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 (NO₃) 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 NO₃ or expressed in equivalent ppm of nitrogen (NO₃-N), is used to determine the NO₃ concentration of the sample. Nitrate-N concentration can be converted to NO₃ concentration by multiplying NO₃-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 NO₃-N levels ranging between from 5 to 30 ppm, which would roughly correspond to a range of 10 to 60 ppm of NO₃ 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 NO₃ concentrations (5 to 15 ppm NO₃-N in soil). Past studies have demonstrated that the Merckoquant test strip are accurate for measuring soil NO₃-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 NO₃-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 NO₃ concentration was prepared by dissolving a measured weight of sodium nitrate (NaNO₃) 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 NO₃ concentration of each standard solution was confirmed by spectrophotometric analysis.

Each brand of strip was evaluated at NO₃ concentrations corresponding to the color chips provided by the manufacturer. The Hach Aquacheck and Lamotte Instatest NO₃/NO₂ strips differed from the other brands because the color chips were calibrated in equivalents of NO₃-N rather than NO₃. For convenience of displaying and comparing the data, results for these two brands were converted to NO₃ (by multiplying the NO₃-N values by 4.43). The Merckoquant NO₃/NO₂ 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 NO₃, but was only evaluated up to 250 ppm NO₃ (56 ppm NO₃-N) for this test.

Each brand of test strip was evaluated 4 times for each standard NO₃ solution corresponding to the
manufacturer's chip color chart. The procedure that we followed to determine NO₃ 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 NO₃ 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
NO₃ concentration. The Merckoquant NO₃/NO₂ brand was the most accurate for the full range of NO₃
concentrations (Table 1). The next most accurate brand over the entire range of NO₃ concentrations
evaluated was the LaMotte Instatest NO₃/NO₂. The Hach Aquacheck was accurate for the range of 10 to 90
ppm NO₃ but measured NO₃ lower than the standard solutions at concentrations above 100 ppm NO₃. The
remaining brands of test strips, LaMotte Instatest 5-way, API 5 in 1, Tetra 6 and 1 Easystrips, all measured
less NO₃ than the standard solutions over the range of 20 to 200 ppm NO₃. 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 NO₃/NO₂ also had good accuracy across the range of 20 ppm to 220 ppm
NO₃, it did not have a standard color chip for evaluating NO₃ 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 NO₃-N range.
Both the Merckoquant and Hach brands were accurate for measuring NO₃ at low concentrations (10 to 40
ppm). Although the Hach Aquacheck strip had a color standard of 5 ppm NO₃, the strip was not able to
measure NO₃ at a concentration below 10 ppm (Table 1).

With the exception of the Merckoquant NO₃/NO₂, 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 NO₃/NO₂ 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 NO₃ and can be used to quickly assess the
concentration of NO₃ in soil or water. Both the Merckoquant NO₃/NO₂ and the Hach Aquacheck strips
were accurate for measuring concentrations of NO₃ as low as 10 ppm, which would roughly correspond
to 5 ppm NO₃-N in soil. No brand of test strip measured NO₃ accurately below 10 ppm. Several brands
of strips that measure NO₃ in addition to other constituents in water were found to under estimate NO₃
concentration, especially at high values. While laboratory analysis of NO₃ 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 NO₃ contribution from irrigation water,
and should be useful for quickly assessing soil N status before making a fertilizer decision.
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

<table>
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<tr>
<th>Strip Name</th>
<th>NO$_3$-N (mg/L)</th>
<th>NO$_3$/NO$_2$ (mg/L)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>50</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>500</th>
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<td>20</td>
<td>30</td>
<td>50</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>500</td>
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<td>LaMotte InstaTest</td>
<td>NO$_3$-N 25</td>
<td>NO$_3$/NO$_2$ 50</td>
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<td>10</td>
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<td>30</td>
<td>50</td>
<td>100</td>
<td>200</td>
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<td>500</td>
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<tr>
<td>API 5 in 1 *</td>
<td>NO$_3$-N 25</td>
<td>NO$_3$/NO$_2$ 50</td>
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<td>30</td>
<td>50</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>500</td>
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<td>NO$_3$/NO$_2$ 50</td>
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<td>20</td>
<td>30</td>
<td>50</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>500</td>
</tr>
<tr>
<td>LaMotte InstaTest</td>
<td>NO$_3$-N 25</td>
<td>NO$_3$/NO$_2$ 50</td>
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<td>10</td>
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<td>50</td>
<td>100</td>
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<td>Merckoquant</td>
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<td>NO$_3$/NO$_2$ 50</td>
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<td>25</td>
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<td>100</td>
<td>200</td>
<td>300</td>
<td>500</td>
<td>1000</td>
</tr>
</tbody>
</table>

* The manufacturer instructs users to read test results after 45 seconds, but results were more accurate when read after 60 seconds.
** Test actually measures NO$_3$-N at values: 0.1, 2.5, 10, 20, 50
*** Test actually measures NO$_3$-N at values: 0.5, 10, 25, 50
application. Postemergent applications of both Caparol and Lorox were more effective in reducing weeds and weeding time, but reduced the yield of cilantro and parsley 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 flame) 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

<table>
<thead>
<tr>
<th>Material</th>
<th>Lbs a.i./A</th>
<th>Application</th>
<th>Phytotoxicity</th>
<th>Pigweed</th>
<th>Purslane</th>
<th>Nightshade</th>
<th>Lambsquarters</th>
<th>Total Weeds</th>
<th>Weed time Hrs/A</th>
<th>Yield Lbs/A</th>
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<tr>
<td>Caparol 4L</td>
<td>1.5</td>
<td>Preemergence</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<td>Postemergence</td>
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<td>0.3</td>
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<td>Lorox</td>
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<td>Preemergence</td>
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<td>1.0</td>
<td>0.3</td>
<td>5.3</td>
<td>0.0</td>
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<td>26.6</td>
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<td>Lorox</td>
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<td>Preemergence</td>
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<td>0.0</td>
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<td>Preemergence</td>
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<td>0.0</td>
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<td>0.0</td>
<td>1.7</td>
<td>98.1</td>
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<td>Untreated</td>
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<td>---</td>
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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.

<table>
<thead>
<tr>
<th>Material</th>
<th>Lbs a.i./A</th>
<th>Material/A</th>
<th>Application</th>
<th>Phytotoxicity</th>
<th>Malva Nightshade</th>
<th>Lambs Quarter</th>
<th>Sow Thistle</th>
<th>Purslane</th>
<th>Total Weeds</th>
<th>Weed time hr/A</th>
<th>Yield Grade/m²</th>
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<tr>
<td>Caparol 4L</td>
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<td>3 pints</td>
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<td>0.00</td>
<td>12.33</td>
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<td>Caparol 4L</td>
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<td>0.00</td>
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<td>0.00</td>
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<td>37.00</td>
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<tr>
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<td>Prefar</td>
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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)
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 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.
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.
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.
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).