Cooperative Extension • Monterey County

Crop Notes

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In This Issue:

OUTBREAK OF PYTHIUM WILT DISEASE OF LETTUCE

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During the latter part of the 2015 Salinas Valley season (August through October), significant crop losses have been caused by Pythium wilt disease of lettuce. This problem is a new development for our coastal lettuce industry. California's first case of Pythium wilt of lettuce was reported from the Coachella Valley in 1993, though this issue appeared to be short-lived and has not recurred. The first coastal case was found in the Salinas Valley in 2011. Since 2011, this disease appeared to be of minor importance. However, during 2014 and 2015 seasons, the problem spread to a number of other locations in the valley and caused perhaps 30% or more losses in some fields. Thus far, this disease has been confirmed on iceberg, romaine, and greenleaf lettuce types.

Symptoms: In contrast to Pythium root rots of spinach and other vegetables, this lettuce pathogen does not cause damping-off on newly emerged, young lettuce seedlings. Instead, Pythium wilt mostly develops on lettuce that is at the rosette stage or older. Infected plants will be stunted and lag behind healthy lettuce. As disease progresses, outer leaves will start to wilt during the warmer times of the day and eventually turn yellow before becoming brown and dead. All leaves can wilt and the plant can collapse in advanced stages of the disease. Below ground, the pathogen first attacks the small feeder roots of the lettuce, making them soft and brown gray in color. Late in disease development the taproot can also be darkly discolored and the entire root system can be rotted. Pythium wilt does not cause a rot of the lettuce crown.

Diagnostic challenge: Because Pythium wilt causes a general wilting and collapse of lettuce foliage, this disease can be confused with other problems. *Sclerotinia* and *Botrytis* infections both can result in plant wilt and collapse. However, in these cases the symptoms result from crown infections; neither *Sclerotinia* nor *Botrytis* infect lettuce roots. Verticillium and Fusarium wilts, which also cause lettuce to collapse, will exhibit the distinctive discolorations of the lettuce vascular tissues while likewise leaving the roots intact. The other root disease new to Salinas Valley lettuce growers, black root rot (pathogen: *Thielaviopsis basicola*), causes dark bands to form on roots but does not result in the extensive feeder and tap root decay as seen with *Pythium*. Finally, foliar symptoms caused by Impatiens necrotic spot virus or Lettuce necrotic stunt virus can add further confusion to the diagnostic task because of the yellowing and browning of infected lettuce leaves. Accurate diagnosis of these lettuce diseases usually requires laboratory analysis. For assistance in diagnosing these problems, submit samples to the UC Cooperative Extension diagnostic lab in Salinas. See Table 1 for a comparison of symptoms caused by soilborne pathogenic fungi of lettuce.

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Table 1. Comparison of symptoms caused by soilborne pathogens of lettuce.

Symptoms	Pythium	Sclerotinia	Botrytis	Fusarium	Verticillium	Thielaviopsis
Small, stunted plants	yes	yes	yes	yes	no	yes
Wilted leaves	yes	yes	yes	yes	yes	no
Yellowed leaves	yes	yes	yes	yes	yes	no
Collapsed plants	yes	yes	yes	yes	yes	no
Decayed crowns	no	yes	yes	no	no	no
Vascular discoloration	no	no	no	yes	yes	no
Rotted root system	yes	no	no	no	no	no
Brown bands on roots	no	no	no	no	no	yes

Causal pathogen: Pythium wilt is caused by *Pythium uncinulatum*. In addition to California, this lettuce pathogen has been reported from The Netherlands, Japan, and Arizona. *Pythium uncinulatum*, like most *Pythium* species, produces swimming spores (zoospores) that are released and move within the water film in the soil. In addition to zoospores, the pathogen also produces a sexual spore (oospore) that is encased within a spiny outer covering. It is the oospore that allows the pathogen to survive in the soil in the absence of susceptible plants. *Pythium uncinulatum* is host specific to lettuce and apparently does not infect other vegetable crops such as broccoli, cabbage, carrot, onion, pepper, radish, spinach, or tomato.

Disease management: *Pythium* species are soil inhabitants and persist in agricultural soils for extended periods of time, especially if soils are moist. Specific information on how *Pythium uncinulatum* might persist in coastal California soils is lacking; however, the following management strategies are advisable steps to take and should be considered. (1) Avoid planting lettuce into fields with a known history of the problem. (2) For infested fields, rotate to non-lettuce crops. Various research studies demonstrated that *Pythium uncinulatum* is host-specific to lettuce. (3) Implement field sanitation practices to minimize the movement of contaminated soil from infested to clean fields. (4) Be aware that surface water run-off from infested fields may contain the pathogen. Flooding events, a concern if El Nino weather patterns result in extensive rains, may also spread the pathogen to previously uninfested areas. (5) Prior to planting lettuce, prepare beds so that drainage of water is enhanced, since the pathogen is favored by wet soil conditions. (6) Manage the irrigation so that excessive soil moisture is avoided. (7) The effectiveness of pre-plant soil treatments, addition of amendments, or post-plant application of fungicides for controlling Pythium wilt is currently unknown and will require research and field trials.

