Cooperative Extension • Monterey County

Crop Notes

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In This Issue:

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LOW RESIDUE COVER CROPS FOR WINTER FALLOW VEGETABLE PRODUCTION FIELDS: SUMMARY OF TWO YEARS OF EVALUATIONS

Richard Smith, Michael Cahn, Aaron Heinrich and Barry Farrara

Cover crops planted in fallow vegetable fields are an effective cultural practice for reducing erosion and protecting water quality during the winter. By reducing run-off volume and protecting the soil from erosion cover crops also minimize sediment and nutrient loads during rain events, and by taking up residual soil nitrate, they minimize nitrate leaching. In addition, cover crops provide needed soil organic matter that improves soil tilth and quality. However, it is difficult to find opportunities to include cover crops in Salinas Valley cropping systems due to the intensive planting schedules and high land rents. Over the past several years we have experimented with the use of low residue cover crops in order to find a way to include cover crops and provide some of the benefits that they provide for vegetable production fields.

Low residue cover crops are planted on listed winter beds and are either planted on the furrow bottom or are broadcasted; in both cases the seed is spread and then lillistoned into the soil. The cover crop is germinated with soil moisture, with rain or is irrigated. Unlike full-maturing cover crops, low residue cover crops are grown for 50-60 days, until they produce 0.5-1.0 ton/A of dry biomass, and then are killed with glyphosate. After being killed with the herbicide, the cover crop residue begins to decompose. The goal is to allow time for the cover crop residue to decompose sufficiently to allow normal bed preparation operations to proceed, thus not causing delays in crop planting schedules (to see video footage of low residue cover crops, go to http://www.youtube.com/watch?v=k0oVVJ_BA7s). To test the impact and practical application of low residue cover crops, we conducted large-scale trials with a cooperating grower on the eastside of the valley over two years: Trial No. 1, winter of 2009-2010 and Trial No. 2, winter of 2010-2011 in fields with 40 and 80 inch beds, respectively. The trials allowed us to test low residue cover crops under diverse conditions and gave an opportunity to see the benefits and disadvantages of this cultural practice.

Table 1 shows the cover crop varieties, planting dates and kill dates. The weather pattern between the two years varied. The weather remained sufficiently wet during Trial 1 to allow good decomposition of the cover crop residue; at the end of the cover crop cycle the residue had broken down sufficiently so that planting operations were carried out normally (see YouTube video mentioned above to see the lilliston pass through the field at the end of the cover crop cycle). However, in Trial 2 two issues reduced cover crop biomass decomposition and disrupted bed preparation operations: 1) due to the presence of an adjacent strawberry field, we used clethodim to kill the cover crop but it was not as effective as we had hoped and the cover crop died slowly. We resprayed the rye by hand three weeks later with glyphosate to speed death of the cover crop. 2) The weather was dry during February which further slowed decomposition of cover crop residue. As a result, too much cover crop residue remained, and due to the approaching planting schedule,

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it was decided that we could not work the beds with a lilliston, and the field was disced and relisted. As a result of the positive results in Trial 1 and the difficulties in Trial 2 we have a fuller appreciation for benefits as well as the drawbacks of low residue cover crops for winter vegetable production beds.

Methods used for evaluating water quality benefits of cover crops

In both trials, runoff from the plots was measured during all rain events during the winter. Run-off from each plot was channeled through flumes at the lower end of the plots. Flumes were instrumented to measure the flow rate and total volume of runoff. An automatic sampler collected composite samples of runoff during storm events. Run-off samples were analyzed for suspended sediments and nutrients at the UC Davis Analytical laboratory. Three suction lysimeters were installed at a two foot depth in each plot to sample leached nitrate during rain events. A vacuum pump maintained 20-25 cbars of suction in the lysimeters to capture gravitational water during rainfall events. Nitrate leaching was estimated from the concentration of nitrate in leachate samples and by estimating the amount of percolation during storm events from rainfall, soil moisture storage, and evapotranspiration data. Mineral nitrogen in the top foot of soil was monitored on a bimonthly basis over the course of the trial. Nitrate in the soil profile was measured to a depth of 3 feet at the beginning and end of the trial. Cover crop biomass was measured by cutting the biomass from 2 square meter areas in the plots every two weeks during the course over the growth and decomposition cycle of the cover crop. Samples of the cover crop biomass were sent to the UC Davis Analytical laboratory for total nitrogen analysis.

