Vegetable Seed Pathology:
A Summer Internship at WSU's NWREC in Mount Vernon, WA

Cynthia Hansen
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Introduction

The air was warm and still when I arrived for my first day as a summer intern at the Washington State University Northwest Research and Extension Center in Mount Vernon. Stepping inside the brand-new Agricultural Research and Technology Building, I left the realm of textbooks and late-night study sessions for another side of science, one in which both mind and body are engaged in a fast-paced work environment. My first day of work, July 2, came long after the beginning of the field season, and many research trials were already well underway. I plunged right into summer in Dr. Lindsey du Toit's Vegetable Seed Pathology program. Throughout the summer I had the opportunity to participate in research projects involving spinach, radish, carrot, and onion seed crops, and I was able to spend time working in both the laboratory and in the field, using a variety of equipment. I came to appreciate numerous hours of hard work by many people, the precision, repetition, and attention to detail, and the mountains of painstakingly recorded data that go into a single research project that is later distilled into a scientific paper of only a few pages. My internship provided me with an in-depth look at scientific research in action, and I learned how valuable agricultural research is to farmers, and by extension to every person, as we are all consumers of agricultural products. I was privileged to work with an amazing group of people, including time slip employees (Barbara, Kerri, and Jennifer), a high school intern (Carrie), two graduate students (Jamie and Leigh Ann), two lab technicians (Mike and Louise), and occasionally another WWU intern (Alyse). From these people (and, of course, Dr. Lindsey du Toit) I was able to accumulate a wealth of valuable knowledge that I will carry with me into the future.

The Science of Vegetable Seed Pathology

One important part of my internship was learning some of the fundamental principles of the science of vegetable seed pathology. Prior to beginning the internship, I read a basic plant pathology textbook loaned to me by Dr. du Toit. Through numerous conversations while working and several lunch meetings in which we discussed VSP research and concepts relating to plant pathology, I was able to gain a better understanding of plant pathology and apply its principles to what I was working on. Two fundaments I found especially useful were the disease triangle and Koch's postulates, and I was able to apply them to my work on many occasions.

The disease triangle is a useful model of the factors which, in combination, contribute to the onset, presence, and severity of disease in plants. In one corner is the pathogen itself. The genetic makeup of the pathogen, its requirements for growth and reproduction, its life cycle, and its pathogenicity are important determinants of disease. Moving to another corner we find the host plant. Resistance of the host to the pathogen and the characteristics of its life cycle contribute to disease. The third corner is the environment, in which a wide variety of biological and physical factors such as soil chemistry, presence of other microbes which interact with the pathogen or host, temperature, and weather influence disease (5). A fourth corner, time, could also be added to form a disease pyramid. Disease develops over a particular span of time, and all the other components of the disease triangle are also, to some extent, time-dependent. Each disease I worked with this summer was the result of a complex combination of factors represented in the disease triangle.

Koch's postulates outline a method of determining the causal agent of a disease. The pathogen must be first isolated from the sick organism, and must not be present in the healthy organism. Next, the pathogen is cultured. Inoculation of a healthy organism with the culture should result in disease, and the pathogen should be able to be re-isolated from this organism and shown to be identical to the pathogen initially observed (4). Koch's postulates are absolutely necessary in plant pathology. Plants are hosts to many different fungi, bacteria, and other organisms, but only one of the many species present on a plant may be responsible for the disease symptoms observed. Without satisfying the requirements of Koch's postulates, it is impossible to determine with certainty which organism is causing disease. The procedure outlined above cannot always be followed exactly, as some pathogens are obligate parasites and can't be practically cultured in vitro. However, Koch's postulates underlie the procedures of much of the research occurring at the station.

Spinach

Bagged salad mixes featuring "baby spinach" leaves frequent supermarket produce shelves, and young, tender spinach greens have recently skyrocketed in popularity. While much of this spinach comes from California growers, many a baby spinach leaf owes its existence to our region. The Pacific Northwest is one of the only areas on the planet where spinach may be grown as a seed crop. Spinach needs a period of relatively dry weather in midsummer, excluding the eastern United States. It also needs a long day length to flower, so the farthest south it can be grown is northern Oregon. The heat of Eastern Washington and other dry, northern areas is also too extreme for spinach. For these reasons, the Pacific Northwest is the source of approximately 50% of the United States' and 25% of the world's spinach seed (1).

