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Crop Notes

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ACCURACY OF TEST STRIPS FOR ASSESSING NITRATE CONCENTRATION IN SOIL AND WATER

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Nitrate test strips are an affordable tool for quickly measuring nitrate (NO_3) in soil and water, and can help farmers and crop advisers adjust fertilizer inputs to match the nitrogen (N) needs of crops. There are now a variety of brands of nitrate test strips available, many of which are manufactured for testing the quality of aquarium water. All of the strips are used in a similar fashion: the strip is briefly dipped into an extractant solution (for soil) or in water, and allowed to develop color during a standard interval of time, usually ranging between 30 and 60 seconds. After color develops on the strip, a color chart, calibrated to either parts per million (ppm) of NO_3 or expressed in equivalent ppm of nitrogen (NO_3-N), is used to determine the NO_3 concentration of the sample. Nitrate-N concentration can be converted to NO_3 concentration by multiplying NO_3-N concentration by a factor of 4.43. Because the strips may continue to develop color with time, it is important to always read the strips at a standard time interval, or the measurements will not be accurate or repeatable. More detailed information on using the nitrate test strips for monitoring soil nitrate levels was presented in several of our past bulletins, newsletters, and blogs.

Depending on the soil type and crop nutrient requirements, vegetable farmers need test strips that are accurate for soil NO_3-N levels ranging between from 5 to 30 ppm, which would roughly correspond to a range of 10 to 60 ppm of NO_3 in the extractant solution. For strawberry production, and other crops that have a slower N uptake rate than vegetables, growers need test strips that are accurate over a narrower range of soil NO_3 concentrations (5 to 15 ppm NO_3-N in soil). Past studies have demonstrated that the Merckoquant test strip are accurate for measuring soil NO_3-N in the range of 10 to 40 ppm. Because more brands of test strips have become commercially available in recent years with varying ranges of sensitivity, and the need to identify test strips that are accurate for measuring low concentrations of soil NO_3-N (0 to 15 ppm), we evaluated the accuracy and ease of use of six commercially available brands of test strips over a range of nitrate concentrations found in commercial agricultural fields.

Procedures:

A stock solution of a known NO_3 concentration was prepared by dissolving a measured weight of sodium nitrate ($NaNO_3$) into 1 liter of distilled water. This stock solution was further diluted with distilled water to standard nitrate concentrations that matched the values of the color chips of the various test strips evaluated in this study. The NO_3 concentration of each standard solution was confirmed by spectrophotometric analysis.

Each brand of strip was evaluated at NO_3 concentrations corresponding to the color chips provided by the manufacturer. The Hach Aquacheck and Lamotte Instatest NO_3/NO_2 strips differed from the other brands because the color chips were calibrated in equivalents of NO_3-N rather than NO_3. For convenience of displaying and comparing the data, results for these two brands were converted to NO_3 (by multiplying the NO_3-N values by 4.43). The Merckoquant NO_3/NO_2 test strip was the brand originally tested by UC Cooperative Extension for use with the soil nitrate quick test, and was considered the standard in this evaluation. This strip measures to a maximum of 500 ppm NO_3, but was only evaluated up to 250 ppm NO_3 (56 ppm NO_3-N) for this test.

Each brand of test strip was evaluated 4 times for each standard NO_3 solution corresponding to the

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manufacturer's chip color chart. The procedure that we followed to determine NO_3 concentration was to dip the strip briefly in solution, and hold it horizontally after removing it, allowing color to develop for the interval specified by the manufacturer. Most strip manufacturers recommended a 1-minute time interval between wetting and reading the strip color. The manufacturer for API 5-in-1 and LaMotte Instatest 5-Way recommended reading test strips after 30 seconds, but results appeared to be more accurate after a 60 second interval, therefore all results reported for these strips are from readings taken 60 seconds after placing the strip in the test solution. After waiting the specified interval, the color of the test strip was compared to the color chips provided by the manufacturer. If the test strip color matched one of the chips, then the value of the chip was recorded. In many cases, the color of the test strip was between 2 of the standard chips, and in these cases an estimate was made based on comparing the intensity of the color development with the 2 closest matching chips. Because this method relies on visual observations, all tests were made in a room with ample lighting and by one observer.

