DIAGNOSING PROBLEMS IN THE FIELD

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ABSTRACT

Determining unknown causes of poor crop growth in a field is one of the most daunting tasks faced by alfalfa growers and crop advisors, yet correctly diagnosing the reasons for reduced yield is necessary to maximize profitability. The actual causes of problems are often not immediately visible. In addition, several factors can interact to reduce crop growth, making diagnosis more problematic. Examination of field indicators and plant symptoms may provide clues as to the reason for poor growth or plant injury. Common causes may be soil fertility or pH problems, diseases, insects, nematodes, weather, irrigation effects, soil limitations, or general mismanagement. Here, we suggest a systematic approach to diagnosing plant problems that will simplify the process and help producers or field personnel determine the nature of the problem and identify corrective action. This will include 1) Describing the problem, 2) Observing patterns, 3) Distinguishing abiotic and biotic stress, 4) Reviewing crop and field history, 5) Considering changes over time, 6) Checking published references and confirming your analysis with tests, 7) Synthesizing and eliminating alternative concepts. In some cases, little can be done immediately about a symptom, but correctly eliminating alternative hypotheses and correctly diagnosing field problems is the first step to addressing them.

Key Words: Alfalfa, *Medicago sativa*, plant damage, injury symptoms, pathogens, insects, herbicide injury, nutrient deficiency symptoms

INTRODUCTION

There are a multitude of problems in a field that can reduce yield and profitability. Determining precisely what these are in an individual field is a necessary first step to address the issue. It is important to correctly determine the cause of the problem so that corrective action can be taken to restore the health of the crop. Even if there isn't a way to "fix" the problem, it is still helpful to determine the cause, if nothing more than for personal satisfaction or better yet to prevent the problem from occurring again.

THE PROCESS

Determining the reason behind damaged plants in a field, or the cause for poor alfalfa growth, can be baffling at times. Oftentimes the cause is not readily apparent, and the causal agent may

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not even be visible. Complicating matters further is the fact that sometimes plant damage symptoms don't appear until a long time after the event or situation that actually caused the damage in the first place. In addition, some symptoms can be caused by a number of different factors. In this paper we outline a method for diagnosing problems in the field taking a systematic approach.

Understanding Complexity. Diagnosing the cause for plant damage observed in a field can be a complicated process—it is akin to detective work. It involves gathering clues from the whole-field scale or even multiple fields down to individual plants or even specific plant parts. It is often like putting together a complex puzzle. The key is to try to get as many pieces of the puzzle as possible and arrange them in a logical fashion that recreates the actual events. A systematic approach involving a thoughtful process of deduction and elimination is required. The investigator must remain open minded and not come to any conclusions until the entire situation is thoroughly investigated. Careful and meticulous observation of plant symptoms and the surroundings is also a requisite of proper diagnosis.

A systematic process for diagnosing plant damage was developed by James Green, a Horticulture Specialist at Oregon State University (Green, 2003). While this process was developed for horticultural crops, the procedure used can be applied to all cropping systems. It outlines a logical step-by-step progression. This does not mean that the deductive procedure laid out in this article must be followed verbatim, but the steps outlined here present a logical order and all these steps should be at least be considered before a diagnosis is made.

Identify and Describe the Problem – a keen eye and a shovel. The first step toward developing a proper diagnosis is to clearly describe and define the problem. This can be useful to be sure that a "*real"* problem exists. Sometimes the symptoms may actually be typical for that time of year and completely normal. A prime example is frost injury in the early spring or in the fall. Another example is the presence of small bumps on the roots. To the untrained eye these may appear like the galls caused by root-knot nematodes. Actually these nodules are completely normal for alfalfa and are beneficial because nodules are where the *Rhizobium* bacteria which are responsible for fixing the nitrogen essential for alfalfa plant growth reside (Figure 1).

