Induced Resistance in Potato

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Potato Disease Control

As every grower knows, there is no shortage of diseases to which potato is susceptible. Consequently, growers must spend a good deal of time and money combating disease using pesticides and good management practices. The perfect potato would have such excellent disease resistance that it would not require a pesticide regime. Although scientists cannot yet make such plants, the incredible pace of advances in technology and knowledge is bringing the debut of such plants ever closer.

Another result of our increasing knowledge about how plants protect themselves is that scientists are now able to manipulate plant **I**nduced **R**esistance (**IR**). This is a technology that will be very useful for growers in the years ahead. Because of its exciting potential, more plant molecular biologists are researching the area of IR and defense signaling than any other area of plant biology. This illustrates how important scientists think this area will be for improving plant disease resistance.

This may surprise readers, but many potato varieties are susceptible to some pathogens not because they lack the ability to resist the pathogen but because the plant does not mobilize its defensive 'armies' in time. Therefore, although a plant may have a significant 'army' at its disposal, if it does not have its troops awake and at the right place at the right time then its defenses are compromised. Another way of looking at this is that it is critical for plants to realize they are being attacked by a pathogen and respond rapidly with defenses. When we activate the defenses of a plant with 'activators' we are helping the plant to protect itself and are essentially putting the plant on 'alert status.'

Induced Resistance

IR in plants has been shown to be effective against a broad range of pathogens, including viruses, bacteria, fungi, nematodes and insects. There are several different types of IR in plants but the most studied is called Systemic Acquired Resistance (SAR). This refers to a process whereby plants activate a wide range of defense mechanisms that are not normally active—i.e. an 'inducible defense.' What eventually came to be called SAR was first observed in the 1930s in the field when it was noted that plants that survived an initial infection became much more resistant to subsequent infection by the same and many other pathogens as compared to plants which had not previously been attacked. Another type of IR is called Induced Systemic Resistance (ISR) and is similar to SAR but is turned on by different classes of compounds and also by certain non-pathogenic soil bacteria. Disease is just one type of stress that plants are subject to; research has

also shown that in some instances IR can also give enhanced tolerance to environmental stresses, including cold, drought, and salt stress.

Why should you care about SAR?

1. Many of today's varieties have excellent traits, other than their poor disease resistance. If SAR can be made to work in potato, this would be a method of enhancing disease resistance in existing potato varieties without having to wait years for development and release of future varieties that have been bred to have superior disease resistance.

2. SAR activating compounds are regarded as safe to both humans and the environment. The EPA has encouraged their use. Because SAR is a natural response, it avoids consumer concerns over pesticide residues in their food or in the environment. It is important to remember that SAR activators are not traditional pesticides and do not act directly against the pathogen, but rather cause plants to activate a battery of their own disease and stress resistance mechanisms.

3. SAR is effective against a wide range of pathogens, including certain viruses, fungi, bacteria, nematodes, and insects.

4. One of the rare treatments known to work against viruses.

Will SAR protect against PVY, PLRV, or other viruses?

Methods of virus control are limited. Most spraying strategies are not effective against the virus itself, but rather against the vector. On the other hand, SAR is probably best known for giving protection against viruses and has been most studied in tobacco. Figure 1 shows tobacco plants that have been activated (plant on the left) or not activated, then challenged with Tobacco Mosaic Virus (TMV). The lesions on the activated plant are much smaller than the untreated plant, because the activated plant has mobilized its defenses and is consequently better able to restrict the spread of the virus.

Figure 1: Two tobacco plants treated with TMV. The one on the left was activated for SAR before being inoculated with TMV, whereas the one on the

right was not. Notice the necrotic lesions are much larger and more numerous on the untreated plant.

Note that this plant would now be expected to have a high level of resistance against a wide range of pathogens, not just TMV and this protection lasts for weeks to months. In several Southern states, about 45% of tomato growers are using SAR to protect against Tomato Spotted Wilt Virus (TSWV). Because better methods of virus control are urgently needed by the potato industry, the question of whether SAR will protect against potato viruses, including PVY or PLRV, is one we are currently addressing in a greenhouse study. We will also be looking at the effect of SAR on non-viral potato pathogens and from these studies will have a much better idea of which potato pathogens SAR is effective against.

How does SAR get turned on and who makes the products?
Over the last 15 years, scientists have made tremendous advances in understanding how SAR works—and consequently achieved a much great ability to manipulate it for our own purposes. SAR develops in a plant because hundreds of genes are turned on or off, whereas in untreated plants there is no change in these so called 'defense genes.'

A compound made by plants called salicylic acid (SA) has been found to be the master regulator of SAR. Most plants make very small amounts of SA until challenged by a pathogen, after which plants start making much more SA. It is this SA that is responsible for turning on the many defenses mechanisms that make up a successful SAR response. This discovery meant that one no longer needed a pathogen to turn on SAR, but instead one could spray SA on a plant and induce SAR.

There are many other compounds that mimic the effect of SA and at least 15 companies are now marketing treatments purported to activate SAR. A few examples include Actigard by Syngenta, Messenger by Eden Biosciences and VacciPlant from Goemar Industries. When applying these compounds it is not necessary to get 100% coverage of plants in the field, because these compounds activate defenses throughout the plant, even in parts of the plant that were not directly sprayed. If the reader is not interested in some of the more technical aspects of SAR in potato it is suggested that they skip the next couple of paragraphs and read the final paragraph.

