Cooperative Extension • Monterey County

Crop Notes

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WEED CONTROL IN CARROT FAMILY CROPS

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The Apiaceae or carrot family includes important vegetable crops such as carrots, celery, cilantro, dill, fennel and parsley. All of these crops have a distinctive inflorescence known as an umbel. They also produce aromatic oils that give these plants their characteristic aromas and flavors. Many of these crops germinate slowly and are quite susceptible to weed pressure early in the production cycle. As a result, crops like celery are nearly 100% transplanted to give the crop a head start in the production cycle and on the weeds. However, other crops in this family such as carrots, cilantro and parsley are direct seeded in dense stands on 40 or 80 inch wide beds; dense plantings limits the use of mechanical cultivation for weed control, thereby increasing the need for other weed control strategies. Cultural practices can provide significant weed control; practices such as careful field selection and rotations, as well as pre-irrigation followed by cultivation can significantly reduce weed pressure in production fields. Carrot, cilantro and parsley seed germinate slowly which creates an opportunity to burn off an initial flush of weeds (with an herbicide or propane flaming) following planting but prior to the emergence of the crop. This is a tricky, but effective technique for reducing weed density. Starting with low weed pressure in the production field is exceedingly helpful in reducing subsequent hand weeding costs no matter the weed control strategies that are employed.

Chemical weed control is particularly critical for crops such as carrots and cilantro which are highly susceptible to weed pressure and exceedingly expensive to hand weed because high-density plantings makes weeds difficult to see and makes removal disruptive to the crop stand (Photo 1). Crops such as cilantro and parsley that are commonly mechanically harvested need excellent weed control to produce a salable product. For the larger acreage crops in this group such as carrots and celery, there are a number of materials registered such as linuron, prometryn, S-metolachlor, pendimethalin (carrots), bensulide (celery), trifluralin, as well as grass herbicides such as clethodim and sethoxydim (Table 1). However, for the lower acreage crops in this group, the availability of registered herbicides has been an issue and growers have struggled controlling weeds in these crops for a number of years. Prometryn and linuron were recently registered for use on cilantro; prometryn has been registered on parsley for a number of years, but linuron is a relatively new registration for this crop. Both of these materials have increased the spectrum of weeds controlled in cilantro and parsley which has reduced weeding times in fields infested with weeds not controlled by other materials such as hairy nightshade (Table 2). Currently, both materials have a 12-month plant back to lettuce and spinach, which presents an obstacle to their use in the Salinas Valley where these are common rotational crops.

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In general, carrot family crops respond similarly to linuron and prometryn. Both material are in different chemical families (linuron, substituted urea and prometryn, triazone), but are both photosystem II inhibitors. However, in trials conducted over the past few years, we have noticed that some of the carrot family crops respond differently to these herbicides. For instance, linuron is exceedingly safe for use on carrots preemergence and post emergence. Prometryn is also safe for preemergence use on carrots; at higher post emergence rates we have noticed yellowing of the carrot foliage, but no difference in yield was observed between preemergence and post emergence applications of prometryn. In cilantro and parsley, preemergence applications of both linuron and prometryn are safer than post emergence applications. Fennel showed the most dramatic difference in response between linuron and prometryn. In a screening trial evaluating linuron and prometryn on fennel the post emergence application of prometryn was very safe on the crop, but linuron reduced the growth of this crop at the rates used in the trial. Linuron is not yet registered on fennel, but it is clear that we will need to evaluate lower rates on this crop for post emergence use.

Gratefully, the list of weed control options for carrot family crops has increased. Carrot family crops are a unique and challenging group in which to manage weeds. Slow initial growth and high density plantings increases the challenge of controlling weeds. However, with an integrated approach of cultural, mechanical and chemical weed control options good weed control can be achieved on this important group of crops.

Crops such as cilantro and parsley that are commonly mechanically harvested need excellent weed control to produce a salable product.

Table 1. Partial list of registered herbicides on carrot family crops in California

Crop	linuron	prometryn	bensulide	*S*-metolachlor	clethodim	sethoxydim
Carrots	Yes	Yes	No	Yes	Yes	Yes
Celery	Yes	Yes	Yes	Yes	Yes	Yes
Cilantro	Yes	Yes	No	No	Yes	Yes
Dill	Yes	Yes	No	No	Yes	No
Fennel	No	Yes	Yes	No	Yes	Yes
Parsley	Yes	Yes	Yes	No	Yes	Yes

Prometryn and linuron were recently registered for use on cilantro; prometryn has been registered on parsley for a number of years, but linuron is a relatively new registration for this crop.