The primary culprit limiting spinach seed production in the Pacific Northwest is *Fusarium oxysporum* f. sp. *spinaceae*, a soilborne fungus that wreaks havoc on the vascular system of spinach plants. The vascular tissue is discolored, and the roots become fragile, breaking easily. Agricultural land available for spinach production is limited, and this pathovar of *F. oxysporum* remains in the soil for many years. Crop rotations of 6-15 years (depending on the level of resistance of the parental spinach lines) are one of the only ways to reduce or eliminate the crop loss associated with this fungus (1). Reducing the rotation period would be beneficial to growers in the Skagit Valley and elsewhere in the Pacific Northwest, as it would allow the expansion of spinach seed production.

Dr. Lindsey du Toit applies lime to a spinach plot.

Reduction of the need for extensive crop rotation periods was a major objective of the spinach trial conducted by the Vegetable Seed Pathology program over the summer. Dr. du Toit explained that, in Denmark, another area where climatic conditions are conducive to spinach seed production, Fusarium wilt is not problematic. A major difference between agricultural lands in Denmark and the Skagit Valley is the soil pH. In Denmark, soils are alkaline, while local soils are acidic (1). This is the basis of the lime amendment trial, as lime ($CaCO_3$) raises soil pH and could affect the impact of Fusarium wilt on spinach crops. This summer's lime amendment trial was a replication of the previous year's trial, with alterations based on that data. The amount of lime applied was increased, as the desired pH changes had not been achieved the previous year due to the high buffering capacity of the soil. Additionally, a Manganese/Zinc foliar feed trial was run. Changing the pH affects the bioavailability of important mineral nutrients in the soil. This has consequences for soilborne pathogens, but these nutrients also become less available to the spinach. Applying Mn/Zn to the foliage provides these minerals to the spinach crop but not to the soil-dwelling *Fusarium*. Spinach is dioecious, and two female lines were used in the trial- one highly susceptible to Fusarium wilt and the other moderately susceptible. The male line was the most susceptible of all. The lime amendment (LA) trial contained five replications of five different rates of lime application. The Manganese-Zinc (MZ) trial contained five replications of three lime application rates.

I spent the majority of the summer working with spinach. Located several miles west of the research station on Highway 20, the spinach trial was surrounded by wheat fields and a cabbage seed crop. Unfortunately, the weed presence was extensive! Prior occupants of the field included potatoes and beets (a beet seed crop had been grown there last year). According to Jennifer, beets are not damaged heavily by *Fusarium oxysporum* f. sp. *spinaciae* but do harbor the pathogen and contribute to high levels of *Fusarium* in the soil, which then affects the spinach. Much of my first few weeks at the station were spent hoeing in between the rows of spinach, and then getting down on hands and knees to pull out the weeds growing under the canopy of spinach leaves or peeking out from between spinach plants. Most of the weeds were volunteer potatoes and beets (I ate quite a lot of beet greens this summer, incidentally), and other common weeds such as henbit and lambsquarter. We returned to the field every week or two throughout the summer to spend a few hours hoeing, but the weed presence was significantly reduced after the intensive weeding in July.

There were a wide variety of spinach-related tasks which I and the other time slip employees worked on over the course of the summer. My first day on the job was spent with Barbara and Carrie, weighing dried spinach samples for the Fusarium wilt trial. These samples were then crushed and mailed to SoilTest labs for analysis of their nutrient content. At regular intervals throughout the summer we cut all the plants in a 3-foot section of one row, removing the roots. These collected samples were placed in paper bags and allowed to dry in large, propane-heated dryers. Daily, we would remove the bags from the dryers and pull apart the

Some of the VSP crew poses with the poles used to measure row sections for stand and wilt counts.