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Photo 1. Lettuce field severely infected with Pythium uncinulatum.

Photo 2. Severely stunted lettuce plants affected by Pythium wilt disease. A healthy plant is on the left.

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Photo 3. *Pythium uncinulatum* can cause extensive rotting of lettuce roots.

EVALUATION OF INSECTICIDES AGAINST CABBAGE MAGGOT LARVAE IN THE LABORATORY

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Cabbage maggot (Delia radicum) is a serious insect pest of Brassica crops such as broccoli and cauliflower in the Central Coast of California (Fig. 1). These crops are grown throughout the year; as a result cabbage maggot problems persist year long. Cabbage maggot eggs are primarily laid in the soil around the crown area of the plant. A single female fly can lay 300 eggs under laboratory conditions. The eggs hatch within 2-3 days and the maggots feed on the taproot for up to three weeks and can destroy the root system of the plant. The maggots pupate in the soil surrounding the root system and emerge into flies within 2-4 weeks. Severe cabbage maggot feeding injury to the roots cause yellowing, stunting even plant death.

Control of cabbage maggot on Brassica crops primarily involves the use of soil applied organophosphate insecticides such as chlorpyrifos and diazinon. However, the persistent

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use of organophosphate insecticides has resulted in high concentrations of the insecticide residues in the water bodies posing risks to non-target organisms and public health through contaminated water. Currently, use of organophosphate insecticides is strictly regulated by California Department of Pesticide Regulation. There is therefore an urgent need to determine the efficacy of alternate insecticides for cabbage maggot control.

The efficacy of 29 insecticides was determined against cabbage maggot through a laboratory bioassay by exposing field collected maggots to insecticide treated soil immediately after application. Three parameters were used to evaluate efficacy (1) proportion of maggots on the soil surface after 24 h, (2) proportion of change in weight of turnip bait, and (3) dead maggots after 72 h (Table 1, Figs. 2, 3, and 4). To determine overall efficacy ranking, efficacy index was developed. Based on the assays, 11 insecticides performed better and they were Mustang, Torac, Danitol, Belay, Capture, Warrior II, Lorsban, Mocap, Durivo, Pyganic and Vydate in the order of highest to lowest efficacy (Table 2). Eight insecticides were selected based on superior efficacy to determine the length of residual activity on cabbage maggot larvae. The persistence of insecticide activity was greater with Capture, Torac and Belay than with other insecticides tested (Table 3).

Based on the assays, 11 insecticides performed better and they were Mustang, Torac, Danitol, Belay, Capture, Warrior II, Lorsban, Mocap, Durivo, Pyganic and Vydate in the order of highest to lowest efficacy (Table 2).

The mode of exposure of insecticides in this study was entirely by contact (through skin) and other modes of exposure such as ingestion (through mouth) or through respiratory holes (spiracles) were not investigated. Some of the insecticides tested in the study were insect growth regulators (IGRs) (Dimilin, Rimon, Trigard, and Aza-direct), which normally interfere with the growth and development of the insect and they showed a low efficacy against cabbage maggot larvae. Entrust (spinosad) showed a moderate efficacy possibly because the primary mode of exposure to Entrust is by ingestion. The diamide insecticides (Beleaf, Coragen and Verimark) have systemic activity as they move within the plant and likely away from the site of application. It is possible that the soil applied diamide insecticides are absorbed by the roots and translocated to the above ground plant parts with little effect on the feeding larvae in the tap roots.

These studies were conducted under controlled conditions in the laboratory and the results may not be consistent in field conditions. The Brassica fields in the California's Central Coast are profusely sprinkler irrigated up to three weeks after sowing to ensure uniform germination and proper establishment of plants. It is likely that applied insecticides are partially or completely leached out of the root zone area without providing anticipated maggot control. In this study, insecticides were drenched into the cup and none of the applied insecticide solution leached out. Therefore, it is likely that the insecticides were more effective in the laboratory assay than they would be in the field. Certain insecticides such as pyrethroids tend to bind to the soil organic matter. The organic matter in the California's Central Coast soils can be up to 4%, which could reduce the availability of soil applied pyrethroid insecticide to the root zone where cabbage maggot larvae typically colonize. In situations with poor insecticide spray coverage, invading cabbage maggot larvae are possibly exposed to no or sub-lethal doses of the soil applied insecticide and may be able to penetrate the soil and infest the roots. The air temperature in the field at the time of insecticide application may influence the efficacy of the applied insecticide. The efficacy of pyganic decreased as the temperature increased against onion maggot. This

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suggests that application of pyrethroid insecticides should be avoided during warmer periods of day.

