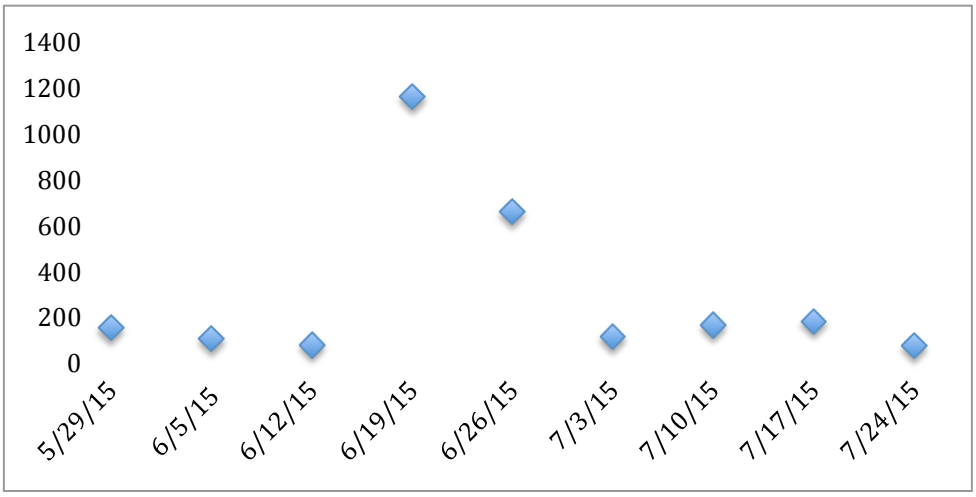

Fig 9 repeated. Thrips flight period --- Georgeson Botanical Garden, Fairbanks, AK.

Goals 2 & 3. Identify when thrips require management. Compare thrips on all cultivars at the UAF Georgeson Botanical Garden to identify preferences.
A total of 1,720 Peony buds representing various stages (1, 1.5, 2, 2.5, 3, 4, and 5 or full) of 45 cultivars from the Georgeson Botanical Garden were collected and individually placed in ziplock bags for analyses. Buds were placed in shipping containers with cold packs and shipped overnight to Washington State where they were dissected and thrips presence recorded. All were dissected. Color, life stage and numbers of thrips were counted for each bud. A few buds in stage 5 buds, full bloom, were rotten when studied and in that case only presence or absence of thrips was recorded.

Buds were scored infested or uninfested and % infested calculated for both bud stage and cultivar (Table 1). For all buds, 45% were infested. The cultivars dissected with the highest % infestation was 'Sadie Fisher' with 77.8% and Joker at 73.1%

Over fourteen percent of Stage 1 of the 1,720 buds dissected, were infested with thrips. Observations indicate thrips first settle between the bracts and sepals or between sepals and petals of early stage buds. From these protected locations, thrips lay eggs and progressively move further into the bud as the bud slowly opens. The progression of movement into the bud along with observation of the new generation provides some clues as to arrival and of passage of time, so notes on level of penetration were recorded, such as row of petals where thrips were observed or whether the thrips were found in the center of the bud.

Once the thrips have settled into the buds in these protected locations, contact insecticides will no longer be effective against them but they could protect the buds from additional incoming thrips for a few days depending on the residual activity of the insecticide. Peony buds should be protected from thrips, beginning with the *button stage* to minimize infestation at harvest. For growers who want a less toxic approach, there

are a few options but efficacy and speed of results are slower, see *Biological/sustainable management options*.

Borders versus within field

Immature thrips were first observed inside the bud as far as the petals by stage 1.5 ('Nippon Beauty' 25 June; 'Petite Renee' 29 June; 'Bridal Icing' 6 July), indicating thrips had infested these cultivars earlier than others. The plot map (Fig. 21) shows the location of all three cultivars. Likewise, the *highest numbers* of thrips/cultivar based on aerial sticky cards (Fig. 9) were observed in: 'Festiva Maxima' (plots 6,15), 'Festiva Power Puff' (plot 6) and 'Sadie Fisher' (plot 6). Both of these incidences, (earliest observed immatures and highest aerial trap captures) were border plots. Thrips primarily enter the fields from borders.