Results:

The mean NO_3 values measured using different brands of test strips were compared to the standard solution values in Table 1. Some brands of test strips appeared to be accurate at specific ranges of NO_3 concentration. The Merckoquant NO_3/NO_2 brand was the most accurate for the full range of NO_3 concentrations (Table 1). The next most accurate brand over the entire range of NO_3 concentrations evaluated was the LaMotte Instatest NO_3/NO_2. The Hach Aquacheck was accurate for the range of 10 to 90 ppm NO_3 but measured NO_3 lower than the standard solutions at concentrations above 100 ppm NO_3. The remaining brands of test strips, LaMotte Instatest 5-way, API 5 in 1, Tetra 6 and 1 Easystrips, all measured less NO_3 than the standard solutions over the range of 20 to 200 ppm NO_3. These strip brands should probably not be used for the soil nitrate quick test and for assessing nitrate concentration in irrigation water.

Although the LaMotte Instatest NO_3/NO_2 also had good accuracy across the range of 20 ppm to 220 ppm NO_3, it did not have a standard color chip for evaluating NO_3 at low concentrations, and therefore may not be suitable for strawberries and other crops where soil nitrate is typically in the 5 to 15 ppm NO_3-N range. Both the Merckoquant and Hach brands were accurate for measuring NO_3 at low concentrations (10 to 40 ppm). Although the Hach Aquacheck strip had a color standard of 5 ppm NO_3, the strip was not able to measure NO_3 at a concentration below 10 ppm (Table 1).

With the exception of the Merckoquant NO_3/NO_2, all test strips were purchased online through Amazon.com. The price reported for the strips in Table 1 was the purchase price advertised at the time our study was conducted (January 2014). Some strips were available in larger quantities or from other vendors, for different prices. The Merckoquant NO_3/NO_2 can be purchased from Cole-Parmer (http://www.coleparmer.com) or at EMD Millipore (http://www.emdmillipore.com).

Summary

We identified 3 brands of test strips that accurately measured NO_3 and can be used to quickly assess the concentration of NO_3 in soil or water. Both the Merckoquant NO_3/NO_2 and the Hach Aquacheck strips were accurate for measuring concentrations of NO_3 as low as 10 ppm, which would roughly correspond to 5 ppm NO_3-N in soil. No brand of test strip measured NO_3 accurately below 10 ppm. Several brands of strips that measure NO_3 in addition to other constituents in water were found to under estimate NO_3 concentration, especially at high values. While laboratory analysis of NO_3 is generally more accurate than using colorimetric test strips, the strips tested in this study appear to be sufficiently accurate to estimate the level of residual mineral N in soil samples and for determining the NO_3 contribution from irrigation water, and should be useful for quickly assessing soil N status before making a fertilizer decision.

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Table 1.

Nitrate Test Strip Evaluation Results

Strip Name	Measures NO_3-N or NO_3	Strips per pkg ($ per strip)	Manufacturer's Color Chip Intervals (NO_3 mg/L)	NO_3 Concentration of Test Solution (mg/L)													
				0	5	10	20	40	50	80	90	100	110	160	200	220	250
				----------------Mean Test Strip Readings (mg NO3/L)----------------													
Hach Aquacheck	NO_3-N	25 ($0.35)	0, 4.4, 8.9, 22.2, 44.3, 88.6, 221.5**	0	0	11	20	44	x	x	89	x	x	x	x	170	x
LaMotte Instatest NO_3/NO_2	NO_3-N	50 ($0.25)	0, 22.15, 44.3, 110.8, 221.5***	0	x	x	21	44	x	x	x	x	111	x	x	207	x
API 5 in 1 *	NO_3	25 ($0.40)	0, 20, 40, 80, 160, 200	0	x	x	15	33	x	60	x	x	x	87	135	x	x
Tetra 6 in 1 EasyStrips	NO_3	100 ($0.25)	0, 20, 40, 80, 160, 200	0	x	x	13	23	x	47	x	x	x	123	135	x	x
LaMotte Instatest 5-way *	NO_3	25 ($0.55)	0, 20, 40, 80, 160, 200	0	x	x	15	33	x	63	x	x	x	133	160	x	x
Merckoquant NO_3/NO_2	NO_3	100 ($0.47)	0, 10, 25, 50, 100, 250, 500	0	x	10	25	x	56	x	x	95	x	x	x	x	250