Photo 1. Weeds in cilantro

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Table 2. 2013 Parsley weed trial, San Juan Bautista

Material	Lbs a.i./A	Material/A	Application	Phyto[1]	Weeds[2] No./ $meter^2$	Weed time hr/A	Yield Tons/A
prometryn	1.5	3 pints	Preemergence	0.0	2.7	24.1	11.62
prometryn	1.0	2 pints	Post emergence	4.3	0.2	5.6	9.13
linuron	0.75	1.5 lbs	Preemergence	0.0	7.9	47.8	12.75
linuron	1.5	3.0 lbs	Preemergence	0.0	1.9	19.4	11.31
linuron	0.5	1.0 lbs	Post emergence	1.3	0.6	8.7	9.76
bensulide	4.0	4 qt	Preemergence	0.0	9.0	46.6	10.48
Untreated	---	---	---	0.0	11.1	63.5	12.15
LSD (0.05)				0.52	ns	35.7	3.13

1 – scale: 0 = no crop damage to 10 crop dead; 2 – weeds at this site included purslane, malva, lambsquarter and hairy nightshade

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MANAGEMENT OF THRIPS ON VEGETABLE CROPS IN THE SALINAS VALLEY

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Western flower thrips [*Frankliniella occidentalis* (Fig. 1)] is the most destructive species of thrips that attack several vegetable crops in the Salinas Valley. They can cause severe feeding injury to all stages of crop plants. If severe feeding occurs in the early stages of the crop, plants may appear stunted and it affects their normal development. On the other hand, if they attack plants late in their development, they cause scarring and brown streaks on the produce. In both instances, thrips feeding affects marketable yield. Western flower thrips can transmit plant viruses such as *Impatiens Necrotic Spot Virus* (INSV) and *Tomato Spotted Wilt Virus* (TSWV). This year (2015), INSV and TSWV damage already reported on vegetable crops such as lettuce in the Salinas Valley (personal communication with Steve Koike). In addition to direct feeding injury and viral damage, mere presence of dead or live thrips has resulted in rejections of shipments in certain export and domestic markets.

The mouthpart of thrips is often referred as "piercing-sucking". Feeding apparatus of thrips called mouthcone involve two primary structures used for feeding. One is the mandible and the second one is a tube formed of stylets or needles (Fig. 2). Thrips uses the mandible to pierce or punch the plant cell wall and then uses the stylets to suck the liquid food. It uses mouthcone to feed on liquid food on the surface and within the plant cell. Thrips injury on lettuce may appear as brown streaks or scarring on the leaves (Fig. 3). If examined closely using a magnifying glass, injured cells appear punctured with no content remaining (Figs. 4 and 5). On celery, the thrips feeding injury is similar as in lettuce but the injured cells appear as raised or ridged (Fig. 6). Thrips can attack young plants right at the cotyledon stage, colonize and feed on the growing tips (Fig. 7), which later results in deformed true leaves (Fig. 8). Also, silvering on the leaves is a common thrips feeding symptom (Fig. 9).

To prevent direct feeding injury and viral transmission on plants, it is important that we

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manage thrips on the growing crops and keep the populations down. Insecticides such as Radiant, Entrust, Lannate, and generics of abamectins are widely used to prevent colonization of thrips on the plants. It is likely that thrips populations develop resistance to insecticide(s) when insecticides that fall under same IRAC class (http://www.irac-online.org/documents/moa-classification/?ext=pdf) are used back-to-back. Recently, two insecticide trials were conducted in 2013 and 2014 to examine efficacy of newer insecticides (some unregistered products) as possible tools for thrips management.

Methods

Both the trials were conducted in leafy lettuce in Gonzales, CA. Four replicates of each treatment were assigned to plots according to a completely randomized block design. The trials were initiated after 28-30 days (immediately after thinning). Insecticides were applied two times at 7-d interval. An adjuvant was added at 0.25% v/v to all the insecticide treatments. The details on insecticide products, rates and application dates are shown in Tables 1 and 3. Ten lettuce plant samples were randomly collected from each plot at three and seven days after each application and number of thrips were quantified.

Results

Trial 1: 2013

After three days of first application, number of adult thrips was less in Radiant, Entrust, and Gladiator treatments than in Movento + Requiem and untreated check (Table 1). The rest of the treatments were not significantly different from the untreated check treatment. Four days later (seven days after application), number of adult thrips was significantly lower in Exirel, Gladiator, and Lannate treatments than in untreated check or Requiem treatment. Radiant and Entrust treatments continued to suppress adults compared with Requiem treatment. On August 23 (three days following the second application), number of thrips was not different among treatments. However, three days later (seven days after second application), all the insecticide treatments, except Requiem suppressed adult thrips compared with untreated check. The lowest number of thrips was found in Radiant treatment than in untreated check, although number of thrips in Radiant treatment was not significantly different from Entrust, Lannate, Torac, Torac + Movento or Gladiator treatments.

On August 12 (three days after first application), number of thrips larvae was significantly lesser in Movento + Requiem, Exirel, Radiant, Entrust, Lannate, Torac + Movento and Gladiator treatments (Table 2). Between Requiem and untreated check treatments, there was no difference in number of larvae. The trend was similar four days later (seven days after first application) too. No statistical difference in number of larvae was detected among treatments after three days of second insecticide application. On the sample collected after seven days of second application, all the treatments, except Gladiator and Requiem had significantly lesser number of larvae than in untreated check. The thrips numbers (both adults and larvae) were unusually low and inconsistent in the sample collected after three days of second application. However, the exact reason is uncertain.

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Trial 2: 2014

Adult thrips were similar in number in the precount sample (Table 3). Three days after first application, number of adult thrips was significantly lower in Exirel, Radiant, Lannate, Torac, Torac + Movento, and Gladiator treatments than Beleaf. Similarly, all treatments except Gladiator, and Beleaf suppressed adult thrips compared with untreated check at seven days after first application. Three days after second application, all the insecticide treatments showed significant suppression relative to untreated check. Four days later, there was no significant difference among treatments.