The appearance of immatures in late June represents first observations of the F1 generation for the 2015 season at the Georgeson Botanical Garden. A comparison of infestations (adults + immatures) among cultivars is shown in Table 1. The bud stage with the highest incidence of immature thrips is stage 4. Bud stage with highest incidence of mature thrips is stage 5. Last reported immature thrips was 7 July.

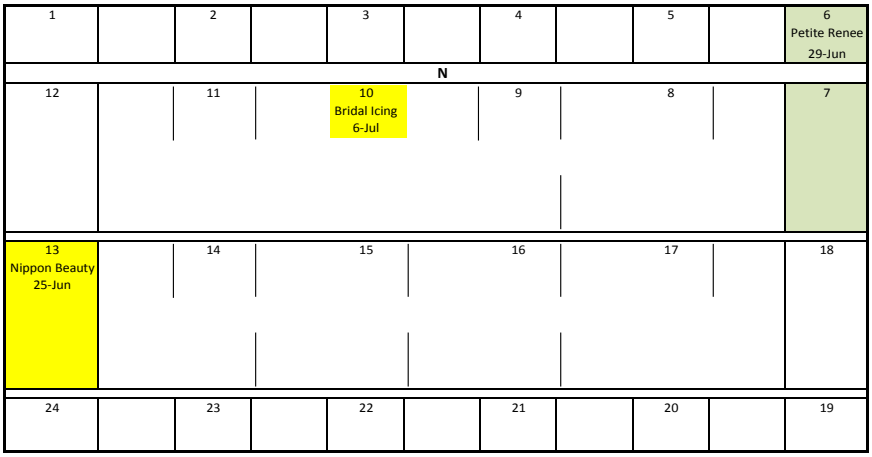

Fig. 21. Georgeson Botanical Garden Plot Map 2015.

Thrips Identification

In 2010, Alberto Pantoja identified four thrips species associated with peonies: *Thrips tabaci*, *Taeniothrips orionis*, *Thrips vulgatissimus* and *Frankliniella occidentalis* based on collections from 3 localities. This study focused on thrips species from peonies at Georgeson Botanical Garden in Fairbanks. One hundred and fourteen thrips were mounted on 49 slides with Strandtmann's mounting medium. Strandtmann's requires ringing in glyptol for longterm preservation. Thrips were sorted to 4-5 morphospecies. Species identified included members of 2 families of thrips, Thripidae and Aeolothripidae. Members of Thripidae included Western flower thrips, *Frankliniella occidentalis*. Several morphospecies did not match any of the 4 species Pantoja identified and likely after 6 years there are new species especially with the rapid growth in the peony industry and increase in plant movement within Alaska. The thrips slides may provide useful information for further studies but should be maintained at the UAF

museum to increase access and longevity. This study was not intended to be an

exhaustive survey of thrips infesting peonies in Alaska. The Pantoja survey 6 years ago provides a baseline for that data.

Goal 4. Define peony flower color and correlate thrips infestations with color and form.

Peony Flower Attractivity

Thrips were observed on all except two cultivars, 'Shirley Temple' and 'Singing in the Rain. The lack of thrips on these cultivars is possibly due to small sample size.

Peony exudates

Peonies are noted for their sticky exudates, which contain sugar and are highly attractive to numerous insects including ants and wasps. The exudate is produced by nectaries located on the edge of the sepals. Presence of a sticky exudate on the peonies was observed from the very beginning with the first bud shipment. At UAF, Dr. Pat Holloway reported that the entire plants were sticky and questioned whether lack of rain could have been the cause. It is obvious that volume and viscosity of the exudates diminish as the season progresses as the buds open and also perhaps washed off with rain as Dr. Holloway suggests. It is logical that the sugary exudate could attract thrips and provide nutrients required for oviposition, however there was no evidence of specific attraction in stage 1 buds from exudates. Alternatively, the sticky nectar may actually entrap thrips as has been reported in some Australia flowers with copius nectar, http://thrips.info/wiki/Thrips_and_plants. Buds were harvested and placed into plastic bags for shipment to Washington State, which eliminated the chance to observe if thrips were found trapped in the sticky exudate. Curious and sharp-eyed growers can answer this question if they regularly monitor their fields.

