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Crop Notes

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FIELD EVALUATION OF MATERIALS FOR CONTROLLING SPINACH DOWNY MILDEW IN ORGANIC SYSTEMS

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Introduction: Downy mildew is the most widespread and destructive disease of spinach grown in California and Arizona, and growers, pest control advisors, and other field personnel are very familiar with this problem. Early symptoms consist of light green, irregularly shaped lesions or blotches on cotyledons and true leaves. These lesions later enlarge and turn bright yellow. With time, the lesions can become tan and dry; if wet conditions are present the tissue can become soft and rotted. Examination of the underside of the leaf, opposite the yellow or tan area, usually reveals the purple growth of the pathogen. Downy mildew is caused by *Peronospora effusa*, which is a complex pathogen and consists of multiple races. Races are identified by testing their ability to infect differential sets of spinach cultivars having various resistance genes. By the end of 2014, fifteen races have been characterized.

Organic spinach and mildew trials: Downy mildew is a serious challenge for organic spinach production. Organic growers rely heavily on cultivar resistance to prevent disease but have no reliable fungicides or materials for spraying on susceptible crops. We conducted two trials in the summer of 2014 in Watsonville to evaluate candidate materials for managing downy mildew in organic spinach. In both trials, spinach (cultivar Corfu) was planted on 80-inch beds in a conventional field. Materials were sprayed onto replicated plots using a backpack sprayer and delivered at 65 gallons of water per acre equivalent. The conventional fungicide Zampro was included for comparison. Disease incidence was determined as the percent of infected leaves in a 1 ft-sq area, with six measurements per replicate. Spray timing was consistent with grower practices.

Results: Downy mildew pressure was moderate to high in the two trials. In the first trial, Taegro, Cueva, and Milstop were significantly better than the untreated control, as was the conventional Zampro treatment. In the second trial, only Actinovate and Zampro were better than the untreated control. No phytotoxicity was observed in any of the treatments in either of the trials. Additional research and large plot applications would be needed to further explore the feasibility of obtaining downy mildew control with any of these materials. Prior to using any fungicides, check product labels and consult with your local Agricultural Commissioner's Office for information on California fungicide registrations and allowable usage.

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Table 1. Spinach downy mildew incidence following fungicide applications

	Trial 1		Trial 2	
Treatment	% Disease Incidence[z]		% Disease Incidence[z]	
Zampro 14 fl. oz./A [y]	2.4	a	37.2	a
Taegro 5.2 oz/A	3.9	ab	---	---
Cueva 2.5 qt/A	4.2	ab	51.5	bc
Milstop 5 lbs/A	5.4	ab	---	---
H. perox. + per. acid 1%v/v [x]	8.0	abc	---	---
Actinovate 12 oz/A	11.2	bc	42.2	ab
Regalia 2 qt/A	11.2	bc	---	---
Untreated Control	14.3	c	59.0	c
Serenade Optimum 16 oz/A	15.1	c	56.5	c

[z] Means with the same letter in a column are not significantly different according to Tukey's HSD test at $P \leq 0.05$.

[y] Conventional fungicide standard was Zampro.

[x] Hydrogen peroxide + peroxyacetic acid.

EVIDENCE OF SPRINGTAIL FEEDING ON GERMINATING LETTUCE IN THE SALINAS VALLEY

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Growers in the Salinas Valley facing an irregular lettuce stand are usually uncertain about what caused the problem and often blame the factors such as poor seed quality, planting error, irregular irrigation timing or distribution, high salt levels in the soil or water, soilborne pathogens of seedlings, bulb mites, and garden symphylan feeding for the losses. Several springtails were collected from the soil associated with lettuce and it is not clear if they were feeding and contributing to the irregular lettuce stand. Often, this springtail is misidentified as garden symphylan.

Recently, I found a large number of a subterranean springtail (*Protaphorura fimata*) (Fig. 1) in the monitoring potato slice traps deployed in Salinas lettuce fields. I did a series of laboratory and field studies to determine its pest status in lettuce. This springtail (*P. fimata*) is less than 2.5 mm long, white in color and lacks eyes. Unlike other springtails, this springtail lack a furcula (jumping organ), and when disturbed it does not jump instead curls up. Other similar species of springtails primarily reproduce parthenogenically meaning they reproduce without mating; however, sexual reproduction is also seen on this one (*P. fimata*). This species (*P. fimata*) seems to be widely distributed in Europe, but has not been previously reported from the U.S.

Springtails occur in diverse habitats worldwide and are generally considered as beneficial arthropods because they aid in the decomposition of decaying plant material by feeding, thereby contributing to the cycling of carbon and nitrogen which in turn improves soil health and structure. This springtail is primarily known to feed on soil fungi but also feeds on live plant roots. Other springtails in the same family have been associated with

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feeding damage to germinating sugar beet seeds, sugarcane, poppy seeds and weed seeds (*Plantago major*). Foliage-feeding springtails (lucerne flea and garden springtail) attack several plants including Lucerne (*Medicago sativa*), clover (*Trifolium sp.*), sugar beet (*Beta vulgaris*) and bean.

Objectives: The major objectives of the present study were to document:
1. The ability of springtail (*P. fimata*) to injure germinating seeds of lettuce in laboratory and field
2. Characterize the feeding injury of springtail on germinating seeds and seedlings of lettuce.