Pre-counts of thrips larvae suggest that the number of larvae were not similar among treatments in the beginning of the study (Table 4). Three and seven days after first application, the number of thrips larvae remained not different among treatments. Three days after second application, number of larvae was significantly lower in the Gladiator than the untreated check. After seven days of second application, number of thrips larvae was significantly lower in all insecticide treatments compared with untreated check.

Summary

Based on two years of study, data suggest that efficacy of newer products, Torac, Exirel and Gladiator were comparable to industry standards, Radiant, Entrust and Lannate. In 2013 trial, Requiem did not show any activity against thrips but it needs further study. On thrips larvae, although most of the insecticides except Requiem provided reasonable suppression, the lowest number of larvae was collected from Lannate treatment especially after three and seven days of first application. In 2014, it is noteworthy that none of the products provided thrips suppression for longer period (~three weeks) possibly new populations of thrips constantly moved to lettuce field by wind dispersal or disturbance such as crop harvest in the surrounding fields.

With high pressure of thrips in the Salinas Valley early this year (2015), newer chemistries, Exirel and Beleaf can be used and rotated with Radiant, Entrust and Lannate for insecticide resistant management. Gladiator and Torac are not registered yet for thrips management but will be additional tools when available.

Acknowledgements

I appreciate the technical assistance provided by J. Martinez, J. Zarate, R. Ahedo, S. Just, S. Cosseboom, and C. Bettiga for technical assistance. I thank the grower, pest control adviser, farm manager for providing the field and plant materials for the research, and CA Leafy Greens Research Program and Agro-Chemical companies for providing funding for these projects.

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Table 1. Trial 1 (2013): Number of adult thrips on leafy lettuce treated with various insecticide treatments.

Treatment	Active ingredient	Amt formulated/ acre	Days after first insecticide application		Days after second insecticide application	
			3 (Aug. 12)	7 (Aug. 16)	3 (Aug. 23)	7 (Aug. 30)
Movento	Spirotetramat	5 floz	41.5 ± 8.6bc	37.3 ± 9.3ab	23.3 ± 5.5a	34.0 ± 5.4bc
Movento + Requiem	Spirotetramat + **Chenopodium* extract	5 floz + 2 qt	80.3 ± 14.1a	27.0 ± 4.9b-d	3.0 ± 0.0a	29.3 ± 6.3b-d
Requiem	**Chenopodium* extract	4 qt	50.5 ± 16.4bc	41.8 ± 5.1a	27.0 ± 0.0a	43.0 ± 6.1ab
Beleaf	Flonicamid	2.8 oz	41.8 ± 10.5bc	21.3 ± 2.3c-e	8.0 ± 0.0a	26.3 ± 3.7cd
Exirel	Cyantraniliprole	20.5 floz	46.3 ± 5.2bc	11.3 ± 2.6e	23.6 ± 6.7a	37.3 ± 6.9bc
Radiant	Spinetoram	8 floz	25.8 ± 4.8c	16.3 ± 3.7c-e	13.5 ± 1.2a	10.3 ± 0.3e
Entrust	Spinosad	8 floz	28.5 ± 7.9c	17.0 ± 4.5c-e	17.0 ± 0.0a	24.3 ± 4.9c-e
Lannate	Methomyl	3 pint	38.0 ± 12.2bc	13.8 ± 4.7de	13.5 ± 0.5a	16.3 ± 4.6de
Torac	Tolfenpyrad	21 floz	35.8 ± 8.9bc	24.3 ± 3.8b-e	14.0 ± 9.0a	25.0 ± 2.2c-e
Torac + Movento	Tolfenpyrad+ Spirotetramat	3 + 5 floz	51.0 ± 14.3bc	26.8 ± 5.8b-d	19.0 ± 6.0a	22.3 ± 5.3c-e
Gladiator	Zeta-cypermethrin and Avermectin B1	19 floz	23.0 ± 8.6c	13.0 ± 3.7e	15.0 ± 0.0a	25.8 ± 7.1cd
	UTC	Water	58.8 ± 10.4ab	28.8 ± 4.9a-c	17.3 ± 5.8a	54.0 ± 10.3a

Received two applications on 9 and 21 August 2013. Means within columns followed by the same letter are not significantly different according to ANOVA and LSD test at α = 0.05. *Extract of *Chenopodium ambrosioides* near *ambrosioides*.

Table 2. Trial 1 (2013): Number of thrips larvae on leafy lettuce treated with various insecticide treatments.