Other field conditions that influence efficacy of insecticides are cabbage maggot phenology and frequency of invading cabbage maggot flies on Brassica crop in the Central Coast of California. The earliest peak of cabbage maggot infestation occur a month after sowing broccoli seeds and infestations can be continuous until harvest. Also, insecticides applied at sowing as a banded spray on the seed lines did not provide adequate cabbage maggot control based on the insecticide efficacy trials conducted in commercial broccoli fields. These findings suggest that delaying the insecticide application by 2-3 weeks after sowing is more likely to maximize maggot control. Because the cabbage maggot infestation can last several weeks, insecticides with extended persistence of efficacy would increase the value for cabbage maggot control. Overall, results show that Capture, Torac and Belay which performed effectively against cabbage maggot for a month after application. This indicates that insecticides used before the first peak of infestation may protect the younger stages of the Brassica plants allowing them to establish and tolerate milder cabbage maggot infestations thereafter.

Overall, results show that Capture, Torac and Belay which performed effectively against cabbage maggot for a month after application.

In conclusion, 11 insecticides with high efficacy were identified for future investigation. Future studies will focus on determining the effects of application timing and delivery methods compatible with cabbage maggot phenology in both directly sown and transplanted Brassica crops in the Central Coast of California.

Table 1. Insecticides tested in the bioassay.

Class	**Insecticide**	**Brand name**	**Rate (per acre)**
Neonicotinoids	Clothianidin	Belay	12 fl oz
	Dinotefuran	Venom	3, 6 oz
	Acetamiprid	Assail	8 oz
Pyrethroids	Bifenthrin (LFR)	Capture LFR	6.8 fl oz
	Bifenthrin (WBC)	Brigade WBC	16 fl oz
	Zeta-Cypermethrin	Mustang	4.3 fl oz
	Lambda-Cyhalothrin	Warrior II	1.92 fl oz
	Fenpropathrin	Danitol	23.3 fl oz
	Permethrin	Pyganic	17 fl oz
Neonicotinoids + Pyrethroids	Thiamethoxam + Lambda-Cyhalothrin	Endigo ZC	4.5 fl oz
	Thiamethoxam + Chlorantraniliprole	Durivo	13 fl oz
	Imidacloprid + Beta-Cyfluthrin	Leverage 360	6 fl oz
Organophosphates	Ethoprop	Mocap	32 oz
	Chlorpyrifos	Lorsban advance	2.6 pint
Carbamates	Oxamyl	Vydate	32 oz
	Methomyl	Lannate LV	32 oz
Spinosyn	Spinetoram	Radiant	10 fl oz
	Spinosad	Entrust	10 fl oz
Ryanodine receptor activator	Cyantraniliprole	Verimark	13.5 fl oz
	Chlorantraniliprole	Coragen	7 fl oz
	Cyclaniliprole	IKI 3106	16 fl oz
Pyridinecarboxamide	Flonicamid	Beleaf	2.8 oz
Pyridazinone	Tolfenpyrad	Torac	21 fl oz
Butenolides	Flupyradifurone	Sivanto	28 fl oz
Tetramic acid	Spirotetramat	Movento	10 fl oz
s-triazine	Cyromazine	Trigard	2.66 oz
Benzoylurea	Novaluron	Rimon	12 fl oz
Benzamide	Diflubenzuron	Dimilin	4 fl oz
Tetranortriterpenoids	Azadirachtin	Aza-Direct	32 fl oz

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Table 2. Overall insecticides ranking against cabbage maggot larvae.