To define a plant problem one must examine the entire plant and not just the foliage. A good field detective always has a shovel—and uses it! Foliar symptoms are often caused by root damage and unless one examines the roots they may miss the "root" of the problem. When the entire foliage expresses the same damage, the cause may often be due to a root problem. It is important to fully describe the problem. Are the plants stunted and to what degree? What are the symptoms on the foliage? Are the leaves necrotic (burned back) or is the foliage chlorotic? Is there a specific pattern to the foliage symptoms? Do they occur on the entire plant or are they restricted to the new or old growth. This is particularly important when diagnosing nutrient deficiencies. Some nutrients such as nitrogen, phosphorus and potassium are mobile in the plant, so that when a deficiency occurs, the plant can remobilize/steal the nutrient from older leaves to be used for new growth. In this case, the older leaves will show symptoms while the newer leaves will not. Conversely, for weakly mobile nutrients such as boron, and iron, the new growth

will be symptomatic. When moderately mobile nutrients such as sulfur are limiting, deficiency symptoms are usually seen over the entire plant.

When looking at a problem field, the tendency is to focus in and concentrate on just the affected poor-growth areas. However, it is important to observe both poor and good growth areas and directly compare affected plants with healthy or normal looking plants. By comparing healthy and unhealthy plants it is much easier to pinpoint the "abnormality" in the poor growth area. In addition, when examining the poor growth areas don't just concentrate on the center of the affected area—carefully examine alfalfa plants in the fringe areas that are just starting to show symptoms. These areas typically hold the best clues. It is common for the most affected areas to have severe necrosis (dead tissues) and many of the plants may have already succumbed to the stress and died. Completely dead plants are often almost useless to determine the cause of the problem. It is far more useful for diagnostic purposes to examine plants that are less affected and are "in the process of dying".

When describing a problem, it can be helpful to distinguish between *signs* and *symptoms*. *Signs* are the evidence left by whatever caused the damage—typically a pest. This includes such things as insect frass or excrement, a life stage of the disease or insect pest, a chemical residue, etc. In contrast, *symptoms* are a description of the appearance of the plant and how it is affected by whatever is responsible for the damage.

Plant sampling for nutrient analysis is an extremely valuable tool for diagnosing potential causes for poor growth. Oftentimes to save money or simply for ease of sampling, samples are only taken from the poor growth area. The problem with this approach is that nutrient concentrations in a plant change over time. The concentration of many nutrients decreases with advancing plant maturity. There are not accurate guidelines to indicate what plant tissue levels should be at different growth stages and especially for small stunted plant at an early growth stage. It is best to have a sample from an area growing well to compare to the problem area to compare and contrast differences at that growth stage.

Observe Damage Patterns. A crucial step to identify the cause of plant damage is to look for patterns. The shape of the affected area(s) can provide useful clues as to the cause. To detect a pattern step back and look at the big picture. Gaze further off in the distance to discern the pattern or find an elevated vantage point to look down on the field. There is no substitute for an aerial view of a field. From ground level patterns can sometimes be difficult to perceive. Unfortunately, it may not be possible to get an aerial view of the field at the time when the damage is present. However, every grower should use Google Earth to get an aerial perspective of your fields. It is an effective way to observe the variability in a field and can help the grower or consultant differentiate between normal differences in plant growth due to soil differences and whatever other problem may arise due to biological or management factors.

