CALIFORNIA MELON RESEARCH BOARD

2012 RESEARCH SUMMARY / REPORT

Investigating the possibility for mosaic virus incidence reduction using applications of materials acting as repellents or antifeedants to aphid vectors.

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Summary

Mosaic viruses of cucurbits if infection is early, may result in extensive yield losses, and occur annually in some regions of California. Traditional pesticide control of aphid insect vectors does not control virus incidence, as the virus is transmitted to the plant before the pesticide kills the aphid. Thus, there is a need for an alternative management method in order to prevent virus movement into a field. Ten products with repellent/antifeedant properties through changing the odor or tactile perception of the plant, and one product with visual repellent properties, were tested for their effects on alate (winged) aphid density and virus incidence. Winged aphids were focused on, as they are more likely to be coming in from other areas within the agroecosystem and carrying virus from local reservoirs. It was found that under field situations with high aphid pressure and high virus pressure (late season planting, local virus reservoir known), three treatments were shown to significantly reduce aphid density and virus incidence compared to the control, and an additional six treatment were shown to significantly reduce virus incidence exclusively. Under field situations with low aphid pressure and low virus pressure (mid season planting, no local virus reservoir known), treatments did not show any effect with lowering aphid density and virus incidence any further than their already low levels. Methods for use of treatments identified as showing potential in this system may be economically viable when loss due to virus is expected to be high, though effective treatment duration associated with spray interval and number of applications needs to be refined. No significant differences in yield or soluble sugar content (Brix) were found between treatments.

Introduction

Worldwide, cucurbits are subject to several viral mosaic pathogens, resulting in extensive yield losses. Disease incidence to some degree or other occurs almost annually in some regions of California. The four most common and important of these viruses, *Cucumber mosaic cucumovirus* (CMV), *Watermelon mosaic potyvirus 2* (WMV2), *Papaya ringspot potyvirus type W* (PRSV-W), and *Zucchini yellows mosaic potyvirus* (ZYMV), are all transmitted in a nonpersistent manner by various aphid species. Transmission requires only seconds of stylet probing by a feeding aphid and can be accomplished by many (if not all) aphid species. These mosaic viruses have a wide host range and are likely to infect and be harbored by many other agricultural crops and weeds simultaneously growing in the agroecosystem. This diverse landscape likewise supports many aphid species, all of which are

potential vectors, regardless of whether they establish breeding populations on melons (colonizing species). In fact, it has been argued that non-colonizing (transient) species are more efficient vectors of nonpersistent viruses since virus retention and transmission ability decrease rapidly once a viruliferous aphid is allowed to feed on an uninfected plant. Pesticides are relatively ineffective at reducing virus incidence because any transient alate aphid can create new infection centers daily while passing through the crop prior to ingesting a lethal insecticide dose. For this reason there is a need for alternative protective measures such as repellants, dissuadants, and antifeedants, used in conjunction with appropriate insecticide management, to reduce alate aphid feeding rates in order to minimize new infection centers and overall virus incidence.

Aphids respond to visual, olfactory, and tactile stimuli from the foliage of potential hosts in order to initiate both landing and feeding processes, and these cues are known to be important in aphid plant selection behavior. Interference with the receipt of these appropriate stimuli could reduce the frequency of aphid settling and/or corresponding feeding rates, perhaps especially of transient species, and therefore decrease virus transmission. Interference of olfactory or tactile stimuli has been associated with lower aphid plant selection rates, lower feeding rates, and subsequent lower incidence of disease. Several commercially available and experimental formulations of botanical essential oils, plant extracts, biostimulants, and other product classifications have shown the potential to repel and/or reduce feeding in a wide range of arthropod pests. Such products may interfere with alate aphids' in-flight and/or near-landing selection of host plants, and also the perception of these plants related to feeding rates. In some cases, it is suggested that products such as oils may prevent the transmission of virions to an uninfected plant selected for feeding by physically blocking the stylet probe. In agricultuual pathosystems including nonpersistent viruses with wide host and vector ranges, applications of repellants and antifeedants may alter the aphid density, possibly by interfering with odor-mediated and/or tactile-mediated host cues. This may reduce aphid feeding rates and virus incidence.

Objectives

A. Determine what effect repellents and antifeedants have on aphid density within melon plantings, as compared to reflective particle films and to no protection at all.

B. Determine what effect repellents and antifeedants have on mosaic virus incidence, yield, phytotoxicity, and fruit quality, as measured at harvest time.

C. Determine the effect of protection duration (weeks of repellent/antifeedant/dissuadant applications) on mosaic virus incidence, yield, phytotoxicity, and fruit quality, as measured at harvest time.

