Cooperative Extension • Monterey County

Crop Notes

March / April 2009

In This Issue:

FOOD SAFETY AND SALINAS VALLEY CROPS: 5: Research on soil survival of E. coli in the Salinas Valley

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This is the fifth of a series of articles dealing with the pathogenic bacterium *Escherichia coli* (abbreviated *E. coli*) within the context of leafy vegetable crops in California. The purpose of this article is to summarize a two-year study on the soil survival and ecology of *E. coli* under field conditions in the Salinas Valley. Outbreaks of foodborne pathogens on leafy vegetables, especially the 2006 outbreak on spinach, have highlighted the need for practical information on the dynamics of such organisms in the field. However, studies on *E. coli* as it might function and survive under coastal California field conditions were lacking.

Because of the need for such information, we expanded the activities of our collaborative team and initiated studies that were conducted on farmland in Monterey County. It is hoped that our research will contribute to a better understanding of foodborne pathogens and help validate or guide improved food safety metrics. Our objectives were the following: (1) Examine soil survival of generic and attenuated O157:H7 strains of *E. coli* under commercial field situations, and (2) Examine the impacts of soil moisture levels, different irrigation systems, and fertilizer levels on *E. coli* survival in an open field environment. Experiments initially used generic (non-pathogenic) *E. coli* strains selected from leafy greens farms in the Salinas Valley and later also included attenuated O157:H7 strains. Attenuated strains are *E. coli* O157:H7 bacteria that lack the genes that code for toxin production; these naturally selected strains are therefore of greatly reduced risk to humans.

Role of soil moisture in *E. coli* survival: In two different small plot field experiments, mixtures of generic *E. coli* strains were applied to pre-wetted seedbeds using a backpack sprayer; beds were then irrigated with overhead sprinklers, and the soil periodically tested to examine persistence of the applied bacteria. Subsequent sprinkler waterings were scheduled to simulate irrigations used to germinate a lettuce crop. With catch-buckets, the irrigation rates in the plots were recorded. All of our *E. coli* strains, inoculated to soil at high rates (10^6 or 10^8 CFU/ml), were recovered from soil for only a short period. By 8 days after inoculation, recovery was at or near the detection limit for most plots. By 14 days, *E. coli* was no longer detected from soil. Catch-bucket data indicated that the downwind side of the plots (block B) received more water, and had higher *E. coli* recovery rates, than the upwind plots (block A) that had less water and lower *E. coli* recovery rates (2007 results: Figure 1). Further analysis of our data confirmed that the most significant factors affecting the survival of *E. coli* in the soil were the initial concentration of the bacteria, the amount of applied water, and time.

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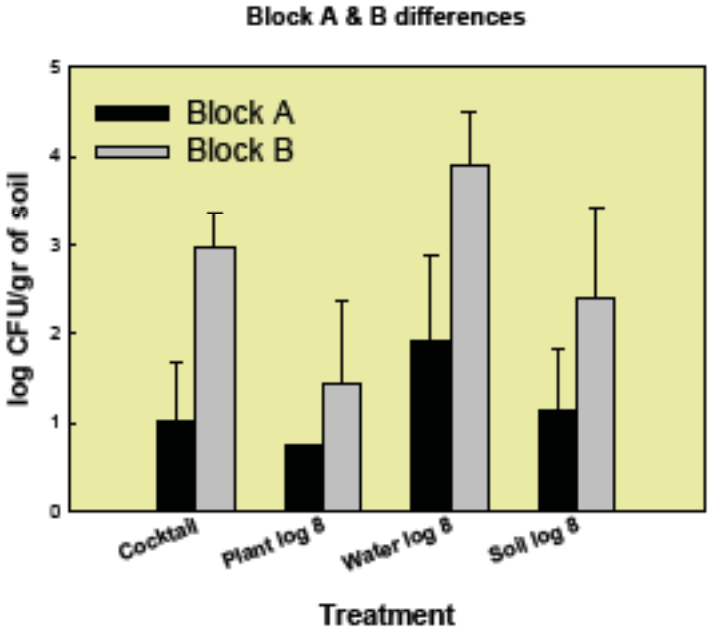