Rank	**Insecticide**	**Efficacy index**	**Overall efficacy**
1	Mustang	94.8 ± 2.2 a	High
2	Torac (full rate)	92.7 ± 1.4 ab	High
3	Danitol	92.1 ± 1.9 ab	High
4	Belay	89.5 ± 2.5 ab	High
5	Capture	88.9 ± 2.1 ab	High
6	Warrior II	85.9 ± 2.1 bc	High
7	Lorsban advanced	83.8 ± 2.0 bc	High
8	Mocap	83.4 ± 2.3 b-d	High
9	Endigo ZC	82.6 ± 2.8 b-d	High
10	Pyganic	79.2 ± 3.3 b-e	High
11	Torac (half rate)	78.4 ± 4.1 b-e	High
12	Vydate	71.9 ± 3.1 c-f	High
13	Durivo	66.1 ± 2.7 d-g	Moderate
14	Lannate	64.1 ± 2.3 e-h	Moderate
15	Brigade	63.7 ± 4.7 e-h	Moderate
16	Venom (full rate)	62.7 ± 2.5 e-i	Moderate
17	Entrust	54.7 ± 3.1 f-j	Moderate
18	IKI-3106	54.3 ± 2.9 f-j	Moderate
19	Venom (half rate)	53.6 ± 2.8 f-j	Moderate
20	Sivanto	52.3 ± 3.1 f-j	Moderate
21	Assail	46.8 ± 2.9 g-k	Moderate
22	Leverage	45.1 ± 4.8 g-k	Moderate
23	Verimark	43.1 ± 3.7 h-l	Moderate
24	Radiant	42.2 ± 3.8 i-m	Moderate
25	Dimilin	34.5 ± 3.3 j-n	Low
26	Rimon	31.2 ± 4.9 k-o	Low
27	Movento	26.8 ± 3.3 k-o	Low
28	Coragen	25.2 ± 5.2 n-o	Low
29	Distilled water	24.9 ± 1.4 l-o	Low
30	Trigard	24.7 ± 4.2 m-o	Low
31	Beleaf	23.9 ± 4.2 m-o	Low
32	Aza-Direct	15.8 ± 2.9 o	Low

Similar letters within the column (efficacy index) are not different.

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Table 3. Persistence of insecticide efficacy based on D. radicum on soil surface and mortality when exposed to field aged insecticide treated soil.

Insecticide	Field age interval (days)				
	1	3	7	14	30
D. radicum on soil surface					
Belay	79.0 aA	78.0 aA	72.0 aA	80.0 abA	92.6 aA
Capture	61.0 abB	89.0 aA	83.0 aAB	92.0 aA	92.0 aA
Durivo	42.0 bcB	73.0 aA	80.0 aA	82.0 abA	87.0 aA
IKI-3106	12.0 dA	13.0 cdA	24.0 bcA	10.0 eA	14.0 cdA
Mustang	66.0 abB	82.0 aAB	89.0 aA	87.0 aA	93.0 aA
Radiant	27.0 cdA	30.0 bcA	38.0 bA	37.0 cdA	32.0 cA
Torac	42.0 bcAB	40.0 bAB	39.0 bB	63.0 bcAB	64.0 bA
Verimark	17.0 cdAB	10.0 cdB	32.0 bA	22.0 deAB	37.3 cA
Dist. water	11.5 dA	4.0 dA	6.5 cA	6.5 eA	11.2 dA
D. radicum mortality					
Belay	82.0 bCD	68.0 bcC	84.0 aB	100.0 aA	92.6 aB
Capture	80.0 bA	83.0 abA	82.0 abA	84.0 bcA	58.0 bB
Durivo	42.0 cdB	77.0 abcA	74.0 abA	47.0 deB	54.0 bAB
IKI-3106	18.0 deB	44.0 cdA	30.0 cdAB	16.0 fB	17.0 cB
Mustang	67.0 bcA	75.0 abcA	67.0 abA	68.0 cdA	59.0 bA
Radiant	82.0 bAB	56.0 bcB	59.0 bcB	94.0 abA	68.0 abAB
Torac	99.0 aA	96.0 aAB	91.0 aB	92.0 abB	91.3 aB
Verimark	24.0 deAB	24.0 deB	21.0 dB	28.0 efAB	59.3 bA
Dist. water	13.5 eA	8.0 eA	12.0 cA	17.5 fA	17.2 cA

Lower case letters indicate comparisons of insecticides within each field aged interval, while upper case letters indicate comparisons of field age intervals by insecticide. Letters with similar case (upper or lower) are not different.

Fig.1 (A) Broccoli root infested with cabbage maggot larvae, (B) cabbage maggot infested and uninfested root, (C) and (D) cabbage maggot infested cauliflower field.

