



# Crop Notes

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## FERTIGATING THROUGH DRIP DOES NOT ALWAYS RESULT IN EVEN NITROGEN APPLICATIONS

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**A**n important benefit of drip irrigation is the ability to apply fertilizer through the irrigation water, permitting growers to spoon-feed nutrients, such as nitrogen (N), to their crops. By avoiding applications of large amounts of N fertilizer when the crop is small and uptake rates are low, losses of nitrogen by leaching can be minimized. Also, unlike furrow and overhead sprinklers, drip can deliver fertilizer in the zone where roots are most concentrated.

While drip fertigation offers several advantages for managing nitrogen fertilizer during the season, success depends on the management of the drip system and using best practices for fertigation. Drip systems with poor distribution uniformity may likely cause fertilizer to be unevenly distributed within a field. Also, the strategy of injecting fertilizer into a drip system can affect the distribution of fertilizer to the crop. Proper fertigation requires injecting at a steady rate and at a location that provides sufficient mixing of fertilizer with irrigation water. To assure that the fertilizer uniformly distributes within the field after an injection, sufficient irrigation time with clean water is needed so that all of the fertilizer is flushed out of the drip tape before the irrigation ends.

For drip to be economical for vegetable growers on the central coast, most farming operations retrieve drip tape after each crop is harvested and repair and reuse the tape for 8 to 12 crops. Breaks and leaks in the tape are repaired using a splicing machine (Figure 1). Growers have expressed concern that fertigating through their drip systems is not resulting in even applications of N fertilizer after the tape has been reused for multiple crops. Splicing machines often do not fully repair leaks in tape, and emitters tend to plug over time unless the tape was adequately maintained by flushing and chemical treatment.

In response to grower concerns, we evaluated the uniformity of applied water and nitrogen fertilizer for surface placed drip in 11 commercial lettuce fields during the fall of 2012 and during the spring of 2013.

### Procedures

All fields were planted with romaine or iceberg lettuce varieties on 40-inch or 80-inch wide beds. At each site irrigation, pressure, and fertilizer uniformity were evaluated during a single irrigation event. Field sizes ranged from 8 to 20 acres, and the maximum row lengths ranged from 600 to 1340 ft. Drip tape at all field sites was 7/8 inch diameter, medium flow tape (0.34 gpm/100 ft), but varied by manufacturer and age. The location where fertilizer was injected into the irrigation system, and start and end time of the fertigation, as well as the duration of the irrigation, were recorded. Before irrigating, couplers fitted with ¼ gallon per hour pressure compensating emitters that were spliced in to the drip tape at 24 locations within the field, representing the head, tail and middle areas. Water from these emitters was collected into 5 gallon containers during the entire irrigation (Figure 2) and analyzed for NO<sub>3</sub>-N and NH<sub>4</sub>-N. The discharge rate of 4 emitters and pressure of the tape was measured near each of the 24 fertilizer sampling locations (total of 96 emitters). Mass (lbs) of N applied at each of the 24 collection locations within a field was estimated by multiplying the measured discharge rate of the drip tape by the irrigation time and by the concentration of N in the collected water. Uniformity of applied water, tape pressure, and fertilizer was calculated by comparing the lowest 25% of measurements to the average of all 24 measurements. In addition to evaluating fertilizer distribution uniformity, we evaluated the time required for fertilizer to travel to the furthest distance from the injection point by injecting food dye for a 5 minute period into the irrigation

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system and monitoring the water for color at the furthest point from the injection location.

## Results

Distribution uniformity of applied water for the 11 fields averaged 73% and ranged from 38% to 88% (Table 1). The industry standard for irrigation uniformity of surface drip is 85%. Fertilizer application uniformity averaged 67% and ranged from 46% to 82%. The distribution uniformity of the drip systems of 7 fields evaluated was greater than 74% (avg = 82%) and fertilizer uniformity was greater than 72% (avg = 77%) (Figure 3).

One of the causes for poor distribution uniformity of some drip systems may have been related to pressure. Pressure uniformity averaged 80% and ranged from 43% to 99% (Table 1). Average pressures in the drip tape ranged from 3.5 to 13.8 psi (Table 2). Where the system pressure averaged 4.3 psi, the tape discharge rate was 30% less than the manufacturer's rating. Irrigation distribution uniformity decreased substantially when the average field pressure was less than 5 psi (Figure 4). Additionally, a substantial percentage of emitters of some drip systems were plugged (Table 2) which would reduce irrigation system uniformity. Leaks were evaluated in 5 fields and ranged from 1 to 5 leaks per 1000 ft of tape (Table 2). Significant leaks can potentially reduce drip uniformity by lowering the downstream pressure. Other limitations to good drip uniformity included mixing different types of tape in the same field, fluctuating pressure during the irrigation, and row lengths longer than 800 ft.

Field 8 had a high uniformity of pressure and irrigation distribution but a low fertilizer uniformity. We speculate that the fertilizer which was injected at a "T" connecting the valve in the field with the submain did not have sufficient time to mix with the irrigation water before the flow split into opposite directions. Hence, the average concentration of N on one side of the field was approximately half the concentration measured on the other side of the field. The distribution uniformity of fertilizer on individual sides of the fields was greater than 87%.

With the exception of field 8, fertilizer distribution uniformity was closely related with irrigation system uniformity (Figure 4). Fields with the lowest fertilizer uniformity were operated at the lowest average pressure and/or had the highest percentage of plugged emitters (Table 2).

Fertilizer was injected at the well in 4 of the fields and at the submain valve in the other 7 fields (Table 3). Injections were made simultaneously using 2 valves at 3 of the fields. Fertilizer was injected during an average of less than 30 minute period often at the beginning of the irrigation (Table 3). The time required for the fertilizer to travel to the furthest point of the irrigation system averaged 42 minutes but ranged from as short as 22 minutes to as long as 1 hour. Field size, row length, and injection location appeared to affect the travel time of the fertilizer. The average time for flushing the fertilizer was 3.75 hours, which was ample time to allow the fertilizer to completely flush from the system. The irrigation industry recommends that for long irrigations (> 4 hours), fertilizer should be applied in the middle of the irrigation cycle. Only at field 10 was the fertilizer applied during the middle of the irrigation. The long flush time after injecting could potential leach nitrate forms of fertilizer below the root zone of the crop. On average, half of the applied fertilizer N measured in the collection buckets was in the nitrate form.

## Conclusions

This survey of commercial lettuce fields demonstrated that N fertilizer applied by drip has an average distribution uniformity of 77% when the injection is properly made and the drip system is operated and maintained to achieve an average distribution uniformity of 82%. The results also showed that N fertilizer applied by drip is frequently distributed to fields unevenly due to poor uniformity of the drip systems, or because proper injection procedures were not followed. Operation procedures observed at these sites would suggest that irrigators may need training to better understand the principles of fertigation so that fertilizer is applied at the highest uniformity possible, and in a manner that will prevent leaching losses of nitrate.

## Acknowledgements

We thank the California Leafy Green Research Board for funding this project and the many growers that cooperated with the field trials.

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**D**rip systems with poor distribution uniformity may likely cause fertilizer to be unevenly distributed within a field.