Table 1. Details on the growth and management of low residue cover crop both trials

Cover crop species		Wet date		Kill date	
Trial 1	Trial 2	Trial 1	Trial 2	Trial 1[2]	Trial 2[3]
Rye AG 104	Rye AG 104	Nov. 24	Nov. 16	Jan. 15	Jan. 11
Trios 102	Triticale 8881	Nov. 24	Nov. 16	Jan. 15	Jan. 11

1 – the seed was incorporated with a Perfecta and was buried too deep and this treatment; the plots were reseeded with barley UC603 on December 3, 2010 and incorporated with a wheel hoe harrow on the same day; 2 – Sprayed with 2% glyphosate; 3 – sprayed with clethodim @ 1 pint/A and the rye was resprayed on February 7 with 3% glyphosate.

Results

Impact of Low-residue cover crops on runoff, sediment and nutrient loss: In both years of trials, there were intensive periods of rainfall that allowed us to measure differences in the quantity and quality of runoff from the cover cropped and bare treatments. In Trial No. 1, 47% of the rainfall (about 120,000 gallons per acre) ran off of the bare plots. However, low residue cover crops reduced the volume of storm induced run-off by 95% for the rye treatment and by 80% for the triticale treatment (Figure 1). Cumulative sediment loss from the bare plots averaged 1199 lbs of sediment/acre for the winter season whereas rye reduced sediment loss by 99% (2.1 lbs of sediment/acre) and triticale by 94% (73 lbs of sediment/acre) (Figure 2). Losses of sediment were highest during the first major rain events of the season when the fine particles in the soil were most susceptible to erosion. In Trial 2 an early rain occurred before the cover crop was big enough to protect the soil surface from the impact of the rain droplets; as a result, the ground sealed and the effect of the cover crop on runoff was much less than in Trial 1. Additionally, despite having similar soil types, run-off volumes were much less for the bare treatment in Trial 2 which had 80- inch wide listed beds than in the bare treatment of Trial 1 which had 40-inch wide beds. Presumably less run-off was measured from the 80-inch beds because they were essentially flat while the 40-inch beds were peaked. Also there were more furrows in the field with 40-inch wide beds.

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Cover cropped treatments also reduce nutrient losses in surface water run-off. Total N and P losses were reduced by 95% for the rye treatment and by 87% for the triticale treatment (Table 2) compared to the bare plots. Soluble nutrient losses were also reduced under the cover crop treatments. Reductions in nitrate-N losses were 92% and 93% for the rye and triticale treatments, respectively, compared to the bare plots. Reductions in soluble P (ortho-P) losses were 84% and 78% for rye and triticale treatments, respectively compared to the bare control. Also a significant reduction in ammonium and potassium losses was measured in the cover crop treatments relative to the bare plots (Table 2). Although the losses in nutrients may not have an agronomic impact on the subsequent vegetable crops, these losses can cause significant impairments to the quality of surface water. Both nitrogen and phosphorus spur algal growth in surface waters which can reduce dissolved oxygen levels.

Impacts of low residue cover crops on nitrate leaching: As mentioned above low residue cover crops decreased surface water runoff. As a result, they increase infiltration of water into the soil. Even minimal cover crop residue such as winter dormant triticale Trios 102 greatly increased infiltration. Increased infiltration removes salts from the soil profile and helps to recharge ground water resources. This is particularly important on the eastside of the Salinas Valley. Unfortunately nitrate is one of the anions (negatively charged ion) that is lost along with sodium and chloride (Table 3). In a separate trial examining the impact of low-residue in comparison with full-term cover crops we observed that nitrate was lost from both cover crop systems during rain events before the cover crop was big enough to absorb substantial quantities of residual soil nitrate. However, once the cover crop was sufficiently established it was able to absorb significant amounts of nitrate from the soil. Full term cover crops can take up 150 lbs or more N/A from the soil. Low residue cover crops absorb less than half that amount, depending on how long they are allowed to grow before being terminated. Another problem is that the nitrogen contained in the cover crop biomass is rapidly mineralized to nitrate and can be lost in winter storms (Figure 3). As such, it appears that low residue cover crops can only reduce nitrate leaching in situations in which there are low to moderate amounts of residual soil nitrate.