SAR in Potato is different from most crops
SAR has been most studied in plants other than potato. Each crop will likely respond a little differently to these compounds, so successful utilization of SAR activators will require optimization for use with potato. We are currently characterizing potato defense gene activation and SAR and have found significant differences in potato compared to other crops. How do we typically check to see if SAR has been turned on by a treatment? By looking at whether particular defense genes are turned on. Usually these defense genes are not detectable

unless the plant has been activated. The black bands in Figure 2 simply show that defense genes are turned on. Notice that in potato, even the untreated plants have a significant level of defense gene activation. This is different from most other crops, as normally no band would be present in an untreated plant.

Figure 2: Russet Burbank leaves treated with salicylic acid or untreated. The black band shows defense gene activation. Note that the defensive gene is already on in the untreated plant. Similar results were seen in Russet Norkotah. This is different from other crops.

Thus Russet Norkotah and Russet Burbank appear to have at least a low level of SAR turned on all the time. What the consequences of this are for potato disease resistance are not yet understood. In other experiments we found that we could activate SAR to a much greater extent after treatment with Actigard or Messenger. Defenses were activated both in leaves and tubers, showing that SAR functions in both leaves and roots of potato. Because we can activate SAR in tubers, this suggests SAR may also be useful against post-harvest diseases.

Potato has high levels of salicylic acid

As mentioned earlier, salicylic acid levels are usually very low in most crops, unless the plant is activated or under pathogen attack. We measured SA concentrations in leaves, flowers, stems, roots and tubers of Russet Norkotah (Figure 3).

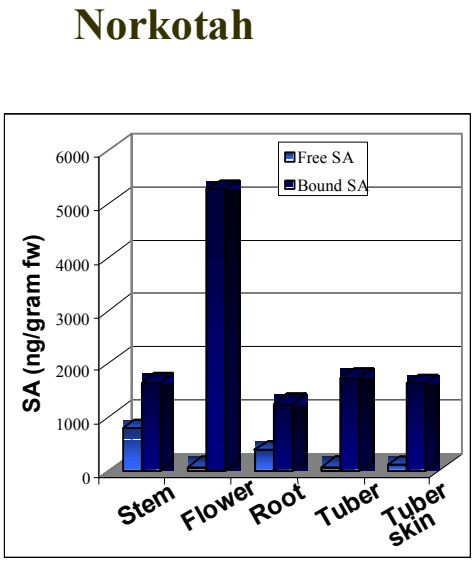

Figure 3: Salicylic acid levels in Russet Norkotah.

Similar levels of SA were found in Russet Burbank and Umatilla Russet. These potato varieties have SA concentrations over 100 fold higher than that found in most other crops in the absence of infection (Figure 4).

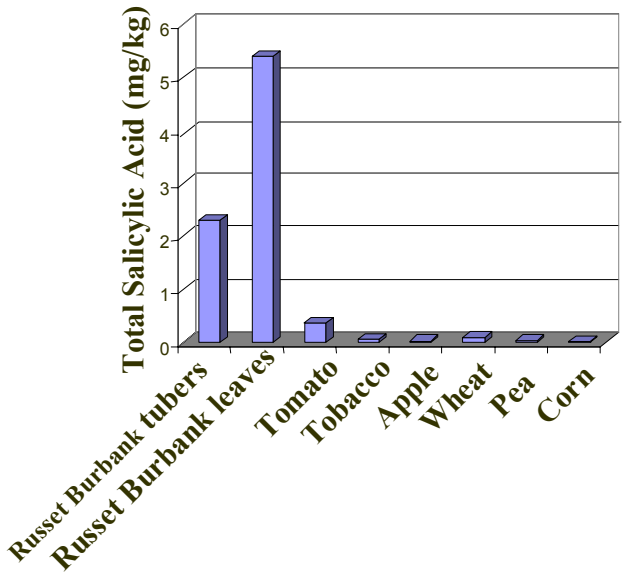

Figure 4: Salicylic acid levels in potato and other crops.

The consequences of these high SA concentrations for potato disease resistance are not clear, but are intriguing. These high basal levels of SA are probably the reason that potato has some defense genes turned on all the time, as opposed to being turned on only after stimulation. Thus, at least some of the genes that are usually turned off until activated by compounds such as Actigard or Messenger, are already on in potato in the absence of any treatment. It is probable that these genes are already activated because of the high levels of SA found naturally in potato.

Bottom Line: Will SAR help growers?

The optimal use of SAR for potato growers is yet to be determined. SAR has already been very helpful for disease control in other crops and is an important part of many growers' disease management regime. As mentioned, SAR and defense signaling is an intensely studied area in the plant sciences—that so many scientific experts in plant disease resistance around the world focus on this area shows how important scientists think this will be for disease control. It is quite likely that more and more potato growers will use SAR during the next couple of years. To maximize the effectiveness of SAR in potato, several issues still need to be resolved. We need a better idea of exactly what pathogens it is effective against in potato and how long a treatment lasts. SAR will not protect against all pathogens, so it is essential the grower know beforehand which pathogens they

might be able to control with SAR. We need to know when is the best time to apply treatments during the potato lifecycle—this could be a very important criterion. How will SAR fit into a pest control regime? Is it a replacement? An addition?

It is unlikely that SAR will give 100% protection for a given pathogen. Thus, the most effective use of SAR will likely be in combination with other control methods. For example, a grower using SAR might find they can significantly decrease the amount of pesticides they use—i.e. that smaller amounts of pesticide are sufficient or that a less expensive pesticide combined with SAR gives good disease control.