**O**ne of the causes for poor distribution uniformity of some drip systems may have been related to pressure.



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Table 1. Summary of irrigation, fertilizer, and pressure uniformity of drip irrigated lettuce fields.

Field #	Lettuce Type	Bed width inches	Irrigation	Fertilizer	Pressure
			DU <sup>1</sup> ----- % -----	Uniformity	Uniformity
1	Romaine	40	58	54	82
2	Romaine	80	75	82	87
3	Romaine	80	81	73	62
4	Iceberg	40	80	75	89
5	Romaine	40	83	74	91
6	Romaine	80	46	66	79
7	Romaine	80	86	78	77
8	Iceberg	40	88	46	89
9	Romaine	80	38	32	43
10	Iceberg	80	81	80	86
11	Romaine	40	87	74	99
<b>Average</b>			<b>73</b>	<b>67</b>	<b>80</b>

<sup>1</sup> Distribution Uniformity of the lowest quarter

Table 2. Drip tape characteristics at commercial lettuce sites

Field	Distribution Uniformity %	Tape re-use # of crops	Wall thickness mil	Emitter spacing inches	Average pressure psi	Plugged emitters %	Tape leaks #/1000 ft	Tape Discharge Rate	
								measured	manufacturer
								----- gpm/100 ft -----	-----
1	58	15	8	8	7.2	5	--	0.28	0.34
2	75	>8	15	8	4.3	4	--	0.24	0.34
3	81	>3	10	12	8.3	1	--	0.34	0.34
4	80	10	10	8	13.8	2	--	0.42	0.34
5	83	10-11	10	8	10.8	3	--	0.41	0.34
6	46	4-5	10	8	4.6	16	--	0.24	0.34
7	86	3	10	8	7.0	2	0.8	0.31	0.34
8	88	12	10	8	9.0	0	4.3	0.39	0.34
9	38	2-3	9	12	3.5	2	0.4	0.23	0.34
10	81	4	8	12	7.2	3	3.4	0.23	0.34
11	87	3	10	12	12.4	0	5.4	0.43	0.34
<b>Average</b>	<b>73</b>		<b>10</b>		<b>8.0</b>	<b>3</b>	<b>2.9</b>	<b>0.32</b>	<b>0.34</b>



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Table 3. Irrigation summary for drip irrigated lettuce fields.

Field	Lettuce Type	Travel time	Irrigation time	Injection time	Flush time	field size	Average row length	Max row length	Injection location
		hours:min				acres	ft		
1	Romaine	1:04	5:20	0:23	4:30	8.0	610	620	well
2	Romaine	0:47	6:00	0:30	2:30	10.5	860	890	well
3	Romaine	0:40	7:00	0:20	4:20	20.2	940	1340	field, 2 valves
4	Iceberg	0:51	6:00	0:14	5:30	9.3	630	640	well
5	Romaine	0:22	6:00	0:13	5:00	8.7	530	640	field, 1 valve
6	Romaine	0:47	5:00	0:13	5:00	9.5	850	850	field, 1 valve
7	Romaine	0:40	6:00	0:22	3:00	8.5	600	675	field, 1 valve
8	Iceberg	0:41	5:20	0:19	2:30	10.6	685	800	field, 1 valve
9	Romaine	0:33	9:00	0:15	2:50	20.2	1030	1300	field, 2 valves
10	Iceberg	0:33	3:40	2:07	1:22	15.0	350	630	well
11	Romaine	0:47	5:00	0:13	5:00	18.3	575	600	field, 2 valves
Average		0:42	5:50	0:28	3:46	12.6	696	817	

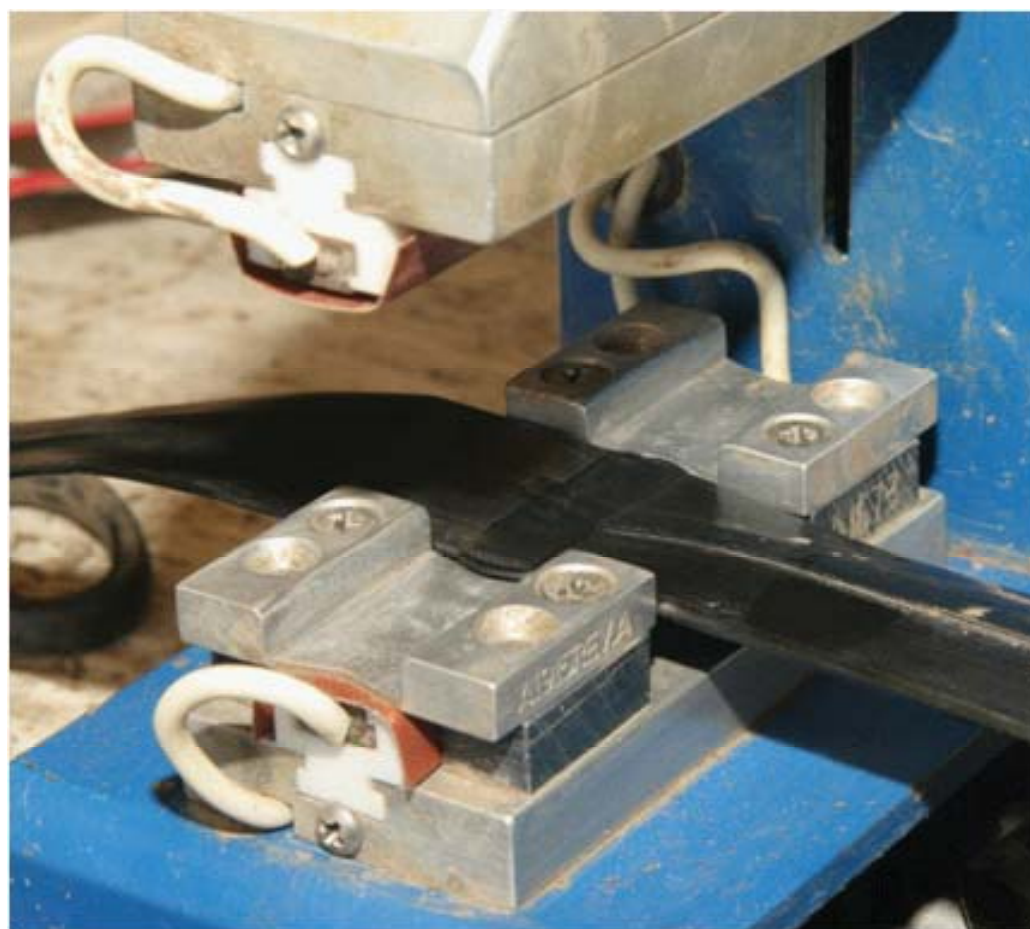


Fig. 1. Splicing machines are used to repair leaks and breaks in drip tape.





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Fig. 2. Low flow (1/4 gph) pressure compensating drip emitters were used to collect samples of the irrigation water during the entire irrigation cycle.

