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CALIFORNIA OAKWORM AND LIGHT BROWN APPLE MOTH

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California oakworm (oakmoth) is a native species that feed on oaks in California. This summer, there is an extremely high population of California oakworm in Salinas Valley. Many people confused the California oakworm with the introduced light brown apple moth because the adults of California oakworm are light brown colored moths. In the past few weeks, I have many phone calls from nurseries and homeowners about an infestation of "light brown apple moth" on their trees; however, most of the samples that I have received are California oakworm.

The California oakworm belongs to the oakworm family (Dioptidae), whereas the light brown apple moth belongs to the leafroller family (Tortricidae). The larva of California oakworm does not make a nest by rolling a leaf of the host as the larva of light brown apple moth does. The California oakworm has two generations per year in California. The second generation larvae usually appear from late July through September. If more than 25 oakworms were observed per 100 twigs of oak in the next two months, insecticide application is justified. The adult moths feed on nectar and do not cause any damage on plants.

The light brown apple moth, which is native to Australia, is known to feed on more than 250 plants. The moth was confirmed in California during March 2007. In early July, about 4900 light brown apple moths were discovered in nine counties, including Alameda, Contra Costa, Marin, Monterey, Napa, San Francisco, San Mateo, Santa Clara, and Santa Cruz. More than 90% of the moths captured were trapped in Santa Cruz and northern Monterey Counties. The characteristics of different stages of California oakworm and light brown apple moth (and other leafrollers) are compared and presented in Table 1. Please contact the University of California Cooperative Extension, Monterey County at 759-7359, if you have questions about the identification and management of California oakworm and light brown apple moth.

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FOOD SAFETY AND SALINAS VALLEY CROPS: 2. BIOLOGY AND ECOLOGY OF *E. COLI* O157:H7 IN ANIMAL SYSTEMS

Steven Koike, Plant Pathology Farm Advisor

This is the second of a series of articles dealing the pathogenic bacterium *Escherichia coli* (abbreviated *E. coli*) within the context of leafy vegetable crops in California. The purpose of this article is to provide information on the biology and ecology of *E. coli* O157:H7 within animal systems. The role of human sources of contaminating *E. coli* is not included here but may be the focus of a future article. Other articles will present additional research-based information on the biology, ecology, and management of pathogenic *E. coli*.

<u>Background</u>: The 2006 outbreak of *E. coli* O157:H7, associated with spinach grown in California, was followed by an unprecedented Food and Drug Administration nation-wide advisory against eating spinach. Industry, government, regulatory agencies, non-government organizations, and research groups have since mobilized to devise programs to improve food safety for fresh vegetable commodities and to conduct needed research on the dynamics of *E. coli* O157:H7 in plant production agriculture. Though *E. coli* O157:H7 is not a new problem, the continued and periodic occurrence of this virulent human pathogen is a serious current concern for producer and consumer alike.

<u>Why talk about animals</u>: *E. coli* is a common and significant microbial component of the gastrointestinal tract of humans and animals. Because a primary source of this microorganism includes animals, *E. coli* contamination of leafy vegetables could indicate that animals or their feces (e.g., manure compost) were in contact with these commodities at some point in the production cycle. While it is true that human contact with leafy vegetables along the farm-to-fork continuum may serve as a source of this bacterium, the focus of this article is on the potential role of animals in spreading *E. coli* O157:H7 to leafy vegetables. *E. coli* O157:H7 biology and ecology in animal systems is relevant for trying to understand how vegetables may become contaminated. Information on how *E. coli* O157:H7 infects and is transmitted within animal systems may help researchers and industry further understand this pathogen in the vegetable crop context.

<u>*E. coli* as complex organism in cattle systems</u>: Our previous article (see May/June 2007 issue of Monterey County Crop Notes) highlighted the complexity of *E. coli* as a bacterial organism. The relationship of *E. coli* and animals is likewise involved and complex. Because human foodborne outbreaks of pathogenic *E. coli* have been associated in the past with improperly cooked beef products, it is widely held that cattle are a significant source (reservoir) of *E. coli* O157:H7 for agricultural areas. It is important to

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note, though, that because most of the research on this subject focused on cattle, we do not have equivalent research into the ability of many of our wildlife species to harbor this bacterium. Hence, we tend to think of cattle when talking about *E. coli* O157:H7 due to the large amount of research on this pathogen in bovines.

Being an intestinal bacterium, pathogenic *E. coli* is encountered in cattle feces. Where cattle are raised and housed, spread and contamination by feces accounts for *E. coli* O157:H7 being found on cattle hides, in their mouths, in water troughs, in runoff water, in cattle feed, and anywhere else that cattle are active and infective manure is present. The transfer of the pathogen among cattle (called horizontal transmission) takes place via feces-contaminated water and feed and animal-to-animal contact. Researchers have thoroughly shown that these intestinal bacteria are readily transmitted among cattle and also between livestock and people or animals in contact with the cattle.

The precise extent of contamination in the bovine industry is difficult to determine. Surveys appear to suggest that well over 50%, and perhaps closer to 100%, of herds in the USA are infected to some degree. Regarding the percent of cattle within herds that harbor *E. coli* O157:H7, estimates vary greatly and range from below 1% of cattle to as high as 28% of a herd. Both dairy and beef cattle are infected. The *E. coli* O157:H7 pathogen can be recovered from cattle raised in enclosed feedlots as well as animals in pasture-based environments.

As a host, cattle manifest infection by *E. coli* O157:H7 in complicated ways. Young, weaned calves seem to carry the bacterium more often than adult cattle. Both weaned calves and older cattle, however, harbor the pathogen but appear healthy and do not develop actual disease. There is often a distinct seasonality with the release (shedding) of *E. coli* O157:H7 in cattle manure. Cattle infected with the pathogen may not consistently shed *E. coli* O157:H7 throughout the year, but rather release the pathogen in manure during the warmer months of late summer. Additionally, cattle that shed the pathogen can at some point stop releasing the pathogen and no longer be a carrier. Researchers are not clear on the reasons for these shedding patterns. It is unclear if a similar pattern would be found in non-bovine livestock or in wildlife.

Modern molecular tools have demonstrated that cattle are not infected by just a single type of pathogenic *E. coli*. In fact, a diversity of *E. coli* O157:H7 subtypes (based on PFGE analyses) can be obtained from any one individual animal. Such detection methods also show that other, non-O157:H7 pathogenic *E. coli* are present in cattle populations. For cattle herds to carry a number of different subtypes, and for those subtype populations to vary and change over time, argues that herds may be exposed to multiple sources of the pathogen, possibly including non-bovine animals, contaminated environmental elements (such as water), and new animals introduced into the existing herd.

<u>Pathogenic *E. coli* in commercially produced, non-bovine animals</u>: Many studies have examined the presence of pathogenic *E. coli* in animals other than cattle. For example, pathogenic *E. coli* have been confirmed in sheep, goat, pig (uncommon in the USA)**,** and rabbit. Researchers find that *E. coli* O157:H7 operates similarly in cattle and sheep. Infested sheep show no symptoms of disease, shed the pathogen intermittently, and exhibit a seasonality (late summer) of *E. coli* O157:H7 shedding in manure. Also like cattle, non- *E. coli* O157:H7 pathogens are found in these various animals. It is unknown whether these non-bovine sources of pathogenic *E. coli* have any bearing on leafy vegetable contamination cases.

<u>Pathogenic *E. coli* in non-commercial and feral (wild) animals</u>: A number of non-commercial and feral animals have been shown to carry pathogenic *E. coli*: birds (sparrow, swallow, starling, gull, pigeon), horse, dog, cat, opossum, raccoon, pig, deer, rat, and rabbit. Even insects, mostly flies, can carry or vector *E. coli* O157:H7. The precise role of feral animals and insects in disseminating *E. coli* O157:H7 to cattle, other commercially raised animals, and leafy vegetable fields is unclear. While it is probable that such animals play some sort of role in pathogen dissemination, very little practical, field based research information addresses this question. In addition, the role of wild animals is likely to be complex. For example, some studies found that *E. coli* O157:H7 strains obtained from wild animals were identical to those isolated from nearby domesticated animals; on the other hand, other wild animal surveys found that *E. coli* O157:H7 strains were completely unrelated to those found in domestic animals.

<u>Issues and implications for the leafy vegetable industry</u>:

1. While cattle and other domestic and wild animals carry and shed the pathogen, managing the problem of *E. coli* O157:H7 contamination should not focus only on the animals but must also examine the environment in which the animals are placed. For example, while cattle can contaminate water and soil, it is also possible that contaminated water, dirtied from a non-bovine source, could contaminate the cattle. Some researchers go further and suggest that rather than viewing cattle as the primary source and reservoir of *E. coli* O157:H7, cattle may be "conduits" that are contaminated by external factors and then pass on the pathogen to other environments, such as crop plantings.