Management of low residue cover crops: Low residue cover crops can be broadcast or planted in the furrow only. Normal seeding rates can be used for broadcast plantings. The furrow bottom plantings can be assumed to occupy about 1/3 of the field area and planting rates can be adjusted accordingly. However, given the difficulties of planting the furrow and issues with compaction, it is advisable to plant an extra amount of seed to make sure you get an adequate plant population. One challenge in planting the furrow is getting the seed incorporated, but not too deep. We experienced germination problems when we incorporating seed in the furrow too deep with a Perfecta. In general, cereal cover crop varieties should not be planted deeper than 2 inches deep.

Broadcast plantings of rye grew rapidly, covered the soil and were highly effective in reducing surface runoff as well as sediment and nutrient loss (Photos 1&2). Winter dormant varieties of triticale such as 888 planted in the furrow bottoms were also reasonably effective (Photos 3&4). The winter dormant types were more forgiving as to when they needed to be terminated vs vigorous and rapidly growing standard cover crop varieties such as cereal rye and oats. It is important to carefully plan when and how the cover crop will be terminated. In general, as soon as the cover crop seed begins germinating (either from soil moisture, precipitation or irrigation) it is critical to mark your calendar for 50-60 days in the future and plan for terminating the cover crop in this time frame. The use of grass selective herbicide is helpful for safeguarding adjacent crops, but they do not remove broadleaf weeds which can become problematic. As a result, it is best to use glyphosate or a mechanical means to terminate the cover crop.

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Conclusions and Recommendations

- Low residue cover crops are able to significantly reduce surface water runoff, sediment and nutrient loss during in surface water during winter storm events
- Target this technique to soils with high runoff and sediment loss potential (e.g. eastside of the Salinas Valley)
- They greatly increased water infiltration into the soil, thereby providing a cultural practice that can increase ground water recharge and move accumulated salts out of the soil profile
- Establish as early as possible to provide protection from early rains
- They must be killed before they produce too much biomass that would disrupt subsequent planting operations – keep in mind that once killed they still provide effective sediment loss reduction and increased infiltration for a good amount of time
- They are only able to accumulate moderate amounts of nitrate from the soil and may not reduce nitrate leaching in storms later in the cover crop growth cycle
- Planting cover crops just in the furrow bottom may be the safest approach to using these cover crops so that they do not disrupt subsequent vegetable planting operations (especially true on 80 inch beds)

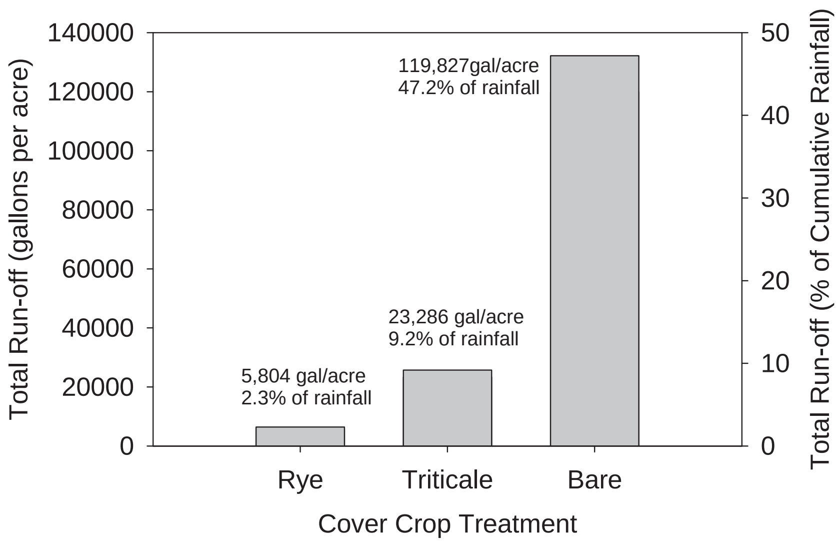

Figure 1. 2009-2010 Trial. Total runoff from cover crop and bare treatments between mid January and March 7, 2010.