Figure 1. Soil survival of *E. coli* in the wetter downwind (block B) vs. drier upwind (block A) sides of the 2007 small plot study. The applied strains were designated as Plant (originally isolated from romaine lettuce), Water (isolated from an irrigation reservoir), and Soil (isolated from a clay loam soil in a romaine field). Strains were applied at log 8 CFU/ml (= 100,000,00 cells/ml) to the seedbed. The Cocktail treatment was an equal mixture of all three *E. coli* strains and was applied at log 7 CFU/ml (= 30,000,000 cells/ml).

Practical field studies examined survival of *E.coli*.

Soil mositure appears to be important for bacterial survival.

Effects of irrigation systems and fertilizers: For the large plot field experiments, different fertilizer treatments (grower standard and supplemented rates) and romaine lettuce seed were first placed into the replicated seedbed plots. Mixtures of generic and attenuated O157:H7 *E. coli* were then sprayed onto beds at high rates (up to 10^7 CFU/ml). After the initial sprinkler irrigation for all plots, half of the plots were subsequently irrigated with overhead sprinklers and the other half with surface drip tape. Lettuce was germinated and grown, using commercial practices, to harvestable size. Soil, irrigation runoff (from sprinkler plots only), and romaine plants were periodically tested for the inoculated bacteria. *E. coli* was recovered from soil for only a short period (3 and 14 days post inoculation for 2007 and 2008, respectively) (2008 results: Figure 2). Beyond this period only low levels of *E. coli* could be detected using an enrichment method. Neither irrigation (sprinkler vs. drip) or fertilizer (standard vs. supplemental) treatments influenced the survival of *E. coli*.

We did not recover *E. coli* from lettuce plants, growing in inoculated beds, at any stage (seedling, rosette, harvest size) of growth. An enrichment detection method used on lettuce seedlings also did not recover applied strains. For runoff water from the sprinkler plots, we recovered *E. coli* for up to 12 (in 2007) and 30 (in 2008) days post-inoculation. We also learned that generic and attenuated O157:H7 *E. coli* strains behaved similarly. Both strains survived for only a short time in soil, and we failed to detect the transfer of either strain moving from soil and onto lettuce.

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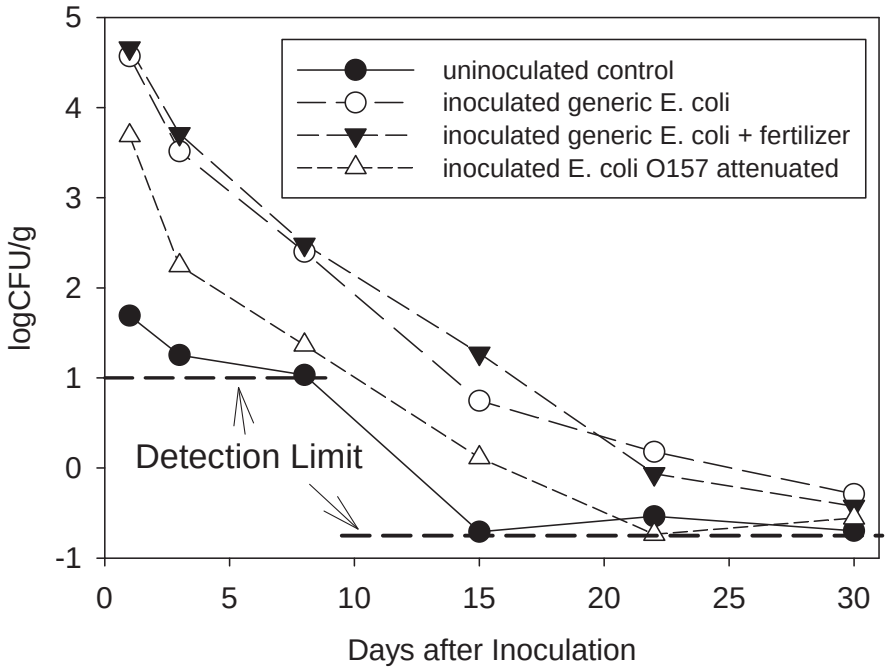