2. For both animal and plant agricultural systems, our knowledge of how *E. coli* O157:H7 functions is incomplete. Regulatory safeguards, while needing to start somewhere, are based on this incomplete understanding. For example, the installation of fences around vegetable fields is suggested even though we do not know which wild animals might be implicated in *E. coli* O157:H7 spread; if research later indicates that birds or rodents are a possible pathogen source, then these fences may have negligible benefit. Research might even find that wild animals have no significant role in the spread of *E. coli* O157:H7 and that fences would not address the overall problem. Applied field research is needed to increase our understanding of *E. coli* O157:H7 in both animal and plant settings.

3. Industry, researchers, and regulators must also confront the myth of "zero risk" regarding *E. coli* O157:H7. A complete, absolute, and constant elimination of this contagious, widely disseminated microscopic organism cannot be guaranteed in cattle operations. Likewise, for vegetable commodities that are consumed without cooking (hence have no "killing stage"), the complete and constant eradication of *E. coli* O157:H7 will not be possible. Yet, it is very important to realize that offsetting the sporadic food safety risk caused by *E. coli* O157:H7 are the very real and documented health benefits of maintaining a diet rich in leafy greens and other vegetables. Also of value are the cultural, rural, economic, and food security benefits that are created when we maintain our livestock industries within our state.

4. An examination of the biology of *E. coli* O157:H7 in animals reveals that this complex microorganism exists and functions in a complicated relationship with a variety of domestic and wild animals. Unless new research findings indicate otherwise, animal feces will likely be a significant source of *E. coli* O157:H7 contamination for the leafy vegetable industry. Therefore, any input or element in contact with animals could be a contaminating source of *E. coli* O157:H7 (manure amendments, composts with manure components, surface water originating from animal production areas, water in previous contact with manure, soil containing manure or contaminated water, wild animals and their activities). Beyond that, however, the factors influencing pathogen populations, dissemination, survival, and spread are quite involved. Fruitful collaborations between animal-based and plant-based researchers will assist the leafy vegetable industry in dealing with this foodborne pathogen issue.

Steve Koike thanks Rob Atwill (for contributing to this article) and Wayne Jensen (for reviewing this article).

Animals continue to be the main suspected source of pathogenic E. coli.

Though harboring pathogenic E. coli, cattle do not become sick.

Sheep and other commercially raised animals can carry O157:H7.

The significance of wild animals in carrying pathogenic E. coli is very uncertain.

DETECTING AND CORRECTING SOIL CALCIUM LIMITATIONS

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The issue of calcium (Ca) availability in alka-line, mineral soils has long been a matter of contention. Based on the commonly used 'exchangeable cations' test (ammonium acetate extraction), most California soils are well supplied with Ca. However, in alkaline soils, a substantial percentage of 'exchangeable' calcium identified by this test can be in chemical forms not readily available to plants or active in soil solution. Calcium-related physiological disorders such as blossom end rot of tomatoes and peppers, and tipburn on lettuce, are distressingly common. To combat these disorders, improve postharvest quality, and improve soil structure and water infiltration, California vegetable growers use significant quantities of calcium-based fertilizers and amendments. In the past two years we have studied soil calcium relations, attempting to answer three fundamental questions:

- Are California soils really high in *available* calcium?
- How important a role does soil calcium availability play in disorders such as tipburn in lettuce?
- Is calcium fertigation effective in improving crop Ca nutrition and product quality?

Here are our findings:

How available is calcium in California soils?

To evaluate soil Ca availability we collected a set of 20 representative agricultural soils from fields in vegetable rotations in the Sacramento, Salinas, San Joaquin and Santa Maria Valleys. These soils were chosen to represent a range of texture (sandy loam to clay), pH (6.7 - 7.8) and calcium status. Air-dried samples (top foot of soil) were analyzed for cation content (Ca, Mg, K and Na) by two standard laboratory tests:

- 'exchangeable' cations by ammonium acetate extraction
- 'soluble cations' by saturated paste extraction

Additionally, to simulate the actual cation content of soil water, each soil was wetted to field capacity, allowed to equilibrate overnight, and then spun in a laboratory centrifuge at high speed to extract liquid solution from the soil. These solutions were analyzed for cation content.

Soil solution Ca in these soils was quite high, ranging from 5 - 80 milliequivalents/liter and averaging 34 meq/liter. Since each meq/liter equals 20 PPM, soil solution Ca ranged from 100 - 1,600 PPM Ca, averaging about 680 PPM. As a standard of comparison, consider hydroponic nutrient solutions used in greenhouse vegetable production. These solutions, formulated to provide optimum levels of all nutrients, typically contain only 150-250 PPM Ca; all but one of the soils tested had soil solution Ca greater than 200 PPM.

Using soil solution obtained by centrifugation as the standard of accuracy for predicting soil calcium availability, saturated paste Ca was a much more accurate estimation of soil Ca status than was ammonium acetate extraction. There was no correlation between soil solution Ca and ammonium acetate exchangeable Ca (Fig. 1); there was a good correlation between saturated paste Ca and soil solution Ca (r = 0.88). However, on average the saturated paste extract had only 19% of the Ca concentration in soil solution; multiplying the saturated paste Ca concentration by 5 gave a good estimate of the Ca concentration in soil solution.

What role does soil calcium availability play in calcium disorders?

We chose to focus on tipburn in romaine lettuce, one of the more common calcium-related disorders of vegetable crops. Fifteen Salinas Valley romaine fields were sampled in 2005-06. Soil samples (top foot) were collected and analyzed for Ca by saturated paste extraction. At commercial maturity 24 plants per field were evaluated for tipburn severity, defined as the number of inner leaves showing tipburn. Inner leaves were oven-dried and analyzed for Ca. Prior research suggested that environmental conditions, particularly factors that limited the rate of crop transpiration, could have a significant effect on tipburn development; this is because calcium moves within the plant only in the transpirational stream, and not by subsequent redistribution from one plant part to another. Therefore, daily air temperature and reference evapotranspiration (ET_o) for each field were collected for the final 2 weeks of growth, the period when tipburn typically develops. From this information a daily 'transpiration index' was calculated which estimated the relative amount of crop transpiration per unit of growth potential; the higher the index, the greater the transpirational flow of soil solution (containing Ca) into the plant.

Three of the 15 fields had significant tipburn. There was no relationship between soil Ca availability and either inner leaf Ca concentration, or tipburn severity (Fig. 2). There was, however, an apparent link between the transpiration index and tipburn. Two of the three fields with significant tipburn were located near the coast, and encountered persistent foggy weather from 6-10 days before harvest. The reduced transpiration during that period may have temporarily limited the supply of Ca to the developing leaves, resulting in a transient Ca deficiency.

Is calcium fertigation effective in improving crop calcium uptake and product quality?

We evaluated calcium fertigation on romaine lettuce, cantaloupe and honeydew to test claims that supplemental calcium can suppress lettuce tipburn, and increase fruit firmness in melons. Two trials were conducted on melons, a 2005 trial on honeydew in Yolo County, and a 2006 trial on cantaloupe in Fresno County. In the 2005 trial three Ca fertilizers [calcium nitrate (CN), calcium thiosulfate (CATS) and calcium chloride (CC)] were applied during fruit development in three weekly applications of 10 lb Ca/acre, for a seasonal total of 30 lb Ca/acre. In 2006 two applications of 15 lb Ca/acre from CATS or CC were made. These fertigation rates were similar to those in commercial use. Treatments were replicated 5 times in 2005, and 4 times in 2006. At commercial harvest stage fruit yield, soluble solids concentration (SSC, °brix) and flesh firmness were compared among the Ca fertilizers and a control treatment receiving no fertigated Ca. Additional fruit were evaluated for SSC and firmness after refrigerated storage of 14 days (2005) or 7 days (2006). Fruit flesh samples were analyzed for Ca concentration.

Two trials were conducted on romaine lettuce in the Salinas Valley in 2005 to evaluate the effects of fertigated Ca on romaine yield and expression of tipburn; a third trial was conducted in 2006. In 2005, CN, CATS and CC fertigation were compared with a control treatment not receiving fertigated Ca. Two applications of 15 lb Ca/acre each were made approximately 14 and 7 days before harvest. In the 2006 trial a single application of either CN or CATS was made at 25 lb Ca/acre a week before harvest. In all trials treatments were replicated 5 times. At commercial maturity plant weight, tipburn severity and Ca concentration of inner leaves (those most susceptible for tipburn) were measured.