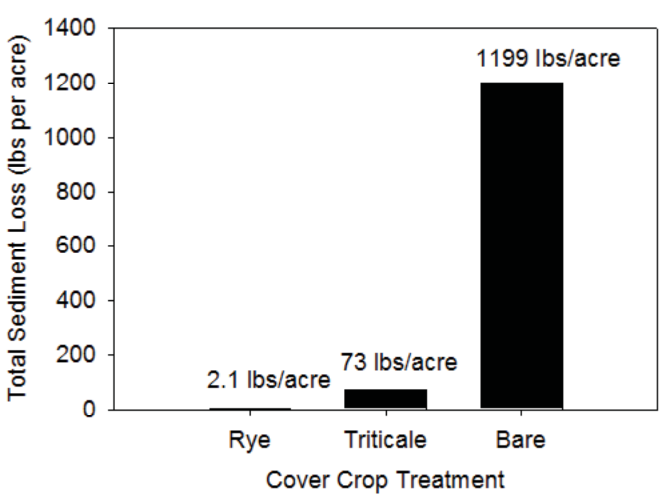

Figure 2. 2009-2010 Trial. Total sediment loss in run-off from cover crop and bare treatments between mid January and March 7, 2010.

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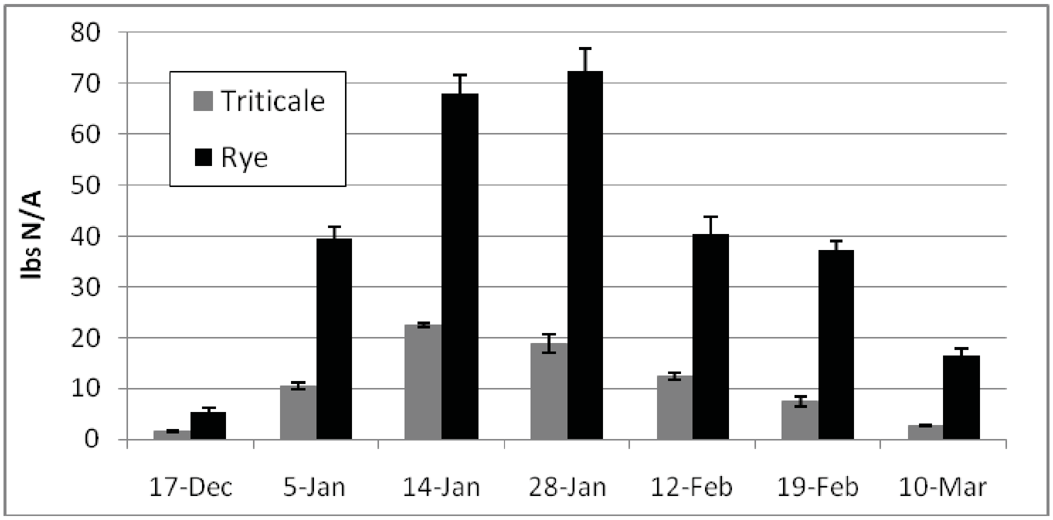

Figure 3. 2009-2010 Trial. Nitrogen in cover crop biomass

Table 2. Seasonal nutrient loss in run-off of cover crop treatments.

Treatment	Total N	Ammonium-N	Nitrate-N	Soluble-P	Total P	K
	------------- lbs/acre -------------					
Rye	0.21	0.05	0.04	0.17	0.20	0.80
Triticale	0.60	0.05	0.03	0.24	0.47	1.30
Control	4.78	0.12	0.49	1.06	3.71	4.12
	------------ % reduction in loss compared to control ------------					
Rye	96	59	92	84	95	81
Triticale	87	58	93	78	87	69

Table 3. Estimate of cations and anions leached during November 2009 to March 2010. Greater infiltration in the cover crop treatments leached more cations and anions through the soil.