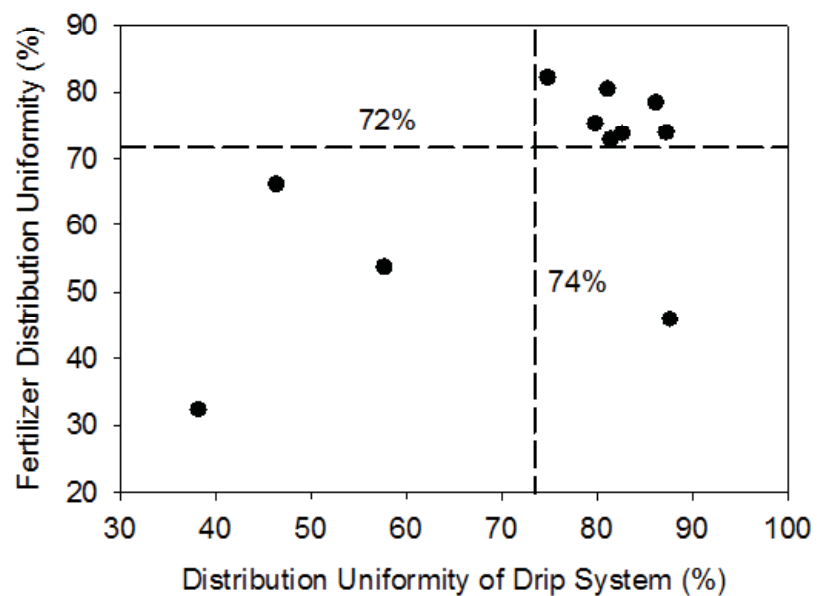


Fig. 3. Relationship between distribution uniformity of retrievable drip systems and fertigation uniformity. Each symbol denotes a commercial lettuce field evaluated during the study.

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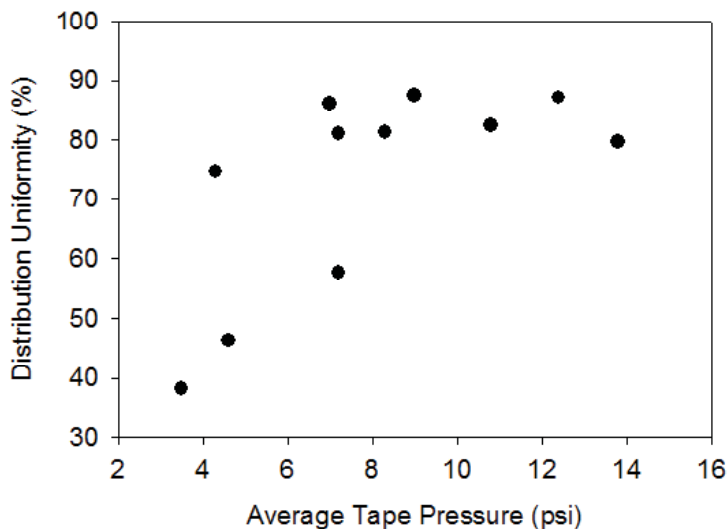


Fig. 4. Effect of tape pressure on the distribution uniformity of retrievable drip systems. Each symbol denotes a commercial lettuce field.

## IRIS YELLOW SPOT VIRUS: NEW CONCERN FOR ONION ON CENTRAL COAST

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*Iris yellow spot virus* (IYSV), a damaging pathogen found on allium crops throughout the world, has come to California's central coast. IYSV was first found in the USA in 1989 and now is present in a dozen or more states. This pathogen was detected in California perhaps as early as 2003 and is found in onion production fields in the southern desert counties and the San Joaquin Valley, and in onion seed crops in the north part of the state. For our central coast region, IYSV was confirmed in onion from San Benito County in 2011 and in onion and leek from Monterey County in 2013. This article is a brief review of this iris yellow spot disease that now is affecting allium crops in the central coast region.

**Symptoms:** Like many virus diseases, the symptoms of iris yellow spot disease can vary greatly, and an accurate diagnosis based on symptoms alone may be difficult to achieve. On onion leaves, symptoms start out as small yellow (chlorotic) flecks. The flecks enlarge and develop into yellow, light tan (straw colored), or whitish (bleached) lesions. One of the distinctive features of this disease is the lesion shape that has been described variously as spindles, eyes, ovals, or diamonds (Photos 1A and B). A second notable, typical symptom is that the lesions can contain concentric, alternating rings of green and tan tissue, causing them to have a target or ring spot appearance (Photo 2). As disease develops, multiple lesions can grow into each other, resulting in large areas of dead, dried out leaf tissue; in severe cases, onion foliage can die prematurely and collapse (Photo 3), resulting in reduced bulb size. For onion seed crops, similar lesions can occur on the tall flower stalks (scapes).

However, iris yellow spot symptoms can look very different depending on the onion cultivar, age of plant when infected, strain of the virus, environmental conditions, and other factors. Lesions can be less distinctive and more irregular in shape (Photo 4). Diamond shaped lesions and concentric ring symptoms may be absent. Symptoms caused by IYSV also can appear similar to leaf damage caused by downy mildew, *Stemphylium* purple blotch, or abiotic damage. Dark green to black saprophytic or secondary molds can grow on old IYSV lesions, which might lead some to think that the problem was caused by fungi. Because of this diagnostic challenge, confirmation of IYSV requires serological or molecular tests.

**Pathogen:** Iris yellow spot disease is caused by *Iris yellow spot virus* (IYSV). IYSV is vectored by thrips and is a member of the tospovirus group that includes well known viruses such as *Tomato spotted wilt virus* (TSWV) and *Impatiens necrotic spot virus* (INSV). Researchers continue to investigate whether

A virus new to central coast onions has been detected.

IYSV is not easy to diagnose based only on symptoms.

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The onion thrips is the main vector of IYSV.

IYSV-resistant onion cultivars are not available.

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distinct strains of IYSV exist. The most common and important vector of IYSV is the onion thrips (*Thrips tabaci*) (Photo 5). Recently, researchers have determined that the tobacco thrips (*Frankliniella fusca*) is also a vector but transmits the virus much less efficiently than onion thrips. The western flower thrips (*Frankliniella occidentalis*), which is extremely common in the central coast region, is generally considered not a vector of IYSV.

**Host range:** The host range of IYSV is narrow compared to those of TSWV and INSV, which have hundreds of host plants. IYSV infects mostly monocots, especially alliums such as chives, garlic, leek, onion, and shallot. Other monocot hosts include amaryllis (*Hippeastrum* species), iris (*Iris* species), and Peruvian lily (*Alstroemeria* species). A few reported dicot crop hosts are chicory, chrysanthemum, common vetch, geranium, lisianthus, petunia, and tomato. Various weeds are hosts of IYSV; some of these weeds are listed in Table 1.

**Disease cycle:** Details on how IYSV causes disease in onion are similar to those for TSWV and INSV. Because IYSV is apparently not seedborne, the virus is mostly introduced into onion fields by in-coming onion thrips, though infected onion transplants have been found in some states. Thrips carrying the virus move from left over (overwintered or volunteer) onions, weeds, or other plants and infect new onion crops. The thrips are also solely responsible for in-field spread of the virus over the course of the season.