E. coli persisted for only a short time in the soil.

Figure 2. Recovery of generic *E. coli* and nonpathogenic *E. coli* O157 strains that were inoculated to soil in the 2008 large plot field study. Detection limit = 10 (log 1) colony forming units per gram of soil (cfu/g) up to 8 days after inoculation and 0.13 (log -0.70) cfu/g after 8 days. Note that recovery of *E. coli* is expressed on a log scale, such that log 0 = 1 cfu/g, log 1 = 10 cfu/g, log 10 = 100 cfu/g, etc.

Conclusions: Our simulation of a one-time, high level contamination event to a lettuce seedbed resulted in very short persistence of *E. coli*. Increased *E. coli* survival was apparently associated with higher rates of sprinkler applied water. Though water, soil moisture levels, and environmental conditions likely influence bacterial survival, we could not document significant differences between drip and sprinkler plots due to the very short survival time. *E. coli* persisted for a short period in surface water runoff. Romaine grown in the experimental plots did not test positive for *E. coli* at anytime. Generic *E. coli* strains behaved similarly with attenuated O157:H7 *E. coli* strains. Additional applied, field-oriented research is needed so that industry and regulators can make informed decisions on growing practices and future food safety policies

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CARROT WEED CONTROL TRIAL - 2008

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Post emergence applications of Caparol were less effective than preemergence applications.

Summary: Caparol will provide an important new weed control tool for use on carrots. Preemergence applications of Caparol were safer than post emergence applications at the 4 pint rate/A. Post emergence applications of Caparol were less effective than preemergence applications. Preemergence applications of 4 pints/A of Caparol provided weed control comparable to a pre plus postemergence application of Lorox at 1.5 lb/A.

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Background: Lorox was registered for use on carrots in 1966 and has been the principle herbicide used on that crop since that time. It provides excellent control of many broadleaf and grass weed species, as well as partial control of yellow nutsedge. In 2008 there were some indications that Caparol was going to be registered on carrots. This materials would provide weed control similar to Lorox for the most part (except for yellow nutsedge - Table 1), but provide an alternative to Lorox in situations where you may not be allowed to use Lorox due to label restrictions. As it turned out, the registration of Caparol on carrots is still at the EPA awaiting action on registration (Caparol is being reviewed along with cilantro and both will emerge from the registration process together). Given the impending registration, we decided to conduct a trial in order to have a better understanding of its strengths and weakness.

Preemergence applications of 4 pints/A of Caparol provided weed control comparable to a pre plus postemergence application of Lorox at 1.5 lb/A.

Methods: The trial was conducted in cooperation with Bolthouse and Bragga Farms in San Ardo. The trial was established on March 13. The soil type at the site was Garey sandy loam. Each plot was one 15 feet of bed long by one 40-inch bed wide and was replicated four times in a randomized complete block design. The preemergence applications were applied immediately following planting on March 13 and the post emergence application was made on April 25 when the carrots were at the 2-3 true leaf stage (Table 2). A second post emergence application was planned for treatments 5 and 7 (see table 2 below), but was discontinued based on the significant phytotoxicity observed from the first postemergence application. All treatments were applied with a CO2 backpack sprayer applying the equivalent of 72 GPA with two passes of a one nozzle boom with an 8008E nozzle at 30 psi. See tables for evaluations and dates.

The registration of Caparol on carrots is still at the EPA awaiting action on registration (Caparol is being reviewed along with cilantro and both will emerge from the registration process together).

Results: The first two evaluation dates measured the impact of the preemergence applications. On the April 3 evaluation date preemergence application of Caparol at 4 pts/A provided the highest level of weed control followed by Lorox at 1.5 lb/A, Caparol at 2 pts/A and Norton at 48 ounces/A (data not shown). The same trend was observed on April 10 except that Caparol at 2 pints/A had declined to the lowest level of weed control (Table 3).