Method:

1. Lab experiments. I conducted experiments in plastic petri dish with and without soil and sprigtails. Then I recorded the ungerminated lettuce seeds due to feeding injury, total number of feeding injury sites, and number of germinated seedlings with distinct feeding injury. I also documented the location (e.g. leaf, stem, plant crown or root) of the feeding injury on the plants.

2. Field experiment. The assumption of this study was that the repeated use of maximum label rate of selected insecticides at early stages of plant development would suppress springtails and protect the seeds or seedlings from feeding. Two commonly used pyrethroid insecticides were applied (by the grower) three times: 2 days before planting, at planting, and 20 days after planting. Applications were made using a commercial tractor mounted sprayer. Two pyrethroid insecticides used were Mustang (4 fl oz per acre) and Warrior II (1.6 fl oz per acre). Both the Mustang and Warrior II were tank mixed and applied at 2 days before planting and 20 days after planting but only Warrior II was applied at planting to conform to the label. An adjuvant, Widespread Max (2 fl oz per acre) was added with all the applications. I used bait slices to monitor the springtails at weekly intervals. They were placed in the soil at 1.5 inches deep along the seed line and were covered with disposable white plastic bowls. At the end of each 2 days exposure period, beet root slices were removed, placed into plastic bags and transported to the laboratory. In addition, plant samples were collected to assess the plant growth. Please read the full Journal article for details.

Results and discussion: Results demonstrate that this springtail (*P. fimata*) can feed on germinating lettuce seeds or young seedlings, resulting in reduction in lettuce growth (Figure 2). Springtails attacked seeds and young seedlings alike. In the laboratory, springtails directly fed through the seed coat (pericarp) of a few seeds. This is possibly due to the moistening of the pericarp, enabling springtails to feed through the softened coating (Fig. 3a and b). In some instances, springtails fed on the growing radicle of the germinating seeds (Fig. 3c). However, most of the feeding at the seed radicle or elsewhere did not entirely sever it (Fig. 3d), which allowed the seedling to survive but affected the normal development of the plant. Moreover, most of the feeding injury was evident at the crown area rather than on leaf, stem, or root (Fig. 4).

In the Salinas Valley, before the lettuce seeds are planted, fields are watered deeply and irrigations continue for at least three weeks after planting. I observed that the springtail density increased when the field was recently irrigated or after a rain event. This cultural

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practice which maintains high moisture levels for seed germination on the sub-surface profiles of the soil might be favoring faster buildup of springtail populations. In the field trial, the springtail captures were greater immediately after irrigation in the untreated beds than insecticide treated beds which was reflected in reduced number of springtails and in the untreated beds (Fig. 5).

Conclusion: This study clearly demonstrates that springtail (*P. fimata*) is an important pest of lettuce and is capable of reducing the crop stand. Incidence of high populations of springtail could be detrimental to germination of seeds in the field (Fig. 6 and 7). Springtails could be effectively suppressed to a large extent with early applications of insecticides directed to the seed line. Monitoring is the key to determine the presence and population size of springtail. Currently, I'm conducting for laboratory and field studies to determine the efficacy and application timing of insecticides.

Acknowledgments: I appreciate the help provided by growers and pest control advisor, and the help provided by the Chris Bettiga (staff research associate) and Hartnell students, Christian Ramirez, Jesus Martinez, and Scott Cosseboom in sample collection. Also, I want to thank Larry Bettiga, Steve Koike for much needed help in various phases of the project. I thank the California Leafy Green Research Program for providing funding for this project.

Again, please use the link below to read the full article.
http://cemonterey.ucanr.edu/files/206762.pdf

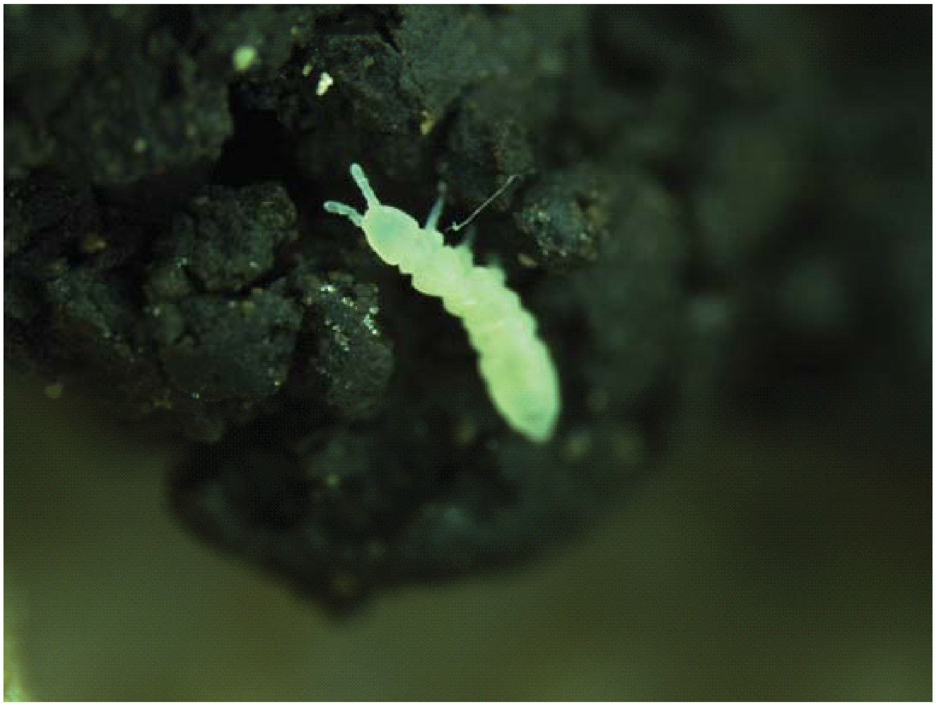

Fig. 1. The springtail (*Protaphorura fimata*) that attack lettuce seed.