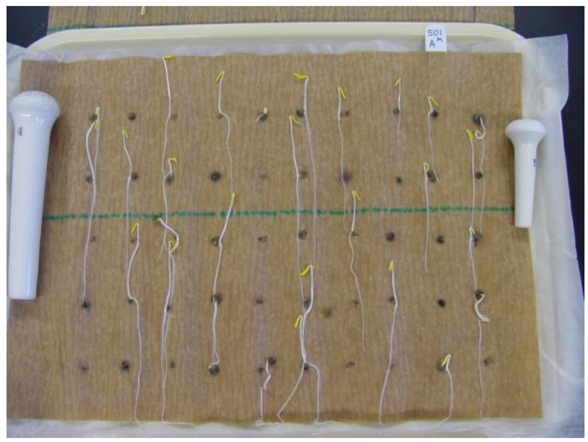
moist clumps of spinach leaves within, in an attempt to prevent rotting and accelerate the drying process. Once dry, we weighed each spinach sample. Another task involved counting the numbers of wilted and healthy spinach plants in a section of 2 rows of each female line within each plot. I did a “stand count,” counting the total numbers of plants within this section. A graduate student, Dr. du Toit, or Mike would then count all of the plants in the row section exhibiting symptoms of Fusarium wilt. *Fusarium* causes wilting because its mycelium clogs the plant’s vascular tissue as it spreads upwards from root to shoot, interfering with uptake of water. Disease symptoms (leaf wilting associated with water stress) increased in the plants as the summer progressed. As the female spinach plants began to set seed, obvious differences were seen between the moderately and highly susceptible lines: The former stayed green much longer than the latter. Differences between the plots were also pronounced. The MZ trial seemed to be especially healthy. Interestingly, plots with the highest rates of lime were exhibiting symptoms of another soilborne fungal disease, Verticillium wilt. In the previous year’s trial, *Verticillium* was most prevalent on seeds from the plots with the highest rates of applied lime, indicating that the limed plots could have more disease pressure from this pathogen (1).

Spinach plots on 7/11/07 (left) and 8/2/07 (right). The darkest green rows in the photo to the left are the moderately susceptible female line. The brown rows in the center and outer edges of the plots are the male line.

As the summer days grew shorter, the spinach plants began to die, and the plots changed color from green to brown. This is a normal part of the spinach life cycle. The female plants set seed and begin to senesce, slowly drying up as the seeds mature. (The male plants also produce seed, but because it contains only genetic material from the father instead of being a hybrid of two parental lines, this seed is not harvested. Occasionally, female plants will produce pollen; these so-called “rogues” are removed by hand from the seed crop.) As the plants dried, we hand-cut a 10-foot section from the middle four rows of each female line in each plot. The plant matter was laid on large sheets of remay (a type of fabric) in the field to complete the drying process. Unfortunately, the weather did not cooperate! A period of rainy, humid weather resulted in the cut spinach needing to stay outside for multiple weeks to dry thoroughly. Saprophytic fungi, appreciating the moist weather, began to accumulate on the plant tissue and the corky pericarp of the spinach seeds. Lindsey explained that, while these fungi will generally not harm seed germination, they have the potential to make assays for Fusarium,

Cutting spinach prior to seed harvest.

Verticillium, and other pathogenic fungi very difficult. Once the rains ceased and all the spinach was cut, we ran each of the 60 samples through a plot thresher. This involved two long afternoons (dew prevented us from threshing in the morning) of hot, dirty work, made even dirtier by the clouds of black spores (from the saprophytic fungi) emerging from the thresher. Each large pile of spinach was reduced to one or two grocery-store-sized paper bags of seed and small debris. Now the work of seed cleaning began. All samples were run through a large clipper, with two sieve plates. The first plate let anything spinach seed-sized or smaller through, while removing large debris. The second plate sifted out dust and small debris. Next, each bag was cleaned using a draper, which is a large sheet of canvas tilted backwards. The canvas moves upwards, and if the seed is poured onto this moving surface at a slow but steady rate the round, heavy seeds will roll downwards off of the canvas into a box for collection, while light and flat debris will be carried up and over the top of the draper. After draping, we ran the spinach seed through a smaller clipper, which removed even more of the debris. The large bags initially brought in from the field had been reduced in size to a small bag containing nearly 100% seed. The seed was weighed for each sample. I left the research station to return to WWU shortly after the seed cleaning had been completed, so was unable to participate in the steps that came next, including germination and health assays (to determine seed viability and the prevalence of pathogenic fungi) for each sample.