Treatments	Active ingredient	Amt formulated/ acre	Days after first insecticide application (date)		Days after second insecticide application (date)	
			3 (Aug. 12)	7 (Aug. 16)	3 (Aug. 23)	7 (Aug. 30)
Movento	Spirotetramat	5 floz	66.0 ± 14.8a-c	46.8 ± 9.9bc	12.6 ± 5.3a	18.5 ± 6.4cd
Movento + Requiem	Spirotetramat + **Chenopodium* extract	5 floz + 2 qt	31.3 ± 8.4c	29.3 ± 2.8cd	11.0 ± 0.0a	12.0 ± 2.7d
Requiem	**Chenopodium* extract	4 qt	119.5 ± 64.8a	82.8 ± 20.5a	22.0 ± 0.0a	38.7 ± 3.3ab
Beleaf	Flonicamid	2.8 oz	50.0 ± 8.5bc	40.8 ± 3.9b-d	8.0 ± 0.0a	17.7 ± 7.8cd
Exirel	Cyantraniliprole	20.5 floz	27.8 ± 11.8c	32.5 ± 7.2cd	9.0 ± 1.5a	14.5 ± 4.6cd
Radiant	Spinetoram	8 floz	19.0 ± 7.5c	27.3 ± 4.0cd	11.5 ± 2.9a	20.3 ± 1.9b-d
Entrust	Spinosad	8 floz	17.3 ± 2.1c	21.5 ± 3.4cd	12.0 ± 0.0a	25.3 ± 5.7a-d
Lannate	Methomyl	3 pint	9.8 ± 5.5c	14.8 ± 3.0d	7.0 ± 3.0a	13.3 ± 5.4cd
Torac	Tolfenpyrad	21 floz	47.3 ± 14.3bc	42.3 ± 8.5b-d	17.0 ± 5.0a	16.0 ± 3.8cd
Torac + Movento	Tolfenpyrad+ Spirotetramat	3 + 5 floz	43.0 ± 15.2c	34.0 ± 8.6cd	18.5 ± 0.5a	12.0 ± 4.4d
Gladiator	Zeta-cypermethrin and Avermectin B1	19 floz	28.5 ± 18.2c	41.3 ± 9.7b-d	21.0 ± 0.0a	31.5 ± 10.7a-c
	UTC	Water	111.0 ± 37.1ab	67.8 ± 20.1ab	16.6 ± 3.2a	43.0 ± 12.6a

Received two applications on 9 and 21 August 2013. Means within columns followed by the same letter are not significantly different according to ANOVA and LSD test at α = 0.05. *Extract of *Chenopodium ambrosioides* near *ambrosioides*.

Table 3. Trial 2 (2014): Number of adult thrips on leafy lettuce treated with various treatments.

Treatment	Active ingredient	Amt formulated/ acre	Pre-count (21 Jul)	Days after first insecticide application (date)		Days after second insecticide application (date)	
				3 (24 Jul)	7 (28 Jul)	3 (4 Aug)	7 (8 Aug)
Beleaf	flonicamid	2.8 oz	16.5 ± 4.8a	40.0 ± 12.9a	35.3 ± 15.0a	32.3 ± 8.9b	41.5 ± 18.6a
Exirel	cyantraniliprole	20.5 fl oz	26.3 ± 9.1a	11.5 ± 4.4b	8.3 ± 4.4b	10.3 ± 2.7bc	52.0 ± 10.5a
Radiant	spinetoram	8 fl oz	39.3 ± 15.9a	12.5 ± 1.8b	6.8 ± 2.9b	10.8 ± 1.9bc	43.0 ± 12.7a
Lannate	methomyl	3 pint	22.3 ± 7.9a	10.8 ± 1.8b	10.8 ± 4.0b	5.0 ± 0.8c	35.5 ± 7.5a
Torac	tolfenpyrad	21 fl oz	23.0 ± 6.9a	20.5 ± 6.4b	8.8 ± 3.3b	15.8 ± 5.7bc	52.8 ± 5.4a
Torac + Movento	tolfenpyrad + spirotetramat	21 fl oz + 5 fl oz	21.5 ± 8.2a	18.5 ± 3.5b	11.0 ± 4.6b	13.8 ± 8.5bc	55.5 ± 11.3a
Gladiator	zeta-cypermethrin + abamectin	19 fl oz	45.8 ± 9.5a	10.0 ± 3.9b	17.8 ± 8.1ab	14.3 ± 3.3bc	33.8 ± 5.0a
UTC			25.5 ± 4.6a	25.3 ± 6.6ab	31.5 ± 10.7a	89.3 ± 15.3a	38.5 ± 11.8a

Received two applications on 21 and 29 July 2014. Means within columns followed by the same letter are not significantly different according to ANOVA and LSD test at $\alpha < 0.05$.

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Table 4. Trial 2 (2014): Number of thrips larvae on leafy lettuce treated with various treatments.

Treatment	Active ingredient	Amt formulated/ acre	Pre-count (21 Jul)	Days after first insecticide application (date)		Days after second insecticide application (date)	
				3 (24 Jul)	7 (28 Jul)	3 (4 Aug)	7 (8 Aug)
Beleaf	flonicamid	2.8 oz	22.0 ± 3.1bc	18.0 ± 6.2a	17.3 ± 4.5a	37.0 ± 6.3bc	10.3 ± 5.1b
Exirel	cyantraniliprole	20.5 fl oz	28.8 ± 13.8abc	11.5 ± 4.1a	13.8 ± 4.6a	43.0 ± 4.9bc	9.5 ± 4.3b
Radiant	spinetoram	8 fl oz	55.8 ± 22.3a	17.0 ± 8.7a	17.5 ± 4.6a	56.0 ± 7.4ab	5.3 ± 1.5b
Lannate	methomyl	3 pint	12.0 ± 3.4c	9.3 ± 1.3a	17.5 ± 5.6a	64.3 ± 15.1a	2.3 ± 0.9b
Torac	tolfenpyrad	21 fl oz	16.0 ± 3.9c	9.5 ± 2.1a	12.8 ± 3.3a	63.0 ± 6.1a	5.5 ± 1.9b
Torac + Movento	tolfenpyrad + spirotetramat	21 fl oz + 5 fl oz	31.3 ± 9.6abc	20.0 ± 9.4a	22.0 ± 4.6a	43.0 ± 7.4bc	0.8 ± 0.5b
Gladiator	zeta-cypermethrin + abamectin	19 fl oz	55.3 ± 23.9a	13.3 ± 5.1a	10.0 ± 3.0a	27.3 ± 5.5c	5.8 ± 0.8b
UTC			48.5 ± 17.9ab	25.3 ± 10.7a	15.3 ± 1.9a	54.8 ± 3.3ab	23.0 ± 8.4a

Received two applications on 21 and 29 July 2014. Means within columns followed by the same letter are not significantly different according to ANOVA and LSD test at α < 0.05.