In neither melon experiment did fertigated Ca significantly increase fruit yield, SSC or flesh firmness (Table 1). Melon flesh Ca concentration was unaffected by Ca fertigation. The relatively low soil Ca status of the 2005 site was reflected in the very low fruit Ca concentrations observed across treatments. Similarly, applying calcium fertilizers through surface drip irrigation had no measurable effects on romaine yield or Ca concentration in the inner leaves of the head (Table 2). No tipburn was observed in any treatment in the first trial; a low level of tipburn was detected in the second trial, but Ca fertigation did not reduce it.

The lack of benefit from Ca fertigation can be explained by considering the relatively high level of available Ca at these sites (which were representative of the production areas), and the lim-

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The issue of calcium (Ca) availability in alkaline, mineral soils has long been a matter of contention.

Based on the commonly used 'exchangeable cations' test (ammonium acetate extraction), most California soils are well supplied with Ca. However, in alkaline soils, a substantial percentage of 'exchangeable' calcium identified by this test can be in chemical forms not readily available to plants or active in soil solution.

To combat tipburn on lettuce, improve postharvest quality, and improve soil structure and water infiltration, California vegetable growers use significant quantities of calcium-based fertilizers and amendments.

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ited amount of Ca applied (also representative of current commercial practices). These fields averaged 5.4 meq Ca/liter, or about 110 PPM Ca; based on the soil calcium availability study, Ca in soil solution would be about 5 times higher, or 550 PPM. This means that, at field capacity moisture content, Ca in the soil solution in these fields averaged approximately 200 lb/acre in the top foot of soil. The application of 10-15 lb Ca/acre in an irrigation would thus represent only a small increase in soluble Ca.

The other factor limiting the effectiveness of Ca fertigation is the close connection of Ca uptake with plant transpiration. Since Ca moves mostly in transpirational flow, Ca concentrates in the most actively transpiring tissue – fully exposed leaves. Due to the waxy rind, melon fruit (and fruits in general) have very limited transpiration. Similarly, the inner leaves of romaine, protected within the head, transpire much less than older, more exposed leaves. Even if one is successful in substantially increasing plant Ca uptake, little of that additional Ca is likely to move into these Ca-sensitive plant parts.

Conclusions

Mineral soils in California generally have high calcium availability; the only common exception to this rule would be very sandy soils, which have low levels of all cations due to limited cation exchange capacity. The most appropriate laboratory test to determine soil Ca status is saturated paste extraction. At the modest rates at which they are typically applied, calcium-containing fertilizers will have little effect on crop Ca status, or the occurrence of calcium-related disorders such as tipburn or blossom-end rot. These disorders do not usually occur due to low soil Ca availability, but rather are induced by factors such as soil water stress or low ET_o that result in a transient deficiency of calcium in rapidly expanding plant tissues.

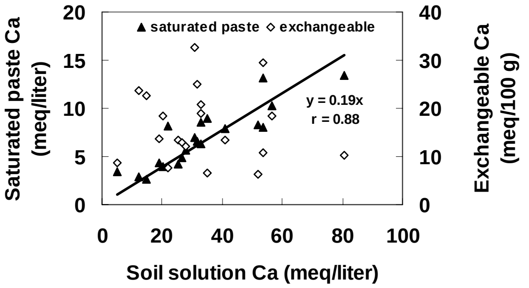

Fig. 1. Relationship between soil exchangeable Ca or saturated paste Ca and Ca concentration of soil solution extracted by centrifugation.

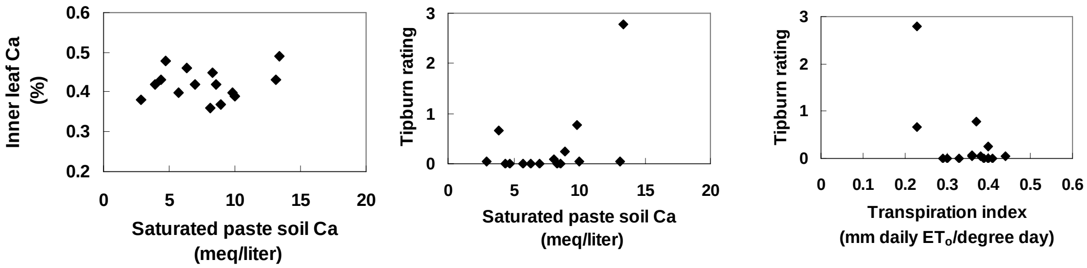

Fig. 2. Relationship among inner leaf Ca, tipburn severity, saturated paste soil Ca and transpiration index in romaine lettuce fields. Tipburn rating was the mean number of

Table 1. Effect of calcium fertigation on melon fruit yield, soluble solids, flesh firmness and calcium concentration.

Trial	Soil Ca^{z} (meq/liter)	Ca treatment^{y}	Fruit yield (boxes/acre)	Soluble solids (^{o}brix)	Flesh firmness (lbs) at harvest	Flesh firmness (lbs) after storage	Fruit Ca (% dry wt)
2005 honeydew	2.1	no Ca	1,362	11.5	9.2	6.6	.041
		CN	1,279	12.0	8.5	7.3	.043
		CATS	1,234	11.8	8.7	6.3	.040
		CC	1,355	11.8	8.4	6.1	.040
			ns	ns	ns	ns	ns
2006 cantaloupe	3.0	no Ca	1,252	11.2	4.1	2.0	.070
		CATS	1,344	11.0	4.1	2.0	.075
		CC	1,139	10.3	3.8	2.0	.093
			ns	ns	ns	ns	ns

^{ns} Ca treatments not significantly different at $p < 0.05$

^{z} saturated paste extraction

^{y} CN = calcium nitrate; CATS = calcium thiosulfate; CC = calcium chloride

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We chose to focus on tipburn in romaine lettuce, one of the more common calcium-related disorders of vegetable crops. Fifteen Salinas Valley romaine fields were sampled in 2005-06.

Prior research suggested that environmental conditions, particularly factors that limited the rate of crop transpiration, could have a significant effect on tipburn development; this is because calcium moves within the plant only in the transpirational stream, and not by subsequent redistribution from one plant part to another.

Three of the 15 fields had significant tipburn. There was no relationship between soil Ca availability and either inner leaf Ca concentration, or tipburn severity (Fig. 2). There was, however, an apparent link between the transpiration index and tipburn.

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Table 2. Effects of calcium fertigation on romaine lettuce yield, inner leaf Ca concentration and tipburn severity.

Trial	Soil Ca ^{z} (meq/liter)	Ca treatment^{y}	Mean plant wt. (lb)	Marketable plants (%)	Tipburn rating^{x}	Leaf Ca (%)
1	4.4	no Ca	1.67	97	0	0.43
		CN	1.74	98	0	0.47
		CTS	1.74	97	0	0.46
		CC	1.76	98	0	0.44
			ns	ns	ns	ns
2	8.9	no Ca	1.85	98	0.3	0.37
		CN	1.87	98	0.4	0.41
		CTS	1.83	97	0.2	0.39
		CC	1.83	98	0.2	0.39
			ns	ns	ns	ns
3	8.6	no Ca	1.58	97	0	0.42
		CN	1.54	98	0	0.39
		CTS	1.52	95	0	0.43
			ns	ns	ns	ns

^{ns} Ca treatments not significantly different at $p < 0.05$

^{z} saturated paste extraction

^{y} CN = calcium nitrate; CATS = calcium thiosulfate; CC = calcium chloride

^{x} mean number of affected leaves per plant

These disorders do not usually occur due to low soil Ca availability, but rather are induced by factors such as soil water stress or low ET_o that result in a transient deficiency of calcium in rapidly expanding plant tissues.

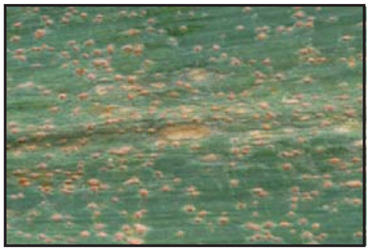
OUTBREAK OF RUST DISEASE ON LEEK

Steven Koike

Plant Pathology Farm Advisor

In April, 2007, an outbreak of rust disease was found on commer-cial leek (*Allium porrum*) grown in coastal Santa Cruz County. Ini-tial symptoms on leaves consist of small (less than 1/8 inch long), circular to elongate, white flecks that later expand into oblong lesions. The leaf tissue covering the lesions breaks open and masses of brown orange spores (called urediniospores) become visible as raised pustules. Pustules were mostly found on the top sides of leaves. The dark brown spore stage (teliospores) was not observed on diseased leeks. Severely affected leaves were heavily covered with pustules and leaf tissues dried out. In April and May, 2007, disease was limited to small areas in a few fields. However, by June the disease was much more extensive and was detected in most of the leek plantings in the region. To our knowledge this is the first report of a rust disease on leek in California.