On the third evaluation date, May 8, the numbers of weeds in the untreated decreased due to competition and mortality which caused the total number of weeds to decline from the April 10 levels (Table 4). A preemergence application of Caparol at 4 pints/A with or without a follow up post emergence application of Caparol provided 100% weed control on this date; in addition, these applications had the lowest time to weed (Table 5). Post emergence applications of Caparol at 2 pints/A did not provide as good of weed control as a post emergence application of Caparol at 4 pints/A. In addition, the 4 pints/A post emergence rate of Caparol was more injurious to carrots as evidenced by yellowing and stunting of the plants (Table 5). Four pint/A rates of Caparol applied preemergence did not cause stunting of the carrots which indicates that preemergence applications of Caparol are safer than post emergence applications of Caparol on carrots; in addition, post emergent applications of Caparol alone were not as effective as preemergent applications. Pre followed by post emergence applications of Lorox provided 98.4% control of weeds and a preemergent application of Nortron followed by 2 pints of Caparol post emergence provided 100% control of weeds and low time to weed on May 8. Both of these treatments also had low phytotoxicity ratings. It is important to note that without the herbicide treatments carrots required 632 hours per acre to weed at this site. There were no statistical differences in yield between any of the treatments (Table 5).

Caparol applied preemergence did not cause stunting of the carrots which indicates that preemergence applications of Caparol are safer than post emergence applications of Caparol on carrots.

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Pre followed by post emergence applications of Lorox provided 98.4% control of weeds and a preemergent application of Nortron followed by 2 pints of Caparol post emergence provided 100% control of weeds and low time to weed

It is important to note that without the herbicide treatments carrots required 632 hours per acre to weed at this site.

Table 1. Comparison of weed control between Lorox and Caparol (C=control; P=partial control; N= no control)

BROADLEAF	**Lorox**	**Caparol**
CHICKWEED	C	C
GOOSEFOOT	C	C
GROUNDSEL, COMMON	C	C
HENBIT	C	C
KNOTWEED	P	C
LAMBSQUARTERS	C	C
LONDON ROCKET	C	C
MALVA	C	C
NETTLE, BURNING	C	C
NIGHTSHADE, BLACK	C	C
NIGHTSHADE, HAIRY	P	C
NUTSEDGE, YELLOW	P	N
PIGWEED	C	C
PINEAPPLE WEED	C	C
PRICKLY LETTUCE	C	C
PURSLANE	C	C
SHEPERDSPURSE	C	C
SOWTHISTLE	C	C
SWINE CRESS	C	C
WILD RADISH	C	C
GRASSES		
BARNYARDGRASS	C	P
BLUEGRASS, ANNUAL	C	C
CEREALS	P	P
LOVEGRASS	C	P
RYEGRASS	N	P

Table 2. Explanation of weed control materials, timing of application and rates.

Treatment No.	**Treatment**	**Application Timing**	**Rates/A**
1	Caparol 4L	Preemergence – March 13	2 pt
2	Caparol 4L	Preemergence – March 13	4 pt
3	Caparol 4L Caparol 4L	Preemergence – March 13 Post emergence – April 25*	2 pt 4 pt
4	Caparol 4L Caparol 4L	Preemergence – March 13 Post emergence – April 25	4 pt 4 pt
5	Caparol 4L Caparol 4L	Post emergence – April 25 2nd post emergence - discontinued	2 pt 2 pt
6	Caparol 4L	Post emergence – April 25	4 pt
7	Caparol 4L Caparol 4L	Post emergence – April 25 2nd post emergence - discontinued	4 pt 4 pt
8	Lorox 50WP Lorox 50WP	Preemergence – March 13 Post emergence – April 25	1.5 lb 1.5 lb
9	Nortron Caparol 4L	Preemergence – March 13 Post emergence – April 25	48 oz 2 pt
10	Untreated	----	-----

* 2-3 true leaves

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Untreated foreground of middle row (with weeds); standard Lorox treatment behind

Untreated on left bed and Caparol at 4.0 pints/A on right bed

Table 3. Percent weed control and weed count on April 10 (31 days after planting). Gray shaded number is percent control & non-shaded number is number of weeds per 3 ft^2 (note that postemergence application was not applied until April 25).