x = not measured

* The manufacturer instructs users to read test results after 30 seconds, but results were more accurate when read after 60 seconds. Results reported here are for readings taken after 60 seconds.

**Test actually measures NO3-N at values: 0, 1, 2, 5, 10, 20, 50

***Test actually measures NO3-N at values: 0, 5, 10, 25, 50

WEED CONTROL IN CILANTRO AND PARSLEY

Richard Smith, Farm Advisor UCCE Monterey County

Excellent weed control is essential for economically producing cilantro and parsley. Both crops have had various weed control challenges over the last few years. Cilantro and parsley are in the celery family and both are small acreage crops (cilantro 980 acres and parsley 533 acres in Monterey County in 2012) that are important to the local economy. In our modern production systems, both crops are planted in dense plantings (24-33 seedlines) on 80-inch wide beds. Parsley has been mechanically harvested for dehydrated products for many years, and cilantro is now increasingly mechanically harvested for fresh product; the combination of high-density plantings and mechanical harvest precludes growing these crops on weedy fields and necessitates excellent and economical weed control.

In the last two years, two significant herbicide registrations have brought excellent weed control options to these crops: prometryn (Caparol, Syngenta and other companies) and linuron (Lorox, TKI NovaSource). Both of these registrations were new for cilantro, but Caparol was already registered on parsley and Lorox was a new registration for parsley. Both registrations came with restrictions: Prometryn has a 12-month plant back to lettuce and spinach which is a difficult obstacle for Salinas Valley producers. The registration for linuron currently only has a Federal label, but the California registration is in process and hopefully will be completed before the end of the year.

Prefar is also registered for use on cilantro and parsley but due to a regulatory snafu (EPA moved cilantro out of the "leafy vegetables" crop group and placed it in the "herbs and spices" crop group), which resulted in the loss of the Prefar tolerance, by cilantro. It is unclear how long it will take to resolve this issue, but again it is in the process for reestablishment of the tolerance, but that may take time.

We conducted weed evaluations of these herbicides in 2012 and 2013. In the 2012 trial on cilantro preemergent applications of both Caparol and Lorox were safer than postemergent applications (Tables 1&2) as indicated by the phytotoxicity ratings. Lorox was less phytotoxic than Caparol as a postemergent

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application. Postemergent applications of both Caparol and Lorox were more effective in reducing weeds and weeding time, but reduced the yield of cilantro and parley relative to preemergent applications. Prefar did not control nightshade in either trial and had greater weeding times as a result.

Other weed control options: bed fumigation of cilantro and parsley prior to planting can be highly effective, but issues with the cost and working around buffer zones makes this option difficult to fit into a grower's production budget as well as schedule. Cultural practices such as pregermination followed by shallow cultivation of emerged weeds prior to planting can help reduce weed pressure. Cilantro and parsley seed germinates slowly which opens the possibility of burning off a flush of weeds (with an herbicide or propane flamer) following planting but prior to the emergence of the cilantro. This is a tricky, but highly effective technique for reducing weed density.

Table 1. 2102 Cilantrol Trial: Weed counts (3 ft2), phytotoxicity rating and time of weeding evaluations of all treatments on September 4 and yield on September 11