Fig. 1: Adult western flower thrips (Photo: D. Riley).

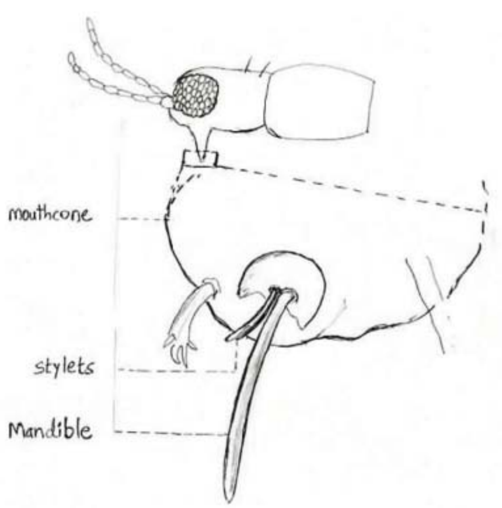

Fig. 2: Mouthpart of thrips (mouthcone) showing structures, a mandible and maxillary stylets used while feeding on plants.

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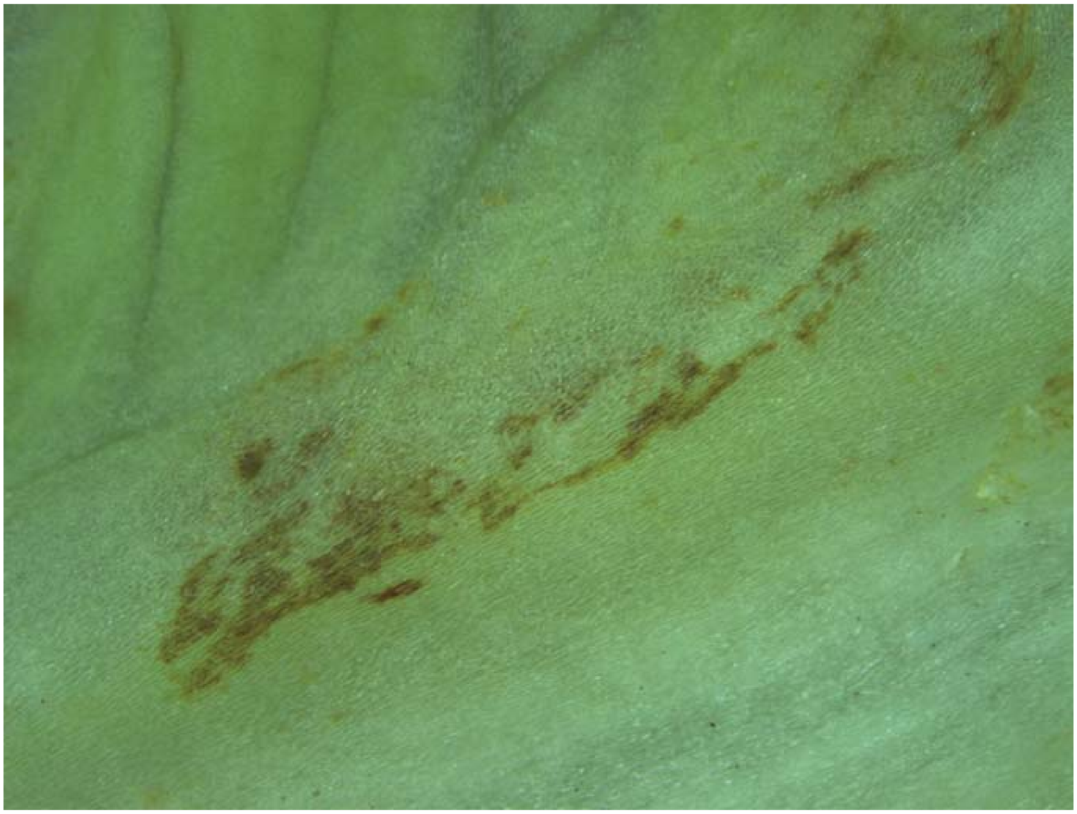

Fig. 3: Thrips feeding injury on lettuce.