Materials and Methods

Field site establishment and maintenance

Two plantings of honeydew, open pollinated cultivar 'sweet delight' from TS&L Seed Company, were established at the Armstrong Plant Pathology field complex on the UC Davis south campus in Davis, California. Beds (80" or 72" from center to center) were mechanically shaped, seeds were directly sowed in a single line per bed, and the crop was subsequently furrow irrigated as needed throughout the season until the weeks approaching harvest. A pre-plant spray fertilizer application was made, as well as a pre plant application of Admire Pro systemic insecticide for early cucumber beetle control. Later season cucumber beetle control was determined as needed according to IPM guidelines, and controlled by Assail insecticide application. These insecticide applications also served to keep colonizing aphid populations under control within the field, as the focus of this research was on alate aphids coming from surrounding areas. Weed control was achieved through manual cultivation. The first planting ('trial 1') was established on June 19th, and the second planting ('trial 2') was established just south of trial 1 on August 1st. Surrounding agroecosystem components at the research complex included one field of honeydew melons seeded approximately 2 weeks after trial 1 seeding directly to the east, various weeds within a natural creek area to the south, small grape vineyards directly to the north and west, as well as a variety of other row crops and perennial crops including grape, almond, peach, apricot, cotton, cherries, corn, persimmon, and ornamentals in the local area.

Trial layout, treatments, and application

Both trial 1 and trial 2 were organized into four experimental blocks, with each block then divided into twelve treatment areas of equal size, representing experimental units ('plots'). Each plot consisted of two rows approximately 50 feet in length, planted as described above. Plots were spread out such that each was surrounded by approximately 20 feet of unplanted bare ground in all directions. Each plot was then assigned to receive one of twelve total treatments: attempted vector reduction via one of ten repellent/antifeedant property materials, attempted vector reduction via a reflective particle film, or untreated control receiving no treatment at all. Repellent/antifeedant materials included Sporatec™ (Treatment #3, Rosemary/clove/thyme oils, 3pts/100gal), Cedar oil (Treatment #4, cedar oil, 500ppm), MBI203 (Treatment #5, antifeedant bacteria, wettable solid, 1lb/acre), IRF161 (Treatment #6, amino acid extract, 3pts/100gal), Garlic Barrier® (Treatment #7, Garlic oil, 2gal/100gal), ORSAPA (Treatment #8, citrus oil, 3pts/100gal), IRF160 (Treatment #9, amino acid extract, 3pts/100gal), Joshua (Treatment #10, yucca tree extract and cinnamon oil, 600ppm), Hot Pepper Wax (Treatment #11, capsaicin pepper extract, 1gal/16gal), and ORSA076 (Treatment #12, citrus oil, 2pts/100gal). Surround® (Treatment #2, kaolin clay, wettable solid, 25lbs/acre) was used as the one reflective particle film product. In this way, each treatment was represented one time within each of the four experimental blocks, for a total of four treatment replications per trial. Summary of treatment details, including chemical company references, can be found in Table 1.

All products were first applied approximately two weeks after seeding (5-8 days after seedling emergence), when plants were at the 1 true leaf stage. Applications were then continued at a weekly interval for a total of five applications for all materials. The first two applications were carried out using a CO2 backpack sprayer, and the remaining three applications were carried out using an air-blast assisted backpack sprayer. Carrying volumes for each application were determined in order to ensure good coverage of all foliage (Table 2). At the conclusion of treatment application, plants had grown to the point where they were closing canopy. Applications were only made when plants were young because it has been shown that virus infection late in the season does not affect yield; early season is the critical protection period for virus management. The first application of materials was made on July 5th for trial 1, and on August 15th for trial 2.

Aphid traps

Aphid trapping stations were set up immediately following the first application of materials for each trial. One trap was used per plot, and with twelve experimental units per block, this made for a total of 48 trapping stations at each trial location. Stations consisted of yellow sticky cards (10cm X 16cm; Seabright Laboratories, Emeryville, CA), oriented horizontally and rigidly mounted, approximately 30-60cm from the ground, on one meter lengths of bamboo stake with a wooden clothespin. During each sampling period, sticky traps were positioned directly above the melon canopy level. Traps were collected and replaced weekly. Trapping continued until the week before harvest, for a total of 10 trap collection dates for trial 1 and a total of 8 trap collection dates for trial 2. Collected traps were brought back to the laboratory, and the number of aphids on each trap was counted and recorded using a dissecting microscope. Apterous aphids migrating from adjacent plants were disregarded in this study since aphid landing rates and infection center initiations were the primary foci. Alate aphids were identified from other insects by visually confirming the presence of key morphological characteristics unique to aphids including siphunculi (cornicles), the cauda, and the unguis of the terminal antennal segment. Sampling dates were also expressed as crop age (in weeks after planting), a discrete variable common to all. Statistical analysis of aphid density was conducted separately for trial 1 and trial 2, as these trials represent separately mid and late season plantings with different aphid and virus population pressures. A mixed model approach was used for data analysis, with block assigned as a random variable, and with treatment and crop age as fixed variables. Treatment and crop age effects on overall aphid density were measured via fixed effect F tests. Means comparisons between treatments were achieved using Student's t-test on least squared means from the mixed model, at an alpha value of 0.05 (95% confidence interval). All statistical analysis was conducted using JMP Start Statistics software (SAS Institute, Cary, North Carolina, USA).