Treatment	Application timing	Rates/A	Lambs-quarter	Night-shade	Pig weed	Sow thistle	Other weeds	% control Weed count
Caparol 4L	Preemergence	2pt	21.6	5.0	49.6	37.5	25.0	36.4
			23.0	2.3	5.3	0.8	1.3	32.5
Caparol 4L	Preemergence	4pt	66.0	62.5	72.2	62.5	75.0	70.6
			9.8	1.3	1.3	0.5	1.0	13.8
Caparol 4L	Preemergence	2pt	19.2	50.0	15.5	62.5	0.0	8.6
Caparol 4L	Post emergence	4pt	24.0	1.8	20.3	0.3	3.0	49.3
Caparol 4L	Preemergence	4pt	63.7	37.5	43.2	87.5	62.5	67.0
Caparol 4L	Post emergence	4pt	8.8	1.3	6.3	0.3	0.5	17.0
Caparol 4L	Post emergence	2pt	----	----	----	----	----	----
	Post emergence	2pt[1]	----	----	----	----	----	----
Caparol 4L	Post emergence	4pt	----	----	----	----	----	----
	Post emergence		----	----	----	----	----	----
Caparol 4L	Post emergence	4pt	----	----	----	----	----	----
	Post emergence	4pt[1]	----	----	----	----	----	----
Lorox 50WP	Preemergence	1.5lb	45.7	66.7	24.6	75.0	50.0	46.6
Lorox 50WP	Post emergence	1.5lb	9.8	0.5	1.8	0.0	0.5	12.5
Nortron	Preemergence	48oz	25.9	27.5	66.7	62.5	0.0	49.2
Caparol 4L	Post emergence	2pt	12.8	1.5	1.0	0.3	1.8	17.3
Untreated	----	----	0.0	0.0	0.0	0.0	0.0	0.0
			22.0	3.0	18.3	1.3	1.8	46.3
LSD 0.05 - % control	----	----	40.315	48.703	48.786	47.292	44.751	39.153
Pr>F - % control	----	----	<0.0001	0.0005	0.0007	0.0032	<0.0001	<0.0001
LSD 0.05 weed count	----	----	13.906	NS	14.754	0.699	NS	22.824
Pr>F weed count	----	----	0.0028	0.0720	0.0499	0.0160	0.0938	0.0003

1 - second postemergence application discontinued

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Table 4. Percent weed control and weed count on May 8 (56 days after planting). In each cell, upper number is percent control and lower number is number of weeds per 3 ft^2

Treatment	Application timing	Rates/A	Lambs-quarter	Night-shade	Pig weed	Sow thistle	Other weeds	% control Weed count
Caparol 4L	Preemergence	2pt	54.6	75.0	57.8	75.0	33.3	53.7
			7.5	0.3	3.0	0.3	1.5	12.5
Caparol 4L	Preemergence	4pt	100.0	100.0	100.0	100.0	100.0	100.0
			0.0	0.0	0.0	0.0	0.0	0.0
Caparol 4L	Preemergence	2pt	100.0	100.0	100.0	100.0	75.0	96.6
Caparol 4L	Post emergence	4pt	0.0	0.0	0.0	0.0	0.3	0.3
Caparol 4L	Preemergence	4pt	100.0	100.0	100.0	100.0	100.0	100.0
	Post emergence	4pt	0.0	0.0	0.0	0.0	0.0	0.0
Caparol 4L	Post emergence	2pt	100.0	100.0	95.3	100.0	50.0	89.6
	Post emergence	2pt[1]	0.0	0.0	0.8	0.0	2.0	2.8
Caparol 4L	Post emergence	4pt	100.0	100.0	100.0	100.0	62.5	95.3
	Post emergence		0.0	0.0	0.0	0.0	0.8	0.8
Caparol 4L	Post emergence	4pt	100.0	100.0	96.9	100.0	29.2	90.6
	Post emergence	4pt[1]	0.0	0.0	0.3	0.0	1.8	2.0
Lorox 50WP	Preemergence	1.5lb	100.0	100.0	100.0	100.0	87.5	98.4
Lorox 50WP	Post emergence	1.5lb	0.0	0.0	0.0	0.0	0.3	0.3
Nortron	Preemergence	48oz	100.0	100.0	100.0	100.0	100.0	100.0
Caparol 4L	Post emergence	2pt	0.0	0.0	0.0	0.0	0.0	0.0
Untreated	----	----	0.0	0.0	0.0	0.0	0.0	0.0
			16.0	0.8	6.0	0.3	2.3	25.3
LSD 0.05 - % control	----	----	19.365	22.940	20.863	22.940	46.950	20.136
Pr>F % control	----	----	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001
LSD 0.05 weed count	----	----	3.612	NS	3.637	NS	1.654	7.574
Pr>F weed count	----	----	<0.0001	0.0938	0.0306	0.4635	0.0349	<0.0001