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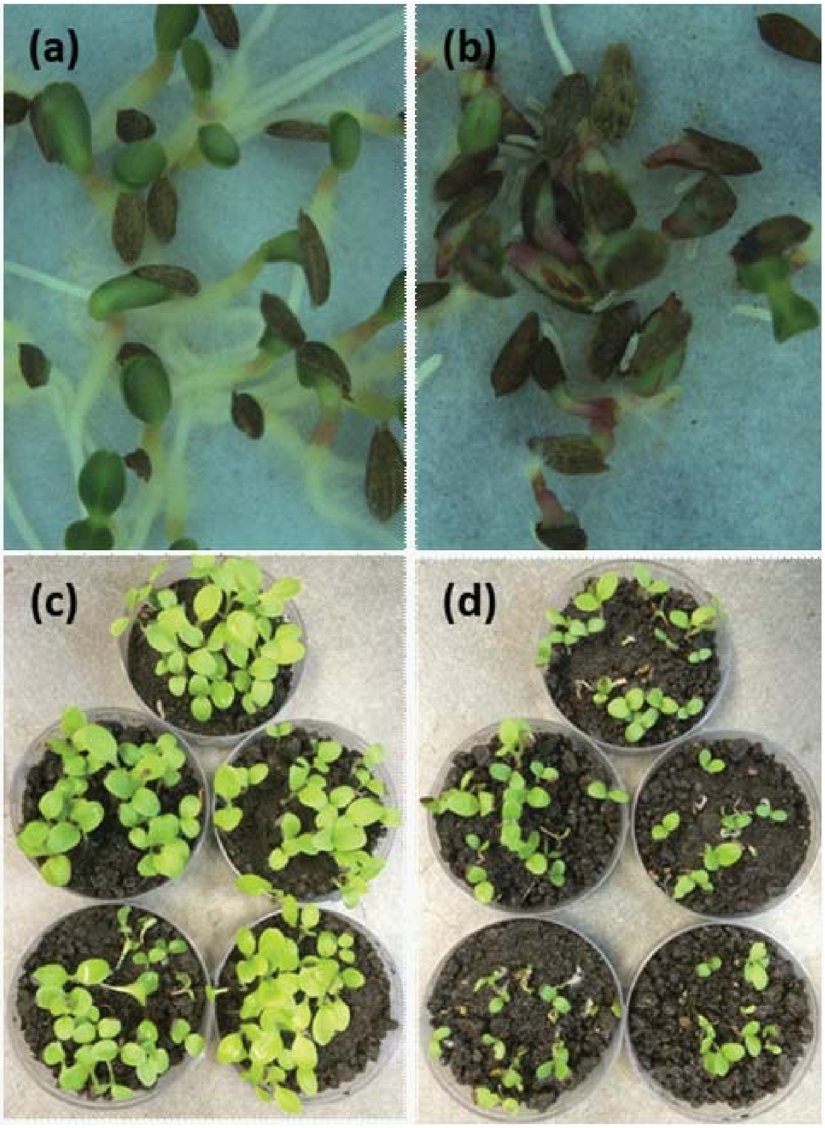

Fig. 2. Effects of springtail on germinating lettuce seeds exposed (a) without soil and springtail, (b) without soil but with springtail, (c) with soil but without springtail and (d) with soil and springtail.

Fig. 3. Feeding injury of springtail on (a) seed – completely injured, (b) seed – incompletely injured, (c) radicle – completely severed, and (d) radicle –partially severed.

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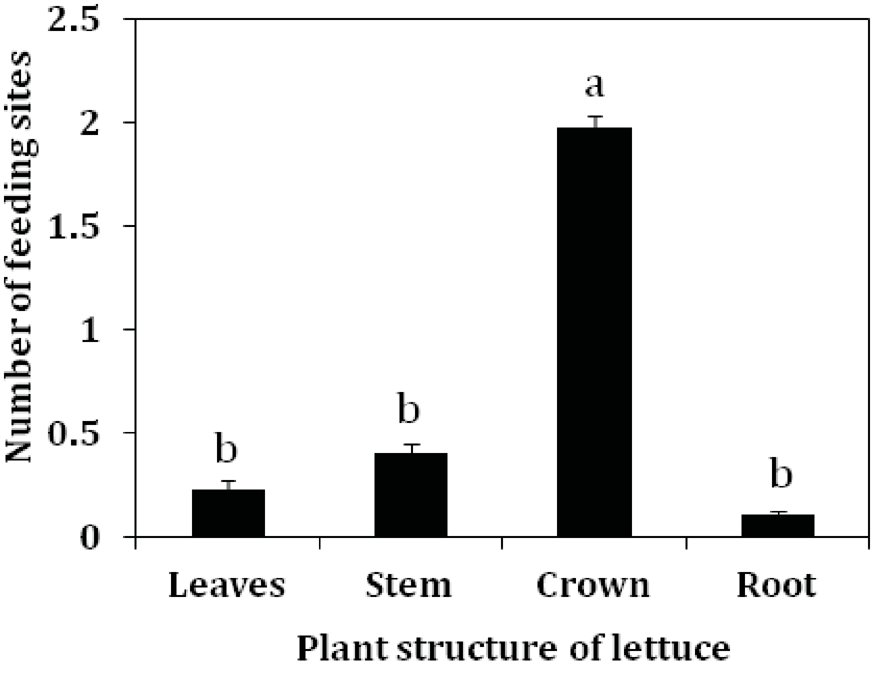