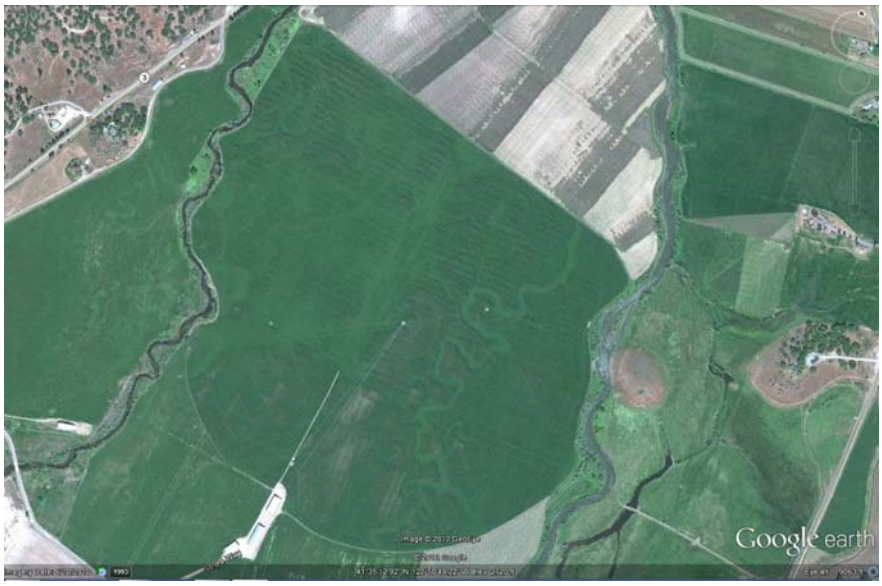

Figure 2. An aerial view of the field can be extremely useful to observe patterns in a field. A Google Earth image of a field helps pinpoint variation due to soil type. Note the variability in this alfalfa field and evidence of an old river channel.

Distinguish Between Biotic and Abiotic Causes. The causes for poor alfalfa growth or crop injury fall into two broad categories—biotic (living) or abiotic (non-living). When looking at damaged or poor growth areas, determine the overall shape of the affected area and look for the existence of a repeating pattern.

Is the damage somewhat circular or irregular in shape or does it follow straight lines or a uniform pattern? Growth irregularities caused by living factors (such as diseases, insects, rodents or nematodes) are generally circular or irregular in shape. Damage caused by living factors is typically non-uniform, and especially in the case of diseases, only scattered plants may be affected rather than uniform damage across all plants. Infestation levels for plant pests are typically not uniform and the effect on alfalfa plants can vary significantly depending on the resistance level in individual plants. This is particularly true for a crop like alfalfa where there is considerable genetic variability even within a single variety.

Straight lines are characteristic of something caused by nonliving factors such as cultural practices (i.e., herbicide application, fertilizer application, a planting issue, harvest pattern, etc.). Furthermore, if the damage occurs more or less uniformly over a large area, this is indicative of a non-living factor.

Look for the presence of other plant species such as weeds or a companion crop and determine whether only the alfalfa is affected or if other plant species are affected as well. The host range for most diseases and insects is very species specific. Therefore, if other vegetation as well as the alfalfa is equally affected, then the cause is more likely due to abiotic factors. If all plant growth is affected then the cause is more likely non-living such as soil factors, salinity, irrigation, spray application or some other management-related issue.

A repeating pattern through the field is also a clear indicator that the problem is abiotic. If in fact a repeating pattern can be detected, it is crucial to measure the distance associated with the pattern. This can provide useful clues as to the cause of the problem. Determine whether the distance matches the width of any field equipment (i.e, spray rig, fertilizer applicator, swather,

planter, ripper or other tillage implement). If the pattern matches any field implement this is usually a dead giveaway of the cause.

Pay attention to the damage pattern on individual plants as well as the field damage pattern. For some non-living causes, plant damage is likely to occur on leaves of all the same age. This is typical for an herbicide toxicity-related problem where all the leaves that formed the plant canopy at the time the application was made are damaged. By the time the field is inspected the new growth may appear normal.

Review Field Records. Knowing the field history can be critically important, underscoring the importance of complete field records for proper crop management. A thorough review of field records can offer important pieces to the puzzle and can often provide a useful timeline of events. The principal field records to review are as follows:

Previous Crop History. Consider the crop rotation that was used in the problem field including pesticides that may have been used on the previous crop and records of any insects or diseases encountered in the field. Also take into account previous weed problems and fertilization practices. Were there any abnormalities or poor growth issues with the previous crop and was there a similar pattern?