Treatment	Nutrient leached (lbs/A)						
	Potassium	Calcium	Magnesium	Sodium	Chloride	Sulfate-S	Nitrate-N
Bare fallow	9	133	32	88	158	36	69
Low residue Triticale Trios 102	18	216	55	178	275	60	110
Low residue Rye AGS 104	16	226	63	191	289	69	111
Pr>F treat	0.260	0.179	0.074	0.008	0.062	0.120	0.252
LSD 0.05	NS	NS	27	50	115	NS	NS

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Photos 1&2. AGS 104 cereal rye broadcast planted. Photo on right is 3 weeks after being treated with glyphosate. Note dense residue covering the furrow bottoms.

Photos 3&4. Trios 102 winter dormant triticale planted on the furrow bottom. Photo on right is 3 weeks after being treated with glyphosate. Note dense residue covering the furrow bottoms.

USING TENSIOMETERS FOR SCHEDULING IRRIGATIONS OF COASTAL VEGETABLES

Michael Cahn, Irrigation and Water Resources Advisor
and Barry Farrara, Staff Research Associate.

Because cool season vegetables are sensitive to water stress, small depletions in soil moisture can slow crop growth. Tensiometers are useful for determining when a vegetable crop has depleted soil moisture to the point that irrigation is needed. Unlike other methods, tensiometers provide a direct measure of soil water tension, which is expressed in units of either kiloPascals (kPa) or centibars (cbar). Since 1 kPa equals 1cbar, these units are often used interchangeably. A high tension means that the crop needs more force or energy to pull water held in soil pores. As a reference, 1500 cbars is considered the permanent wilting point for plants and 0 cbars corresponds to saturated soil conditions. At moderate tensions (30 to 40 cbars), growth of leafy vegetables such as lettuce and spinach slows. Vegetable yields can be maximized by irrigating to maintain soil moisture tension less than these tension thresholds (Table 1).

An advantage of tensiometers compared to other methods of monitoring soil moisture is that a tension reading is less affected by site-specific factors such as soil texture or salinity. A reading of 40 cbars has the same physiological meaning to a plant whether it is in a sandy or clay textured soil. In contrast, the readings from volumetric soil moisture sensors corresponding to moisture stress are dependent on soil texture. A crop may need to be irrigated at volumetric moisture

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content of 25% in a field with sandy loam texture soil but need to be irrigated at 35% in a field with a clay loam texture soil. Since cool season vegetables are sensitive to water stress, they need to be irrigated after small depletions in volumetric soil moisture (usually a depletion of 3 to 5%). Many volumetric soil moisture sensors are only accurate to ± 2 or 3% without calibration, so a single reading may not be sufficiently accurate to determine if irrigating is necessary.

Tensiometers are fairly low tech in that they consist of a water filled shaft fitted with a porous ceramic cup at the lower end and a vacuum gauge and reservoir of water at the top end (Figure 1). Water added to the tensiometer should be degassed by first boiling the water and then allowing it to cool to room temperature. It is important that the tensiometer has no air leaks or it will not accurately reflect the true tension of the soil. When installed in the field, water passes freely through the ceramic cup into the soil creating a vacuum in the tensiometer that equals the soil water tension. It is also important to properly install the tensiometer in the field to achieve good contact between the ceramic cup and soil: using a soil probe, make a pilot hole of a diameter equal to the tensiometer and a few inches shallower that the depth of installation. Add a slurry of soil and water into the hole and push the tensiometer to the desired depth. The soil slurry assures the hydraulic integrity between the ceramic cup and soil. Formation of air gaps between the ceramic cup and the soil will lessen the accuracy of tensiometer readings. After a day of equilibration the tension reading should accurately reflect the tension of the soil.

Some users have expressed a lack of confidence in the tensiometer readings, unsure if low readings reflect moist conditions or are an artifact of a leaky seal. The main cause for faulty readings are vacuum leaks or because the soil became drier than 80 cbars. Tensiometers generally leak air through the ceramic cup or cap when the soil moisture tension reaches more than 70 or 80 cbars. This is because water begins to vaporizes at 80 cbars of negative pressure so the hydraulic continuity between the water column in the tensiometer and the soil breaks down. Tensiometers may not be appropriate for tree, vine, and agronomic crops that are grown under relatively drier conditions than cool season vegetables. For leafy greens, celery, and cole crops, however, soil moisture tensions are infrequently greater than 60 cbars. One can also have confidence that the tensiometer is free of air by testing it before installation. Wrapping an absorbent towel around the ceramic cup should cause the vacuum gauge to rise above 30 cbars within a few minutes. Further exposing the ceramic cup to dry conditions should increase the vacuum reading above 70 cbars. Remember to refill the reservoir with degassed water after testing is completed. Periodic maintenance should be made on tensiometers installed in the field. Check the level of water in the shaft and refill the tensiometer with degassed water at least once per month. Also check that rubber stoppers or gaskets form secure seals.