Fig. 4. Springtail feeding injury sites at various parts of the germinated lettuce seedlings.

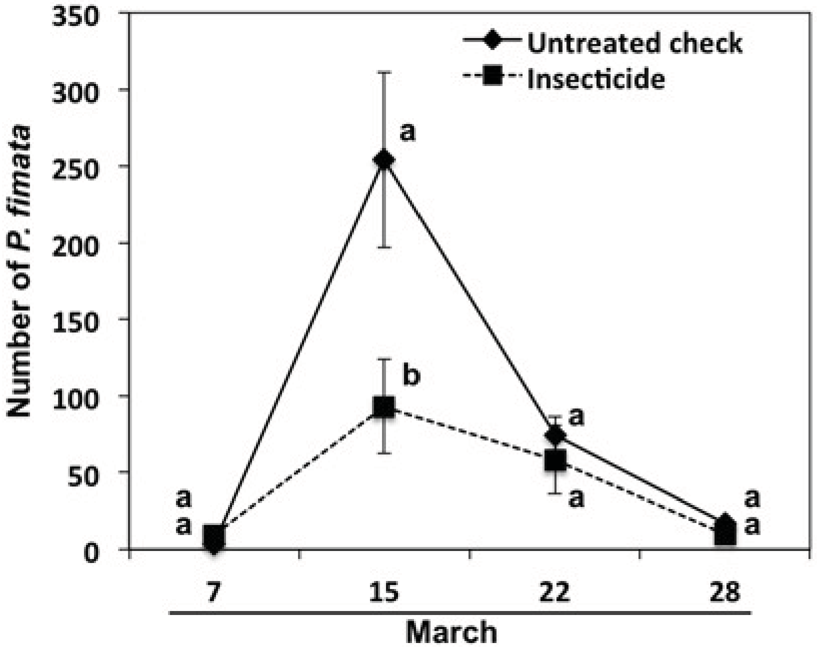

Fig. 5. Effect of insecticide treatment on springtail densities in a lettuce field.

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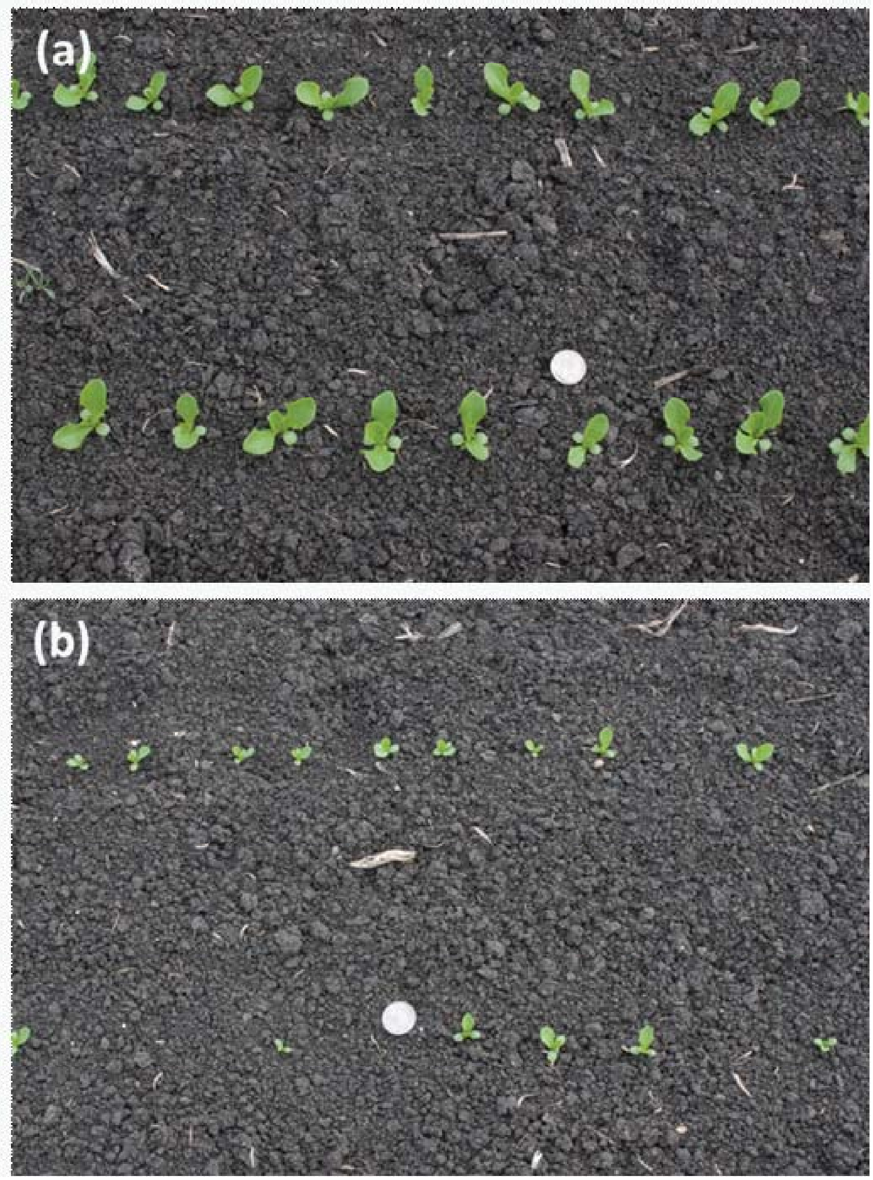