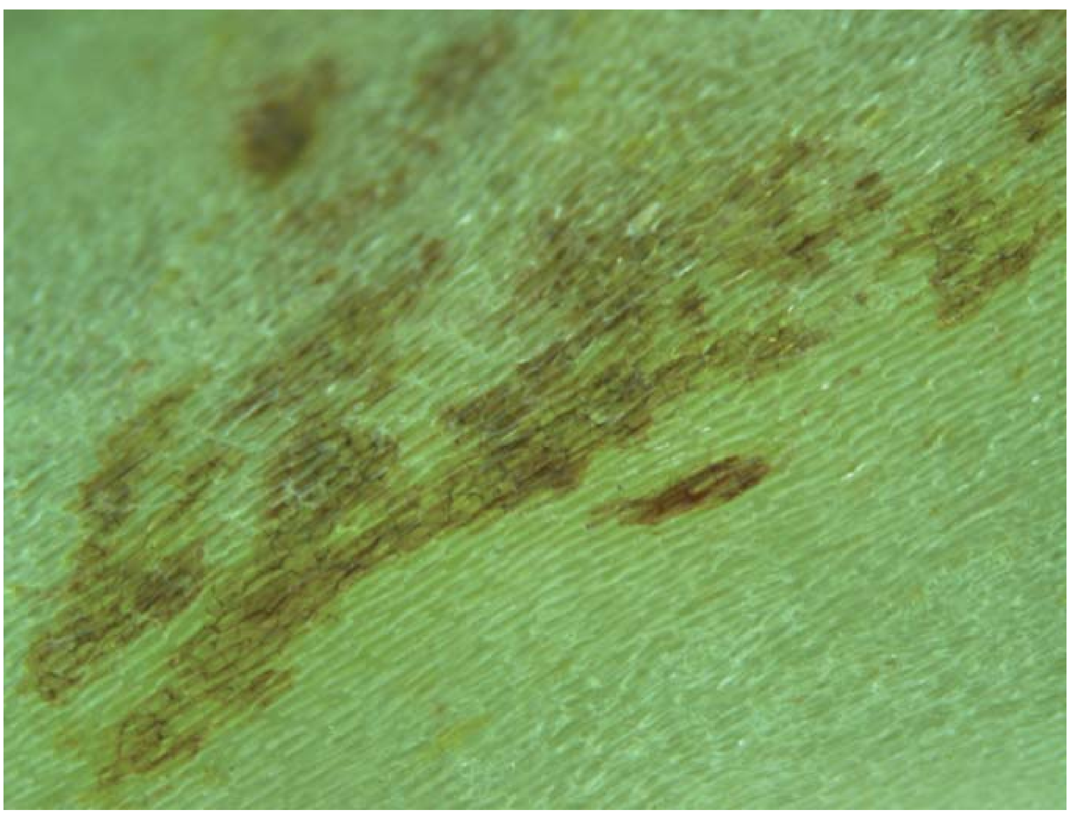

Fig. 4: Thrips feeding injury on lettuce (close-up).

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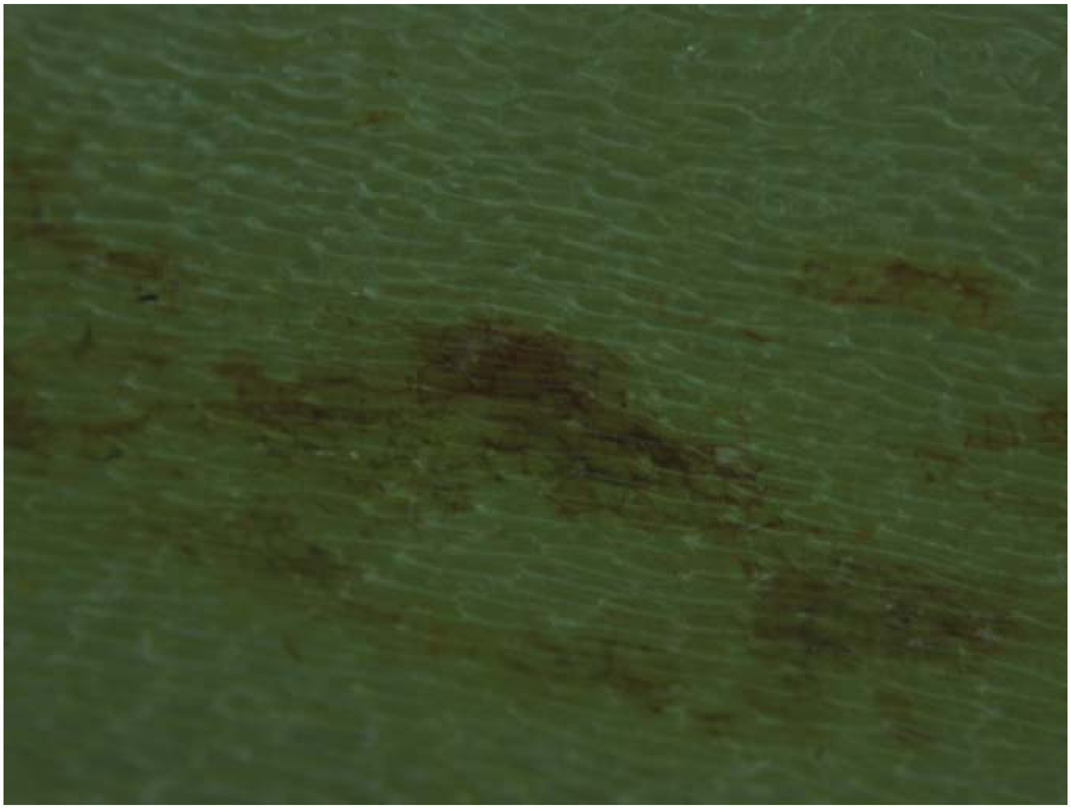

Fig. 5: Thrips feeding injury on lettuce (even closer).

