Organic wheat – preventing fungal disease

Introduction

Conventional wheat seed treated with highly toxic fungicidal chemicals draws a shudder from everyone. However this practice has reduced the incidence of seed borne fungal disease in wheat to the point that we hardly ever hear of *stinking smut* or *loose smut* as a problem. But these diseases are regularly present on susceptible wild grasses in the Western States, and in some years wheat fields are infected, perhaps initially, from these wild grasses. For organic wheat agriculture, we certainly need to know how to deal with this situation without resorting to the dangerous practice of adding toxic chemicals at any point, to a crop that is destined for food use.

For all the fungal and bacterial diseases that are sometimes found on wheat in California, the organic philosophy of *working with nature* appears to offer very good ways to prevent crop losses. But we need to learn the life cycles and the conditions that favor infections in order to work with nature in this prevention process. Infections should not occur except perhaps in those years when the weather is extraordinarily wetter than normal, or selected wheat varieties are grown in a wetter region than their optimal climate range. Discovering the regional limitations of each variety can take many years. If indeed landrace wheat varieties keep their specific immunities to disease longer than recent hybrids, as they seem to, then regional limitations would be very valuable knowledge.

Stinking Smut

Stinking Smut, also known as *Covered Smut, Common Bunt, or Tilletia tritici,* is dramatic in its manifestation: black sooty-looking spores in balls that have replaced the grain, and the smell of rotting fish signaling the presence of trimethylamine, which is explosively flammable and a great fire hazard during harvest with modern combines. At least, most of the spores and smell can be rinsed away from the good grain, which can then be fed to animals. There are no toxins, but the spores can set off allergic reactions in some people. Even so, if the crop was anticipated for human food use, the financial loss and disappointment can be considerable.

The mode of attack by stinking smut *Tilletia tritici* spores is by attaching to the wheat seed and germinating at the same time as the wheat seed. The fungus grows on the developing leaf shoot, the coleoptile, and then almost invisibly inside the wheat plant and eventually resides in the developing grain, where it produces a spore ball. Infected plants can be recognized after heading, and still green, as stunted and with an oddly damaged look to the head. The oddness of the head can still be seen at harvest time. Ideally these infected plants are removed before the grain field matures. The spores are spread during harvesting with a combine, and coat the good grain as well as all the equipment, and the soil. When the contamination is low, the usual mechanical seed cleaning methods remove the brittle spore balls and most spores. Routine thorough cleaning of planting, harvesting and seed cleaning equipment, removes the majority of spores that might contaminate the seed for the following year. Storing seed in clean bags is an obvious way to avoid contaminating the seeds with fungal spores. Choosing to plant in another field following a non-grain crop reduces the possibility of contamination by spores left in the soil. Ideally

a warm temperature day is chosen for planting, above 68ºF, and this discourages germination of *Tilletia tritici* spores. If these routines are followed the next wheat crop will likely again have a very low incidence of infected plants. Seed can also be tested for the presence of *Tilletia tritici* spores, so that a negative test result can give added confidence to the grower that the seed being planted is clear of infecting spores.

Few varieties of wheat are resistant in the long term, because the fungus probably will mutate sufficiently to overcome the wheat immunity. Perhaps spelt and emmer wheat varieties, planted in their husks, are the most likely to consistently resist the disease. However if planted as naked seed they are likely to be just as vulnerable as any other wheat variety.

Other grasses that are particularly vulnerable to *Tilletia tritici*, and which need to be avoided in a wheat planting, are rye (Secale cereale), triticale (Triticale hexaploide), triticum secale species, barley (Hordeum species), goat grass (Aegilops species), ryegrass (Lolium species), wild rye (Elymus species), and wheat grass (Agropyron species). Some of these grasses are natives and are often distributed in cover crop seed mixes. When wheat is introduced onto a farm, this should be a consideration in planning where to plant.

Build-up of the disease in wheat seed stock easily happens when an un-noticed infection is carried over from year to year, in seed that is never cleaned and simply replanted. The temptation to do this occurs when propagating to enlarge a seed stock, and when good cleaning equipment is not easily available and the grain is destined for animal use. Indeed this is the very situation that one farmer had been through when this year, at harvest, he was confronted with the smell, spores and thorough embarrassment of a full-blown infection of *stinking smut*. I also should add that he was growing the wheat in the same field each time so that one area had been in wheat for several years. The incident has been a real stimulus to discover, or should I say re-discover, how to keep the incidence of *stinking smut*, and indeed any fungal infection, at a negligible level in our organic wheat crops, particularly here in California.

Loose Smut

Loose Smut of wheat, also known as *Ustilago tritici* is a seedborne and potentially devastating disease of wheat in the Western States, which we would like to avoid, with methods appropriate to organic agriculture. Knowledge of the lifecycle of *Ustilago tritici* is a great help in managing the prevention of infections.