Fig. 6. Effect of springtail feeding on young seedling of lettuce in the field after (a) insecticide treated, and (b) untreated check (Photo:

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Fig. 7. Effect of springtail feeding on young seedling of lettuce in the field (Photo: Steve Koike).

THE ROLE OF ROTATIONS IN ADDRESSING WATER QUALITY ISSUES

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The basic concepts in addressing water quality issues in cool season vegetable production can be summarized as follows:

- Know the crop nitrogen (N) uptake demand
- Measure residual soil nitrate-N
- Measure nitrate-N in the irrigation water
- Adjust nitrogen fertilizer rates after accounting for nitrate in the soil and contribution from irrigation water
- Apply irrigation water efficiently to minimize leaching losses
- Retrieve nitrate pushed past the rooting zone with deep-rooted cash or cover crops

Following these steps should help minimize over application of nitrogen to a crop and lead to compliance with the Ag Order as put forth by the Regional Water Quality Control Board.

Measuring residual soil nitrate and accounting for it in fertilizer programs is an important tool in improving nitrogen use efficiency (NUE) in crop production and is now carried out by a growing number of growers. However, the role of rotations in mitigating nitrate loss from cropping systems has not been stressed to the extent that perhaps it should. Clearly, we can manage N as efficiently as possible during the cropping season, and still have nitrate that percolates beyond the reach of shallow rooted crops such as lettuce

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and spinach. Figures 1&2 show examples from commercial fields where the roots of lettuce and spinach effectively take up nitrate in the soil depths where the greatest concentrations of roots are located; however, beyond that zone of active roots, nitrate can accumulate and be at risk for leaching by irrigation or rain. One means of retrieving deep nitrate is to grow winter cover crops (Figure 3). However, the use of cover crops in the Salinas Valley is limited due to their high opportunity cost in areas with high rents.

In our research on nitrogen uptake rates by vegetables we were surprised to find that summer-grown broccoli, cauliflower and cabbage typically take up more N than is applied (Table 1). In the fields that we surveyed, broccoli typically took up 155 lbs N/A more than was applied to the crop. This finding issignificant because broccoli is the most important rotational crop for lettuce with 65,577 acres in Monterey County in 2013. Cauliflower (20, 987 acres) took up 63 lbs N/A more than was applied; the average N fertilizer program for cauliflower was higher and therefore there was less scavenging. Cabbage (7,791 acres) took up 104 lbs N/A more that was applied in the fertilizer. Of the total amount of biomass N taken up by these crops 99, 66 and 180 lbs N/A were in the harvested portion of broccoli, cauliflower and cabbage, respectively. Cabbage had a higher percent of its total biomass in the harvested portion of the crop, 61.4%, which was higher than broccoli (24.2%) or cauliflower (17.1%).

Scavenging of soil nitrogen by these crops occurred only during the summer production months. During winter production, broccoli grew slower and did not take up as much N; in addition, more fertilizer N was applied resulting in N application being equivalent to N uptake (Table 2). Cauliflower produced slightly less biomass during the winter, but had greater percent N in the tissue so took nearly identical amount of total N in the crop biomass as it produced during the summer. However, the growers we surveyed applied more N in the winter so crop N uptake was less than fertilizer N applied.

Given the N uptake characteristics of summer-grown broccoli, it is clear that there are quantities of residual soil nitrate in the soil that broccoli is accessing to make up the difference between fertilizer N application and crop N uptake. Broccoli roots reach to beyond 36 inches in the soil by the end of the crop cycle (Figure 4). This data indicates that broccoli is taking up nitrogen from deeper in the soil profile than lettuce or spinach. We conducted a follow-up study to determine how efficiently broccoli took up residual soil nitrate from a previous lettuce crop. This information was also used to refine the algorithms used in the CropManage decision support website for nitrogen management of broccoli. One of the key questions, is given the growth rate of broccoli roots, when should we factor in the N in the second foot of soil into the fertilization program.