**Disease control:** As much as possible, prevent introduction of diseased plants or virus-carrying thrips into the field by using disease-free transplants, removing surrounding volunteer and weed hosts, and destroying nearby cull or discard onion piles. Onion cultivars differ in degree of susceptibility to IYSV, so plant tolerant cultivars; however, highly resistant cultivars are not yet available. Spray for and manage the thrips. Rotating to non-host crops and avoiding back-to-back onion crops may help reduce onion thrips buildup and disease severity. Some research studies indicate that high rates of nitrogen fertilizer can result in elevated thrips populations, so proper fertilizer management may also help reduce the impact from IYSV.

Table 1. Some reported weed hosts of *Iris yellow spot virus*

- curly dock (*Rumex crispus*)
- dandelion (*Taraxacum officinale*)
- lambquarters (*Chenopodium album*)
- prickly lettuce (*Lactuca serriola*)
- puncturevine (*Tribulus terrestris*)
- purslane (*Portulaca oleracea*)
- redroot pigweed (*Amaranthus retroflexus*)
- spiny sowthistle (*Sonchus asper*)

Photos 1A and 1B. IYSV can cause distinctive, diamond to oval shaped lesions on onion leaves. (Photos by H. Pappu. Used by permission.)





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Photo 2. Ring spots, consisting of concentric, alternating rings of green and tan tissue, are another typical symptom of iris yellow spot disease.



Photo 3. Depending on the onion cultivar, time of infection, and other factors, IYSV can cause poor growth of plants and decline of onion foliage.



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Photo 4. Diagnosing IYSV from symptoms alone is not advisable because irregular, non-descript lesions and leaf dieback can also be caused by the virus.



Photo 5. Specimen of onion thrips (*Thrips tabaci*), the main vector of IYSV, examined with a compound microscope.



# EFFICACY OF AT-PLANTING AND BASAL APPLICATIONS OF INSECTICIDES ON CABBAGE MAGGOT IN SEEDED-BROCCOLI

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In the past few years, cabbage maggot has emerged as a serious pest of brassica crops in the Salinas Valley. The larval stages of the cabbage maggot feed on the root system of plants causing retarded growth and even plant death. Although, severity of cabbage maggot is varied across the Salinas Valley, cabbage maggot could be found all year from the entire range of the Salinas Valley. Typically, cabbage maggot flies are developed outside the field. Females lay eggs at the base of the plant causing infestation.

It is a common practice that insecticides are delivered at planting or as side dressing to manage cabbage maggots in broccoli and cauliflower. Growers and PCAs have mixed opinions on efficacy of insecticide applied at planting. Recent research has shown that flies tend to lay eggs a few weeks after planting. Ironically, most of the insecticides applied to manage maggots are less persistent and have restricted movement in the soil. The major objective of this study was to determine if insecticide applied at planting or 3-4 months at plant base have an effect on cabbage maggot infestation.

## Materials and method

In 2013, three trials were conducted in Gonzales, CA. Details on the planting, insecticide application and sampling dates are in Table 1. Four replicates of each treatment were assigned to two 25-foot long 40"beds (with two seed lines/bed) according to a completely randomized block design. Treatments were applied using a two-boom sprayer on 7-inch wide band along the seed line at 30 PSI. No adjuvant or surfactant was added in all experiments.

Ten root samples were randomly collected from each plot at four, and six week after planting (WAP). An additional sample at 8 WAP was collected for trial 1. Sample timing was determined based on current knowledge of peak incidence of egg laying and maggot infestation in a typical broccoli field in the Salinas Valley. Plants were evaluated for number of injured plants and severity of injury from cabbage maggot per plot. A scale system was developed to quantify severity of injury where higher scale value corresponds to more severe injury. Data were subjected to analysis (SAS Institute. 2010. Version 9.3, SAS Institute Inc., Cary, NC.) and means were separated using Tukey's HSD test at  $\alpha < 0.05$ .

### *Trial 1: At-planting application*

Ten insecticide treatments were compared in seeded 'Durapak' broccoli. The details on insecticide products, rates and application dates are shown in Table 2a. The water volume used for first application was 40 gal/acre. Two treatments IKI-3106 and Radiant received a second spray application along the root crown area and the water volume used for this application was 75 gal/acre. The field was sprinkler irrigated an hour after the insecticide application.

### *Trial 2&3: Basal spray application*

Four insecticide active ingredients were included in each basal spray trial. The details on insecticide products, rates and application dates are shown in Table 3a, and 4a. A set of plants received one application and the other set received two applications. The water volume used for all applications was 100 gal/acre.

## Results and discussion

### *Trial 1: At-planting application*

Following the application at planting and later for few insecticides, incidence of cabbage maggot injury was similar among treatments on all three sample dates (Table 2a). Feeding injury was lower a month after planting but was at very high levels on 1 and 17 July samples. Sivanto and IKI-3106 treatments showed some level of suppression to cabbage maggot, at least numerically on 1 July sample. The third samples showed no clear trend on cabbage maggot infestation, where most of sampled roots were infested, regardless of insecticide treatments.

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Severity of cabbage maggot injury did not differ among treatments.

Data suggested that infestation was not influenced by one or two applications of any insecticide.

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Severity of injury on injured planted was not calculated for the first sample (17 June) because of less severe cabbage maggot injury (Table 2b). Overall, severity of cabbage maggot injury did not differ among treatments for both the 1 and 17 July samples. It is interesting to note that even Lorsban granular treatment did not show any suppression to cabbage maggot injury. It appears that cabbage maggot infestation was not affected by these treatments. Data suggested that infestation did not reach damaging levels, until at least six WAP. Few potential possibilities to consider are movement of active ingredients in soil, length of residual activity, time of application and mode of delivery for future studies.

*Trial 2&3: Basal spray application*

Following the applications (one or two applications), neither the incidence of cabbage maggot injury nor severity of injury was different among treatments (Table 3a, b, 4a and b). Infestation was lower a month (8 July or 27 August sample) after planting but was at very high levels on 22 July or 12 September sample. Similarly severity of injury increased toward six WAP as evident in the second sample.

Data suggested that infestation was not influenced by one or two applications of any insecticide. Few potential possibilities to consider are movement of active ingredients in soil, length of residual activity and time of application. It is also possible that the method used to apply insecticides is not appropriate for the given levels of cabbage maggot infestation. Future research will re-examine the same application methods for consistency.

**Acknowledgments**

I appreciate the technical assistance provided by J. Martinez, J. Zarate, L. Reyes, and P. Stuhlmiller. I thank the grower, pest control advisor and farm manager for providing the field and plant materials for the research as well as the agro-chemical companies for providing funding for this project.

Table 1. Dates of planting, insecticide applications and sampling of seeded-broccoli of the trials conducted in 2013.

Trial	Planting	Application		Sampling		
		First	Second	First	Second	Third
1 (At planting)	17 May	18 May	16 Jun	17 Jun	1 Jul	17 Jul
2 (Basal spray 1)	27 May	22 Jun	29 Jun	8 Jul	22 Jul	-
3 (Basal spray 2)	15 Jul	14 Aug	28 Aug	27 Aug	12 Sep	-

Table 2a. Injury from cabbage maggot after band-spray applications in seeded-broccoli.