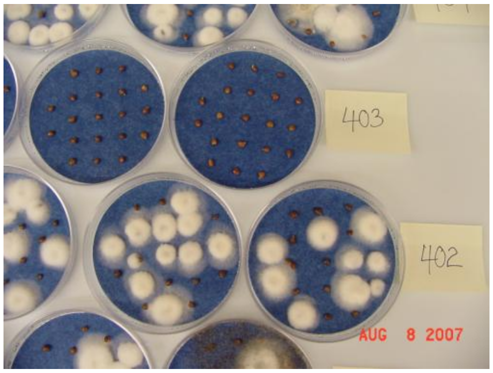
Spinach seed germination assay.

Radishes

Radishes are, like spinach, widely grown as a seed crop in Washington State, which is the source of a large portion of the radish seed supply both nationally and internationally. *Fusarium oxysporum*, which causes Fusarium wilt of spinach, also causes a wilting disease in radishes. The pathovar is known as *F. oxysporum* f. sp. *raphani*. *Verticillium dahliae* also causes disease in radishes (3). Dr. du Toit's lab has worked on these pathogens in radish seed crops through the use of greenhouse trials. When I came to visit the research station in the winter of 2007, prior to beginning my summer internship, I saw the towering radish plants of the most recent trial blooming in the greenhouse. The pathogenicities of several isolates of Fusarium and Verticillium from radish crops were being assayed. Dr. du Toit's lab was the first to report the presence of *F. oxysporum* f. sp. *raphani* in the state of Washington. This was based on samples isolated from a valuable radish stock seed crop in the Columbia basin that was lost to disease, and several of these isolates were used in the pathogenicity test (3).

Radishes from Fusarium/Verticillium trial

When I began the internship, the plants in the greenhouse had already produced seed and died. Louise and I spent a day preparing moist chambers with the dead roots and stems of plants from the trial. The chambers consisted of a plastic box with a moist paper towel laid at the bottom. Kept at room temperature, this humid chamber would provide the ideal environment for the growth of fungi within the vascular tissue of the plants, so it could be examined under a dissecting scope. We sterilized the outer surface of the roots and stems using a dilute bleach solution to eliminate any saprophytes present on the dead radishes, and then cut the roots and stems in half lengthwise to expose the vascular tissue and cortex. The progress the fungi had made up the vascular tissue was to be assayed, and seed health assays were also done for this trial to determine the likelihood of seed transmission of the pathogens. Characterizing new pathogenic fungal strains from the field is an important part of vegetable seed pathology.



Radish seed health assay showing healthy and *Verticillium dahliae*-infected seeds

Carrots

Two different diseases of carrots were being studied at the research station during my internship. One was a fungal disease, powdery mildew. The other was a bacterial blight disease, caused by *Xanthomonas campestris* pv. *carotae*. Another WWU student, Alyse, who was working primarily at WWU with Dr. Brodhagen, was heavily involved in the bacterial blight project, which was based on developing molecular techniques able to distinguish living Xanthomonas cells from those killed by pesticide treatments. Located across the Cascades in Quincy, Washington ("Opportunities Unlimited!"), I had only three opportunities over the summer to participate in work on the powdery mildew trial, which dealt with the effects of time of onset and severity of symptoms of powdery mildew on a carrot seed crop. Powdery mildew is aptly named; its signs on the plant resemble a light dusting of white powder. Fungicides are available to control powdery mildew, but can be expensive to farmers. Research that sheds light on when fungicides are necessary or unnecessary to prevent crop loss is very important- it can save farmers money and prevent the introduction of unneeded pesticides to the environment. Different plots were inoculated at different times with powdery mildew-infected carrot


Carrot umbel showing powdery mildew signs.

plants brought from the research station. I was able to assist with this task. The infected plants were planted inside each plot to be inoculated; because powdery mildew spores spread readily by wind the whole plot would soon become infected. Other plots were sprayed with a fungicide that is highly effective at preventing the disease.