The trial was conducted with commercial growers evaluating the N uptake dynamics of broccoli grown following a crop of lettuce. Uptake of N in the crop, soil nitrate-N to three feet, crop rooting depth, crop canopy development and total applied irrigation water were measured in each field. Table 3 shows the data from the five survey sites. The quantities of residual soil nitrate to three feet in the soil at the beginning of the broccoli crop cycle varied from field to field. Site 2 had 372 lbs and sites 1 and 3 had 146 and 134 lbs N/A, respectively. Fertilizer programs for sites 1-4 were modest

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considering that each of these fields took up over 268 lbs of N/A in the crop biomass. It is interesting to note that the field with the highest residual N (site 2) had the highest percent N in the biomass indicating that broccoli may consume luxury amounts of N. The quantity of irrigation water applied was higher than crop ET at all the sites, but the application of water was close to crop ET at site 4 resulting in no nitrate leaching. Site 5 was transplanted broccoli on a loamy sand soil; water management at this site was more challenging which probably accounted for low NUE.

In 2014 we conducted a study where we applied N fertilizer using subsurface drip at four depths to different treatments: (0, 12, 18 and 24 inches). The trial site had low residual soil nitrate and we observed reductions in marketable head weight when all N applied to the crop was injected at 24 inches in the soil. The plants in the deep N application treatments were stunted until the roots reached the 24 inch depth where the N was placed. This observation indicated that broccoli needs good nutrition in the first foot of soil to grow efficiently. Broccoli roots begin to take advantage of nitrate in the second foot of soil at the midpoint of the growth cycle and that is when you can begin factoring in the N in the second foot into fertilizer decisions. CropManage has an algorithm that estimates root growth during the crop cycle of broccoli. The fertilizer recommendation accounts for the soil nitrate concentrations at the 1 and 2 foot depths when the roots reach the 2 ft layer.

These studies indicate that broccoli rotations act like a cover crop and scavenges nitrate-N from the soil left by the prior crop. The next obvious challenge for making efficient use of the N scavenged by broccoli rotations is to make effective use of the N contained in broccoli residue for crop growth of subsequent crops.

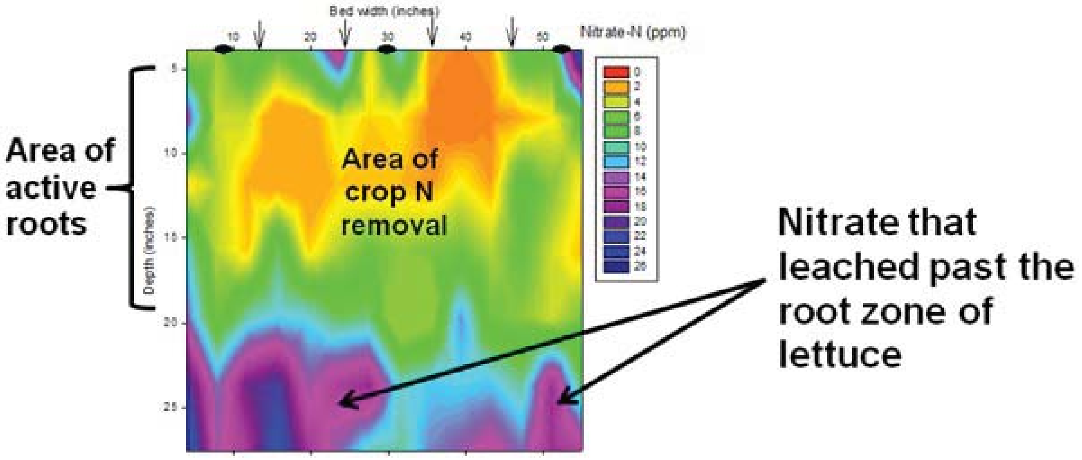

Figure 1. Nitrate removal by lettuce is nearly complete in the root zone, but below the root zone, soil nitrate accumulated just out of the reach of roots.

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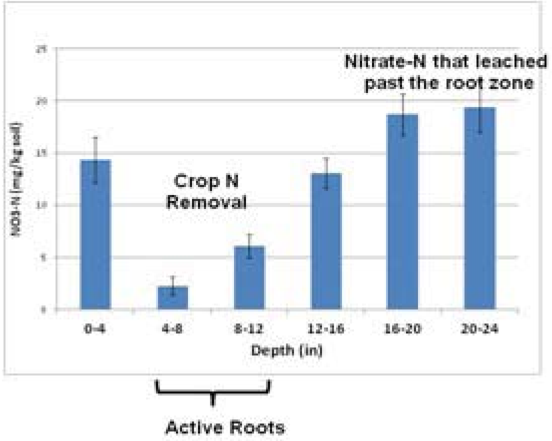

Figure 2. Nitrate removal by spinach. Nitrate removal is greatest at in the 4-12 inches deep in the soil. Higher soil nitrate levels at 12-24 inches deep in the soil, indicate nitrate leached past the root zone.