Infection occurs when *Ustilago tritici* spores in the air, land on flowering grain heads. Moderate temperatures 60-70º F, wind, rain, heavy dew and irrigation, seem to increase the possibility of infection. The spores develop a mycelium inside the embryo of the maturing grain, which looks quite normal at harvest. Only examination of the embryo with a microscope can reveal infection. When these infected grains are planted the following year, the fungus grows with the plant and eventually resides in the developing grain where spores form an open, loose, black sooty mass in place of the grains. This is visible at the time when the grain would normally flower, and is the source of new spores to infect flowering plants. It is difficult to prevent the spreading of the spores, but if possible all loose smut wheat plants should be removed from the field. If loose smut heads are left in the field, they eventually shed all the spores and leave a bare rachis, which was originally the wheat-head's stem.

Immunity to infection among all the wheat varieties, including spelt and emmer, is rare because the infection occurs when the heads are flowering. In any case the fungus is likely to mutate until infection occurs in a previously immune wheat variety. *Triticale* and *rye* can also be attacked by the *Ustilago tritici*,

An important part of preventing an attack of *loose smut* is knowing whether or not the seeds are infected, via microscopic examination. If there is a possibility that some infected seed is present, and it is needed for planting, that seed can be heat-treated to kill the fungal mycelium in the embryo of the wheat. A hot water treatment has been designed so that good wheat seed remains viable. If an infection has actually been seen in a crop during the previous year, sensibly, that crop should not be used for planting. Planting in a field following a non-grain crop will reduce the possibility of infection from spores left on the soil from a previous season. In any case the seed should be as thoroughly cleaned as possible to avoid carrying spores on the outside of the seed, and it should be stored in clean bags. All equipment should be well cleaned to avoid transfer of spores to the grain or to another field, even though there is nothing to prevent the wind carrying the spores long distances. In the case of organic wheat grown in California, the best chance of avoiding initial infection, is to plant varieties that will flower in hot (above 70ºFº), dry, weather, and to avoid irrigating the crop, especially at the time of flowering. The risk of infection drops to zero in 7 days after flowering.

Karnal Bunt, also known as *Tilletia indica,* was originally recognized in the Punjab, India in the 1930s. It appeared in Mexico in 1972, and infections were reported in the USA in 1996 in regions bordering Mexico. No infections have been reported in the USA since then. Spores of *Karnal Bunt* can be carried on wheat seed, straw and in soil, as well as on equipment and transporting vehicles. Several countries including the USA, will reject wheat imports if these spores are found on wheat grain, or the grain comes from countries where the disease is active. Conversely as wheat exporters, the USA and California do not want their exports rejected. This is the reason for heightened concern here in California, to avoid infection. Vulnerable crops are all kinds of wheat and rye.

Karnal Bunt spores are activated under high humidity and cool (59-72ºF) weather during a three-week period after the head emerges. These active spores infect wheat heads. The spores grow into the grain as it forms, and will fill the grain with spores during the three-week period. Some new grains will be completely filled with black, fishy-smelling spores while some will be only partially blackened. Infected wheat heads containing blackened and somewhat enlarged grains, are noticeable when the grain is fully ripe, but are easily missed. At harvest the spores will be spread onto grain, equipment and especially onto the soil. Grain that is only partially filled with spores, will also infect the soil at the next planting. The life of the spores on soil is several years .

When wheat is found to be contaminated with *Karnal Bunt* spores it is confiscated and steam rolled into flakes that are used as animal feed, since there are no toxins from infection. There is a compensation program in place for wheat crops confiscated, because *Karnal Bunt* spores are found.

The first line of defense is to choose varieties which head into conditions of dry heat, when planted at locally appropriate time, and not to irrigate after heading. Otherwise, the most important method of controlling *Karnal Bunt* is to avoid planting seed contaminated with spores.

Black Point

Black Point disease of wheat is caused by several fungi that do not produce toxins, such as *Alternaria*. However, *Alternaria* spores can cause respiratory allergic response in some people. The name is descriptive of the unsightly blackened embryo tips of infected wheat. Blackened embryo and bran appear as black specks or grey colored flour, when the grain is milled. *Black Point* infected grain is therefore particularly undesirable for use in whole grain products, and as seed it will likely have reduced germination.

Black Point appears on grains when they are subjected to high humidity after the heads are filled with grain. Lodged grain is vulnerable and so is grain subjected to irrigation or unseasonable rain, as the head fills with grain.

Prevention of *Black Point* disease rests with sparse enough planting, and adequate rather than excessive fertilization, to prevent lodging; choice of varieties that head up into dry heat in your location; and avoidance of irrigation after heading.

Rust disease

Rust disease on wheat includes several infecting fungi.