In California, leek has previously not had a rust disease.



Leek rust is characterized by the familiar orange pustules on diseased leaves.

The pathogen is *Puccinia allii*. Previous research has shown that *P. allii* is a complicated organism and is not considered a single species, but rather is a "species complex" that is made up of different "types." Our molecular and host range studies confirm that this leek disease is caused by what is called the "leek type" *P. allii*. This "leek type" pathogen can cause rust on leek and garlic, but will not infect onions or chives (see Table 1). Similar "leek type" *P. allii* are found in Europe and the Middle East. It is possible that this pathogen was introduced into California from one of these other regions. While this introduction is unproven and is only a guess, it is interesting to note that the "leek type" *P. allii* from Europe does not form the dark teliospore stage, like the pathogen in California, while the "leek type" *P. allii* from the Middle East readily forms this second spore stage (Table 1).

Our research also confirms that this leek disease development is unrelated to the devastating garlic rust disease, caused by "non-leek" *P. allii*, that affected California in the late 1990s and early 2000s. The "non-leek" rust pathogen can infect garlic, onion, and chives, but will not cause rust on leek. The California "non-leek" rust pathogen makes the both the orange spore (urediniospore) and dark brown spore (teliospore) stages (Table 1).

Leek rust and the garlic rust from the 1990s are caused by different pathogens.

Control of rust on leek will probably rely on preventative fungicides that are applied prior to infection. Against rust on garlic, the fungicides Folicur and Quadris provided excellent control when applied in a timely manner. For leek, check with product labels and your local Agricultural Commissioner's Office for which products are available for this crop.

Table 1. "Leek" and "Non-Leek" categories of the Puccinia allii rust fungus on Alliums

Type and source	non-leek from CA	leek from CA	leek from Europe	leek from Mid.East
CA situation	garlic outbreak in 1990s, early 2000	leek outbreak in 2007	not known in California	not known in California
Teliospores? (dark spore stage)	yes	no	no	yes
Infect onion?	yes	no	no	no
Infect garlic?	yes	yes	yes	yes
Infect leek?	no	yes	yes	yes
Infect chives?	yes	no	no	no

NEW VIRUS DISEASE OF LETTUCE CAUSED BY *IMPATIENS NECROTIC SPOT VIRUS*

Steven Koike, University of California Cooperative Extension
Bob Gilbertson, University of California at Davis

Introduction and significance. In September, 2006, we received samples of severely diseased lettuce plants that later proved to be infected by the *Impatiens necrotic spot virus* (abbreviated INSV). To our knowledge, lettuce was not previously known to be a host of this virus. During the spring of 2007, plants from numerous lettuce fields in the Salinas Valley tested positive for INSV. Diseased fields were found in the following regions: Castroville, Salinas, Chualar, Gonzales, Soledad, and Greenfield. Because of this new finding and the fact that affected plants are unmarketable, growers, PCAs, and field personnel should be aware of this new disease.

Diagnostic features of INSV. Symptoms caused by INSV in lettuce are indistinguishable from those caused by the closely related *Tomato spotted wilt virus* (TSWV). TSWV is already known to infect lettuce. TSWV in lettuce in the Salinas Valley and other coastal areas is infrequently found, though in the fall of 2006 TSWV was fairly common in lettuce in Fresno County.

INSV-infected plants have leaves with brown to dark brown spots and dead (necrotic) areas; this necrotic tissue can resemble burn damage caused by pesticide or fertilizer applications. Extensive necrosis can cause much of the leaf to become brown, dry, and dead. Some leaf yellowing can also be observed. Yellowing and the brown spotting tend to be observed on the newer leaves near the center of the plant's growing point. If plants are affected with INSV early in their development, growth may be stunted. Thus far it appears all lettuce types are susceptible, and INSV has been confirmed on iceberg, romaine, and greenleaf lettuces. In most fields where INSV has been confirmed, disease development has been limited to only a portion or edge of the field; in these areas of the field, disease incidence is generally very low (less than 5%). However, in a few cases disease incidence was extensive and significant crop loss was experienced.

Causal agent. INSV is a tospovirus and, like the more commonly known TSWV, is also vectored by thrips. Whereas TSWV can be vectored by up to eight different thrips species, it appears that INSV is carried from plant-to-plant only by the western flower thrips (*Frankliniella occidentalis*). Only thrips in their larval stage are able to acquire the virus via feeding on infected plants, but they then can carry and transmit the virus for the remainder of their life. Typically, INSV is known to be more of a greenhouse disease concern on flowering ornamental plants; the infection of lettuce, therefore, is an apparent departure from this pattern. The exact reasons behind the INSV outbreak on lettuce are not known. Presumably, the thrips insects are feeding on weeds, ornamentals or other surrounding vegetation that are already infected with INSV; these vectors then move into the lettuce and transmit the virus. Alternatively, migrating viruliferous adult thrips could be introducing the virus from more distant locations. Research is needed to confirm if INSV is infecting alternate hosts in the vicinity of lettuce fields. There is no evidence that INSV is seedborne in lettuce.

Confusion with lettuce dieback disease. Presently there is some confusion between symptoms of this new INSV outbreak and those caused by the two lettuce dieback pathogens: *Lettuce necrotic stunt virus* (LNSV) and *Tomato bushy stunt virus* (TBSV). There is, in fact, some overlap of the symptoms of these diseases, but there are a number of significant differences. Whereas INSV causes spotting, burning, and yellowing of newer foliage, LNSV and TBSV cause older, lower leaves to turn bright yellow and develop large, brown, necrotic sections. In the case of plants infected with LNSV/TBSV, the central new leaves remain green, but may have a leathery texture. INSV apparently infects all types of lettuce, whereas LNSV/TBSV only infects romaine, leaf, and butterhead (iceberg lettuce is immune to lettuce dieback disease). Field distribution of INSV is fairly random and spotty in a field, presumably reflecting the movement of viruliferous thrips vectors. Because LNSV and TBSV are soil-borne and water-borne viruses, disease distribution will appear in the field as patches where contaminated soil has been moved and spread. See Table 1 for an outline of these various differences.

Research planned. Investigations of INSV of lettuce are under way by University of California researchers (Koike and Gilbertson) who will attempt to clarify the nature of these INSV strains, determine where the virus is coming from, and devise management strategies. Notify Steve Koike of possible INSV cases and submit samples to the UC Cooperative Extension Diagnostic Lab in Salinas.

New lettuce virus has been found throughout Monterey County.

INSV is vectored by thrips insects.

This new problem can be confused with lettuce dieback disease.

Table 1. Characteristics of INSV, TSWV, and LNSV/TBSV on Lettuce in California *

	INSV	**TSWV**	**LNSV / TBSV**
Virus family	Tospovirus	Tospovirus	Tombusvirus
Vector	thrips	thrips	none known
How spread	insect movement	insect movement	infested soil and water
Types affected	probably all lettuce types	all lettuce types	romaine, leaf, butter
Key symptoms	upper leaves w/ brown spots	same as for INSV	lower leaves w/brown patches
	new leaves can have spots		new leaves remain green
	some yellowing of leaves		lower leaves are bright yellow
	severe stunting possible		often see severe stunting
Non-lettuce hosts in coastal CA	mostly flowering ornamental plants	many vegetables, ornamentals, and weeds	none confirmed

* INSV = *Impatiens necrotic spot virus*

TSWV = *Tomato spotted wilt virus*

LNSV/TBSV = *Lettuce necrotic stunt virus* and *Tomato bushy stunt virus*

INSV causes irregular brown leaf lesions.

INSV symptoms can resemble those caused by spray burn.