Virus incidence, rating, and identification

Virus incidence was assessed approximately two weeks before harvest. The virus rating for trial 1 was conducted by visually assessing each shoot tip within a plot, and counting the number of shoot tips that showed characteristic mosaic virus symptomology (no extensive virus colonization was observed). This resulted in a rating characterized by the number of shoots affected per plot. For the virus rating for trial 2, plots were first divided into four evenly spaced 'transects', each consisting of approximately six feet of the fifty foot row lengths, and spanning across the width of the foliage from

both of the plot rows. Within each transect, the number of symptomatic shoot tips compared to the total number of shoot tips was taken, resulting in an overall rating characterized by the percent of shoots affected per plot. All ratings were conducted by personnel with multiple years' experience in rating mosaic viruses in honeydew. A mixed model approach was used for data analysis, which was conducted separately for trial one and for trial two, with block as a random variable, and treatment as a fixed variable. Treatment effect on virus incidence was measured via a fixed effect F test. Means comparisons between treatments were through use of the Students' t-test on least squared means from the mixed model, at an alpha value of 0.05 (95% confidence interval). All statistical analysis was conducted using JMP Start Statistics software. Virus identification was done using characteristic symptomology.

Yield, Fruit Quality, Phytotoxicity

Yield was measured by counting the number of marketable fruit harvested from one of the two rows within each plot. This number was then converted into number of fruit per acre by multiplying by two rows per plot, and assuming an average plot size of 0.0153 acres. A marketable fruit was determined as having a fruit diameter greater than five inches, having a white-ish coloration (compared to green), and lack of pubescence. Fruit quality was determined by fruit size and soluble sugar content. For sizing, melons were categorized as having a diameter of 5-5.5", 5.5-6", 6-6.5", 6.5-7", and greater than 7". All harvested fruit in each plot were sized, creating a size distribution for each plot. Soluble sugar content (Brix) was measured from ten representative fruits from each plot. Brix measurements were taken on juice extracted from both the blossom end and stem end of each fruit using a refractometer. These values were then averaged to get a single Brix value per fruit. Phytotoxicity ratings were made throughout the trial durations, particularly after product applications when plants were young and likely more sensitive to material components. No phytotoxic effects of materials were observed throughout the season.

Results

Aphid density

Both Trials. According to mixed model analysis considering trial 1 and trial 2 together, an extremely large portion of variation was contributed to trial differences (47.001%). Because of this, and also because trial 1 and trial 2 represent mid and late season plantings with different biological system pressures, the two trials were also considered separately. Trial 1 had significantly lower average aphid density (# aphids/card) compared to trial 2 (Figure 1, $P<0.0001$). The pattern of aphid density when compared to crop age (weeks after seeding) is also very different for trial 1 versus trial 2 (Figure 2), with aphid density reaching its peak 5 weeks after planting in trial 1, but not until 8 weeks after planting in trial 2. Aphid densities started out higher in trial 2 versus trial 1. However, when trials were considered together, there was no significant treatment effect on overall aphid density recovered ($P=0.6480$).

Trial 1. According to mixed model analysis for trial 1 aphid density, there was no significant treatment effect on overall aphid density recovered ($P=0.1274$). No treatments were found to be statistically different in number of aphids/week from the untreated control, though some statistical differences were seen among treatments (Figure 3). Block 4 had statistically higher aphid density compared to blocks 1 and 2. There was also a significant effect of crop age on overall aphid density in trial 1 ($P<0.0001$), with aphid density generally increasing until five weeks after seeding, and then declining gradually until about 9 weeks after seeding as fruit mature and vegetative growth declines, and leveling off at/near fruit maturity (Figure 2).

Trial 2. According to mixed model analysis for trial 2 aphid density, there was a significant treatment effect on overall aphid density recovered ($P=0.0371$). Three treatments were found to be statistically lower in number of aphids/week (in descending order: IRF161, 17.8 ± 2.11SE aphids / card / week; Hot Pepper Wax, 17.72 17.8± 2.26SE aphids / card / week; IRF160, 16.84 ± 1.91SE aphids / card / week) compared to the untreated control (21.56 ± 2.75 aphids / card / week) (Figure 3). Block 4 had statistically higher aphid density compared to all other blocks. There was also a significant effect of crop age on overall aphid density in trial 2 ($P<0.0001$), with aphid density generally remaining equal and then increasing at eight weeks after seeding, and then declining sharply as fruit develop and vegetative growth declines.

Virus incidence

Trial 1. Virus incidence was overall very low for trial 1, with an average of only 2.81 ± 0.94 single shoots showing mosaic virus symptomology per plot. Additionally, virus symptoms were almost exclusively found in the northeast edges of the field, and within the plots located in this section of the field virus was located only on shoots from plants located at the very ends of the affected plots. Thus, virus distribution in trial 1 was low, unevenly distributed throughout the field, and unevenly distributed within plots where it was found (clumped). According to mixed model analysis for trial 1 virus incidence, there was no significant treatment effect for number of shoots showing mosaic virus symptoms per plot (P=0.7243).