Plant volatiles

Specific plant volatiles can play a role in thrips attractivity. Certain thrips such as western flower thrips prefer unopened buds to open flower buds which is attributed to higher amounts of the chemical (E)-β-farnesene found in the buds compared to leaves and open flowers (Manjunatha et al 1998). It is likely other species exhibit similar preferences. The notion that thrips could be attracted or repelled by plant volatiles and that these same chemicals could be utilized to assist in controlling or repelling thrips on peonies sounds appealing but this avenue of research is in its infancy and a lot of variables exist. More research is needed in this area.

Pollen

While some species of thrips are omnivores and can be predatory on their own immatures, they are best known for feeding on plant tissue and on pollen (Fig. 22). Thrips reportedly are more attracted to peony cultivars with pollen. However, thrips were observed on cultivars regardless of pollen. Pollen is not available in early stages of bud development because anthers do not mature and split open with pollen until later stages, thus presence of pollen is not a requirement for infestation.

Fig 22. Thrips feeding on pollen

Pollen is a rich food, high in proteins that promote egg-laying (fecundity) and thrips population increase as the season progresses, coinciding with an increase in availability of pollen. The increase in availability of pollen as the season progresses could stimulate egg-laying, therefore while initial infestation is not influenced by presence of pollen, increasing availability of pollen in mid to late season may play a role in overall field populations.

Color

Thrips are reported to be attracted to light colored flowers and to investigate this we looked at both light and dark peony buds. Cultivars dissected included white, pink, dark fuchsia and apricot. Thrips were found infesting all colors. Furthermore, over 14% of buds stage 1, were infested, when no color is visible. Initial movement into the field from overwintering sites and settling is not influenced by color, but does flower color influence within-field movement? When cultivars (Table 1) are divided between light colors (white, light pink, yellow) and medium to dark colors (medium pink, dark pink, red), surprisingly the % infested for each group is nearly identical, with 46.3% of light flowers infested (266/574) and 46.2% of dark flowers infested (379/821).

Human eyesight is not the same as thrips and generalizing about bud color and attractivity can be misleading. Insects are attracted to the ultraviolet portions of the color spectrum (Menzel 1975) and surface properties can further influence color (Hunter & Harold 1987). Color is considered a short-distance attractant compared with plant volatiles that can attract thrips from long distances and are considered the major attractive factor for thrips such as western flower thrips.

This research did not find any differences in preference based on color but as we know from the research mentioned above a simple comparison between colors will not provide these answers. Observations of large numbers of thrips on stage 5 light colored flowers may be due to several factors:

- Thrips are easier to see on light flowers.
- Stage 5 blooms of any color will have higher numbers of thrips than earlier stages simply from exponential growth of thrips populations.
- Presence of pollen available on late season blooms can boost egg production.

Goal 5. Conduct a literature review on thrips management. A literature review is attached separately and includes links to websites, articles and information on thrips' biology, sampling, management including fumigation. References at the end of this report are specific citations for this report.

Management

- The initial protective spray is critical, time the insecticide spray to protect button peonies. Effects of the exudates and their potential to dilute the protective insecticides should be evaluated. Effects of insecticides at this time on beneficial non-target insects attracted to exudates should be investigated. Season-long insecticide control programs may not be compatible with picking schedules.

Use of synthetic pyrethroids can be challenging to pickers, because of the REI interval (restricted entry interval) required by the label.

- Ideally monitor thrips activity with sticky cards.
- Weekly sample buds for infestation by tapping them hard over a white plate or pan and watch for minute elongate thrips.
- Most likely protective cover sprays will need to be applied throughout the season based on flight activity.
- Perform proper sanitation, deadheading spent blossoms and remove all plant debris from the field and dispose properly to prevent buildup of thrips.
- Removing weeds to create a border around the field sounds logical but is it feasible?
- Use of weed barrier may reduce thrips overwintering in the field but it won't prevent infestation.
- Growers could determine direction and intensity of incoming thrips using sticky cards to delineate thrips movement identifying any hot spots.
- This knowledge also identifies most vulnerable areas of the field, which could be closely monitored.