Stripe Rust

In California the most damaging is *Stripe Rust* also known as *Puccinia striiformis*. Therefore the most basic trait desired in a wheat variety for California, is resistance to this *Stripe Rust*. California wheat breeders maintain an ongoing battle to outdo the ability of *Stripe Rust* to adapt until it can cause full-blown disease on very specific wheat varieties, in just a few years. This is also the reason why, before releasing the landrace varieties listed in our *Whole Grain Connection* seed catalog we have established that they are reasonably immune to current *Stripe Rust* strains, at least until the present date.

Over-wintering spores survive on off-season volunteer plants of susceptible varieties. Stripe rust disease is manifested when infecting spores land on the developing wheat leaves and are perpetuated there, and so spoil the photosynthetic action in those green leaves. The damaged leaves also loose moisture from the plant, so making it dry too soon. The yellow-orange striped pattern of the spores on the leaves, gives the disease its name. Spores can over-winter, or arrive on the wind from a distant field, and infect a susceptible wheat variety while temperatures are between 41and 59ºF. At the upper end of this temperature range, 50-59ºF, and in rainy or heavy dew conditions, the disease develops with extreme rapidity in a series of cycles lasting just 8 days each. These are the conditions that occur before heading in most seasons in California, where a rain fed crop is grown. When these cool wet conditions occur after heading, the wheat heads are also attacked and losses are magnified. Infected plants are stunted and yield of grain is much reduced.

Leaf Rust

Leaf Rust, also known as *Puccinia recondita*, is a late season infection of wheat that has usually already headed, and occurs under a combination of warm temperatures, 60 – 72ºF, and high moisture. In most years in California, non-irrigated wheat is

unaffected, since hot dry conditions are the most usual after heading. Infections last only while there is green material on the plant. Spores are a dark orange color and initially form a speckled pattern on the leaves. This gives some distinction between *Stripe Rust* and *Leaf Rust*.

Infection results from spores that have over-wintered on susceptible volunteer wheat plants, and from spores blown in from regions where wheat has leaf rust disease. The number of spores increases rapidly if conditions are favorable, since the time for regeneration of spores is only 7-14 days. Losses occur by reducing the number of kernels per head and the protein content of the grain.

Stem Rust

Stem Rust also known as *Puccinia graminis,* is considered to be potentially the most devastating of the rust diseases of wheat, but it is not currently significant in California. Spores can be blown from infected crops or infected over-wintering volunteer wheat, in other regions. Conditions that would allow infection are high humidity from rainfall, dew or irrigation, and high temperatures, 65-85ºF, after the wheat has headed. We are fortunate that, most wheat in California seems to be immune, and in moat years it heads up into dry heat. Provided the dryness at this stage is not compromised with irrigation or unseasonable rain, *stem rust* is unlikely to be a problem in much of California. The infection is seen as dark orange pustules on the stem particularly, that eventually turn black; the stems collapse and losses are usually devastating.

The *stem rust* strain discovered in Uganda in 1999 (Ug99) has flourished in Africa because, according to Borlaug writing in the *New York Times* in April, 2008: *Today's lush, high yielding wheat fields on vast irrigated tracts are ideal environments for the fungus to multiply, so the potential for crop loss is greater than ever.* These are the conditions encouraged by modern conventional wheat agriculture, whereas we have an opposite strategy for organic wheat of relatively sparse planting, of locally appropriate varieties, and avoidance of irrigation.

Septoria

Septoria fungus on wheat, causes the disease known as *Leaf Blotch*. Infection occurs in two stages. Spores (sexually produced ascospores) survive in a dormant form from the previous season, in the soil, and on wheat debris and seeds, under the dry conditions of Summer in California. In California release of these spores into the air, occurs inevitably when the first fall rains occur, they can travel over a considerable distances and are a continual source of infection during a continuously wet growing season. Early in the season these airborne spores cause infections on the lowest leaves of the wheat plant if there is sufficient moisture. Black spore sacs (pycnidia) surrounded by blotched areas on the leaves, ouze pink-brown asexual spores. Spores (asexual at this stage) released from the infected leaves travel only short distances and if moisture persists they can only infect nearby leaves. This means that short wheat varieties are more susceptible at this stage of infection, than taller varieties. Sparse plantings are also less vulnerable. Infections are greatest in continuously wet seasons, and in irrigated crops, at temperatures from 60 – 77ºF. Damage occurs in the form of fewer grains per head and if infection continues while flowering, the grain does not fill properly and is of poor quality. In most seasons in California rain during the growing season is interspersed

with dry weather and by the time of heading it can be hot and dry, with no further rain anticipated.

Septoria disease can cause serious enough losses that wheat varieties are selected or bred to resist infection, even though it is difficult to maintain immunity in wheat against fungal disease.