Trial 2. Virus incidence was overall very high for trial 2, with an average of 32.04 ± 0.013SE percent of shoots showing mosaic virus symptomology for the entire field (number of symptomatic shoots/total number of shoots counted within 4 transects per plot). According to mixed model analysis for trial 2 virus incidence, there was a significant treatment effect for percent of shoots showing mosaic virus symptoms (P<0.0001). Nine treatments were found to be statistically lower in percent of shoots affected (in descending order, Sporatec, ORSAPA, Garlic Barrier, MBI203, Hot Pepper Wax, IRF161, ORSA076, IRF160, and Joshua, ranging from a mean of 31.57 ± 3.12SE % affected for Sporatec to a mean of 20.18 ± 3.58SE % affected for Joshua; for other mean/standard error values, see Table 6) (Figure 5). All of the treatments showing significantly lower aphid densities for trial 2 compared to untreated were also found to have significantly lower virus incidence ratings compared to untreated. Block 4 had statistically higher virus incidence compared to all other blocks.

Yield, Fruit Quality, Phytotoxicity

Yield was significantly higher in trial 1 compared to trial 2 (Trial 1 average of 10,019 ± 310SE melons/acre, Trial 2 average of 2,825 ± 96 melons/acre), with 84.5% of variation observed contributed to trial differences . There was no significant treatment effect for total number of fruit harvested in either trial 1 or trial 2 when considered separately (P=0.8108, P=0.9059).

Fruit were significantly larger in trial 1 compared to trial 2. All of the fruit harvested from trial two were between >5-5.5 and >5.5-6 inches in diameter (two smallest size distribution classifications). Neither trial showed any significant treatment effect for number of fruit with sizes falling within these two smallest categories (>5-5.5” diameter, >5.5-6” diameter), and trial 1 did not show any significant

treatment effect for the next largest category either (>6-6.5” diameter). In trial 1, the two largest size categories (>6.5-7” diameter and >7” diameter) showed mean separation and letter differences, though a significant treatment effect was only found in size category >6.5-7” diameter (P=0.0378). Here, two treatments (in descending order: Surround, 8.75 melons; Joshua, 8.00 melons) were found to have a significantly lower number of fruit within this category compared to untreated control (Table 7).

Trial 1 Brix soluble sugar content showed no significant treatment effect (P=0.1577). Brix soluble sugar content measurements were not taken for trial 2, as root rot vine collapse prevented the fruit from ripening properly.

Discussion

The most noticeable effect of reflective particle film applications was on aphid density and virus incidence observed in trial 2. When plants were left untreated, generally more aphids were recovered, and percentage of shoots showing mosaic virus symptoms was generally higher within these plots. IRF161, Hot Pepper Wax, and IRF160 (in descending order) showed significantly lower average aphid density compared to the untreated. Treatments including Sporatec, ORSAPA, Garlic Barrier, MBI203, Hot Pepper Wax, IRF161, ORSA076, IRF160, and Joshua (in descending order) showed significantly lower virus incidence. Trial 2 represented a late season melon planting. Overall aphid pressure was much higher for trial 2 compared to that of trial 1, and virus population pressure was also much higher. Significant block effects were observed especially in block 4, which showed significantly higher aphid density, and significantly higher virus incidence ratings compared to all other blocks. Block 4 was located on the most eastern side of the trial 2 planting, surrounded by older melon fields on two sides.. These significant effects in trial 2 suggest that under situations where high aphid and virus pressure are expected, treatments stated above may reduce the aphid and subsequent virus presence within a field, preventing some potential losses associated with high mosaic virus infection. Such losses were seen in trial 2 yield data, with both number of fruit and size distribution of fruit smaller in this late planting compared to trial 1 yield and size distributions. Other factors likely contributing to this extremely reduced yield in trial 2 include a slightly more dense planting structure, as well as the environmental factors associated with a late season planting such as temperature.

Alternatively, trial 1, planted mid-season, showed lower overall aphid density and almost no virus incidence. Virus that was observed showed a strong edge effect, found almost exclusively on the northeast corner edges of the field, and also only on the very ends within plots. Overall, virus pressure was not evenly distributed across treatments or across the field area, therefore it was expected that no significant treatment effect on virus incidence was found compared to untreated. Low aphid density also resulted in no significant treatment effect on aphid density, with no treatments showing significantly different aphid densities recovered compared to untreated. This suggests that when aphid and virus pressure are expected to be low, any introduction of virus into the field is driven by an edge-effect mediated random introduction from whatever more distant source of virus infection is present in the production area. Thus, under these conditions, treatments are obviously not needed. Treatments did not show a significant effect on soluble sugar content (Brix), and a significant difference in number of fruit per size category was only found for the two largest size categories.