Another advantage of tensiometers compared to volumetric soil moisture sensors is that they are relatively inexpensive ($70 – $120 per tensiometer) and the vacuum gauge can be read in the field by an irrigator. Some tensiometers have an option for connecting them to dataloggers so that moisture data can be collected continuously (Figure 2). and in some cases viewable through an internet service. The datalogger option increases the cost of the tensiometer but is very useful for checking that the instrument is working properly. Some higher cost tensiometers products can also automatically refill with water.

For those wanting to measure soil water tension at 70 cbars or greater, several indirect methods are available including electrical resistance blocks (granular matrix and gypsum), or volumetric or thermocouple sensors embedded in a porous matrix material (delta-T EQ2, Campbell sci. 229-L, respectively). While these methods can be used in tree and vine crops where soil tensions are relatively higher than in vegetables, they are usually not as accurate as tensiometers at less than 40 cbars of tension. However, these sensors require less maintenance than tensiometers, and in some cases, such as granular matrix blocks, are cheaper.

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Tensiometers should be placed in the field at several locations (at least 3) and preferably include the top, middle and bottom regions of a field. The locations might also be chosen to reflect zones of different soil textures or growth patterns in the crop. Care should be taken to install the tensiometers in a consistent pattern on the beds at each location. A good rule of thumb is to install the tensiometers in the plant row, where roots are concentrated, and taking up the most water. Tensiometers installed at least at 2 depths are preferable for each location. The shallowest depth should be a third to a half of the depth of the effective root zone and the second depth should be just below or at the effective rooting depth (Table 1). Depths of 8 and 18 inches has worked well for lettuce. During the first 30 days of the crop, the 18 inch depth remains close to saturation. After 30 days, moisture decreases at the 18 inch depth between irrigations as roots grow deeper. For vegetables grown longer periods than lettuce or have deeper root systems, such as broccoli or cabbage, 12 and 24 inches may be more appropriate depths to monitor soil moisture.

Tensiometers provide guidance as to when to irrigate rather than how much to irrigate. This is because tension measurements measure potential water stress that the plant is experiencing but do not measure the volume of water removed from the soil. The volumetric water removed from the soil for a given tension will vary among soil types depending on the bulk density and porosity. Table 2 illustrates the relationship between tension and volumetric water content for 4 soil textures and Table 3 shows how much water is removed between almost saturated conditions (10 cbars) and tensions ranging from 20 and 60 cbars for these same 4 soil textures. Perhaps the best method to infer how much water your crop depleted since the last irrigation is to use reference evapotranspiration data as a cross-check.

In summary, tensiometers provide a good method of directly measuring soil water tension for crops that are well-watered such as leafy greens and cole crops. An additional advantage of tensiometers is that they do not need to be calibrated for different soil types and the same tension threshold can be used on a range of soil textures to decide when to irrigate. Tensiometer readings are also easy for irrigators to understand and use, requiring no electricity or electronic devices to function, though they do have the option to be interfaced with datalogging equipment. Finally, tensiometers may require more servicing than other devices for measuring soil moisture. They will work most reliably if installed correctly and if they are serviced regularly.