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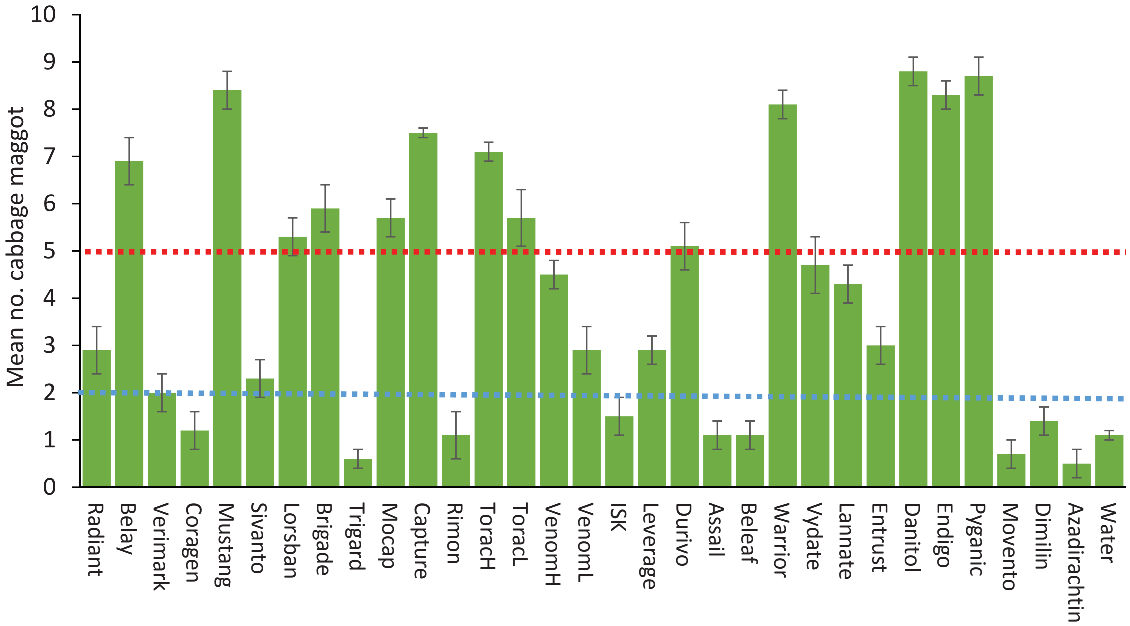

Fig. 2. Mean number of cabbage maggot larvae on the surface of soil. The taller bars suggest that cabbage maggot larvae were not successful in penetrating the soil and were affected by the treated insecticides on the soil surface.

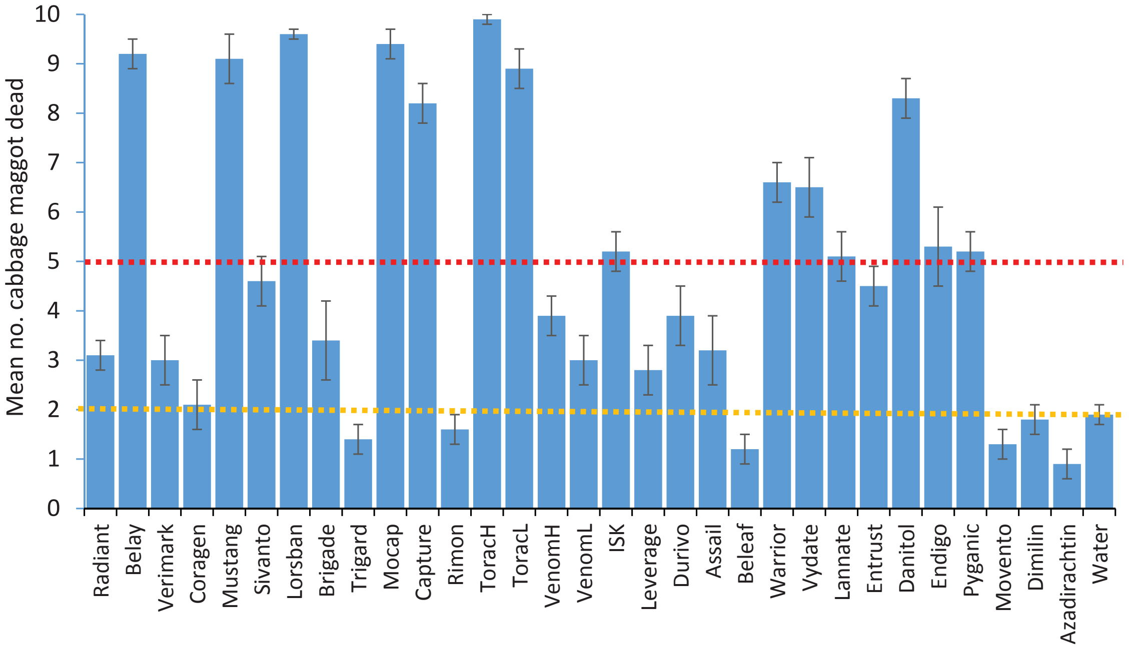

Fig. 3. Mean number of cabbage maggot larvae dead on the surface of the soil. The taller bars suggest that greater number of cabbage maggot larvae were dead.