Attempted aphid dissuasion and corresponding virus reduction was generally more successful using repellent/antifeedant property materials (Treatments 3-12) compared to reflective particle film materials (Treatment 2) when comparing both groups to untreated. The reflective particle film material included in the trial as representative for the group did not show significant aphid density or virus reduction compared to the untreated in Trial 2 (the only trial that showed any significant differences in either group), whereas some repellent/antifeedant property materials did show significant reduction of aphid density and/or virus reduction.

Patterns of average aphid densities across the various weeks after crop planting also varied between trial 1 and trial 2, with crop age showing a significant effect on aphid density for both trials. Trial 1 was planted during a period of time when there were multiple highly vegetative ‘choices’ for alate aphids to select as hosts, and it was also planted after many of the spring aphid flights had already occurred. When trial 2 was planted, it was locally the youngest and most freshly vegetative host in the local area until rains in mid October instigated weed germination, and therefore it was a more opportune host selection for alate aphids. These factors likely contributed to the overall mean number of aphids in each trial. Treatment protection duration for each of the products tested was assumed to be approximately 1 week, and thus the crop was ‘protected’ through 7 weeks after seeding, at which point the fifth and final treatment application had occurred one week prior. In Trial 2, aphid density is fairly even during this protection period, and then spikes after this protection period is complete, and sharply

decreases as vegetative growth declined. Contributions to this vegetative growth decline in trial 2 include both fruit development and vine collapse due to fungal root rot after the first season's rain. The sharp increase in aphid density following the protection period suggest that protection duration is in fact only approximately 1 week for treatment products, though studies involving the same product at different treatment intervals are needed to refine information regarding treatment protection duration of individual products specifically. Aphid densities were at their highest five weeks after seeding for trial 1, and continued in a gradual decrease through the interchange between 7 and 8 weeks after seeding, therefore a treatment duration effect was not seen.

Conclusion

Under field conditions where aphid density and virus pressure is expected to be high, there were differences in aphid density and also in subsequent virus incidence in plants treated with repellent/antifeedant materials. This may translate into an economic benefit to the commercial melon growing, as under these conditions, the cost of these applications may also be shown to offset the losses due to viruses that would occur potentially at a more severe level in their absence. Under field conditions where aphid density and virus presence is expected to be low, no treatment effect was seen, though also under these conditions the cost of applications may not be shown to offset the lower level of losses due to virus.

Table 1. Treatment materials for an investigation into the attempt of aphid vector reduction through antifeedant or repellent property materials, and the effects of these products on aphid density and the resulting incidence of nonpersistently-transmitted mosaic viruses.

Treatment number	Treatment name	Active component	Rate	Interval	Company
1	untreated	n/a	n/a	n/a	n/a
2	Surround	kaolin clay	25 lbs/acre	7 days	BASF
3	Sporatec	rosemary/clove /thyme oils	3 pts/100 gal	7 days	Brandt-Montgomery
4	Cedar oil	cedar oil	500 ppm	7 days	NaturesChem
5	MBI203	antifeedant bacteria	1 lb/acre	7 days	Marrone Bioinnovations
6	IRF161	amino acid derivative	3 pts/100 gal	7 days	Isagro USA
7	Garlic Barrier	garlic oil	2 gal/100 gal	7 days	Garlic Barrier Inc.
8	ORSAPA	citrus oil	3 pts/100 gal	7 days	OroAgri
9	IRF160	amino acid derivative	3 pts/100 gal	7 days	Isagro USA
10	Joshua	cinnamon/yucca oils	600 ppm	7 days	NaturesChem
11	Hot Pepper Wax	capsaicin	1 gal/16 gal	7 days	Hot Pepper Wax Inc.
12	ORSA076	citrus oil	2 pts/100 gal	7 days	OroAgri

Table 2: Application information for all treatments.

Application number	Crop age (from planting)	Spray method	Carrying volume (gal/acre)
1	2 wks	CO2	30
2	3 wks	CO2	50
3	4 wks	Air-blast	70
4	5 wks	Air-blast	100
5	6 wks	Air-blast	100

Figure 1. Mean overall aphid density (# alate aphids/card) for all weeks for trial 1 and trial 2. Letters represent Least Squares Mean separation by Student's t test. True averages are shown, with bars representing standard error.