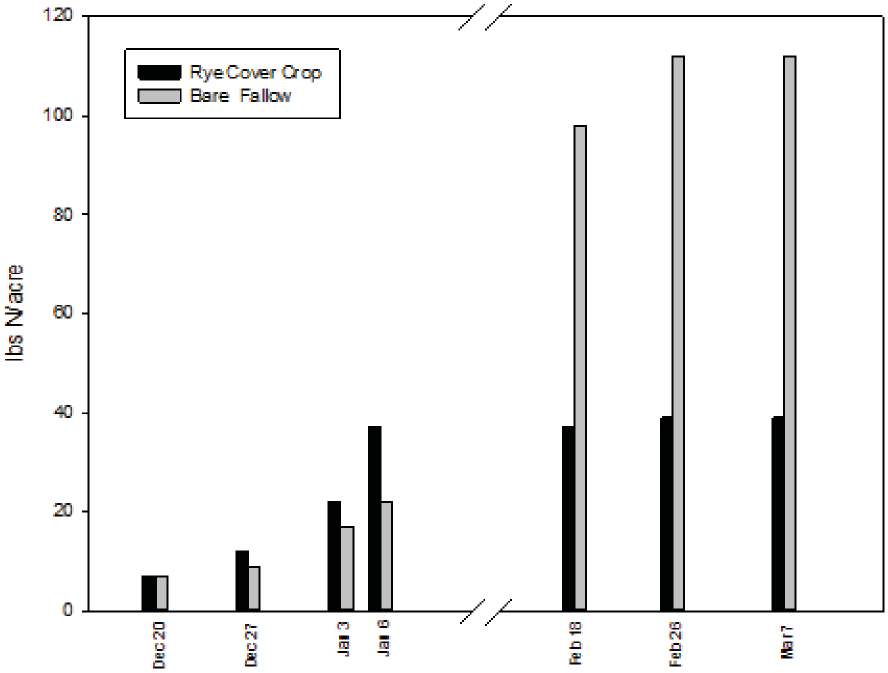

Figure 3. Quantity of N leached beyond 2 feet deep in the soil in winter bare fallow and rye cover cropped treatments

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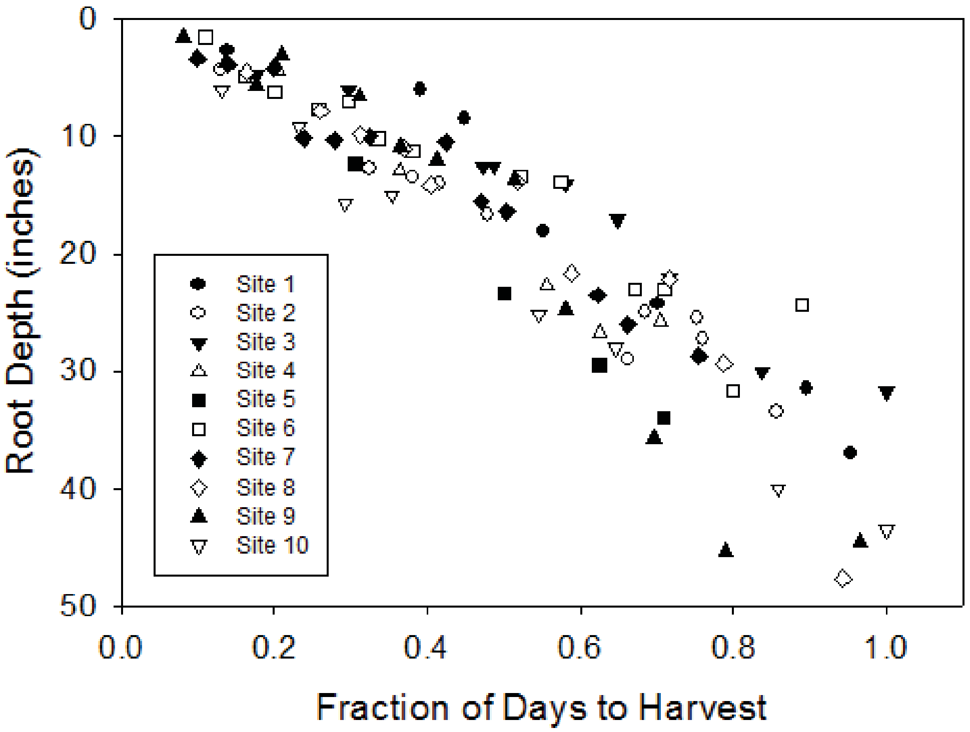

Figure 4. Depth of the deepest broccoli roots over the course of the crop cycle (0.0 = planting to 1.0 harvest)

Table 1. Summers 2012 to 2014. Above ground N/A in crop, applied fertilizer, N scavenged from soil and N in residue at harvest

Crop	Total uptake lbs N/A	Harvested Tissue N/A	Dry biomass Lbs/A	Total biomass %N	Fertilizer applied N/A	Scavenged from soil N/A	Unharvested residue N/A
Broccoli	337.4	99.3	8,585.5	4.0	181.9	155.5	238.1
Cauliflower	284.4	66.6	6,865.6	4.1	220.8	63.6	217.8
Cabbage	354.6	180.3	11,976.2	3.0	249.8	104.8	174.3

Table 2. Winter 2012-13 Evaluations. Above ground N/A in crop, applied fertilizer,Fertilizer:uptake ratio and N in residue at harvest

Crop	Total uptake lbs N/A	Harvested Tissue N/A	Dry biomass Lbs/A	Total biomass %N	Fertilizer applied Lbs N/A	Uptake: Applied Percent	Unharvested residue Lbs N/A
Broccoli	249.5	93.9	5,539.2	4.5	272.7	109	155.6
Cauliflower	273.7	70.2	6,490.5	4.2	351.7	128	174.5

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Table 3. Analysis of total N available from residual soil N and fertilizer, broccoli N uptake and its impact on N utilization and nitrate leaching