Carrot seed crops are, visually, very unlike their counterparts grown for harvest of the root vegetable. Because they are biennial, they require a period of growth followed by vernalization before they will flower and produce seed. The large flower clusters that produce the spiny seeds are called umbels, and the plants in this trial reached heights of 4-5 feet. The king umbel matures first, followed by a continuous progression of secondary umbels. A late seed harvest would result in more mature secondary umbels but a potential loss of king umbels, whereas an early harvest would exclude much seed from the still-green secondary umbels.

My third trip to the Columbia basin was centered on the harvest of the carrot seed crop. Lindsey, her boyfriend Bob (a farmer able to drive, and repair, the plot thresher), Kerri, and I left the temperate air of Mount Vernon for the heat of Quincy. Using a plot thresher, we harvested all of the plots in a single day. It was hot, dirty work, and the fine hairs coating the carrot seeds covered us in an itchy, dry layer of dust. I made sure the seeds weren't clogging the spout on the thresher, moved the bags after each plot was completed, and removed debris from the path of Lindsey and Kerri after each pass of the thresher. Kerri and Lindsey were doing the hardest part of the work, using pitchforks to guide the rows of carrot plants into the thresher. As with the spinach, the harvest of the seed was not the end of the work. Each large bag needed to be dried, weighed, and thoroughly cleaned before the germination and health assays could be run. I spent much of my last week or two at the station cleaning carrot seed.

Harvesting carrot seeds with a plot thresher.

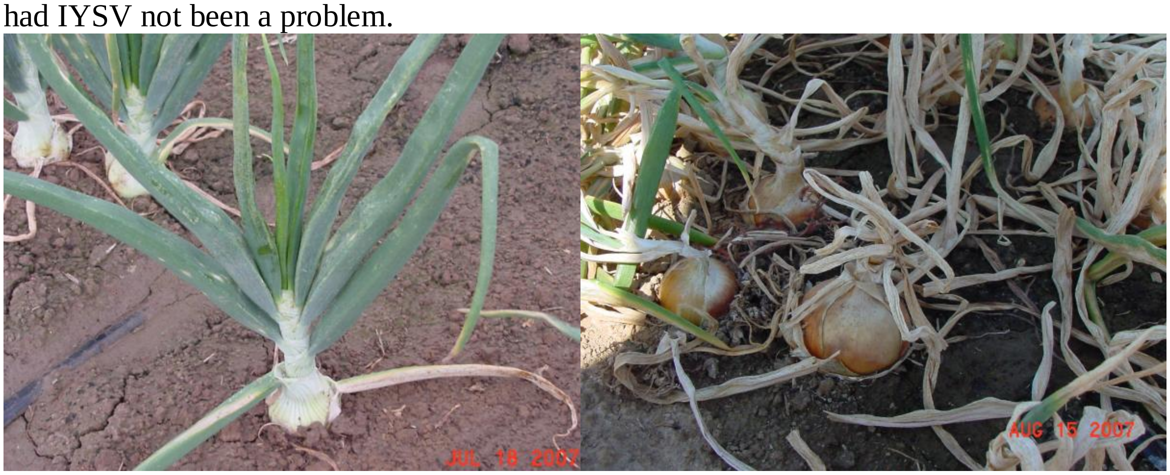
Onions

Vegetable seed pathology deals with many complex plant pathogens. In addition to bacteria and fungi, viruses may also be pathogenic. Iris yellow spot virus causes disease in a number of plant species, and Dr. du Toit's lab has been researching its impact on onion seed and bulb crops. Iris yellow spot virus (IYSV) causes characteristic diamond-shaped lesions with a necrotic border, potentially leading to extensive tissue death and reduced bulb size. In the case of onions grown for seed, lesions on the scape can cause lodging. This cuts off the supply of

IYSV onion bulb crop trial. Differences in disease severity are seen between two onion varieties.

nutrients to the developing seeds, resulting in smaller, less viable seeds that are difficult to harvest. IYSV is spread by thrips, tiny insects with piercing mouthparts that feed on plant fluids. I was able to see the lodging caused by IYSV in an onion seed crop grown by a farmer fairly close to the research station. It appeared that IYSV had spread to his crop via a thrips infestation from a nearby tulip field. In a seed crop, determining the source of an IYSV infection can be a difficult task. Like carrots, onions are a biennial crop. The viruliferous thrips causing an infection may come from a nearby host crop, or, if the vernalized bulbs are produced on a different farm, the infection could be spread by IYSV-carrying thrips residing on the bulbs or from infected tissue in the bulbs themselves. Dr. du Toit published the first report of IYSV in South Africa, and the four seed crops found to exhibit IYSV symptoms had all been grown from bulbs originating at a single farm (2).