(Cont'd from page 1)

Table 1. Compare and contrast the characteristics of California oakworm and light brown apple moth (leafroller)

	California oakworm	Light brown apple moth
Family	Oakworms (Dioptidae)	Leafrollers (Tortricidae)
Egg	Tiny, white eggs (with a reddish spot on top before hatch) are laid on leaves and twigs (Fig. 1)	Shinglelike egg mass are laid on leaves (Fig. 2)
Larva	Larvae do not roll the leaf. Larvae are variable in color. Newly hatched larvae are pale yellow with dark brown spots (Fig. 3), whereas fully grown larvae are dark with prominent yellow stripes (Fig. 4).	Larvae usually roll the leaf or leaves and fruit together with webbing. When fully grown pale green larvae (Fig. 5) are 0.33 inch (male) to 0.66 inch (female) long
Pupa	Pale yellow with black lines and dots (Fig. 6)	Tan to brown in color; wings and appendages of pupae are pressed against the body (Fig. 7)
Adult	Light brown to gray moths about 0.75 inch long with characteristics wing veins. Antennae of male moths are large and branched on two sides (Fig. 8) when compared with those of the females (Fig. 9)	Moths are extremely variable in color and wing patterns between males and females and among individuals (Fig. 10 A and B). Body length varies from 0.33 inch (male) to 0.66 inch (female) long

Fig. 1. California oakworm eggs (Photo by Carlton S. Koehler).

Fig. 2. Shinglelike egg mass of (omnivorous) leafroller (Photo by Jack Kelly Clark).

Fig. 3. Newly hatched California oakworm under microscope (Photo by Frankie Lam).

Fig. 4. Fully grown California oakworm (Photo by Jack Kelly Clark).

Fig. 5. Fully grown larva of light brown apple moth (Photo by Scott Kinnee and Marc Epstein, CDFA).

Fig. 6. California oakworm Pupae (Photo by Frankie Lam).

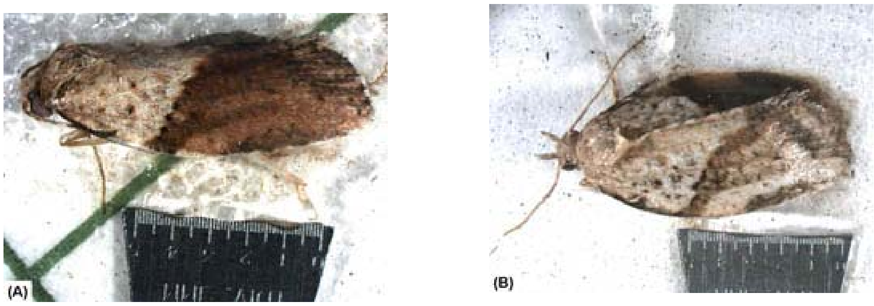
(Cont'd to page 8)

(Cont'd from page 7)

Fig. 7. Pupa of (fruittree) leafroller (Photo by Jack Kelly Clark).

Fig. 8. Male moth of California oakworm (Photo by Frankie Lam).

Fig. 9. Female moth of California oakworm (Photo by Frankie Lam).



Figs. A & B. Two male light brown apple moths (scale = 0.15 inch) (Photo by Scott Kinnee and Marc Epstein, CDFA).

SPINACH WEED CONTROL TRIALS CONDUCTED IN 2006

University of California Cooperative Extension, Monterey County
Richard Smith, Farm Advisor

Summary: Weed control in clipped spinach is challenging. This is particularly true of 80-inch bed production because the beds typically have up to 32 seedlines which precludes the use of cultivation as a cultural practice to control weeds. In addition, mechanical harvest necessitates excellent weed control to maintain the quality of the product. Cultural practices such as preirrigation can help reduce weed pressure, but ultimately any escaped weeds must be removed by hand. As a result, for a number of years we have been investigating alternative weed control materials to supplement weed control provided by the standards: preplant fumigation with metam sodium and the preemergent RoNeet.

In these trials we examined the alternative preplant fumigant Basamid and it provided weed control equivalent to metam sodium. We also evaluated preemergents and Lorox provided the greatest efficacy and safety of the alternative materials evaluated.

Methods: ***Trial No 1:*** The trial was conducted in San Ardo, and Basamid and Vapam applications were made on June 2, 2006 to 80-inch beds. Basamid was applied to the bed with a 5-foot wide Gandy applicator and Vapam was bladed into the beds with a commercial applicator. Each Basamid plot was one 80-inch bed wide by 300 feet long and replicated 3 times. It was compared with the adjacent Vapam treated bed for the weed evaluations. Following the application, sprinkler irrigation was applied three times a day for three days to seal in the material**.** The beds were shaped with a mulcher prior to planting. The beds were treated with a low rate of RoNeet (0.75 pint/A) following planting on July 9 and the germination water was started on July 10. ***Trial No. 2:*** The trial was conducted west of Salinas. All materials were applied post plant preemergence on August 4. Each plot was one 80-inch bed wide by 15 feet long and replicated four times in a RCBD. All materials were applied with four passes of a one nozzle wand with an 8008E teejet tip in the equivalent of 73 GPA of water. The variety was Hellcat. See tables for evaluations and dates.

Results: ***Trial No 1:*** There was moderate weed pressure in the trial. All of the fumigation treatments reduced weeds, especially by the July 25 evaluation date (Table 1). There were no difference between the fumigation treatments, but there was a trend that indicated that 400 lbs of Basamid provided improved weed control over 200 lbs. ***Trial No. 2:*** There was good weed pressure in the trial and the various materials had different strengths and weaknesses. RoNeet was more effective than the other materials in controlling malva (Table 2). Triallate at 4.5 lbs a.i./A and Lorox at 0.10 lb a.i./A provided the best control of sow thistle. Given the various strengths and weakness of the materials, there were no statistical differences in total weeds. The combination of RoNeet + Dual Magnum was the most injurious treatment to the crop. RoNeet alone, RoNeet + Dual Magnum and Lorox had the lowest hours per acre to weed. Treatments with the highest yields included: untreated, Triallate at 1.5 lb a.i./A, RoNeet alone and Lorox at 0.10 lb a.i./A.

> Weed control in clipped spinach is challenging. This is particularly true of 80-inch bed production because the beds typically have up to 32 seedlines which precludes the use of cultivationas a cultural practice to control weeds.

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Jerry Rava, Rava Farms
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Roel Rodriguez, Kleen Globe

(Cont'd to page 9)

Mechanical harvest necessitates excellent weed control to maintain the quality of the product.

The alternative preplant fumigant Basamid and it provided weed control equivalent to metam sodium.

Lorox provided the greatest efficacy and safety of the alternative materials evaluated.

(Cont'd from page 8)

Table 1. Trial No. 1. Weed counts (number of weeds/ 9.3 ft^2) on two dates

Treatment	Material/A	Chenopods	Nightshade	Pigweed	Purslane	Nutsedge	Other	Total Weeds
July 15								
Untreated	---	0.18	0.06	0.04	0.03	0.02	---	0.33
Basamid	200 lbs	0.00	0.00	0.00	0.00	0.01	---	0.01
Basamid	400 lbs	0.00	0.00	0.00	0.00	0.00	---	0.00
Vapam	300 lbs	0.01	0.00	0.00	0.00	0.00	---	0.01
LSD (0.05)		0.05	0.04	0.02	n.s.	n.s.	---	0.01
July 25								
Untreated	---	3.51	0.36	0.52	1.71	0.16	0.34	6.59
Basamid	200 lbs	0.45	0.03	0.00	0.31	0.07	0.34	1.20
Basamid	400 lbs	0.14	0.03	0.00	0.10	0.03	0.07	0.38
Vapam	300 lbs	0.24	0.10	0.12	0.15	0.00	0.10	0.72
LSD (0.05)		1.31	0.23	0.40	0.81	0.15	n.s.	1.63

Table 2. Trial No. 2. Weeds per 60 ft^2 on August 16, time to weed on August 21 and yield on September 5.

Treatment	Lbs a.i./A	Material/A	Malva	Shepherds Purse	Sow Thistle	Total Weeds	Phyto[1]	Hrs/A to weed	Yield Lbs/plot
Untreated	----	---	10.7	8.0	8.0	28.0	0.0	32.9	17.0
Triallate (Far-Go 4E)	1.50	1.50 quarts	11.0	6.7	8.0	26.0	0.0	33.0	17.1
Triallate (Far-Go 4E)	3.00	3.0 quarts	8.7	5.0	4.0	18.0	0.0	29.6	15.9
Triallate (Far-Go 4E)	4.50	4.5 quarts	9.7	4.7	2.0	16.7	0.0	26.0	15.3
RoNeet 6E	0.93	1.25 pints	2.0	1.3	7.3	13.3	0.3	15.1	17.3
RoNeet 6E + Dual Magnum 7.63	0.93 0.48	1.25 pints 0.50 pint	2.7	2.7	9.3	15.0	2.3	13.7	13.8
Dual Magnum 7.63	0.48	0.50 pint	8.0	3.0	4.7	18.0	0.7	23.8	15.2
Dual Magnum 7.63	0.96	1.00 pint	7.7	3.0	3.3	15.7	1.7	20.0	13.1
Lorox 50	0.10	0.2 lbs	12.3	2.0	1.7	16.3	0.0	17.3	16.9
LSD (0.05)			10.3	4.7	7.4	n.s.	0.8	6.9	1.8

1 - Scale: 0 = no crop damage to 10 crop killed.