1 - second postemergence application discontinued

Table 5. Phytotoxicity rating, weeding time on May 8 (56 days after planting) and yield on July 28.

Treatment	Application timing	Rates/A	Phyto[1]	Weeding Time Hrs/A	Yield (T/A)	1000's/A	Mean carrot wt grams
Caparol 4L	Preemergence	2pt	0.0	71.8	47.357	1,065.04	40.4
Caparol 4L	Preemergence	4pt	0.0	6.5	44.842	1,146.71	36.5
Caparol 4L	Preemergence	2pt	1.8	8.3	49.596	1,148.89	39.5
Caparol 4L	Post emergence	4pt					
Caparol 4L	Preemergence	4pt	3.0	7.0	44.823	986.63	42.0
	Post emergence	4pt					
Caparol 4L	Post emergence	2pt	1.3	26.3	-----	-----	-----
	Post emergence	2pt[2]					
Caparol 4L	Post emergence	4pt	3.5	14.3	46.882	1,082.46	40.0
	Post emergence						
Caparol 4L	Post emergence	4pt	3.5	14.8	-----	-----	-----
	Post emergence	4pt[2]					
Lorox 50WP	Preemergence	1.5lb	0.0	8.0	47.693	1,179.38	37.6
Lorox 50WP	Post emergence	1.5lb					
Nortron	Preemergence	48oz	1.3	7.5	43.491	1,057.41	37.7
Caparol 4L	Post emergence	2pt					
Untreated	----	----	0.0	632.3	50.184	1,082.46	43.2
Pr>F	----	----	<0.0001	0.0001	0.7992	0.8323	0.948
LSD 0.05	----	----	0.9261	59.161	NS	NS	NS

1 – Phytotoxicity scale: 0 = no crop damage to 10 crop dead.

2 - second postemergence application discontinued

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OCCURRENCE OF BACTERIAL LEAF SPOT OF PARSLEY IN 2009

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Carolee Bull, USDA-ARS

Beginning at least as early as 2006, a bacterial leaf spot disease of parsley was occasionally observed in California fields. In 2009 the disease is again occurring in growers fields. Symptoms consist of small (less than 1/4 inch in diameter), angular shaped, tan to dark brown leaf spots that are visible from both top and bottom sides of leaves. As disease progresses, the spots usually do not expand significantly and do not coalesce or merge together. A key diagnostic feature is that these spots do not contain any signs of fungal fruiting bodies or structures. This absence of fungal structures differentiates this bacterial disease from the well known Septoria blight caused by *Septoria petroselini*. Septoria blight of parsley can cause a similarly shaped angular leaf spot; however, such spots almost always contain profuse numbers of tiny, black, spherical fruiting bodies called pycnidia.

Bacterial leaf spot of parsley is recurring in the Salinas Valley.

A fluorescent bacterium in the genus *Pseudomonas* has been consistently isolated from diseased flat and curly leaf parsley cultivars. Inoculation experiments have demonstrated that these bacteria, tentatively identified as *Pseudomonas syringae*, are responsible for this problem. Four parsley cultivars were evaluated (Evergreen, Moss, Forest Green, Dark Green Italian) and all appeared to be equally susceptible. A joint research project by UC Cooperative Extension (Monterey County) and the USDA-ARS in Salinas is in progress.