Quincy, Washington was also the site of an iris yellow spot virus trial, which was located as a small segment within a large field of onions being grown as a bulb crop. The focus was a chemical known to induce a defensive response in plants, with the potential to slow the onset of virus infection symptoms or reduce their severity. The efficacy of different application times and amounts of this expensive chemical was being examined. I went on a few trips east of the Cascades to help record data for this trial. A rating system was devised to describe the severity of disease symptoms, ranging from 0 to 5. Towards the end of the summer, a rating category of 6 had to be added for plants that had no green tissue left due to the disease. Lindsey also rated the severity of thrips infestation on individual onion plants by pulling back the leaves and counting the number of thrips present. Throughout the summer it was fascinating to see the changes in the onion field. The directionality of the infestation was apparent, the severity of symptoms corresponding to the movement of thrips across the field. My first trip was to a green field, with most plants scoring a 0 or 1 on the rating scale. By the end of the summer, the disease severity had increased, and most plants were scoring a 4-6. I had to return to Western before the bulb crop was harvested. Undoubtedly, the bulbs in the field had not reached the size they would have been able to attain had IYSV not been a problem.



Disease severity rating “1” displaying a few diamond-shaped IYSV lesions (left), compared to a rating of “6” (right).

Other Projects at WSU NWREC

My internship at the research station required me to work on many routine tasks such as washing or sterilizing lab dishes and greenhouse supplies, cleaning vehicles after muddy, dusty drives, and cleaning the laboratory space or greenhouse bays after completion of a project. While dishwashing may not seem to have given me insight into science, I learned to appreciate such tasks because they are as much a necessary part of a research project as rating disease severity or cleaning seed. Scientific research- especially agricultural research, with its abundance of mud and rotted plant products- is messy. Behind every paper published in a journal undoubtedly stands the many hours of labor involved in washing glassware and sweeping lab floors.

Although I worked for Dr. du Toit and the Vegetable Seed Pathology program for the majority of the summer, occasionally another program would require additional help with one of its projects. WSU's Mount Vernon Research and Extension center has programs focusing on fruit horticulture, small fruit horticulture, vegetable horticulture, weed science, and vegetable pathology (in addition to vegetable seed pathology). I helped push raspberry canes into supporting wires, picked blueberries, weighed watermelons, fed cabbage seedlings into a mechanical transplanter, and potted strawberry plants from cold storage. I also was able to help with a few tasks for a potato trial investigating the onset of silver scurf (a fungal disease) in stored tubers of several potato varieties. This included harvesting potato samples to be washed and stored, and removing clods of soil and non-tuber plant material on a mechanical potato digger, which was used to remove the end rows of the trial in order to prevent volunteer potatoes from being problematic the following year. These were wonderful opportunities to learn about the other research being conducted at the station, and to get some hands-on experience with a wide variety of crops and experimental set-ups.

Personal Response

It is difficult to write a concise summary of the knowledge I gained while working at the research station. How can I describe the subtleties involved in pouring spinach seed onto the draper at just the right rate, the appearance of *Verticillium dahliae* microsclerotia under a dissecting scope, or even begin to summarize all the information I absorbed from overheard conversations and direct observation? Working at an agricultural research station as a full-time employee for 12 weeks is an experience that undoubtedly taught me more about vegetable seed pathology and agricultural research than 12 weeks of studying from textbooks would have. My three years at WWU have provided me with lots of knowledge just waiting to be applied; this internship was my first real opportunity to see more than just a glimpse of science in action.

Aerial photo of IYSV-infected onion seed crop.