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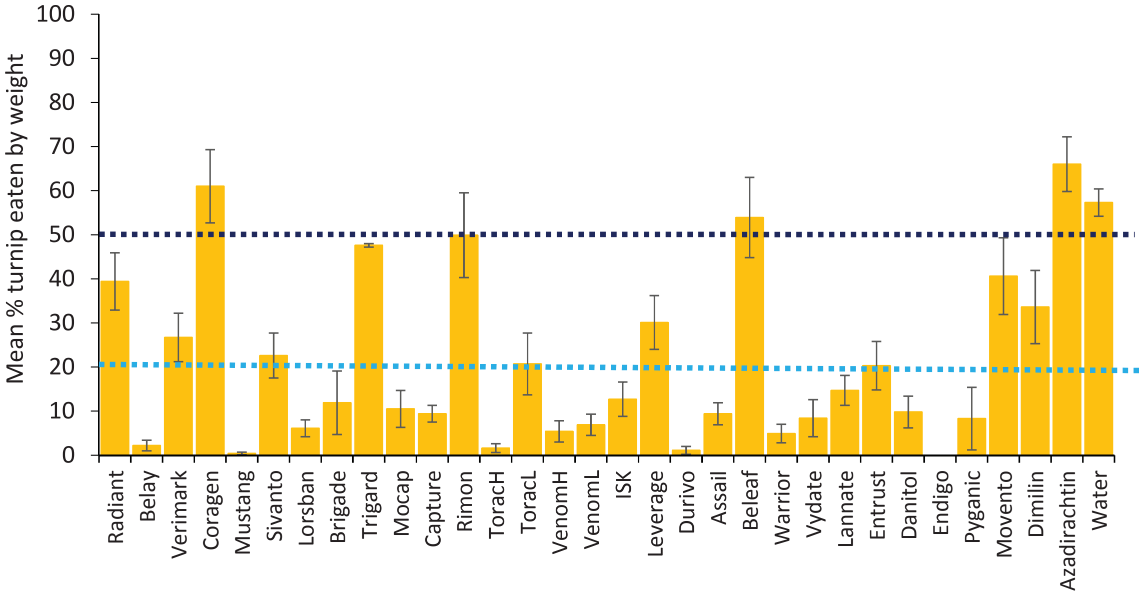

Fig. 4. Mean percent difference in weight of the bait (turnip slice) placed inside the soil after exposing the cabbage maggot larvae. The taller bars suggest that cabbage maggot larvae were successful in feeding the turnip bait and were less affected by the treated insecticides on the soil surface.

2015 EVALUATION OF INTELLIGENT CULTIVATORS FOR USE IN LETTUCE PRODUCTION

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Summary: The current automated weeding machines use cameras to detect plants, and a computer algorithm to process the image, calculate which plants to keep/remove, and activate a kill mechanism. These machines are capable of cultivating within the seedline and removing weeds that would otherwise be left by traditional cultivation. The machines used in these studies included the Robovator, F Poulsen Engineering Aps, Hvalsø, Denmark and Steketee IC Weeder, the Netherlands. Both of these machines use a split knife that as it moves through the field, closes in the seedline to remove unwanted plants and then opens around the desirable 'keeper' plants leaving halo of uncultivated soil around the crop plants. Both cultivators were designed for use in transplanted crops in Europe. In three of the evaluations the machines were used following thinning of the lettuce. On average the automated weeders reduced the lettuce stand by 5.6%. This may be due to incidental damage from the knives opening or closing at the wrong time due to small plant size. This type of damage can be managed by adjustments on the machine that affect the aggressiveness of the blades. On average, intelligent cultivators removed 51.4% of the weeds in the seedlines and reduced follow up hand weeding in the fields by 37.1%. Mechanical weeding technology has developed significantly over the past several years and, in these studies, provided useful levels of weed control, reducing the amount of time to remove all weeds from lettuce production fields.

Background: Most lettuce in the Salinas Valley is direct seeded and thinned by labor

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The current automated weeding machines use cameras to detect plants, and a computer algorithm to process the image, calculate which plants to keep/remove, and activate a kill mechanism.

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crews with hoes. Recently labor available for lettuce thinning has become scarcer. Starting in 2013 and 2014 we have seen automated lettuce thinners become well established in the Salinas Valley. These machines use a camera to capture images of the seedline. A computer analyzes the image and calculates which plants to keep. The computer then activates a "kill mechanism" to remove the unwanted lettuce plants. Four of the five lettuce thinners use a spray solution to kill unwanted plants and one uses a mechanical blade. In just the short time that these machines have been in use we have seen improvements in their speed and accuracy.