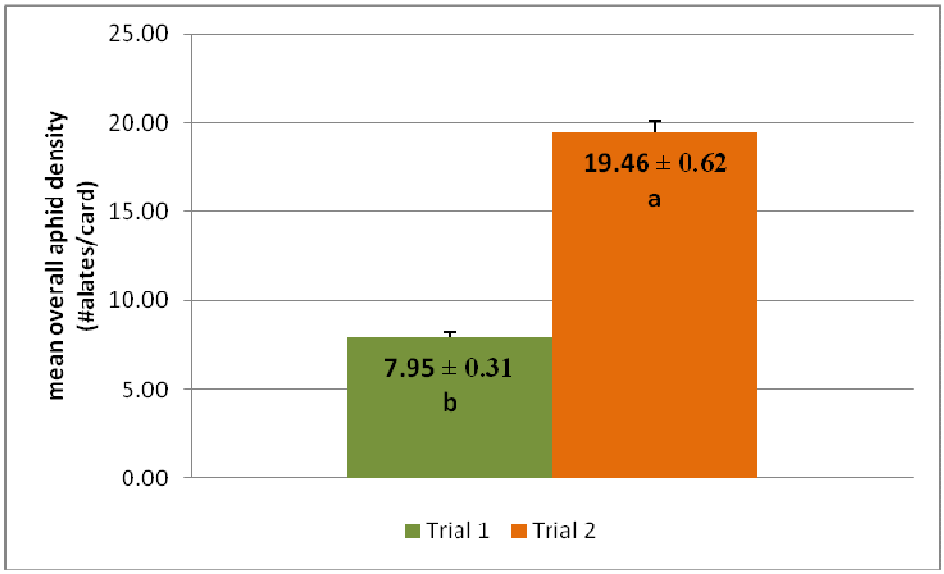
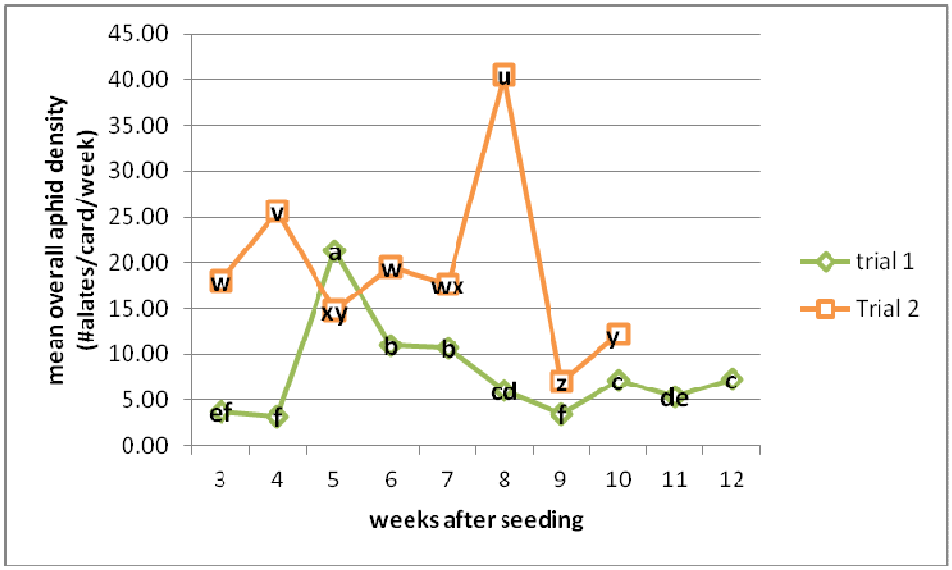


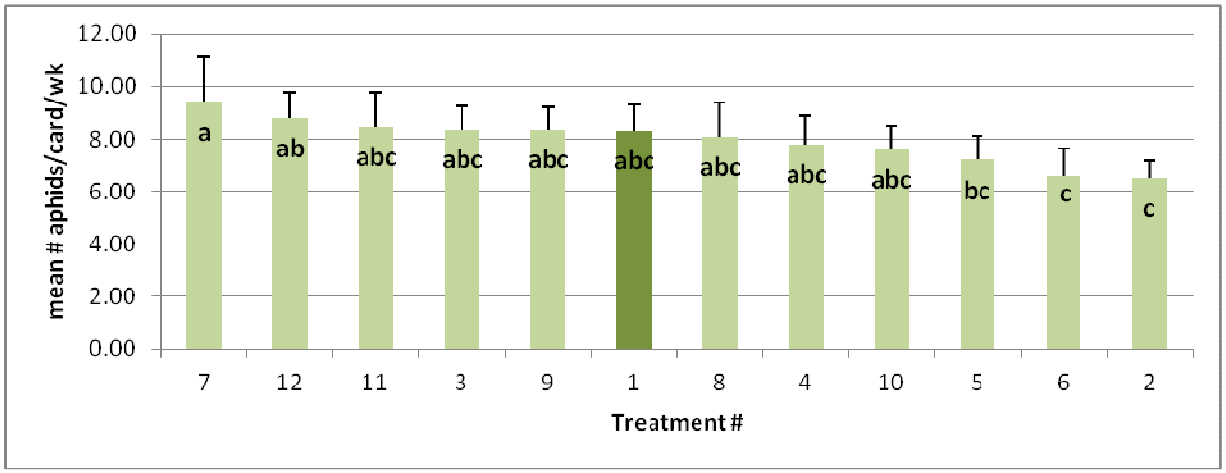
Figure 2. Mean overall aphid density (#alates/card/week) for trial 1 and trial 2 over crop age (weeks after seeding). Values for means and standard errors of each point can be seen in Table 3 below. Letters represent Least Squares Mean separation by Student's t test.