Treatment	Amt formulated/acre	Mean ± SE no. injured plants per 10 plants		
		June 17	July 1	July 17
Belay 2.13 SC	12 fl oz	0.5 ± 0.5a	4.2 ± 0.4a	9.0 ± 0.4a
Belay 2.13 SC + Brigade 2 EC	9 fl oz + 9 fl oz	0.0 ± 0.0a	3.8 ± 0.9a	8.5 ± 0.5a
Danitol 2.4 EC	21.3 fl oz	0.8 ± 0.3a	5.0 ± 1.9a	9.0 ± 1.0a
Sivanto	28 fl oz	0.8 ± 0.5a	2.0 ± 0.7a	9.5 ± 0.3a
Sivanto + Leverage 360	28 fl oz + 3 fl oz	0.0 ± 0.0a	6.5 ± 1.6a	8.8 ± 0.6a
Leverage 360	3 fl oz	0.8 ± 0.3a	5.3 ± 1.1a	9.0 ± 0.6a
IKI-3106*	11 fl oz	0.0 ± 0.0a	2.5 ± 1.2a	8.5 ± 0.5a
IKI-3106*	16.4 fl oz	0.5 ± 0.5a	4.3 ± 1.8a	8.3 ± 0.9a
Radiant*	5 fl oz	0.0 ± 0.0a	3.8 ± 1.3a	8.5 ± 0.6a
Radiant*	10 fl oz	0.0 ± 0.0a	3.8 ± 1.8a	8.0 ± 0.7a
Lorsban 15 GR	9.2 oz wt/1000 row-ft	0.0 ± 0.0a	5.5 ± 1.2a	8.3 ± 0.5a
UTC	Water	0.5 ± 0.5a	4.0 ± 1.9a	9.5 ± 0.3a

\*Received two applications on 18 May and 16 June, and all other treatments received application at planting only. Means within columns followed by the same letter are not significantly different according to ANOVA and Tukeys HSD test at P < 0.05.

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Table 3a. Injury from cabbage maggot infestation after one or two basal spray applications in seeded-broccoli.

Treatment	Amt formulated/acre	Mean $\pm$ SE no. injured plants per 10 plants	
		July 8	July 22
Radiant	7.5 fl oz	4.3 $\pm$ 0.9a	9.3 $\pm$ 0.5a
Radiant*	7.5 fl oz	4.3 $\pm$ 1.3a	10.0 $\pm$ 0.0a
Exirel	20.5 fl oz	4.0 $\pm$ 0.9a	9.0 $\pm$ 0.7a
Exirel*	20.5 fl oz	6.8 $\pm$ 1.3a	8.3 $\pm$ 0.6a
Leverage 360	6 fl oz	5.3 $\pm$ 1.3a	9.8 $\pm$ 0.3a
Leverage 360*	6 fl oz	5.8 $\pm$ 1.9a	8.5 $\pm$ 0.6a
Lorsban advanced	2.75 fl oz/1000 ft row	4.0 $\pm$ 1.7a	9.3 $\pm$ 0.5a
Lorsban advanced*	2.75 fl oz/1000 ft row	5.0 $\pm$ 1.7a	9.3 $\pm$ 0.5a
UTC	Water	3.0 $\pm$ 0.9a	9.5 $\pm$ 0.3a

\*Received two applications on 22 and 29 June. Means within columns followed by the same letter are not significantly different according to ANOVA and Tukey's HSD test at  $P < 0.05$ .

Table 3b. Severity of cabbage maggot injury after one or two basal spray applications in seeded-broccoli.

Treatment	Amt formulated/acre	Severity (Mean $\pm$ SE ) of cabbage maggot injury per injured plant	
		July 8	July 22
Radiant	7.5 fl oz	3.3 $\pm$ 0.4a	5.7 $\pm$ 0.8a
Radiant*	7.5 fl oz	3.5 $\pm$ 0.3a	5.5 $\pm$ 0.5a
Exirel	20.5 fl oz	2.7 $\pm$ 0.3a	5.7 $\pm$ 0.2a
Exirel*	20.5 fl oz	3.3 $\pm$ 0.5a	5.0 $\pm$ 0.5a
Leverage 360	6 fl oz	2.9 $\pm$ 0.2a	5.0 $\pm$ 0.9a
Leverage 360*	6 fl oz	3.3 $\pm$ 0.6a	5.8 $\pm$ 0.3a
Lorsban advanced	2.75 fl oz/1000 ft row	3.1 $\pm$ 0.3a	4.8 $\pm$ 0.5a
Lorsban advanced*	2.75 fl oz/1000 ft row	3.1 $\pm$ 0.2a	4.8 $\pm$ 0.6a
UTC	Water	2.9 $\pm$ 0.3a	4.8 $\pm$ 0.5a

\*Received two applications on 22 and 29 June. Means within columns followed by the same letter are not significantly different according to ANOVA and Tukey's HSD test at  $P < 0.05$ .

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Table 4a. Injury from cabbage maggot infestation after one or two basal spray applications in seeded-broccoli.

Treatment	Amt formulated/acre	Mean $\pm$ SE no. infested plants per 10 plants	
		August 27	September 12
Durivo	13 fl oz	0.8 $\pm$ 0.8a	8.0 $\pm$ 0.8a
Durivo*	13 fl oz	1.8 $\pm$ 0.9a	9.0 $\pm$ 0.7a
Trigard	2.66 fl oz	1.0 $\pm$ 0.4a	6.8 $\pm$ 1.8a
Trigard*	2.66 fl oz	1.0 $\pm$ 0.4a	8.0 $\pm$ 0.4a
Coragen	7 fl oz	1.0 $\pm$ 0.4a	7.5 $\pm$ 1.2a
Coragen*	7 fl oz	2.3 $\pm$ 0.7a	8.3 $\pm$ 1.2a
Lorsban advanced	2.75 fl oz/1000 ft row	3.3 $\pm$ 1.6a	9.0 $\pm$ 0.4a
Lorsban advanced*	2.75 fl oz/1000 ft row	1.3 $\pm$ 0.9a	7.3 $\pm$ 1.4a
UTC	Water	0.5 $\pm$ 0.3a	8.3 $\pm$ 1.1a

\*Received two applications on 14 and 28 August. Means within columns followed by the same letter are not significantly different according to ANOVA and Tukey's HSD test at  $P < 0.05$ .

Table 4b. Severity of cabbage maggot injury after one or two basal spray applications in seeded-broccoli.

Treatment	Amt formulated/acre	Severity (Mean $\pm$ SE ) of cabbage maggot injury per injured plant	
		August 27	September 12
Durivo	13 fl oz	0.8 $\pm$ 0.8a	3.1 $\pm$ 0.4a
Durivo*	13 fl oz	2.6 $\pm$ 0.9a	3.6 $\pm$ 0.9a
Trigard	2.66 fl oz	1.0 $\pm$ 0.4a	2.7 $\pm$ 0.3a
Trigard*	2.66 fl oz	2.0 $\pm$ 0.8a	3.2 $\pm$ 0.2a
Coragen	7 fl oz	2.4 $\pm$ 1.5a	2.6 $\pm$ 0.2a
Coragen*	7 fl oz	3.1 $\pm$ 0.7a	4.8 $\pm$ 0.8a
Lorsban advanced	2.75 fl oz/1000 ft row	3.7 $\pm$ 0.7a	2.9 $\pm$ 0.4a
Lorsban advanced*	2.75 fl oz/1000 ft row	0.9 $\pm$ 0.7a	3.6 $\pm$ 0.6a
UTC	Water	0.3 $\pm$ 0.3a	3.4 $\pm$ 0.5a

\*Received two applications on 14 and 28 August. Means within columns followed by the same letter are not significantly different according to ANOVA and Tukey's HSD test at  $P < 0.05$ .



