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Wheat Symptoms Often Confused With Diseases

Introduction: Many leaf symptoms are easily confused with diseases and can prompt an unnecessary fungicide application. These symptoms are mostly abiotic relating to physiological imbalances which include ***Physiological Leaf Spot Disease*** and ***Salt Exudation***. As diseases and nutrient related problems are ruled out, we begin looking at physiological related problems. Yes, trouble-shooting is often a process of elimination involving eliminating pest related problems and then nutrient deficiencies. If these do not apply begin looking at physiological related problems generally related to environment. What makes trouble-shooting difficult is that, more often than not, there is more than one compounding variable. We could have nutrient symptoms occurring as a result of environment as is seen with Physiological Phosphorous Deficiency in corn early season or Potash Deficiency in cotton due to dry weather. In these cases we often have adequate soil, levels of these nutrients but adverse environments cause symptoms to occur. Granted, under stress, the plant has cross-talking abilities occurring among physiological paths and between physiological paths creating a massive highway system of communication. However, in this case we will look at two very simple maladies (Physiological Leaf Spot & Salt Exudation). It is important to understand why and how these occur.

Physiological Leaf Spot: This leaf spotting malady might be confused with wheat, leaf diseases. It manifests itself initially as a small flecking of chlorotic spots that are about 1-3 mm in size on the upper leaves. The symptoms will be consistent across all plants in the field since it occurs mainly in susceptible varieties. The individual fleck will later expand into an elongated, rectangular lesion that is about 3-4mm long. The color of the lesion will progress into a straw color with a dark brown center. Early stages can be confused with leaf rust or the hypersensitive reaction to leaf rust by a resistant variety. Hypersensitive reactions are a means of reducing disease establishment involving specific plant defense mechanisms like jasmonic acid and Aldehydes or other genetic alterations that facilitates resistance by recognizing and combating foreign proteins. Later, Physiological Leaf Spot lesions will appear similar to Septoria. It can also resemble Ramularia, Tan Spot or Bacterial Leaf Blight.

Conditions favoring Physiological Leaf Spot include the use of susceptible varieties, continuous wheat cropping, conservation tillage, inadequate nitrogen, low chloride (important in photosynthesis and osmotic relations of the guard cells) and calcium (important in reducing membrane damage, membrane leakiness and providing cell strength.

With Physiological Leaf Spot, the leaves affected will depend on the plant growth stage as when the stress occurs. In most cases one will see this malady on the flag leaf and second leaf down from the flag leaf. Symptoms generally occur during late spring at Feekes growth stage 3-5.

This malady is prompted by weather conditions involving extended cloudy and rainy weather that we saw this spring followed by a few bright sunny days. Basically, it results from leaf surface sun-burning, is highly variety specific and does not cause yield loss. However, there are some results that under severe cases yield reduction can occur. More explicit, Physiological Leaf Spot results from Activated Oxygen Species-AOS (These are oxygen's that are more active than the molecular oxygen we breathe, can promote damage at high levels and are problematic when the plant undergoes stress) that are up-regulated due to a metabolic imbalance resulting from the cloudy and cold weather. In cloudy weather the phytochrome system is up-regulated to help the plant during low light intensities but must drop quickly when light levels increase to avoid photo-oxidation. However, this change can be slowed during cold weather since enzyme activity within a physiological path is reduced. In this case the metabolic imbalance can exist between paths (Respiration and Photosynthesis) with photosynthesis being more greatly impacted. This leads to increased activity of Activated Oxygen Species which can be damaging.

***Triplet State and Activated Oxygen Species* (singlet oxygen, hydrogen peroxide, super oxide anion and hydroxyl ions):** Molecular oxygen is essential to all aerobic organisms and is not toxic in this state but it can carry potential danger. In the plant molecular oxygen can exist in what is called the Triplet State or as Activated Oxygen Species.

Triplet State: In the plant there is a Ground state called the Triplet State. This is a very stable state, is the oxygen we breathe and is the lowest energy state in the plant providing a homeostatic environment that is conducive for the plant growth and development. The Triplet State is reactive but not highly reactive due to unpaired electrons (charged particles) being in different electron orbits (Remember, an atom has orbits or shells that electrons move around giving it stability or reactivity). The Triplet State reactivity can be increased via the process of reduction which requires addition of an electron and removal of the spin restriction. Under stress or changes there is an acceptance of electrons from Activated Oxygen Species that can result in damaging effects. A description of Activated Oxygen Species is as follows.

What is Activated Oxygen Species (AOS)? They are by-products of molecular oxygen (O2) resulting from the reduction (adding an electron) of molecular oxygen in univalent steps (Super Oxide anion, Hydrogen Peroxide and Hydroxyl ions respectively) or excitation of the Triplet State to the Singlet State. These can become toxic when the plant is exposed to environmental stress (drought, chilling, high light intensities, ozone, some pathogens and high sulfur dioxide) and especially when AOS scavengers (compounds that impede activity of AOS) have declined in amount. Some AOS can be good at low levels acting as secondary messengers in the signal transduction pathways. These by-products can break down membrane lipids (They love fatty acids found in the membrane), break down nucleic acids, break down proteins, inhibit chloroplast development, damage chloroplast and mitochondrial membranes and inactivate many enzymes (Proteins that catalyze physiological reactions).