GERMINATING LETTUCE USING DRIP IRRIGATION

Michael Cahn, UCCE Irrigation and Water Resources Advisor
Richard Smith, UCCE Weed and Vegetable Advisor
Steve Fennimore, UC Davis Weed Specialist
Arnett Young, Monterey County Farm Advisor Assistant

Introduction - The acreage of lettuce under drip irrigation in the Salinas Valley has noticeably increased during the past 10 years. The 2005 Ground Water Summary for Monterey County reported that 31% of the vegetable acreage is drip irrigated compared with 3% of the acreage in 1993. Despite the increased acreage under drip, overhead sprinklers are used on most of the vegetable acreage from planting until thinning. After thinning and side-dressing of fertilizer, drip tape is usually installed on top of the beds and used to irrigate the crop until harvest.

Growers have justified the costs of using surface-placed drip after sprinklers by such advantages as reducing water use, minimizing foliar diseases, and increasing fertilizer-use efficiency. Also drip does not create irrigation tail water, and unlike overhead sprinklers, the uniformity of the system is not dependent on wind.

For several years, growers in the Salinas Valley have experimented with irrigating lettuce with drip tape from planting to harvest. Full season use of drip maximizes the benefits of drip irrigation and eliminates some of the disadvantages of sprinklers. For full season use, the tape is buried a few inches below ground so that the crop can be planted and thinned without damaging the tape. After harvest, the tape is extracted from the soil, retrieved onto spools, and reused for other crops. Besides eliminating the costs of using overhead sprinklers, using only drip can improve access to the field by keeping the furrows dry, prevent the formation of soil crusts which reduces emergence, and permits growers to irrigate with a high uniformity during windy conditions, which are common in the Salinas Valley.

Challenges to germinating lettuce with drip tape
Obtaining uniform germination with shallowly buried drip tape can be a significant limitation to using full-season drip: particularly, obtaining uniform wetting of the bed tops. Where as overhead sprinklers apply water directly to the seed line, water from the buried drip tape must move both upward and horizontally to the seed. In some cases, growers have needed to irrigate for as much as 24 hours during a single set to obtain a satisfactory level of moisture in the seedline, and on some soil types, such as well-aggregated clays, the drip system was unable to move moisture to the seedline because the soil was initially too dry.

Weed control can be another challenge to germinating lettuce with drip tape. Overhead sprinklers are usually used to activate the commonly applied herbicides, Kerb and Prefar. Sprinkler applied water is considered necessary to obtain full efficacy from these herbicides, because the overhead application of water moves the herbicide from the soil surface to the depth where weed seed are located.

An additional challenge of drip germination is the potential to leach nitrate, a soluble form of nitrogen, from the bed. The potential for nitrate leaching increases when soil nitrate levels are high and when irrigations are excessive. Water that does not move towards the seedline, percolates downward below the drip tape, carrying nitrate below the root zone. This source of nitrogen loss could impact yields in organic fields that may have moderate soil nitrogen levels at planting.

Comparison of drip and sprinkler-germinated lettuce
We conducted both replicated and non-replicated field trials comparing sprinkler and drip germinated lettuce during the 2006 season. A replicated trial was conducted at the USDA Spence research farm on a sandy loam soil and non-replicated trials were conducted in commercial fields on soils ranging from clay to loam textures (Table 1). The characteristics of the drip tape and depth of placement are summarized in Table 1.

Water use
Applied water for sprinkler and drip irrigated fields was monitored from planting to emergence using a flow meter or a sensor that monitored the operation time of the irrigation system. Water applied by sprinklers for germination ranged from 5.3 to 8.1 inches and averaged 6.6 inches for the commercial trials. In comparison, water applied by drip ranged from 1.5 to 8.3 inches and averaged 5.3 inches (Table 2). Drip fields appeared to require less water than sprinkler fields if moisture moved consistently to the seedlines. The drip irrigated field where 8.3 inches of water was applied had dry areas in the center of the field and required long irrigations. The replicated trial at the USDA Spence farm required 3.1 and 3.2 inches of germination water for buried drip and sprinkler plots, respectively, suggesting that the water requirements for well managed drip and sprinkler fields are similar (Table 3).

Germination
Plant stands for sprinkler and drip irrigated fields were similar among 3 of the 5 commercial trials and in trial 2 the drip field had a higher emergence rate than the corresponding sprinkler field (Table 4). Trial 3 had lower germination in the drip field than in the corresponding sprinkler-irrigated field due to inadequate moisture in the center of the field. Trials 4 and 5 were planted to stand so that thinning was not required after emergence. At the USDA Spence trial, emergence rates were highest in the drip germinated plots, presumably because the overhead sprinklers caused crusting of the soil surface (Table 3).

Nitrate leaching.
Nitrogen losses were evaluated by comparing nitrogen in the soil profile to a 3 foot depth before planting and after germination. Of the 4 trials where sprinkler and drip irrigated fields were compared, drip had less nitrate and mineral N loss than sprinklers at 3 sites (Table 5). However, at site 1, where more than 8 inches of water were applied, nitrate losses were as high as 82% for drip and 45% for sprinklers. Average nitrate loss during germination for the 4 sites was 44% for sprinkler-irrigated and 35% for drip-irrigated fields during the same period.

Weed control
Weed control trials were conducted at the drip germinated field at site 4. The materials were applied to the bed tops before the first irrigation. Weed control of Prefar and Kerb was evaluated for drip tape buried at 1-inch and 2-inch depths (Table 6). Weed populations were spotty at this site and the site and there were large differences in the number of weeds at the 1-inch depth plot and the 2-inch depth plot. In spite of the spotty weed populations, Kerb and Prefar both worked well in the 1-inch buried drip irrigation system by controlling nettle and other weeds. In the 2-inch buried tape treatments Prefar did not provide weed control and Kerb provided moderate weed control only at 4 lbs/A. This evaluation will need to be repeated to better under stand the interaction between drip tape depth and the performance of the herbicides.

The 2005 Ground Water Summary for Monterey County reported that 31% of the vegetable acreage is drip irrigated compared with 3% of the acreage in 1993.

Growers have justified the costs of using surface-placed drip after sprinklers by such advantages as reducing water use, minimizing foliar diseases, and increasing fertilizer-use efficiency.

Full season use of drip maximizes the benefits of drip irrigation and eliminates some of the disadvantages of sprinklers.

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Conclusions

Comparison of drip and sprinkler-irrigated fields demonstrated that emergence, water use, and nitrate leaching were similar for both irrigation methods on soils with sandy loam to clay textures. Nitrate leaching during germination appeared to be significant for both methods of irrigation if initial mineral nitrogen levels were high or if excessive water was applied. Prefar and Kerb sprayed on the bed surface and activated with moisture from the buried drip tape provided control of nettle and other weeds, but weed control may be reduced as tape depth increases. Identifying strategies that enhance lateral spread of moisture around the drip lines would increase the efficiency of using drip irrigation for germinating lettuce by reducing water use and nitrate leaching and increasing emergence and weed control.

Where as overhead sprinklers apply water directly to the seed line, water from the buried drip tape must move both upward and horizontally to the seed.

Acknowlegements: We would like to thank D'Arrigo Bros, Top Flavor Farms, T&A Farms, and Boss Farms for their cooperation with the commercial field trials, and finally the California Lettuce Research Board for financial support for this project.

Table 1. Summary of unreplicated trials comparing sprinkler and drip germinated lettuce in commercial fields.

Site	Type	bed width	emitter spacing	tape discharge rate	tape depth average	tape depth S.D.	bulk density (0 3 inches)	soil texture
		----- inches ----		gpm/100 ft	----- inches ----		g/cc	
1	head	40	12	0.53	2.62	0.39	1.13	Loam
2	head	40	12	0.34	3.36	0.41	1.03	Loam
3	romaine	80	12	0.32	3.22	0.40	0.97	Clay loam
4	romaine	40	8	0.34	2.50[x]	--	0.90	Clay
5	romaine	40	8	0.34	2.50[x]	--	1.09	Clay loam

[x] estimated depth

Table 2. Area and applied water to drip and sprinkler areas of non-replicated trials

	Sprinkler-Germinated				Drip-Germinated			
Site	date start	date end	area	applied water	date start	date end	area	applied water
			acres	inches			acres	inches
1	28-Jun	6-Jul	7.9	8.1	27-Jun	5-Jul	7.8	8.1
2	19-Jul	24-Jul	6.1	8.0	11-Jul	15-Jul	5.8	3.6
3	25-Jul	1-Aug	7.3	5.3	30-Jun	10-Jul	7.5	8.3
4	24-Aug	31-Aug	3.8	5.9	24-Aug	31-Aug	4.0	5.0
5	1-Sep	7-Sep	5.9	6.0	1-Sep	7-Sep	2.4	1.5
Average				6.6				5.3

The potential for nitrate leaching increases when soil nitrate levels are high and when irrigations are excessive.