## POWDERY MILDEW OF PEPPER: BIOLOGY AND MANAGEMENT

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**Introduction and significance.** Worldwide, powdery mildew disease of pepper is caused by two different pathogens. One pathogen is named *Golovinomyces cichoracearum* (the old name is *Erysiphe cichoracearum*). *Golovinomyces* is similar to powdery mildew of lettuce, grape, and strawberry in that the fungus grows primarily on the outer surface of leaves and is known as an “epiparasitic” mildew. *Golovinomyces* has not been documented on pepper in California.

The second pepper powdery mildew, in contrast, develops extensive fungal mycelium inside the leaves and is known as an “endoparasitic” mildew. Named either *Leveillula taurica* or *Oidiopsis taurica*, this powdery mildew is widespread on pepper throughout the world and causes significant damage. In California, *Oidiopsis* can be prevalent on both coastal and inland bell and chile pepper crops and if not managed sufficiently can result in crop loss.

**Symptoms and signs.** Powdery mildew caused by *Oidiopsis* initially causes light green, irregularly shaped, angular patches to form on leaves. These patches can become yellow (chlorotic) and later turn into brown, dead (necrotic) tissue. Examination of the undersides of these leaves reveals the whitish powdery growth of this pathogen (Photo 1). In severe cases, the entire leaf curls and rolls up, and the powdery growth can be seen on both sides of the leaf. This pathogen only infects the older leaves, with the younger leaves escaping infection until they mature. A notable symptom of powdery mildew on pepper is that infections cause the loss of foliage; lower, older leaves colonized with powdery mildew will fall off and result in defoliation (Photos 2 and 3). If substantial numbers of leaves defoliate, pepper fruit will be exposed to and burned by sunlight (Photo 4). Powdery mildew therefore causes damage that is both direct (diseased leaves) and indirect (sunburned fruit). Powdery mildew does not infect or colonize stems, flowers, or fruit of pepper.

The leaf drop symptom of pepper is a relatively unique feature since *Oidiopsis* on tomato and other crops does not cause defoliation. Researchers found that when the pepper leaf first becomes infected, chemical levels (between peroxidase and indole 3-acetic acid) become out of balance. This disruption causes the leaf abscission zone (the tissue at the base of the leaf petiole, next to the pepper stem) to begin the physiological abscission or leaf drop process. This process continues until the abscission zone cell walls are weakened and the leaf falls off. Interestingly, the fungus itself is not present at the abscission zone. Researchers also found that if the mildew colony on an infected leaf dies, the abscission process will proceed even if the pathogen is no longer viable.

**Pathogen.** Like many fungi, this powdery mildew pathogen has two different forms and therefore two names. If present, the sexual stage of the fungus (*Leveillula taurica*) forms tiny, brown, spherical structures called chasmothecia (formerly known as cleistothecia); however, this *Leveillula* phase appears to be absent on pepper in California. The other stage is the asexual form (*Oidiopsis taurica*) that produces the spores (conidia) that are always present in active colonies. Diagnosticians and plant pathologists confirm the identity of *Oidiopsis* by looking for the following microscopic features: mycelium forming extensively inside the leaf; conidia-forming stalks that grow out of the leaf stomate openings (Photo 5); two types (dimorphic) of clear, single-celled conidia, primary (cylindrical, with apical points) (Photo 6) and secondary (also cylindrical but lacking the points); conidia not forming in chains (Photo 7).

**Disease cycle.** *Oidiopsis* is an obligate pathogen, meaning that it only survives on living plant tissue. Therefore, in the absence of the chasmothecium stage (which has not been found on pepper in California), this powdery mildew will not survive in the soil or on dead crop residues. For powdery mildew to develop on the new crop, the pepper plants must be exposed to windborne spores coming from living, diseased plants in the area: overwintered or volunteer peppers, alternate host crops, or weed hosts. Spores from these sources land on pepper leaves, germinate, and infect the leaf tissue. Once in the tissue, there is a delay (latent period) before the fungus grows out of the leaf stomates and produces new spores. The estimated latent period varies, with one report giving a latent period of 4 to 6 days but another finding it to be 8 to 14 days long. Once the disease begins on a few plants in a field, large numbers of spores are produced and spread by winds throughout the planting, resulting in disease epidemics. Powdery mildew development is

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Pepper is susceptible to two kinds of powdery mildew.

Leaf drop is a significant symptom of pepper plants infected with powdery mildew.





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avored by temperatures that are above 60° and below 80° F. Though powdery mildew can develop under relatively dry conditions, the disease is favored when humidity is higher.

**Host range.** *Oidiopsis* infects a large number of plants. Researchers report that this powdery mildew can infect over 1,050 crop and weed species that are part of 378 genera in 69 plant families. For the central coast region, *Oidiopsis* has been commonly found on the following: artichoke, pepper, tomato, and on the ornamentals calla lily, gazania, and lisianthus. However, given this extensive host range, the question remains whether *Oidiopsis* can cross infect the different plants. Can powdery mildew of calla lily infect pepper? Or can pepper powdery mildew infect tomato?

Dozens of studies worldwide, intended to answer this question, appear to provide slightly different answers. In most cases, *Oidiopsis* from a particular plant was able to infect many other species. However, in some instances a particular powdery mildew isolate was able to infect only a limited range of hosts and therefore appeared to be a specialized race of mildew. Research on this question is on-going. For practical purposes, growers should realize that powdery mildew appears to freely cross infect crops such as artichoke, pepper, and tomato.

**Control.** While pepper cultivars vary in susceptibility to powdery mildew, with some cultivars being very susceptible and others more tolerant, truly resistant cultivars that fit the needs of the California pepper industry are not available. Plant breeders have determined that sources of powdery mildew resistance are found primarily in species of pepper other than the one (*Capsicum annuum*) that primarily is grown here. This means that resistant pepper cultivars likely will not be forthcoming in the near future.

Because powdery mildew is spread via winds, crop rotations will not help manage this disease, though growers should try to avoid over-planting peppers for other reasons. Growers will therefore need to rely on protectant fungicides to manage powdery mildew on pepper.

A number of registered products (such as Cabrio, Flint, Quadris, Quintec, Rally, and sulfur products) are available for use on pepper. Materials such as mono-potassium phosphate and biocontrol products show some disease suppression potential. Because all of the currently registered products are protectant fungicides, the latent period for powdery mildew development becomes critical for timing of applications. Because several days pass between leaf infection and the appearance of the powdery mildew growth (latent period), seemingly healthy pepper leaves could already be infected. Therefore, timing of applications is critical to deposit a layer of protectant chemical before leaf infection. In addition to monitoring the pepper field for signs and symptoms of the disease, field personnel should also take note if nearby fields are infected with powdery mildew; infected pepper or tomato fields in the vicinity indicate that conditions are favorable for powdery mildew development.