The current technology in use by these weeders cannot effectively distinguish weeds from crop plants. Rather the machines rely on the difference in size of the crop vs the weeds, as well as the location of the crop plant in the seedline to distinguish between the crop and weeds.

Intelligent cultivators have been developed in Europe and have been used there for several years. They were developed there for use primarily on transplanted vegetable crops. The current technology in use by these weeders cannot effectively distinguish weeds from crop plants. Rather the machines rely on the difference in size of the crop vs the weeds, as well as the location of the crop plant in the seedline to distinguish between the crop and weeds. The machines use an algorithm based on pattern recognition of the seedline. Plants of specified size in the seedline are assumed to be crops. Basically the machine images a two dimensional plane and views each plant as a blob of green and makes its distinctions based on that image. That is why the machines work more effectively on transplanted crops where there is initially a large difference between the transplanted vegetable and the emerging weeds. Weed plants that overlap with the image of crop plants will also not be detected.

In 2015 two intelligent cultivators were available in the Salinas Valley: the Robovator, F Poulsen Engineering Aps, Denmark (Photo 1) and Steketee IC Weeder, the Netherlands (Photo 2). Both of these machines use a split knife weed removal mechanism (Photo 3). This knife travels in the uncultivated seedline that is left by traditional cultivation (Photo 4). It closes between crop plants and undercuts the weeds there. It opens around the crop plants. The level of aggressiveness of the machine can be adjusted by allowing the knives to get close to the crop and remove as many weeds as possible without damage to the crop (Photo 5).

Methods: We conducted four evaluations of intelligent cultivators in 2015 to evaluate weed removal efficacy and safety to lettuce plants. All trials were conducted in commercial lettuce fields, and the plantings varied by planting configurations, weed pressure and lettuce variety. The Robovator was used in three of the studies and the Steketee IC Weeder in one. Pre cultivation counts were made of lettuce plants and weeds and post cultivation counts were made of the same parameters one to four days following cultivation. Sample areas where counts were made consisted of two 40-inch or one 80-inch wide beds by 30 to 100 feet long. Sample areas were compared with paired strips that were not cultivated to compare the safety of the intelligent cultivator and their efficacy in removing weeds in the seedline and thereby reducing subsequent hand weeding time.

Trial No. 1: This trial utilized the Robovator intelligent cultivator and was conducted south of Salinas in a commercial head lettuce field following thinning. The field was planted on 80 inch wide beds with 6 seedlines. The field was thinned with an automated thinner that used an herbicide to kill unwanted lettuce plants and weeds, however the

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automated thinner performed poorly and there was a great deal of regrowth of the treated lettuce plants. Weed and lettuce plant counts were made on June 24, 2015 by counting weeds and lettuce plants in each seedline in three replicated 100-foot strips in the field. The field was weeded with the Robovator on June 25. Post weed and lettuce stand counts were made on July 1 by counting surviving weeds, lettuce plants and regrowing lettuce plants in the same area as the pre weeding evaluation areas. The Robovator treated plots were paired with adjacent beds that were hand weeded. Lettuce regrowth, follow up hand weeding time and yield were evaluated in cultivated and non-cultivated plots. Hand weeding evaluations were made by timing how long it took to weed the individual seedlines in each 100-foot sample area. ***Trial No. 2:*** This trial utilized the IC Steketee intelligent cultivator and was conducted west of Castroville in a commercial head lettuce field following thinning. Pre cultivation counts of lettuce and weeds were made on July 14 in three replicated 100-foot long sample areas of two 40-inch wide beds with 2 seedlines per bed. Cultivated plots were paired with 100-foot long sample areas that were hand weeded. On July 15, following mechanical weeding, the number of weeds and lettuce plants were counted, and the time to do follow up weeding recorded. Harvest evaluations were made on August 12. ***Trial No. 3:*** This trial utilized the Robovator intelligent cultivators. This trial was conducted north-west of Salinas in a commercial head lettuce field following thinning. Pre cultivation lettuce and weed counts were made on July 20 in three replicated 100-foot long strips of an 80-inch wide bed with 5 seedlines. The plots were cultivated with the Robovator. Cultivated plots were paired with 100-foot long sample areas that were hand weeded. Following cultivation, weeds and lettuce plants were counted on July 21. Time to hand weed the cultivated and non-cultivated plots was measured on July 21. No harvest evaluation was made at this site. ***Trial No. 4:*** This trial utilized the Robovator intelligent cultivators. The trial was conducted north of San Juan Bautista in a commercial transplanted organic romaine lettuce field. Pre cultivation lettuce and weed counts were made on August 6 in three replicated 30-foot long strips of an 80-inch wide bed with 6 seedlines. The plots were cultivated with the Robovator. Cultivated plots were paired with 30-foot long sample areas that were hand weeded. Following cultivation, weeds and lettuce plants were counted on August 7. Time to hand weed the mechanically treated and untreated plots was measured on August 7. Harvest evaluations were made on September 4.