The development of the disease is clearly linked with splashing water that comes from rain and overhead sprinkler irrigation. Elimination of such water would significantly limit disease development. Fungicides and bactericides are unlikely to provide satisfactory control for fresh market produce standards. The source of the bacterium is not determined, though seedborne inoculum is possible.

Additional samples of this disease would assist in the research effort. If possible bacterial leaf spot is observed on parsley, please contact Steve Koike (831-759-7350; 1432 Abbott Street, Salinas CA, 93901).

1. Bacterial leaf spot of parsley appears as angular, brown to tan leaf spots.

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2. Septoria blight of parsley also appears as angular brown spots; however, spots also contain very small, black fruiting bodies.

SYSTEMIC DOWNY MILDEW OF LETTUCE AND CRUCIFERS

Steven T. Koike
Plant Pathology Farm Advisor

Systemic downy mildew may be difficult to confirm

Introduction: In the late winter of 2008 and early spring of 2009, several cases of systemic downy mildew of vegetables were confirmed by our Diagnostic lab in Salinas. Typical downy mildew disease of lettuce and crucifers is easily recognized by field personnel and consists of the familiar leaf spots and lesions covered with the fuzzy white growth of the sporulating pathogen. In contrast, systemic downy mildew of these crops is much less common and may be puzzling to those making diagnoses. This article describes the systemic phase of downy mildew of lettuce (caused by *Bremia lactucae*) and of cauliflower and broccoli (caused by *Peronospora parasitica*).

Definitions: A systemic infection usually means that the invading pathogen has successfully spread extensively within the internal tissues of the plant. In the case of downy mildews, the pathogens can move between and in various plant cells but are not necessarily dependent on

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conductive vascular tissues (phloem and xylem) for such movement. Therefore, a downy mildew growing in a systemic phase can be in the center of a plant stem (pith tissue) or underneath the plant epidermis; neither of these plant tissues contains much or any vascular tissue.

In comparison, other plant pathogens are known as vascular pathogens because they primarily spread through the xylem or phloem of plant conductive tissues. Examples of typical vascular pathogens are *Fusarium oxysporum* pathogens that cause Fusarium wilt, *Verticillium dahliae* which causes Verticillium wilt, and the black rot pathogen of crucifers, *Xanthomonas campestris* pv. *campestris*. Given our definitions here, these vascular pathogens can result in systemic infections. However, the downy mildews cause systemic infections but are not true vascular pathogens.

Systemic symptoms include darkening of internal tissues.

Symptoms: Lettuce plants infected systemically with downy mildew may not show obvious effects. Such plants may appear completely healthy, or they may exhibit some stunting and restricted growth. Such plants may show signs of early decline near harvest. The main symptom of systemic downy mildew of lettuce is the extensive dark brown to black internal discoloration of the main stem (Fig. 1). Cross- or transverse-sectioning of the main stem will reveal this discoloration in the central core (pith) and sometimes in the vascular ring of the plant. Dark internal discoloration of the leaf petiole can also be seen where the leaf attaches to the main stem. The dark discolored tissues are firm and not soft or rotted.

Cauliflower or broccoli plants infected with systemic downy mildew can also appear healthy and show no stunting or reduction in size. However, the small branches within the developing head can show extensive black to gray scarring and streaking (Fig. 2). This systemic growth underneath the epidermis of the branches detracts from the appearance and marketability of the heads. Cutting into the upper main stem near the cauliflower or broccoli head will also reveal internal black discoloration.

Keep in mind that there are other conditions that can cause similar internal discolorations of lettuce and crucifers. A physiological condition (sometimes called cat's eye or bird's eye) can cause the very center of the lettuce stem to change color, become translucent, then darken and discolor; this may resemble systemic downy mildew. Nutritional or other physiological conditions can cause internal tissues of the cauliflower head to likewise discolor. Blackening of the vascular tissue in taproot and lower stems may be caused by Verticillium wilt.