Tables 1 and 2 present data from small plot fungicide screening trials conducted in 2010 and 2013. Some fungicides in the tables below are not registered for use on pepper (marked with \*). Before using any fungicide, check product labels and consult with your local Agricultural Commissioner's Office for information on fungicide registrations and allowable usage.

**Table 1. 2010 Fungicide field trial for pepper powdery mildew**

<u>Treatment</u> <sup>a</sup>	<u>Mean disease severity</u> <sup>b</sup>
Luna Sensation*, 7.6 fl oz	1.38
Luna Privilege*, 6.8 fl oz	1.68
Cabrio, 8 oz	1.98
Actinovate, 2.4 lb	5.21
Untreated	5.53
LSD ( <i>P</i> = 0.05)	0.53

a Rates are given in amount of product per acre. \* = material is not registered for use on pepper.

b Powdery mildew was assessed using the following disease severity scale: 1 = no powdery mildew; 2 = 1-10% of leaf surface area was colonized; 3 = 11-25%; 4 = 26 to 50%; 5 = 51-75%; 6 = 76-100%. Mean disease severity was then calculated for each set of 20 leaves.

The powdery mildew that infects pepper can infect other vegetable crops.

Fungicides remain the primary tool for pepper powdery mildew management.



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**Table 2. 2013 Fungicide field trial for pepper powdery mildew**

<u>Treatment<sup>a</sup></u>	<u>Mean disease severity<sup>b</sup></u>
Exp18126B*, 7 oz	1.00
Priaxor, 8 fl oz	1.01
Quadris Top, 14 fl oz	1.01
Quintec, 6 fl oz	1.03
Exp18126B*, 5 oz	1.05
Priaxor, 6 fl oz	1.06
Luna Sensation*, 5 fl oz	1.09
Rally, 5 oz alt. Quintec, 6 fl oz	1.14
Priaxor, 4 fl oz	1.41
Fontelis, 1.5 pt alt. Quadris Top, 12 fl oz	1.46
Exp19334A*, 8.5 fl oz	1.91
Exp15457B*, 6.84 fl oz	2.16
Exp19334A*, 13 fl oz	2.29
Vivando*, 10.3 fl oz	2.74
Vivando*, 15 fl oz	2.84
Rally, 5 oz	3.99
Flint, 2 oz alt. Sonata, 4 qt	4.44
Untreated control	5.80
LSD ( $P = 0.05$ )	0.76

a alt. = alternating treatments. Rates are given in amount of product per acre. \* = material is not registered for use on pepper.

b Powdery mildew was assessed using the following disease severity scale: 1 = no powdery mildew; 2 = 1-10% of leaf surface area was colonized; 3 = 11-25%; 4 = 26 to 50%; 5 = 51-75%; 6 = 76-100%. Mean disease severity was then calculated for each set of 20 leaves.

Photo 1: Powdery mildew on pepper forms a whitish growth on the underside of the leaf.



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Photo 2: Severe powdery mildew on pepper can result in the defoliation of leaves.



Photo 3: Severe powdery mildew on pepper can result in the defoliation of leaves.





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Photo 4: If plants lose significant amounts of foliage due to powdery mildew, exposed pepper fruit can become sunburned.



Photo 5: Oidiopsis powdery mildew emerges from the pepper leaf through the stomate openings.



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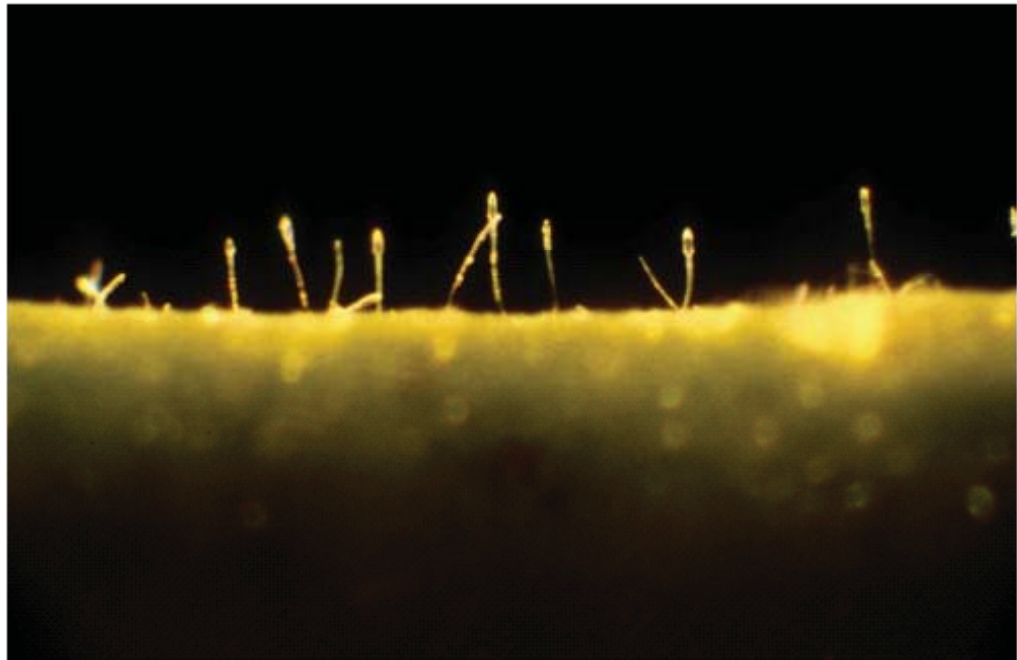


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Photo 6: Oidiopsis powdery mildew forms distinctive pointed spores.



Photo 7: In contrast to other powdery mildews, Oidiopsis spores are borne singly and not in long chains.



## **AUTOMATED THINNER/WEEDERS FOR LETTUCE PRODUCTION**

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**A**griculture is under pressure from regulations, as well as environmental and economic issues. In 2013 there were also widespread labor shortages in the Salinas Valley. These issues put pressure on growers to adapt and resolve each of these problems. Fortunately, new technological developments can provide solutions to some of the issues that growers face.

Commercial lettuce is primarily direct seeded and is hand thinned to a stand at about 25-30 days after planting. Typically lettuce plants are thinned to 10-12 inches apart with one swipe of a hoe which also removes a good number of weeds. In 2013 there was a labor shortage in the Salinas Valley which made it difficult for growers to find sufficient help to get thinning/weeding operations completed in a timely fashion. In 2013 commercial automated thinners for use in lettuce production became available, and growers began testing their use in the Salinas Valley.

Companies producing lettuce thinners (photos 1-4):

Agmechtronix: Silver City, NM. <http://www.agmechtronix.com/>

Blue River Technology: Sunnyvale, CA. <http://bluerivert.com/>

Foothill Packing: Salinas, CA. <http://www.foothillpacking.com/>

Vision Robotics Corporation: San Diego, CA. <http://www.visionrobotics.com/>

The machines utilize a camera to detect the lettuce plants and a computer to process the image and decide which plants to remove and which to leave. Unwanted lettuce plants are sprayed and the desired plants are not sprayed (photos 5&6). The current technology uses spectral evaluation to distinguish lettuce plants, but has limited ability to distinguish lettuce plants from weeds. As a result, the machines work best in situations with low weed pressure and preemergent weed control is critical to the efficient functioning of the thinner. In 2009 the registration for Kerb, the most widely used preemergent herbicide used on lettuce, was lost for leaf lettuce. Growers cope with this situation by utilizing the alternative preemergent herbicides registered for leaf lettuce, Balan and Prefar, in fields where the weed spectrum allows or use the machine in fields with low weed pressure. Thus far, this has not been a major impediment to the use of automated thinners.