Fumigation

Major flower export countries use fumigation to control thrips but effects specifically on peonies, are unknown. Fumigation might provide an additional management safety net but cost and potential phytotoxicity and effects on bud longevity have not been investigated. Is there an advantage to pretreat shipments? Will fumigation certification, or other forms of disinfestation pretreatments be recognized by target countries and simplify the process? Whose responsibility is it and who pays?

Thrips are minute insects that search out tight crevices and cracks to hide. Even so the adults are easily found with careful visual inspection. The cryptic nature of eggs and immature stages indicates shipments with these stages could pass inspection. Effects of postharvest treatments during transport (e. g. cooling) on thrips have not been studied, but it appears that infested flowers could arrive at their foreign ports of entry and be subject to disinfestation or rejection.

Biological/sustainable management options

Use of insecticides can be problematic in a crop that has short picking intervals like peonies and other cut flowers, because of the REI required by the labels, pickers can re-enter the field until a prescribed time following an application. There are several alternative control methods if suppression is adequate. Softer control methods usually don't work as fast as chemical approaches and biological control is always more effective when pest populations are low. Here is the latest research on sustainable approaches to thrips control:

Minute pirate bugs – (Hemiptera: Anthocoridae) (Fig. 23). These small true bugs are already present in peony fields. They insert their eggs into plant tissue like thrips but the nymphs hatch and feed on thrips eggs and larval stages. At the numbers I observed, they are not capable of adequate suppression

Predatory mites – the predatory mites, *Amblyseius cucumeris* and/or *A. degenerans* may provide some protection but most likely not enough. The predatory red whirligig mite, *Anystis* already is present in fields and was observed on peony buds from UAF but at such low numbers natural populations cannot effectively control thrips. Use of either minute pirate bugs or predatory mites would require purchase and shipment from a commercial biological control company, which might be cost prohibitive and the shipment distances could impact quality of the beneficials.

Fig. 23. Minute pirate bugs were occasionally found on peony buds from the Georgeson Botanical Garden. They insert eggs into petals like their thrips prey.

Fungal pathogens – Fungal pathogens are insect specific pathogens whose spores attach to the insect and hyphae grow into the insect's cuticle resulting in death. Fungal pathogens include *Beauveria bassiana,* that can assist in controlling pests and are available as foliar sprays. Some reportedly have shown efficacy against western flower thrips. My experience with fungal pathogens is they are very slow to act but do have some value in other pest systems, where they usually suppress rather than eliminate the pest. Combinations of a fungal pathogen + an insecticide also have shown efficacy.

If there is a zero tolerance for thrips, insecticide applications remain the best option. Thrips have also been known to develop resistance. Development of an effective insecticide program must include the following points:

- The insecticides selected must be effective against thrips.
- They must rotate between different classes of insecticides to minimize resistance development.
- The REI intervals of selected insecticides must be compatible with grower/picker schedules.
- Insecticide choices must meet the particular criteria of your buyer. For example, some buyers advertise that neonicotinoids are not used on their flowers, as a selling point.

Developing a season long effective program will require research and diligent testing but it is possible.

Summary

Results of this study provide many details on thrips and their peony hosts unknown until now. In summary**:**

- Thrips infest peony buds (external sites) as early as stage 1.
- Initial settling preference is independent of color or presence of pollen.
- Thrips primarily overwinter outside the fields with smaller numbers overwintering within the fields.

- Aerial sticky traps indicated two and a partial generation in the Kenai and one and a partial generation in Fairbanks.
- Four to five different species of thrips were identified, including western flower thrips but at least 2 species did not match Pantoja's survey in 2010.
- Development of a season-long program to control thrips, which addresses efficacy, resistance management and grower/picker schedules, is highly recommended.

References: (see also literature review)

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