Singlet Oxygen: When the electron in the Triplet Sate, reverses its spin direction it creates the Singlet Oxygen state that has a higher energy than the Triplet State. This is most common in the chloroplasts where light particles excite the chlorophyll from the Ground State to the Singlet State. Normally chlorophyll (gives leaf its green color) passes energy along to an electron acceptor during the photosynthetic process. If the electron transport is impaired due to stress, oxygen is activated to the Singlet State and can cause problems. However, the chlorophyll is normally de-excited to the ground state by fluorescence (release of light energy at slightly longer wavelengths than what was absorbed), heat absorption or by reacting with other molecules. In the normal process light energy is passed by electron carriers to reaction centers where there is a generation of a phosphate called Adenosine Triphosphate (ATP) that generates energy. This energy can pass to oxygen in a normal manner with no problems. However, chilling and low light levels can result in an imbalance that leads to an imbalance of electron carriers allowing over-energizing the reaction centers (Photosystem I & II). In this case Photosystem II is greatly damaged by increases in the Singlet Oxygen State followed by an increase to the Super Oxide State. Basically, the Singlet State is the precursor to the Super Oxide state which is very detrimental.

Super Oxide: This form is much stronger than the singlet state and accounts for great damage. It is a free radical having an unpaired electron and is looking for a way to donate or accept an electron. Therefore it has oxidizing (donate an electron) and reducing capabilities. It also generally requires a channel to cross the membrane. Membranes can be crossed by channels that are proteinaceous in nature, by pumping systems requiring energy and by diffusion depending on the membrane concentration gradient.

Hydrogen Peroxide: This product is one of the most stable AOS possessing less reactivity at lower levels and can even be an essential secondary carrier in the information transduction pathway. It is not a radical since it has two sets of paired electrons. It has a neutral charge allowing it to cross the cell membranes easily. Hydrogen peroxide is formed through a process called Dismutation where Singlet Oxygen binds with Hydrogen generating Hydrogen Peroxide via reduction and Triplet State Oxygen via oxidation. Hydrogen Peroxide can be produced in the cell wall and plasma membrane. In the cell wall it assists in the formation of lignin and in membrane it signals responses for pathogens and abiotic stress.

Hydroxyl radical: This can be formed by the addition of a hydrogen atom and splitting out water to form the hydroxyl radical. It can also be formed by reacting Hydrogen Peroxide with Super Oxide that forms a hydroxyl radical (bad form), a hydroxyl molecule and Triplet State Oxygen. The hydroxyl radical is one of the most potent oxidizing agents and its action can be best described as random destruction.

Activated Oxygen Specie Scavengers: These can be divided into enzymatic and non-enzymatic that can repair or reduce the activity of Activated Oxygen Species. Enzymatic scavengers include catalase, ascobate peroxidase and superoxide dismutase (SOD). Ascorbate peroxidase breaks down Hydrogen Peroxide while SOD breaks down super oxide. Non-enzymatic scavengers include Glutathione, Ascorbate, Reducing Agents (mannitol, ethanol, formate and thiourea), Vitamin E, Carotenoids (B-Carotene & Xanthophylls) and Flavonoids. If these scavengers are reduced in stress conditions, the AOS can cause plant damage but the plant has great methods to protect this from happening as listed above.

Modes of Action of Physiological Leaf Spot: In this case susceptible wheat cultivars show a higher level of superoxide, hydrogen peroxide, membrane breakdown as shown by the increase in malondialdehyde (product formed by lipid peroxidation of the cell membrane; in this case the chloroplast), lower levels of antioxidants, SOD, catalase and ascorbate peroxidase and non-enzymatic scavengers (Glutathione and Glutathione Reductase).

This symptom results from degradation of the electron transport in chloroplast membranes. It has been shown that light with a higher proportion of blue wavelengths (350-560 nm) found in Photosystem 1 caused more leaf spots than light in the far-red zone containing wavelengths (580-650 nm) found in Photosystem II.

Acclimation (A process of subjecting a plant to short periods of adverse conditions) to low light levels and cool weather can lead to increased scavenger levels that leads to more control of activated oxygen species and plant protection. However, it is very difficult to acclimate a plant to low temperatures while the plant can acclimate itself to low light conditions better.

Salt Exudates: The plant must rid itself of certain impurities to prevent toxic levels from being formed at the cellular level. High levels of Na and Cl can cause imbalances across the membrane greatly affecting solute concentration gradients which can affect the charge at the membrane level. They can also form non-compatible solutes which can negatively affect the hydration shells around the protein causing the protein to be negatively affected in structure which will negatively affect the function of the protein in transduction, translation and transcription. Therefore, the plant will rid itself of impurities by passing them to the vacuole or pre-vacuolar structures that will be passed to outside the plant through hydathodes or stomates. This will cause a silvery exudate on the leaf surface that can be mistaken for powdery mildew. Under a hand lens you can see the white mycelia growth on the lower leaf followed by chlorosis.

Conclusion: As one can see there is a great deal going on at the cellular level of the plant that has nothing to do with biotic issues like insects or diseases or fertility. It is easy to identify pests like insects and weeds, somewhat difficult to identify pathogens, difficult to identify nutritional deficiencies but it is very difficult to identify and understand the relation of environment on physiology of the plant. It is even more complicated when more than two variables are involved. This subject refers to wheat but AOS can apply to any plant under stress whether it is a row crop, forage or horticulture related crop.

Physiological Leaf Spot on Wheat in Covington County.