Ten to fourteen days following the thinning operation, a hand crew goes through the field to remove doubles and weeds that escaped the thinning/weeding operation. The speed with which this crew moves through the field is dependent on how efficient the thinning operation was conducted. One challenge for the automated thinners is to remove doubles (photo 7). It is tricky for the machine to safely spray a lettuce plant that is close to another lettuce plant that it wants to keep; this is an area where the developers of the thinner machines are actively working to make improvements and growers are working to improve lettuce seed singulation.

Spray materials available to remove lettuce seedlings and weeds include acid (sulfuric and NpHuric) or salt (AN20 and UN32) based fertilizers as well as post emergent herbicides registered for use on lettuce. Registered post emergent herbicides for use on lettuce include: glyphosate, paraquat, pelargonic acid and carfentrazone. We initiated trials to evaluate the best materials for use with the automated thinners. We did not consider the use of glyphosate because of its systemic activity might be a problem if small amounts wafted onto adjacent plants. Paraquat has a danger label which might complicate its use and sulfuric acid may also have worker safety issues. We therefore researched the efficacy of pelargonic acid (Scythe), carfentrazone (Shark, Aim) and salt based fertilizers (14-0-0-5).

We observed that Shark at 1.0 oz/A provided good control of lettuce plants and that higher rates of Shark caused greater injury to unthinned lettuce plants (Table 1). Scythe was less effective than Shark. In a subsequent trial Shark was more effective than 14-0-0-5 at removing doubles and in reducing the amount of time in the double removal/weeding operation (Table 2). It should be mentioned that a fertilizer like 14-0-0-5 can do an excellent job at removing lettuce plants, but it is affected by the amount of moisture on that plants at the time of application. The salt based fertilizers do a better job when the lettuce plants are dry, but growers may find it inconvenient to wait until later in the day when plants are dry enough to start thinning operations.

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We therefore conducted a trial to examine the impact of dew on the effectiveness of various organic and conventional post emergent herbicides (Photo 8 – note dew droplets on sow thistle seedling). Applications were made at dawn when dew was still on the plants to test the worst case scenario. Table 3 shows that the organic herbicides, Biolink was highly effective and that Shark was the most effective conventional material. These results indicate that even under conditions where lettuce plants are wet with dew, both Biolink and Shark have the potential to effectively remove unwanted lettuce plants and weeds.

A request for a 24c registration for Shark for use in the automated thinners has been submitted to the California Department of Pesticide Registration; a similar request for Aim (the trade name of carfentrazone in Arizona) in Arizona was recently granted. Biolink is currently not registered for use in organic production, but registration is expected in 2014.

The emergence of the automated thinners opens up new possibilities in crop management. In the short term, they help growers to effectively deal with labor shortages. However, this technology has other potential. One of the companies installed a second manifold on the sprayer that can apply crop protection chemicals or crop nutrients to the unthinned plants (photo 9). This offers growers an ultra precise means of applying these chemicals that can potentially help improve crop production efficiencies and reduce water quality issues. The advent of this type of technology to agriculture is welcome and we look forward to its continued development.

Table 1. Trial 1. Evaluation of materials for use by an automated thinner<sup>1</sup> to remove unwanted lettuce plants

Treatments & Rate/A	Pre-thin plants/A	Doubles & unkilld plants/A	Post thin plants/A	Plant spacing inches	Stunted lettuce plants/A	Harvest Mean head wt lbs
	Feb. 22	Mar. 4	-----March 7-----			April 30
Hand Thinned	121,334	105	33,715	9.3	0	2.87
Shark 1.0 oz COC 0.25% v/v	120,447	1,464	34,003	9.2	810	2.78
Shark 2.0 oz COC 0.25% v/v	122,418	1,555	29,978	10.5	3,502	2.62
Shark 4.0 oz COC 0.25% v/v	116,764	1,594	30,109	10.4	3,215	2.55
Scythe 9.0% v/v	120,243	2,091	32,696	9.6	470	2.69

<sup>1</sup> – Foothill Packing automated thinner applying 20 GPA of spray material on two bands/40 inch bed

Table 2. Trial 2. Evaluation of Shark and 14-0-0-5 for use by an automated thinner<sup>1</sup> to remove unwanted lettuce plants

Treatments & Rate/A	Double/A	Stand Plants/A	Plant spacing inches	Double removal Hrs/A	Stand Plants/A	Plant spacing inches	Harvest Mean head wt lbs
	-----March 28-----			-----April 3-----		May 14	
Shark 1.0 oz COC 0.25% v/v	4,120	37,611	8.4	2.6	33,162	9.5	2.1
14-0-0-5 22 gals	6,344	52,524	6.0	5.1	31,952	9.8	2.1

<sup>1</sup> – Foothill Packing automated thinner applying 20 GPA of spray material on two bands/40 inch bed





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Table 3. Lettuce plant, malva and overall weed control rating on September 30 of the 14 day after planting and 5 days after application

Control Material	Rate	Adjuvant	Rate	Lettuce Control rating <sup>1</sup>	Malva Control rating <sup>1</sup>	Overall Weed Control rating <sup>1</sup>
<b>Organic</b>						
BioLink Herbicide	12% v/v	BioLink Spreader	4 oz/100 gal	9.8	9.1	9.3
Final San-O	20% v/v	Oroboost	100 oz/100 gal	3.5	1.8	4.3
Weed Pharm	100% v/v	Oroboost	100 oz/100 gal	7.0	3.3	6.8
Weed Zap	5% v/v	Oroboost	100 oz/100 gal	3.5	2.8	7.8
<b>Conventional</b>						
Scythe	9% v/v	DynAmic	0.25% v/v	8.1	6.5	8.0
Shark	1.0 oz/A	DynAmic	0.25% v/v	10.0	10.0	9.8
NpHuric	20% v/v	DynAmic	0.25% v/v	4.0	3.0	6.3
14-0-0-5	20 gal/A	DynAmic	0.25% v/v	8.1	4.0	6.6
Untreated	---	---	---	0.0	0.0	0.0
Pr>Treat				<0.0001	<0.0001	<0.0001
LSD (0.05)				1.2	1.3	2.0

1 – lettuce plant and weed control rating: 0 = no control to 10 = complete control



Photo 1. Agmechtronix



Photo 2. Blue River Technology



Photo 3. Foothill Packing



Photo 4. Vision Robotics

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Photo 5. Spray pattern on bed



Photo 6. Unthinned plant with thinned (dying) plants on either side



Photo 7. Lettuce double



Photo 8. Dew on lettuce and sow thistle at dawn



Photo 9. Pattern of spray for the thinning plants (long horizontal pattern), and the 2nd manifold spray pattern (short vertical pattern) applying fungicide and/or plant nutrients (Photo Tom Taggart)