Weeks after seeding	3	4	5	6	7	8	9	10	11	12
Trial 1										
mean	3.71	3.25	21.31	10.94	10.75	6.10	3.54	7.16	5.42	7.27
stderr	0.34	0.32	1.52	0.60	0.67	0.37	0.31	0.49	0.47	0.50
Letter separation	ef	f	a	b	b	cd	f	c	de	c
Trial 2										
Mean	18.02	25.71	14.81	19.60	17.69	40.54	7.04	12.27	.	.
Stderr	0.80	1.11	0.91	1.25	1.02	1.99	0.44	0.66	.	.
Letter separation	w	v	xy	w	wx	u	z	y	.	.

Table 3: Data for table 2, including mean, standard error, and letter separation for trial 1 and trial 2 across all treatments over crop age. Means not connected by letter are statistically different. Trial 2 aphid data was not collected for 11 and 12 weeks after seeding.

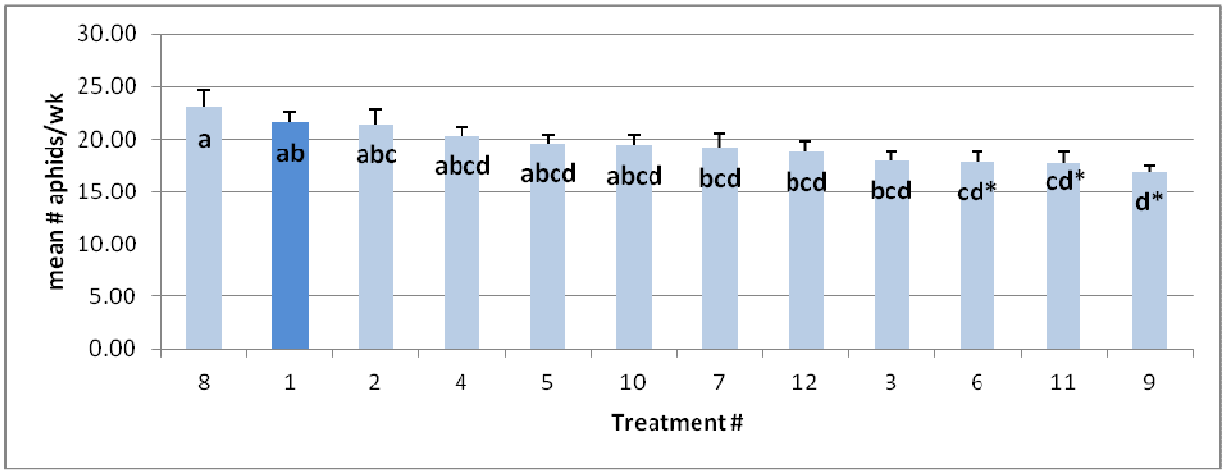
Figure 3: Trial 1 mean number of aphids/card/week for all treatments. Treatments are ordered from highest to lowest average aphid density, with untreated control designated as treatment 1. Values for means and standard errors can be found in Table 4 below. Letters represent Least Squares Mean separation by Student's t test.



Treatment #	Letters difference			Least Sq Mean	Std Err
7	A			9.40	1.69
12	A	B		8.80	0.99
11	A	B	C	8.45	1.32
3	A	B	C	8.38	0.86
9	A	B	C	8.38	0.85
1	**A**	**B**	**C**	**8.33**	**0.99**
8	A	B	C	8.08	1.32
4	A	B	C	7.80	1.09
10	A	B	C	7.63	0.86
5		B	C	7.20	0.94
6			C	6.60	1.05
2			C	6.53	0.65

Table 4: Data for Figure 3, including mean, standard error, and letters difference for aphid density across all treatments. Untreated control is treatment 1, in bold. No treatments were found to be significantly different from the untreated. Means not connected by letter are statistically different.