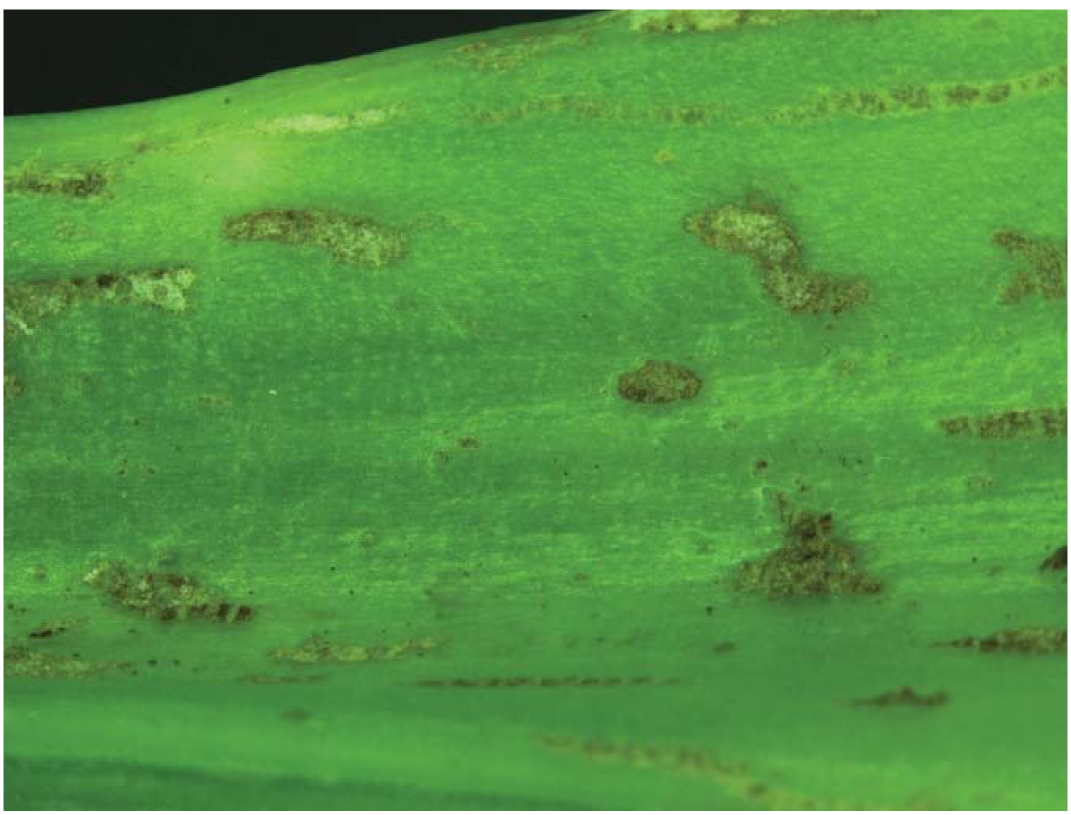

Fig. 6: Thrips feeding injury on celery.

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Fig. 7: Thrips feeding injury on young seeding of Swiss Chard.

Fig. 8: Thrips feeding injury on young seeding of Swiss Chard causing leaf deformation.

VIRUS DISEASES SHOWING UP EARLY ON COASTAL CA LETTUCE

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Virus disease outbreaks have occurred early on coastal lettuce in 2015.

Virus outbreaks: In 2015, beginning as early as March and continuing through April, lettuce crops in the Salinas and other coastal valleys showed symptoms of various virus diseases. Our UCCE diagnostic lab in Salinas has confirmed that several virus pathogens are responsible for these outbreaks. These occurrences are taking place quite early; in a typical season, most of the lettuce virus diseases do not become noticeable until May, June, or even later. These early spring outbreaks are unusual and could indicate that viruses might be important economic factors throughout 2015. Recent weather patterns likely are the driving factors behind these developments. The virtually rainless spring contributed to early drying and senescing of weeds and hillside vegetation; this rapid decline of surrounding vegetation could be forcing insect vector populations into fields earlier than normal. In addition, the relatively mild winter and warm spring temperatures resulted in rapid buildup of insects in the fields. Growers and pest control advisors report that aphid and thrips numbers have been very high this year.

Diagnosing virus diseases: While disease symptoms are presented later in this article, accurate diagnosis based solely on symptoms is not possible for most virus diseases. Experienced field personnel and plant pathologists may have a good idea about which particular virus may be involved; however, to know for sure, clinical tests using serological or molecular methods must be used to pinpoint the virus. Part of the difficulty is that disease symptoms caused by one virus may look similar to the symptoms caused by another virus. Also, symptoms can vary greatly depending on the particular type or cultivar of lettuce infected, age of plant when infected, virus strain, and environmental conditions. The other diagnostic challenge is that symptoms caused by a virus may look like symptoms caused by non-pathological factors such as the following: nutritional deficiencies or toxicities, genetic abnormalities in the plant itself, injury from environmental extremes, and damage from fertilizers or pesticides.

Accurate diagnosis of virus pathogens requires laboratory testing.

Viruses on lettuce: Following are brief descriptions of these 2015 virus outbreaks. Table 1 summarizes these descriptions.