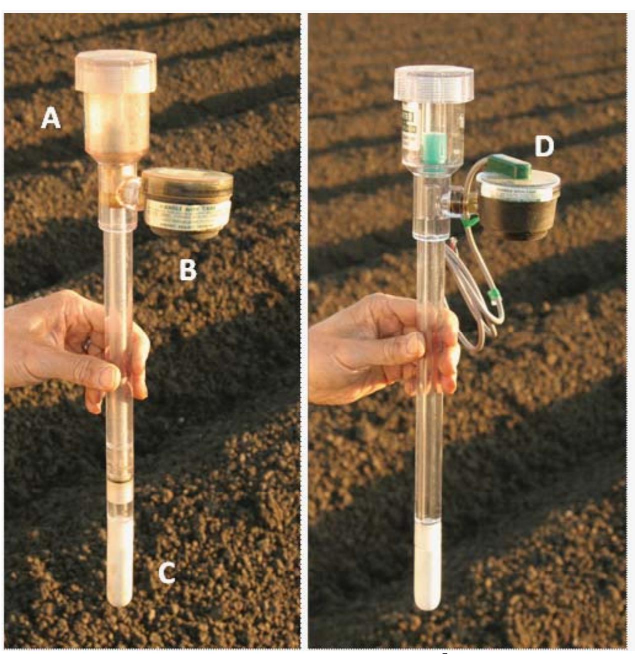

Figure. 1. Tensiometer components: A. Reservoir and cap, B. vacuum gauge, C. ceramic cup, and D. vacuum gauge with electronic output signal.

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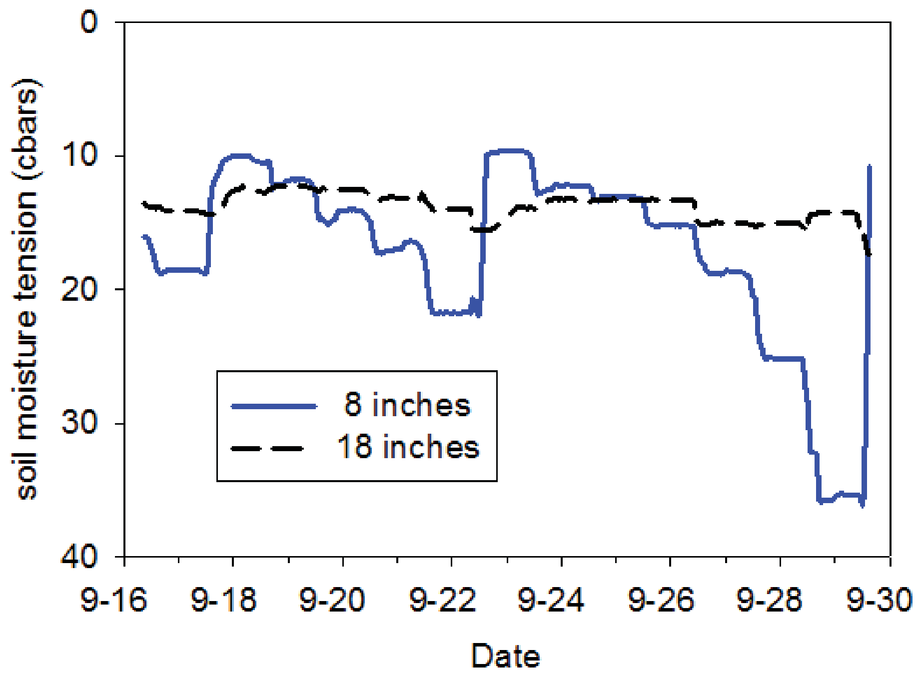

Figure 2. Soil moisture tension at 8 and 18 inch depths in iceberg lettuce during the last 2 weeks of the crop. Tension was measured with irrometer tensiometers interfaced to a datalogger using the irrometer electronic gauge.

Table 1. Effective rooting depth, and recommended maximum soil moisture tension and tensiometer depths for coastal vegetables.