Site	Soil Texture	Dry Biomass tons/A	Initial residual soil mineral N[1] lbs/A	Total N fertilizer Applied lbs/A	Total available mineral N lbs/A	Biomass N percent	Total N uptake by crop lbs/A	Percent of total N taken up by broccoli	Final residual soil mineral N[1] lbs/A	Total soil residual and crop uptake N lbs/A	Total water applied	Total Crop ET	Total N potentially leached[2] lbs/A
Site 1	loam	4.37	146.4	178.0	324.4	3.6	313.4	97.0	8.9	322.3	15.7	10.2	32.1
Site 2	loam	4.38	372.1	178.0	550.1	4.2	370.0	67.3	132.6	502.6	15.6	12.4	77.5
Site 3	loam	4.51	134.3	190.0	324.3	3.0	268.1	82.6	19.2	287.3	17.0	11.5	67.0
Site 4	loam	4.76	183.6	190.0	373.6	3.9	369.6	99.0	48.0	417.6	12.0	10.6	-14.0
Site 5	loamy sand	3.53	257.4	240.0	497.4	3.1	220.5	44.3	92.1	312.6	17.4	8.6	214.8

1 – total N in the top three feet of soil; 2 – calculated by subtracting total residual soil N and crop uptake plus total mineral N from total available mineral N (also includes an estimate of N mineralized from soil organic matter of 30 lbs N/A as part of the total available mineral N)

WHITE MOLD CAUSED BY *SCLEROTINIA SCLEROTIORUM*: AERIAL VERSUS SOILBORNE INFECTIONS

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Plant Pathology Farm Advisor

Winter diseases: During the late-2014 winter and early-2015 months in southwestern desert regions, white mold caused by the fungus *Sclerotinia sclerotiorum* caused damage to a number of vegetable crops. Such damage was reported on cauliflower, carrot, and lettuce. Disease incidence appeared to be greater than normally encountered in these winter growing areas.

Symptoms: The first symptoms of white mold on most vegetable crop hosts are irregularly shaped, water-soaked or discolored areas on stems, leaves, or flower heads (in the case of broccoli or cauliflower). These infections quickly develop into soft, mushy, pale brown rots. Rotted areas can expand rapidly and affect a large portion of the plant. Plants with infections on the main stems can completely collapse and fall over. Diseased tissues eventually are covered with thick white mycelium (Photo 1), white mycelial mounds that are immature sclerotia, and finally mature, hard, black sclerotia (Photo 2). Mature sclerotia usually form after tissues are rotted and broken down. The black sclerotium is the survival stage of the fungus and can measure from ¼ to ½ inch long. This structure allows the pathogen to infect plants in two distinctly different ways. (Note that sclerotia of *Sclerotinia sclerotiorum* are significantly larger than those of *Sclerotinia minor*, causal agent of lettuce drop on coastal lettuce [Photo 3].)

Soilborne infections: Fields having histories of white mold caused by *S. sclerotiorum* will have sclerotia in the soil. These sclerotia remain dormant in the absence of sufficient moisture. However, once the soil is moistened, especially with the planting and irrigating of a crop, shallowly located sclerotia can germinate and produce mycelium that can grow onto and infect the tissues of nearby host plants. This mode of attack is called direct soilborne infection by *S. sclerotiorum*. Soilborne infections always result in the

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decay and disease being initiated at the lower portion of the crown, stem, or leaf that is in contact with the soil. Soilborne infections cannot initiate disease on leaves, stems, or heads high off the ground.

Aerial infections: However, many of these winter cases of white mold are due to the second mode of attack from *S. sclerotiorum*. If sufficient soil moisture is present, shallowly buried sclerotia germinate in a different manner; these sclerotia form small, tan mushroom-like structures called apothecia (Photo 4). Apothecia quickly mature and release spores (called ascospores) that are carried by winds to the host plant (Photo 5). Because ascospores are dispersed via the wind, they generally land only on the upper parts of plants where they cause aerial infections. Therefore, ascospores presumably rarely cause crown infections but are responsible for white mold disease on upper foliage. For example, white mold on cauliflower curds is caused exclusively by ascospore aerial infections (Photo 6).

Management: Controlling white mold under these winter weather conditions is difficult. Foliar fungicides provide some protection against either soilborne or aerial infections; however, such fungicides need to be applied prior to mycelial contact with (soilborne) or ascospore deposition on (aerial) plants. Before using any fungicides, check with your local Agricultural Commissioner's Office and consult product labels for current status of product registration, restrictions, and use information.

Photo 1: The *Sclerotinia sclerotiorum* pathogen can produce thick white mycelium on host tissues.

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Photo 2: In advanced cases of white mold, the fungus produces hard, black survival structures called sclerotia.

Photo 3: The sclerotia of *Sclerotinia sclerotiorum* (left) are significantly larger than those of *Sclerotinia minor* (right), causal agent of lettuce drop on coastal lettuce.

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Photo 4: Under suitable conditions, the *Sclerotinia sclerotiorum* pathogen produces mushroom-like structures called apothecia.

Photo 5: Apothecia of *Sclerotinia sclerotiorum* will release ascospores, shown here stacked inside of tubes called asci, that will become airborne and cause aerial infections on host plants.

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Photo 6: Airborne ascospores are responsible for aerial infections of cauliflower heads and other above-ground plant tissues.