Material	Lbs a.i./A	Application	Phyto-toxicity	Pig weed	Purslane	Night-shade	Lambs-quarters	Total Weeds	Weed time Hrs/A	Yield Lbs/A
Caparol 4L	1.5	Preemergence	0.0	0.0	0.0	0.0	0.0	0.0	9.4	9,022.4
Caparol 4L	1.0	Postemergence	3.3	0.0	0.3	0.0	0.0	0.3	6.4	2,651.0
Lorox	0.75	Preemergence	0.0	1.0	0.3	5.3	0.0	6.7	26.6	10,604.2
Lorox	1.5	Preemergence	0.0	0.0	0.0	0.7	0.3	1.0	10.9	9,846.7
Lorox	0.5	Postemergence	1.3	0.0	0.0	0.0	0.0	0.0	8.8	5,101.6
Prefar	4.0	Preemergence	0.0	0.7	0.0	14.0	0.0	14.7	98.1	8,131.3
Untreated	---	---	0.0	9.0	3.3	30.3	1.3	44.0	238.3	6,883.8
Pr>trt			<0.0001	0.0013	<0.0001	<0.0001	0.0019	<0.0001	<0.0001	<0.0001
LSD (0.05)			0.5	3.6	1.0	8.3	0.6	10.1	44.0	2118.7

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

Table 2. 2013 Parsley Trial: Phytotoxicity, weed counts (50 ft2) and yield on March 25.

Material	Lbs a.i./A	Material/A	Application	Phyto[1]	Malva	Night-shade	Lambs-Quarter	Sow Thistle	Purs-Lane	Total Weeds	Weed time hr/A	Yield Grams/ 0.5 m^2
Caparol 4L	1.5	3 pints	Preemergence	0.00	0.00	12.33	0.33	0.00	0.00	12.67	24.1	1,302.9
Caparol 4L	1.0	2 pints	Postemergence	4.33	0.33	0.67	0.00	0.00	0.00	1.00	5.6	1,024.4
Lorox	0.75	1.5 lbs	Preemergence	0.00	0.00	37.00	0.00	0.00	0.00	37.00	47.8	1,429.4
Lorox	1.5	3.0 lbs	Preemergence	0.00	0.00	9.00	0.00	0.00	0.00	9.00	19.4	1,267.9
Lorox	0.5	1.0 lbs	Postemergence	1.33	0.00	2.33	0.00	0.33	0.00	2.67	8.7	1,094.5
Prefar	4.0	4 qt	Preemergence	0.00	0.33	41.00	0.67	0.00	0.00	42.00	46.6	1,175.4
Vegetable Pro 4L Prefar[3]	1.5 3.0	3 pints 3 qt	Preemergence	0.00	0.67	36.00	2.00	0.00	0.33	39.00	29.5	1,211.3
Untreated	---	---	---	0.00	1.00	45.67	3.67	0.00	1.33	51.67	63.5	1,362.1
Pr>treatment				<0.0001	0.2418	0.2932	<0.0001	0.4706	0.0891	0.2143	0.0382	0.2772
LSD (0.05)				0.52	ns	ns	0.98	ns	0.94	ns	35.7	351.4

1 – scale: 0 = no crop damage to 10 crop dead; 2 – new low VOC formulation of bensulide (Prefar); 3 – standard treatment

SUMMARY OF FENNEL DISEASES

Steven Koike
Plant Pathology Farm Advisor

Fennel (*Foeniculum vulgare dulce*) is one of the many important minor vegetable crops produced in coastal California. This plant is in the parsley family (Apiaceae) and is used as both a vegetable and specialty herb commodity. The foliage consists of narrow, needle-like leaves that give it a fern-like appearance. The main part of the plant is the central, fleshy stem that right above the ground is enlarged and shaped like a bulb. In the Salinas Valley, fennel is grown only as a fresh market commodity, though in other regions it is also produced for its seed. Fennel is distinct from the closely related anise (*Pimpinella*

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anisum). In recent years, some new diseases have been characterized on fennel crops. This article summarizes fennel diseases that could be encountered by growers and pest control advisors.

Cercosporidium blight or leaf spot: This foliar disease is primarily found on the older fennel leaves and does not infect the newest foliage (Photo 1). Affected leaf tips and stems turn brown to black in color, wither, and dry up. Close examination of the stems and leaves will reveal the presence of tiny, discrete, dark brown to black fungal patches. These patches are individually quite small (less than 1/16 inch in diameter) and can be oval, circular, or irregular in shape. If disease is severe, these patches multiply and grow together, resulting in an overall darkened appearance and death of the foliage. If there is sufficient humidity and moisture, a white crusty growth will form on top of the patches (Photo 2); this white crust is made up of clusters of the spores of the pathogen. Cercosporidium blight does not kill fennel plants, but can affect growth and result in poor quality. Cercosporidium blight is probably the most commonly found fennel disease in the coastal region.