Systemic downy mildew can occur in lettuce, cauliflower, and broccoli.

Confirmation of systemic downy mildew will require tests in a lab. Thin sections of symptomatic tissues are cut from samples, soaked in a biological stain (such as aniline or cotton blue), then examined with a compound microscope. Systemic downy mildew can be confirmed when characteristic structures are seen using this method. Alternatively, pieces of symptomatic tissue can be incubated in a moist chamber at cool temperatures. After 24 to 48 hours the characteristic branched structures that bear downy mildew spores can grow out of the discolored tissues (Fig. 3) and can be seen with a hand lens or dissecting microscope.

Little research has been conducted on this phase of downy mildew. Researchers have not documented why this systemic phase occurs, what triggers its development, or why it does not always show up on a crop. The frequency of systemic downy mildew on lettuce, cauliflower, and broccoli is generally low, so specific control measures for this phase of the disease have not been developed. General management of downy mildew through the planting of resistant cultivars and application of protectant fungicides should address this systemic phase, as well. Systemic downy mildew is not unique to lettuce and crucifers but also occurs on other plants such as sunflower, corn, sorghum, and pearl millet.

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Figure 1. Systemic downy mildew of lettuce can cause internal darkening of the lettuce stem.

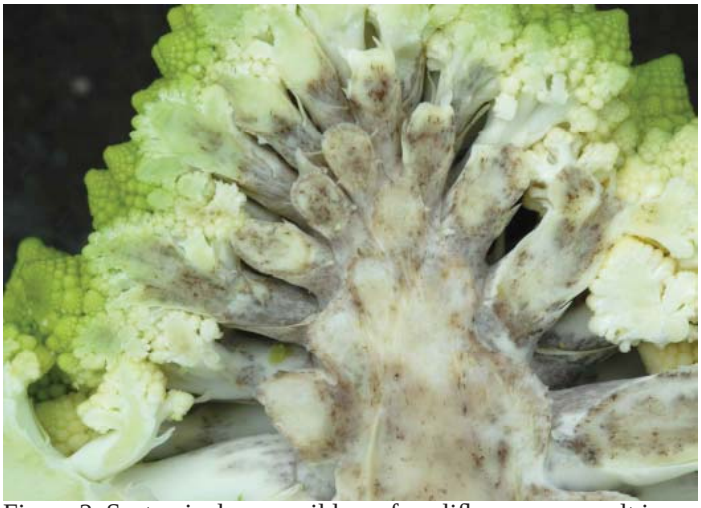

Figure 2. Systemic downy mildew of cauliflower can result in extensive black scarring within the harvested head.

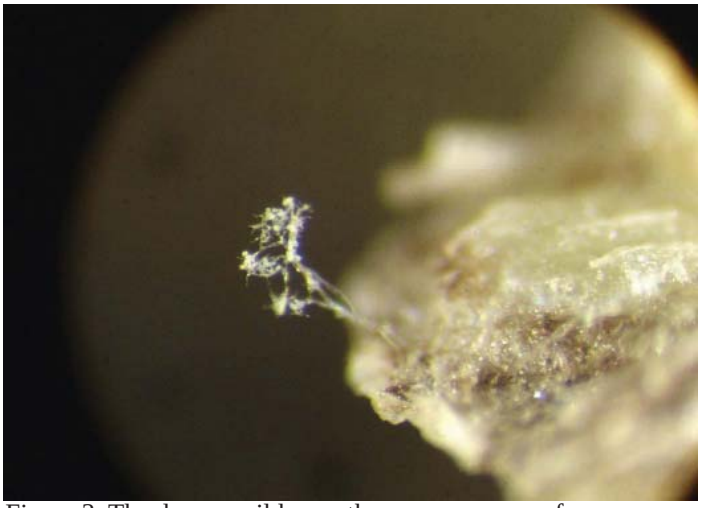

Figure 3. The downy mildew pathogen can emerge from systemic infections if samples are incubated under controlled conditions.