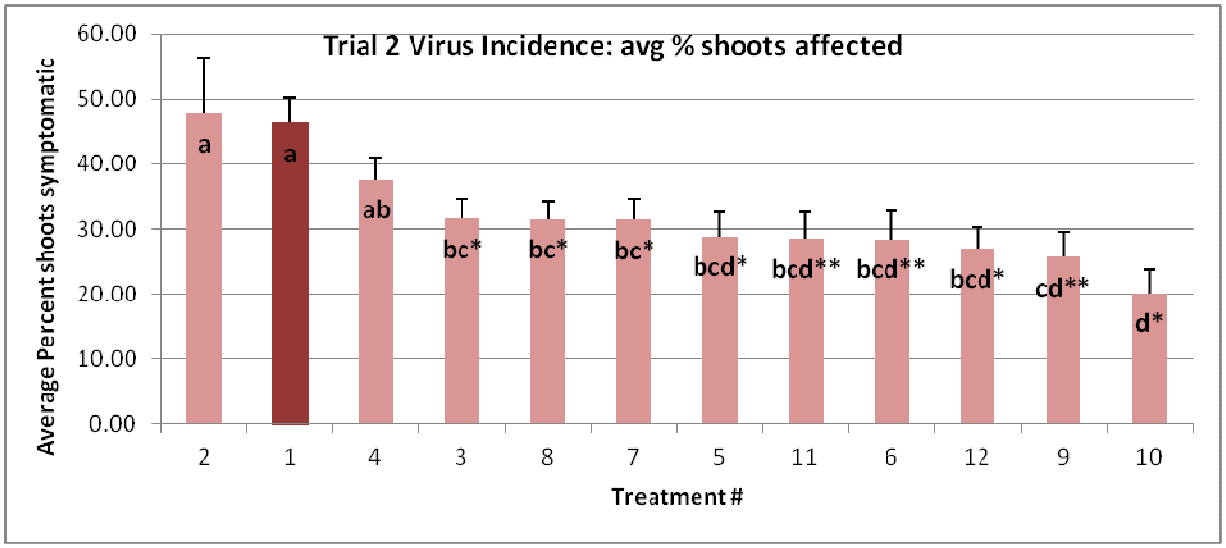
Figure 4: Trial 2 mean number of aphids/card/week for all treatments. Treatments are ordered from highest to lowest average aphid density, with untreated control designated as treatment 1. Values for means and standard errors can be found in Table 5 below. Letters represent Least Squares Mean separation by Student's t test.



Treatment #	Letters difference				Least Sq Mean	Std Err
8	A				23.00	3.19
1	**A**	**B**			**21.56**	**2.75**
2	A	B	C		21.41	2.89
4	A	B	C	D	20.28	2.33
5	A	B	C	D	19.59	2.26
10	A	B	C	D	19.44	2.34
7		B	C	D	19.19	2.81
12		B	C	D	18.75	2.67
3		B	C	D	17.94	2.09
6*			C	D	17.81	2.11
11*			C	D	17.72	2.26
9*				D	16.84	1.91

Table 5: Data for Figure 4, including mean, standard error, and letters difference for aphid density across all treatments. Untreated control is treatment 1, in bold. Treatments found to be significantly different from untreated are designated with an asterisk (*). Means not connected by letter are statistically different.

Figure 5: Average percent of shoots showing mosaic virus symptoms per treatment. Treatments are ordered from highest to lowest average virus infection, with untreated control designated as treatment 1. Values for means and standard errors can be found in Table 6 below. Letters represent Least Squares Mean separation by Student's t test.



Treatment #	Letters difference				Least Sq Mean	True mean %	Std Err
2	A				0.4783	47.83	8.63
1	**A**				**0.4631**	**46.31**	**3.99**
4	A	B			0.3760	37.60	3.37
3*		B	C		0.3157	31.57	3.12
8*		B	C		0.3142	31.42	2.84
7*		B	C		0.3137	31.37	3.32
5*		B	C	D	0.2876	28.76	3.76
11**		B	C	D	0.2851	28.51	3.99
6**		B	C	D	0.2843	28.43	4.25
12*		B	C	D	0.2692	26.92	3.28
9**			C	D	0.2562	25.62	3.83
10*				D	0.2018	20.18	3.59

Table 6: Data for Figure 5, including mean, standard error, and letters difference for virus incidence across all treatments. Untreated control is treatment 1, in bold. Treatments found to be significantly different from untreated for virus incidence only are designated with an asterisk (*), those found to be significantly different from untreated for both virus incidence and aphid density are designate with two asterisks (**). Means not connected by letter are statistically different.

Table 7: Trial 1Average number of fruit found within the two largest size distribution categories, across treatment. Least squared means are shown, along with Student's t test letter differences. Untreated control is designated as treatment # 1 and is in bold. Treatments that showed on average significantly less fruit in these large size categories compared to untreated are designated with an asterisks (*).Means not connected by letter are statistically different. All other size distribution categories showed no statistical differences for both trial 1 and trial 2.

>6.5-7 inches diameter							> 7 inches diameter					
Treatment #	**Letters Difference**					**Least Sq Mean**	**Treatment #**	**Letters Difference**				**Least Sq Mean**
11	A					17.5	4	A				7.25
4	A	B				17	6	A	B			7
9	A	B				16.5	**1**	**A**	**B**			**6**
3	A	B	C			15.25	11	A	B	C		5.5
1	**A**	**B**	**C**	**D**		**15**	7	A	B	C		4.75
6	A	B	C	D	E	12.25	3	A	B	C		4.25
7	A	B	C	D	E	12	12	A	B	C		4
5	A	B	C	D	E	11.75	5	A	B	C		4
12		B	C	D	E	11	9	A	B	C		3.5
8			C	D	E	9	2	A	B	C		3
2				D	E	8.75	10		B	C		2.5
10*					E	8	8*			C		1.25