Table 3. Germination rate and applied water for surface drip, buried drip and sprinkler irrigated treatments for the USDA Spence replicated trial.

	Applied Water (inches)[x]	Wetted Width (inches)	Initial Germination Count (plants/10 ft)	2nd Germination Count (plants/10 ft)
Drip-surface	3.08	16.81	54.0	53.2
Drip-buried	3.08	16.20	54.0	52.3
Sprinkler	3.24	--	26.7	44.3

[x] 8/22/06 - 8/30/06

We conducted both replicated and non-replicated field trials comparing sprinkler and drip germinated lettuce during the 2006 season.

Table 4. Emergence rates under drip and sprinkler irrigated lettuce for commercial trials.

Site	Sprinkler Average	Sprinkler S.D.	Drip Average	Drip S.D
	-------------------- plants/10ft -----------------			
1	42.0	4.9	46.8	2.7
2	27.8	6.3	44.3	4.3
3	36.0	3.7	28.8	16.5
4[x]	12.1	1.1	10.6	1.8
5[x]	11.0	1.8	11.7	1.2

[x] planted to stand density of 12 plants per 10 ft

(Cont'd to page 12)

(Cont'd from page 11)

Table 5. Nitrate losses from commercial fields germinated by sprinkler and drip irrigation.

	Sprinkler		Drip	
Site	**NO3-N**	**Mineral-N**	**NO3-N**	**Mineral-N**
	----------------	% loss	------------------	
1	45.9	48.8	81.9	77.0
2	12.8	21.5	5.4	-1.3
3	30.4	32.0	17.7	14.3
4	71.3	76.8	-20.4^x	-20.0
Average	40.1	44.8	35.0	17.5

^{x} a negative value means nitrogen accumulated in the soil

Applied water for sprinkler and drip irrigated fields was monitored from planting to emergence using a flow meter or a sensor that monitored the operation time of the irrigation system.

Table 6. Weed control from Prefar and Kerb applied to bed tops and activated with buried drip at 1-inch and 2-inch depths.

Herbicide	Product Rate/acre	Nettle	Total weeds	Nettle	Total weeds
		1-inch depth		2-inch depth	
		--------------------	1,000 /acre	--------------------	
Kerb	2 lbs	10.2	12.2	72.6	85.7
Kerb	4 lbs	1.5	4.9	20.3	20.9
Prefar	3 qts	2.9	5.2	104	105.1
Prefar	6 qts	0.9	3.5	98.2	99.3
Kerb + Prefar	4 lbs + 6 qts	0.6	2	14.5	14.5
None	0	22.7	23.8	57.2	61.9
$LSD_{0.05}$		20.3	21.2	89.4	ns

Comparison of drip and sprinkler-irrigated fields demonstrated that emergence, water use, and nitrate leaching were similar for both irrigation methods on soils with sandy loam to clay textures.

UC Davis Magazine
Future Power - by Sylvia Wright
2017: Farm-to-Fork Footprint

Volume 24 · Number 4 · Summer 2007

Once upon a time, food labels told you if tuna was dolphin-safe or milk was BST-free. Today you can scan a food label and tell how much energy it took to bring that food to you.

Just as the UC Davis Institute of Transportation Studies pioneered the measurement of life-cycle environmental impacts of auto fuels, the UC Davis Agricultural Sustainability Institute has quantified the costs of growing, harvesting, processing and transporting food products. The institute's industry partner in the effort was a leader in socially responsible food sourcing, Bon Appetit Management Co. One of the world's largest food buyers, Bon Appetit serves millions of meals daily in offices, museums and university dining halls.

The Agricultural Sustainability Institute's first director, Tom Tomich, launched the Low Carbon Diet labeling project in 2006. An agricultural economist, Tomich held the W.K. Kellogg Endowed Chair in Sustainable Food Systems. His collaborator was food systems analyst Gail Feenstra of the UC Sustainable Agriculture Research and Education Program, which is also based at UC Davis, along with senior researcher Sonja Brodt and graduate student Erica Chernoh.

"Once we figured out how to calculate the energy cost of a number of foods in a reliable way, we could label foods with their carbon footprint," Feenstra said. "In transportation, it was an analysis of energy costs from the oil well to the wheel. In food, it's farm to fork."

For these and other helpful publications, go to anrcatalog.ucdavis.edu

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DRIP GERMINATION OF LETTUCE: STRATEGIES FOR ENHANCING LATERAL MOVEMENT OF MOISTURE AROUND BURIED DRIP TAPE

Michael Cahn, UCCE Irrigation and Water Resources Advisor
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Many growers are successfully using drip systems to irrigate lettuce from planting until harvest without the supplemental use of sprinklers. Full season use of drip may reduce production costs by eliminating the need for sprinklers and minimize irrigation run-off that is often associated with overhead sprinklers.

Attaining uniform germination is a considerable challenge to using drip irrigation for the entire lettuce crop.

Attaining uniform germination is a considerable challenge to using drip irrigation for the entire lettuce crop. Moisture from shallowly buried drip lines must consistently reach the seed at all locations within a field for a uniform stand to emerge. During the last two seasons, we conducted replicated and non-replicated field trials to evaluate strategies for improving the lateral movement of moisture from the drip tape to the seedline. Trials focused on bed preparation and tape characteristics, such as emitter spacing, depth, and emitter discharge rate (high flow, medium flow). We also evaluated chemical polymers for enhancing lateral movement of moisture. The following is a summary of results and recommendations based on these trials.

We were most successful at germinating lettuce with drip on soils ranging from sandy loam to clay loam textures.

Trials conducted on sandy loam soils on the east-side of the Salinas Valley appeared well suited for drip germination.

Soil texture and bulk density

We were most successful at germinating lettuce with drip on soils ranging from sandy loam to clay loam textures. The bulk density of the beds on these soils ranged from 0.97 to 1.13 g/cc. On a well-aggregated clay soil with a bulk density of 0.86 g/cc, moisture from the buried tape did not move adequately to the seedlines and sprinklers had to be used (Figure 1). Trials conducted on sandy loam soils on the east-side of the Salinas Valley appeared well suited for drip germination. Consistently, we obtained uniform emergence on these soils using 2.5 to 3 inches of water.

Bed preparation

A replicated trial, comparing methods of bed preparation, demonstrated an improvement in germination if the beds were mulched to reduce the size of soil aggregates (Table 1). We also found that compacting bed tops using a weighted roller (a roller filled with water) after installing the drip tape increased germination (Table 1) and in another trial soil moisture in the seedline was increased using a weighted roller (Table 2). Rolling the bed tops may help with lateral movement of moisture by improving the contact between the drip tape and soil. Soil was often loosened by the show used to install the drip tape.

High distribution uniformity was one of the most important characteristics of the drip system that assured uniform germination in the commercial fields that we monitored.

Drip tape

High distribution uniformity was one of the most important characteristics of the drip system that assured uniform germination in the commercial fields that we monitored. Old tape with plugged emitters, or tape that was spliced with tapes of different flow rates may have contributed to poor emergence at one of our trials in a commercial field. Poor positioning of the tape between seedlines also reduced germination at other trials conducted in commercial fields.

Tape depth

Tape installed between 2 and 4 inches of depth satisfactorily moved moisture to the seedline and uniformly germinated lettuce on a range of soil types. A replicated trial that we conducted demonstrated that the spread of moisture on the bed surface and the soil moisture content in the seedline increased when the tape was buried at 2 inches rather than 3 inches (Table 3). However in practice, too shallow placement of tape was often problematic because the tape would end up on the bed surface at some locations or twist upside down or sideways. Because cultivation would not be possible in areas of the field where the tape was above ground, the shallowest depth that consistently places the tape below the depth of cultivation should be used. We found that the depth of tape in most fields varied by ± 1 inch.

Emitter spacing and discharge rate

Trials comparing 8 and 12-inch emitter spacing found no significant increase in soil moisture content within the seedline or an increase in germination rate (Table 3). In comparing tapes of different discharge rates (0.34 *vs* 0.5 gpm/100 ft), we found that beds with low flow tape had higher moisture content in the seedline using the same amount of water as high flow tape (Table 2) The low flow tape may allow additional time for the moisture to move across the bed to the seedline.