Soil Analysis: Look at previous soil analysis reports and evaluate nutrient levels, pH, and salinity (EC) and specific ions such as boron. Long-term hay fields can become significantly depleted in phosphorus and potassium which will limit yields. Also consider soil compaction and soil textural changes within a field.

Seed Bed Preparation and Planting : Was the field ripped or sub-soiled? What was used to prepare the seedbed including operations such as chiseling, leveling, seedbed conditioning and preparation? How firm was the seedbed at planting? One of the most common causes for stand establishment problems is too loose a seedbed at planting. A clear indication of this problem is a better stand in the tractor tire tracks or other similarly compacted areas.

Variety and Disease Ratings in Alfalfa: Consider the pesticide resistance ratings for the field variety. However, it is important to recognize that just because a variety it rated as being HR does not mean that it is completely immune and that the disease or insect cannot be present. A variety classified as highly resistant need only have 51% or more seedlings that survive a standard resistance test. How these standard tests performed on seedlings relates to field conditions for established plants is not completely clear. Due to the diversity and genetic heterogeneity of alfalfa it is possible to have susceptible plants adjacent to a plant that does express resistance. Also the disease pressure can be so great in some situations so as to totally overcome plant resistance.

Pesticides Used: What pesticides (herbicides, insecticides, and fungicides) were used on this crop and the previous crop? When were they applied and at what rate? These are all important questions to ask. Many herbicides have crop rotation restrictions. Failure to adhere to these may be damaging to alfalfa seedlings. Pay close attention to the weather records at the time pesticide applications were made. Some pesticides may be completely safe under most environmental

conditions; however, injury may be severe under other conditions such as frost, hot temperatures, drought, excessive moisture, etc.

Irrigation: When was the crop irrigated and how was it determined when to irrigate? How much irrigation water was applied? This is important information to have in hand when assessing alfalfa growth problems in the western states, as irrigation has such a major impact on productivity. It addition to water quantity, it can be important to know irrigation water quality. Water quality issues such as high salts, bicarbonates, sodium and boron can all impact alfalfa growth and are common issues with well water in some areas.

Weather Records: Extreme or abrupt changes in weather (such as extreme heat or cold, water-logging, rapid change in sunlight intensity, etc.) can result in plant injury. Injury symptoms caused by weather conditions are typically widespread in a field but may interact with other factors such as soil type or topography so that only a portion of the field is affected. Weather-related injury often affects neighboring fields as well and is typically not isolated to a single field.

Consider the Effect of Time. The timeline for the development of symptoms can help determine the cause. Damage caused by living factors typically increases with time. The symptoms are progressive because the disease organisms multiply causing the damage to intensify and spread. In contrast, damage caused by non-living factors (particularly phytotoxicity from a spray application) occurs at a given point in time and generally dissipates. There are exceptions to this statement however. For example, alfalfa plants may grow into a layer of herbicide residue left behind from the previous crop and injury symptoms may worsen over time. This can usually be distinguished from symptoms caused by living factors because the affected area typically does not spread as it would with damage caused by most living factors.

Pinpointing the time the first symptoms appeared is often very helpful in determining what the problem may be. If the time coincides with the season when a particular insect or disease often becomes a problem, it is a strong clue that should be further investigated. If you are not familiar with what the common problems are, you can use the Alfalfa Year-Round IPM Program Annual Checklist at http://www.ipm.ucdavis.edu/PMG/C001/alfalfa-checklist.pdf .
Ask questions such as: Does the symptom disappear after a few weeks? Summer vs. winter? A pest may have come and gone, and still leave a damaged plant behind.