Vegetable crop	effective rooting depth[1] at crop maturity	Irrigation criteria: average soil moisture tension in root zone		recommended tensiometer depths
		establishment	post-establishment	
	inches	------------ cbars ------------		inches
Artichokes				
annual	12 to 18	20 to 30	30 to 45	8 and 18
perennial	18 to 24	--	40 to 50	12 and 24
Asparagus	24 to 36	20 to 30	45 to 60	12 and 24
Carrots	12 to 18	15 to 25	25 to 35	8 and 18
Celery	12 to 18	15 to 25	20 to 30	8 and 18
Cole				
broccoli	18 to 24	20 to 30	30 to 45	12 and 24
cauliflower	18 to 24	20 to 30	30 to 45	12 and 24
cabbage (red and green)	18 to 24	20 to 30	30 to 45	12 and 24
brussels sprouts	18 to 24	20 to 30	30 to 45	12 and 24
Lettuce				
iceberg	12 to 18	15 to 25	25 to 35	8 and 18
romaine	12 to 18	15 to 25	25 to 35	8 and 18
leaf	8 to 12	15 to 25	20 to 30	8 and 18
spring mix	8	15 to 20	20 to 30	8
Bell pepper (drip)	12 to 18	15 to 25	25 to 35	8 and 18
Spinach				
bunch	12	15 to 20	20 to 30	8 and 18
baby and teen	8	15 to 20	20 to 30	6 to 8
Fresh market tomato (drip)	18 to 24	20 to 30	45 to 60	8 and 18

1. typical depths that contain 80% of roots in a deep, uniform, well drain soil profile

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Table 2. Volumetric water content of 4 soils at tensions ranging from 10 to 60 cbars.

texture	soil moisture tension (cbar) 10	20	30	40	50	60
	------------------ volumetric soil moisture (%) ----------------					
sandy loam	22.8	20.8	19.6	18.8	18.1	17.6
silt loam	30.2	28.4	27.4	26.6	26.0	25.6
clay loam	32.6	31.1	30.2	29.6	29.1	28.7
clay	42.0	40.8	40.1	39.6	39.2	38.8

Table 3. Volume of water depleted from 4 soils for tensions ranging from 20 to 60 cbars. Assume saturated conditions correspond to 10 cbars unless otherwise notes.

texture	soil moisture tension (cbar) 20	30	40	50	60
	--- inches of water removed per foot of depth[1] ---				
sandy loam	0.24	0.38	0.49	0.56	0.63
silt loam	0.22	0.34	0.43	0.50	0.56
clay loam	0.18	0.29	0.37	0.43	0.48
clay	0.29	0.38	0.44	0.49	0.53

1. assume 5 cbars corresponds to saturation for the clay soil and 10 cbars corresponds to saturation for the other soils.

University of California Cooperative Extension, Monterey County

2012 Irrigation and Nutrient Management Meeting and Cover Crop and Water Quality Field Day

Tuesday, February 21

7:45 a.m. to 3:00 p.m.
RAIN OR SHINE

Irrigation and Nutrient Management Meeting: Agricultural Center 1432 Abbott Street, Salinas, CA

7:45	**Registration and Refreshments**
8:00	***Uptake of nitrogen by spinach*** Aaron Heinrich, Staff Research Associate, Monterey County Cooperative Extension
8:30	***Fertilization trials on spinach and nitrogen fertilizer technology update*** Richard Smith, Vegetable Crop and Weed Science Farm Advisor, Monterey County
9:00	***Tools for improving irrigation efficiency*** Mike Cahn, Irrigation and water resources Farm Advisor, Monterey County
9:30	***Reduction of toxicity associated with pesticide run-off using an integrated vegetated treatment system and Landguard A900*** Bryn Phillips, Specialist, Dept of Environmental Toxicology, UC Davis
10:00	***Break***
10:30	***Nitrogen Management Strategies to Comply with the RWQCB Agricultural Order*** Tim Hartz, Vegetable Crops Specialist, UC Davis
11:00	***Breeding for improved nitrogen and water use efficiency*** Ryan Hayes, Lettuce Breeder, USDA
11:30	***Three-year summary of low residue cover crops for winter fallow beds*** Richard Smith, Vegetable Crop and Weed Science Farm Advisor, Monterey County
12:00	***Conclusion and travel to lunch and field demonstration site***

Field Trip: Spence Research Station, 1752 Old Stage Road, Salinas, CA

12:45	***Lunch – on Site*** Pizza lunch
1:30	***TBD***
2:30	***Conclusion***

- **Sponsors:** University of California Cooperative Extension; Resource Conservation District (RCD); Community Alliance with Family Farmers (CAFF)
- **Continuing Education, Certified Crop Advisor and Water Quality Credits have been requested**
- **For more information call Richard Smith 759-7357 or Michael Cahn 759-7377**

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