Cucumber mosaic virus (CMV; virus group: cucumovirus): On lettuce, CMV causes a mild discoloration, mottling, or mosaic of leaves. Leaves may appear crinkled or distorted. Foliage color can be gray green. If infected early, plants can be significantly stunted and will not achieve harvestable size (Photos 1 and 2). CMV has a very broad host range and can infect hundreds of other crops and weeds. This virus can be seedborne in some plants (spinach, pepper) but is not known to be seedborne in lettuce. Aphids are the vectors of CMV. In 2015, CMV has been confirmed in a number of lettuce plantings as well as in several spinach and Brussels sprouts fields. Historically, CMV rarely has been confirmed on lettuce in the Salinas Valley, making this a rather novel development.

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Photos 1 and 2: *Cucumber mosaic virus* (CMV) on lettuce.

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Impatiens necrotic spot virus and *Tomato spotted wilt virus* (INSV and TSWV; virus group: tospovirus): Diseased lettuce leaves have tan, brown, or blackish spots and dead sections; this necrotic tissue can closely resemble damage caused by pesticide or fertilizer applications (Photos 3 and 4). Some leaf yellowing can also be observed. Symptoms can be found on both the older, outer leaves as well as on the newer leaves near the center of the plant growing point. If plants are affected early in their development, growth can be stunted. Symptoms caused by INSV and TSWV on lettuce are indistinguishable from each other and both viruses can be found on coastal lettuce in California. INSV and TSWV pathogens are spread by thrips; both pathogens also have very large host ranges. Of the two tospoviruses, INSV is much more common on lettuce in the coastal region and has been frequently detected since 2005.

Photos 3 and 4: *Impatiens necrotic spot virus* (INSV) on lettuce.

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Lettuce mosaic virus (LMV; virus group: potyvirus): Plants that are infected at a young stage are stunted, deformed, and show a mosaic or mottling pattern in some varieties. Such plants rarely grow to full size (Photos 5 and 6). Plants that are infected later in the growth cycle may reach full size but the older outer leaves will be yellow, twisted, or otherwise deformed. On head lettuce the wrapper leaves often will curve back away from the head. Developing heads may be deformed. In some cases brown, necrotic flecks occur on the wrapper leaves and leaf margins may be more serrated ("toothy") than normal. LMV is vectored by aphids and can be found in some weed species growing in the coastal agricultural area. An important aspect of LMV is that it can be seedborne in lettuce. Thus far in 2015 LMV has been found only in one field, and the virus remains rare on lettuce due to the integrated control program in place.

Photos 5 and 6: *Lettuce mosaic virus* (LMV) on lettuce.

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Lettuce necrotic stunt virus and *Tomato bushy stunt virus* (LNSV and TBSV; virus group: tombusvirus): These viruses cause severe stunting of lettuce and the disease is called lettuce dieback. Extensive yellowing will develop on the outermost leaves while younger, inner leaves always remain dark green in color but may become rough and leathery in texture. The chlorotic outer leaves usually develop necrotic (dead, brown) spots that progress into extensive areas of vein-associated necrosis (Photos 7 and 8). Romaine and leaf cultivars are susceptible while iceberg cultivars are symptomless. LNSV and TBSV pathogens have no known vectors and are soilborne pathogens. Therefore, these viruses are only spread via flooding that moves infested soil and by equipment and vehicles that are contaminated with soil containing the pathogens. In certain parts of the coast, lettuce dieback is common and is observed every season.

Photos 7 and 8: *Lettuce necrotic stunt virus* (LNSV) on lettuce.

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Managing virus diseases of lettuce: Managing virus diseases of lettuce requires an integrated control program. (1) For LMV, the only seedborne virus of lettuce, use seed that has been tested and found to have an infestation level below the established threshold of 0 infected seed per 30,000 tested seed. (2) For all these lettuce virus pathogens, control weeds in and around the lettuce production areas because weeds can be a significant reservoir of the virus and a source from which vectors obtain the virus. (3) Plow down, in a timely manner, old lettuce plantings because infected lettuce plants, like weeds, are a source of virus. For LMV, a two-week lettuce-free period in Monterey County helps prevent continuous, year-to-year buildup of LMV and reduces the amount of virus that would "bridge" over from one season to the next. (4) Plant resistant lettuce cultivars if such are available; cultivars having good resistance are available for LNSV/TBSV, for example. (5) Control aphid and thrips vectors to slow down the spread of viruses. While insect control is critical, note that these vectors only need a few minutes to inject the virus into a lettuce leaf; therefore, it is not possible to kill or eliminate all vectors before they transmit viruses. (6) Have suspect virus cases identified so that the exact pathogen is known. Plants suspected of being infected with virus or other pathogens can be sent for analysis to the UC Cooperative Extension diagnostic laboratory in Salinas.

High numbers of aphid and thrips vectors are spreading these viruses in lettuce fields.

Table 1. Summary of virus pathogens affecting lettuce in coastal California

Virus pathogen	Key foliar symptoms in lettuce	Vector	Notes
Cucumber mosaic virus (CMV)	Mild mosaic, stunting	aphid	Also on spinach, Br. sprouts
Impatiens necrotic spot virus (INSV)	Necrosis, spotting, yellowing	thrips	Can be common on radicchio
Lettuce mosaic virus (LMV)	Mosaic, necrotic lesions, yellowing, severe stunting	aphid	Can be seedborne
Tomato bushy stunt virus / Lettuce necrotic stunt virus (TBSV / LNSV)	Outer leaves yellow/necrotic; inner leaves remain green	none	Soilborne; iceberg is immune
Tomato spotted wilt virus (TSWV)	Necrosis, spotting, yellowing	thrips	Can be common on radicchio