Consult References – Confirm Visual Diagnosis. After narrowing the probable causes for the symptoms, it is wise to consult references or a specialist (i.e., plant pathologist, entomologist, etc.) to confirm the visual diagnosis. Reference books can be particularly useful to help determine the specific factor causing the observed plant damage. Several alfalfa plant damage keys have been developed and some have color photographs to illustrate the plant damage symptoms (Canevari, 1993; Orloff, 1997; and Summers, 2008). There are several useful websites that provide descriptions for most pest-related problems as well as pest life cycle information and control measures. One such example is the UC IPM website at: http://www.ipm.ucdavis.edu/PMG/selectnewpest.alfalfa-hay.html

It must be recognized that it is not possible to visually diagnose many problems that occur in an alfalfa field. With experience one can definitely narrow the possibilities to a very few, which can then be resolved through more detailed tests. Some state land grant universities have a laboratory that can be used for this purpose. Laboratory analyses may be required to further narrow the range of probable causes. If a disease is suspected, plant tissue should be sent to a qualified plant pathologist for diagnosis. Fresh samples are important and instructions on how to send them can usually be found on their website. Similarly, plant and soil samples can be sent to a trained nematologist when stem or root nematodes are suspected.

Synthesize Information and Eliminate Alternative Possibilities. The final step to diagnose field problems is to synthesize the information collected and eliminate alternative explanations. An example of how to use this stepwise process to diagnose a field problem is outlined in the table below. Often several different explanations can be thought to explain the same phenomenon – for example, yellowing of the plant may be due to low N supply (poor nodulation), sulfur deficiency, or overwatering. Each one of these needs to be examined, while unlikely explanations are eliminated. For example, if 'pink' nodules are found, N is probably not limiting; the cause must be something else. If the pattern indicates a low area with very moist soil, overwatering might be suspected, but plant sampling might be necessary as well to rule out a sulfur deficiency. It is important to remain open minded and consider all possibilities and then work through a process of deductive reasoning to come up with the most likely cause. Keep in mind that many times there is not a single cause—damage symptoms are often caused by a combination of factors. For example, weevil injury can be far worse when plants are also suffering from herbicide injury and drought stress. Or, another example is frost injury which is more severe when plants are under drought stress. After the problem has been properly diagnosed and confirmed by laboratory analysis or other documentation, comes the task of identifying the proper corrective action. How easy or difficult this is to accomplish depends on the issue, but clearly proper diagnosis is the crucial first step or a lot of time, resources and effort may be wasted.

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Steps	Example
1. Describe and define the problem	Plants in the field have stunted growth, shortened internodes, low yields in early spring conditions. What is the cause?
2. Observe patterns	There are significant patches of these symptoms over large areas of the field. They appear to follow the same patterns as the flood irrigation system. Mostly uniform infection, but non-uniform across field, some plant-to-plant variation.
3. Review field history/records	This field has been in alfalfa for 3 years with normal irrigations and production, but problem areas appeared this year. Older alfalfa variety planted.
4. Distinguish between biotic and abiotic causes	If a living organism, symptoms are usually non-uniform. The symptoms in this case are probably biological, since only portions of field affected – associated with water movement. Strong evidence for biotic stress, since no abiotic stress can be identified.
5. Consider time effects	Is it changing over time? Yes-the symptoms disappear when temperatures warm up in the late spring.
6. Find clues from references	Checked with Charlie Summers Chapter 'Diagnostic Key to Problems in Alfalfa' – symptoms resemble Stem Nematode. Check with Chapter 11 on Nematodes-symptoms are similar to my field.
7. Synthesize information, eliminate alternative possibilities, and determine probable causes.	Are there any other possible causes? Aphids? Soil fertility? Wheel traffic? Weevils? No- since no aphids present within 3 months, soil tests look adequate, and symptoms don't follow wheel tracks, and it's too early for weevils. Reading the Nematode chapter, stem nematode is associated with cool conditions and water, similar to my field.
8. Test your hypothesis for probable cause.	Took the sample to the Farm Advisor & leached with water (or did it myself) –looked at the sample under a simple microscope – sure enough, there they are: stem nematode.