Results: *Trial No. 1*: This trial had some problems which made mechanical weeding difficult. There was a great deal of regrowth of lettuce plants from the mechanical thinning operation that did not completely kill lettuce seedlings. Most of these unthinned lettuce plants were stunted, but the Robovator was able to distinguish them from the larger keeper plants, and as a result, removed a great deal of them. There were 64,004 regrowth lettuce plants/A prior to passing through the field with the Robovator and 11,775 regrowth lettuce plants/A after the Robovator passed through the field, an 81.6% reduction. There were fewer weeds following weeding with the Robovator, but there were also fewer of the desired keeper lettuce plants following weeding with the Robovator at this site (Table 1). Overall, there was a dramatic reduction in the number of hours to do the follow up weeding operation following the Robovator: 7.4 vs 16.5 hrs/A ($P>0.0016$). Another issue that may have reduced the effectiveness of the Robovator at this site was the evenness of the speed of the tractor. For some reason the tractor could not maintain a constant speed which made it difficult for the Robovator to work effectively and may

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have contributed to some of the issues with the automated weed removal encountered at this site. ***Trial No. 2:*** There was no significant difference in the number of lettuce plants between cultivated and hand weeded plots at this site. There was also no statistical difference in the number of weeds removed by the automatic lettuce thinner but there was a trend showing a 74.7% reduction. Follow up hand weeding time was significantly reduced 36.8% after the use of the Robovator. There was no significant difference in the mean head weight between Robovator and hand weeded plots. ***Trial No. 3:*** There were significantly fewer lettuce plants in the mechanically weeded plots. Although there were very low numbers of weeds at this site, there was a strong trend indicating that the intelligent cultivators removed 74.9% of the weeds in the plots and it took significantly less time to do follow up hand weeding in the cultivated plots. No yield evaluation was carried out at this site. ***Trial No. 4:*** There was no significant difference in the number of lettuce plants between cultivated and hand weeded plots. There were 52.1% fewer weed plants in the mechanically weeded plots than hand weeded plots, and it took 22.2% less time to do follow up hand weeding of the plots.

Photo 1. Robovator intelligent cultivators

Photo 2. IC Steketee intelligent cultivators

Photo 3. Knives in the open position

Photo 4. Uncultivated band

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Photo 5. Uncultivated 'island' around keeper plant

Table 1. Evaluation of lettuce stand and number of weeds pre and post cultivation

Pre vs Post mechanical weeder	Trial 1		Trial 2		Trial 3		Trial 4		Mean	
	Lettuce plants/A	Weed plants/A	Lettuce plants/A	Weed plants/A	Lettuce plants/A	Weed plants/A	Lettuce plants/A	Weed plants/A	Lettuce plants/A	Weed plants/A
Pre weeding	35,263.6	3,662.4	31,763.3	2,405.0	37,538.4	261.4	44,879.3	48,038.5	37,361.15	13,591.83
Post weeding	31,078.1	2,746.8	30,701.7	606.7	36,122.3	65.4	43,136.2	22,984.0	35,259.58	6,600.73
Pr>treatment	0.0886	0.0728	0.1566	0.2860	0.0333	0.0955	0.1348	0.0637	---	---

Table 2. Follow up hand weeding following cultivation vs no prior cultivation

Treatment	Trial 1		Trial 2		Trial 3		Trial 4		Mean	
	Follow up hand weeding hrs/A	Mean Plant wt lbs	Follow up hand weeding hrs/A	Mean Plant wt lbs	Follow up hand weeding hrs/A	Mean Plant wt lbs	Follow up hand weeding hrs/A	Mean Plant wt lbs	Follow up hand weeding hrs/A	Mean Plant wt lbs
Intelligent cultivators	7.4	1.81	3.6	2.21	3.6	---	9.8	1.16	6.1	1.73
No intelligent cultivators	16.5	2.21	5.7	2.34	4.0	---	12.6	1.15	9.7	1.90
Pr>treatment	0.0016	0.0887	0.0007	0.3952	0.0617	---	0.2012	0.9798	---	---