Seed depth

Seed depth was not compared in the replicated or non replicated trials conducted in commercial fields. In most cases we chose to plant an 1/8 of an inch deeper than normal to assure that the seed was in contact with the soil. Since sprinklers were not used, we were not concerned that crusting of the soil surface would slow emergence. We often observed that seed not in close contact with soil did not germinate.

Polymers for enhancing lateral movement

Another strategy evaluated for promoting the horizontal movement of moisture from the drip tape was to add a chemical polymer to the irrigation water. Polyacrylamide (PAM) is used to reduce soil erosion by aggregating soil particles together. This chemical is a large, chained molecule that also increases the viscosity of water. In previous studies, we found that PAM, added to irrigation water, reduced infiltration into the soil at concentrations above 20 ppm; and may thereby force moisture to move laterally. However, results of our trials were mixed. On some soil types, where beds had settled and the bulk density was more than 1.1 g/cc, PAM enhanced the spread of moisture on the bed top and moisture content in the seedline (Table 4). In trials conducted on newly formed beds where soil bulk densities were less than 1.1 g/cc, PAM did not increase lateral movement of moisture (Table 5), and at concentrations above 50 ppm, PAM impeded the lateral movement of moisture. Possibly, the viscous nature of polyacrylamide reduced the ability of the soil pores to pull moisture horizontally.

Irrigation schedule for germination with drip

Although we did not compare different irrigation times or frequencies for drip germination, the procedure that we followed was to irrigate the longest on the first irrigation in order to allow moisture to reach the seedline. The first irrigation often required 1 to 3 inches of water depending on the soil type and factors discussed above. We observed that moisture moved very slowly on some fields. Rather than continue irrigating, we often stopped the irrigation to allow time for the moisture to redistribute in the bed during the night. In most cases, moisture moved to the seedline by the next morning. After the initial irrigation, we applied less than 0.5 inches every other day until the seed germinated.

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Summary

Results from the numerous trials that we conducted in commercial and research fields suggests that the following factors were most important in achieving uniform germination with shallowly buried drip tape:

1. Soil textures ranging from sandy loam to clay loam were most suitable for drip germination.
2. Beds should be mulched to improve the uniformity of soil aggregates and reduce aggregate size and create more small pores to pull moisture towards the seedline.
3. The drip system should have a high distribution uniformity (> 85%)
4. Low flow tape (< 0.34 gpm/100ft) provided better lateral movement than high flow tape by allowing more time for soil capillaries to pull moisture.
5. Drip tape should be accurately positioned between seedlines and installed between 2 and 4 inches of depth. Shallow placement is preferable as long as the tape is below the depth of cultivation.
6. After installing the drip tape, beds tops should be rolled with a weighted roller to assure that the drip tape is in contact with the soil.
7. Planting depth may need to be increased slightly to assure that seed is in contact with the soil.

Tape installed between 2 and 4 inches of depth satisfactorily moved moisture to the seedline and uniformly germinated lettuce on a range of soil types.

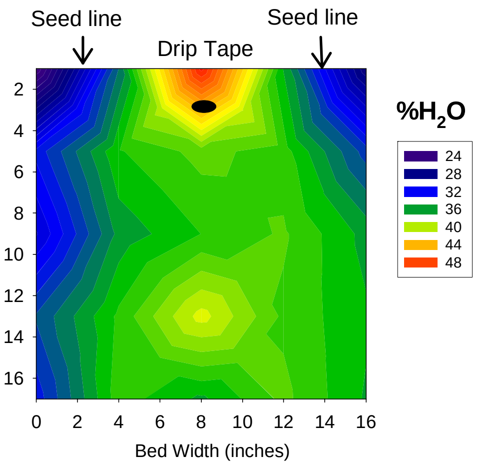

Figure 1. Moisture distribution around a drip line buried at a 3 inch depth on a Clear lake clay soil bedded to a bulk density of 0.86 g/cc.

Trials comparing 8 and 12-inch emitter spacing found no significant increase in soil moisture content within the seedline or an increase in germination rate (Table 3).

Table 1. Effect of bed shaping and rolling of beds on soil moisture content, spread of moisture on bed top, and germination rate. Replicated trial at Hartnell Research farm.

Treatment	Gravimetric Soil Moisture	Wetted Width	Germination Count (4/23/07)	Germination Count (4/25/07)
	%	inches	----------- plants/10 ft -----------	
	---------------------------------	soil preparation	-------------------------------	
spike tooth bed shaper	14.86	12.75	46.7	59.9
mulching bed shaper	14.78	12.88	52.7	63.7
F-test	NS[x]	NS	0.03	0.01
	---------------------------------	bed compaction	-------------------------------	
unweighted roller	14.67	12.68	48.3	61.5
weighted roller[y]	14.97	12.96	51.1	62.1
F-test	NS	NS	0.05	NS

[x] treatment means are not statistically different

[y] first pass with unweighted roller followed by a second pass with a weighted roller

In most cases we chose to plant an 1/8 of an inch deeper than normal to assure that the seed was in contact with the soil.

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(Cont'd from page 14)

Another strategy evaluated for promoting the horizontal movement of moisture from the drip tape was to add a chemical polymer to the irrigation water.

Table 2. Effect of tape discharge rate, and rolling of beds on soil moisture content, spread of moisture on bed top, and germination rate. Replicated trial at Hartnell Research farm.

Treatment Description	Gravimetric Moisture[x]	Wetted Width[x]	Germination 11-Jun	Germination 13-Jun
	g/cc	inches	plants/10 ft	
----------------------- Tape Discharge Rate --------------------				
0.3 gpm/100 ft	16.0	15.0	47.7	57.3
0.5 gpm/100 ft	15.3	15.1	46.3	58.4
F-test	0.003	NS[y]	NS	NS
------------------------------ Rolling -------------------------------				
1X	15.4	14.7	46.5	56.2
2X[z]	15.9	15.3	47.5	59.5
F-test	0.041	0.084	NS	NS

[x] 1st irrigation, 6/06/2006
[y] not statistically signficant
[z] 1st rolling was unweighted, 2nd rolling was weighted with water.

In trials conducted on newly formed beds where soil bulk densities were less than 1.1 g/cc, PAM did not increase lateral movement of moisture (Table 5)

Table 3. Effect of drip tape depth and emitter spacing on soil moisture content, spread of moisture on bed top, and germination rate. Replicated trial at Hartnell Research farm.

Treatment Description	Gravimetric Moisture[x]	Wetted Width[x]	Germination 11-Jun	Germination 13-Jun
	g/cc	inches	plants/10 ft	
--------------------------------- Depth ---------------------------------				
shallow (1.8 inches)	16.3	15.7	49.4	58.2
deep (3.1 inches)	15.0	14.3	44.6	57.5
F-test	0.056	0.027	NS[y]	NS
--------------------------------- Spacing -----------------------------				
8 inches	15.8	14.9	48.0	59.8
12 inches	15.4	15.1	46.0	55.9
F-test	0.079	NS	NS	NS

[x] 1st irrigation, 6/06/2006
[y] not statistically signficant

Table 4. Effect of PAM concentration lateral movement of moisture on a Pico fine sandy loam soil. (tape discharge rate was 0.5 gal/min/100 ft and was buried at a 2 inch depth)

PAM treatment	Wetted Width		Gravimetric Moisture seed line		Gravimetric Moisture shoulder		Gravimetric Moisture average	
	inches		------- g H2O/g soil ----					
0 ppm	12.9	a[x]	17.8	a	15.5	a	16.7	a
50 ppm	15.0	b	22.2	b	18.3	a	20.3	b

[x] means followed by different letters are statistically different

Table 5. Effect of tape discharge rate and PAM concentration on lettuce germination. Replicated trial at Hartnell Research farm.

PAM	Tape Discharge Rate (gal/min/100ft) 0.22	0.45	0.67	Average
(ppm)	--------- germination (plants/10 ft) ---------			
0	14.7	46.4	56.9	39.4
20	11.9	42.7	54.7	36.4
40	14.6	50.3	54.9	39.9
60	14.9	54.2	54.5	41.2
Average	14.0	48.4	55.2	
LSD.05	NS	NS	NS	

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Contact the office 72 hours in advance for special accommodations.

MONTEREY COUNTY

Crop Notes

July/August, 2007

To simplify information, trade names of products have been used. No endorsement of named products is intended, nor is criticism implied of similar products which are not mentioned.

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