The pathogen is the fungus *Cercosporidium punctum*. There is evidence that the fungus can be seedborne in fennel. Once established in the field, spores are spread by splashing water and winds. Free moisture, humidity, and the protective over growth of dense foliage favor fungus survival and development. It is unlikely that C. *punctum* survives in the soil once diseased foliage is disked and buried, though this aspect has not been investigated in California. This pathogen does not appear to infect any other plant or weed grown in California. Disease severity may be lessened if overhead sprinkler irrigation is not used. Effective fungicides have not been registered for this disease.

Bacterial streak: A second foliar disease of fennel is caused by the bacterium *Pseudomonas syringae* pv. *apii* (Psa). Initial symptoms are small, dark brown to black lesions on leaves and stems. As disease progresses, lesions expand in a linear fashion and could eventually spread down the stem and into the bulbs. Once the disease reaches the fennel bulbs the plants are not marketable (Photo 3). The pathogen could possibly be seedborne but is definitely spread between plants by splashing water. This Psa bacterium is the same pathogen that causes leaf spot diseases on celery and parsley; therefore back-to-back plantings of these Apiaceae crops could result in the spread of these bacterial problems between crops.

Sclerotinia white mold: Crown and lower petiole tissues in contact with soil can develop a brown rot caused by two species of the *Sclerotinia* fungus. This brown, necrotic tissue rapidly turns into a soft rot and can result in poor plant growth, yellowing of foliage, and plant death; white mycelium is usually present on diseased tissues (Photo 4). If white mycelium and small (less than 1/4 inch wide) black sclerotia are present on infected tissues, the pathogen is *Sclerotinia minor*, which is the same fungus that causes lettuce drop. The other *Sclerotinia* species, *S. sclerotiorum*, is characterized by white mycelium and large (greater than 1/4 inch wide) black sclerotia and can cause both the crown rot as well as a brown, soft rot of the upper foliage of fennel. In California fennel does not appear to be a preferred host for *Sclerotinia*, so disease incidence is usually quite low and fungicides are not needed.

Fusarium stem and crown rot: With this soilborne disease of fennel, the basal portion of stems in contact with soil develops a brown to gray rot. At the point where diseased stems are attached to the fennel plant, the crown can also become rotted. Leaves on affected stems become yellow. White mycelium and orange deposits of spores (called sporodochia) are observed on affected tissues near the soil line (Photo 5). Diseased stems eventually wilt, die, and result in reduced quality of the fennel. The cause of this disease is the fungus *Fusarium avenaceum*. This disease is not common and so far appears to develop on older fennel plants that have large, established bulbs.

Pythium root rot: Affected plants are stunted and grow poorly (Photo 6). Older leaves turn yellow and later dry up and wither. The fine feeder roots have either discrete, separate brown lesions, or are entirely rotted. This disease has been observed on recently transplanted fennel. Plants in the field occasionally die; however, most plants remain viable but are stunted and delayed in development. The pathogen is a species of *Pythium* (likely *Pythium ultimum*), though research on the exact cause is still on-going.

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Photo 1. Newly developed fennel foliage (right) is not susceptible to Cercosporidium blight (on left).

Photo 2. Cercosporidium blight causes brown to black fungal patches to form on leaves and stems; if conditions favor fungal development, white spores form on the patches.

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Photo 3. Bacterial streak affects both leaves and stems of fennel.

Photo 4. For Sclerotinia white mold, white mycelium is usually present on the brown, decayed fennel tissues.

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Photo 5. White mycelium and orange deposits develop on fennel stems infected with *Fusarium avenaceum*.

Photo 6. Pythium root rot can cause significant root loss on recently transplanted fennel (plants on the right).