My internship changed the way I think about science and how research is applied within and beyond the scientific community. Although I had some prior interest in plant pathology, I had never been exposed to the field of vegetable seed pathology. I did not know of the importance of Western Washington in vegetable seed production. My journeys along roads in rural areas became much more interesting over the summer as I learned what different seed crops look like. Many appear much different when flowering or bearing seed than their offspring, when grown as vegetable crops, will appear, and prior to this internship I would not have been able to identify them. There are a wide range of factors that must be taken into account when researching seed crops that might not be an issue with vegetable crops. Many plants require a period of vernalization (overwintering) in order to produce seed. How and where roots or bulbs are stored over winter can impact disease presence and progress, and overall growth of the crop. For example, in the case of the carrot powdery mildew trial, one edge of the trial area had a higher incidence of carrots killed by harsh winter conditions. Also, seed crops are often in the soil for a much longer period of time than vegetable crops, and time is the fourth corner of the disease pyramid. Healthy vegetable seeds are the essential starting point for healthy vegetable crops. Growers are held to extremely high standards of seed cleanliness and health. I also learned about the difference between stock seed, or the seeds used to grow the parental lines of a hybrid seed crop, and the hybrid seed which is then used in vegetable production. The many concerns unique to vegetable seed pathology make it distinct from other plant pathology fields.

Another important aspect of agricultural research which I learned about over the summer is that research must be relevant to the specific needs of farmers and must take into account not only biological but also economic considerations. The cost of a particular pesticide or soil amendment may be so high that any potential benefits from its use are negated, economically speaking. While a study may require costly methods that might not be practical for a farmer, such as the very high rates of lime applied in the spinach trial, this is something that needs to be considered in experimental design. I also gained a glimpse this summer into just how economically devastating to a farmer plant disease can be. Vegetable seed crops are often grown by farmers who do not own the crop- they are contracted by seed companies, and the seed companies determine what variety is to be grown. Some varieties are highly susceptible to disease, and even a small reduction in yield per acre, when multiplied over many acres, can mean thousands of dollars lost. When bogged down trying to memorize metabolic pathways or genetic principles for my classes at WWU, it is very easy to think of Biology as an insulated bubble and lose track of its relevance to all human endeavors. This internship helped me appreciate the necessity of agricultural research to all professions centered on agriculture.

Surveying suspected chemical damage of an onion crop in Eastern Washington.

Although I have taken many lab classes at WWU, it is hard to get a sense from these courses alone of just how detailed, involved, and precise data collection and experimental techniques must be in scientific research. During trials at the research station, any action taken in one particular plot within a replication (such as counting or cleaning) had to also take place in the other plots, so that the whole replication was treated in the same way. For example, if Leigh Ann and I were doing the stand/wilt counts in a spinach replication, we would need to finish the entire replication. Another team could not do the counts for part of it. Or if seed from a trial were to be harvested over a span of several days, the harvest of an entire replication would need to be finished on a single day. I am now much more conscious of the need to have a single person perform each task in my lab courses.

Another major concept in research I was exposed to over the summer is experimental design. Every trial I worked on contained multiple replications of the same set of treatments. For example, each lime amendment trial replicate contained five plots with the same five rates of lime applied. This is important for the statistical validity of the results, and in the case of a mistake or some event that would cause an abnormality in only one of the replications, that replication can be discarded and valid data can still be obtained. The randomization of trials is also important. For example, in the spinach trial, all of the plots from each replicate with low rates of lime were not concentrated at one end of the field. Controls were also used in each experiment, as the effects of, say, the act of inoculating a radish seedling with *Verticillium* could cause symptoms in the plant unrelated to the presence of the pathogen. Seedlings would also have to be subjected to the same procedure with a sterile solution to confirm that observed results are due to disease and not other factors. I will hopefully have many opportunities in the future to apply this knowledge.

There are many difficulties in agricultural research. Confounding factors in an experiment may include variations in soil chemistry, moisture, or physical composition across a field. Randomized plots can help control for some of this variability. Also, many phenomena do not occur evenly across an entire field, such as thrips infestation or winter kill. The plants themselves may also show a very high degree of variability in their morphology, disease resistance, or other properties. Additionally, rating scales must be developed to quantitatively assess phenomena which do not occur in discrete units. An example is the rating scale used in the IYSV bulb trial, which put a numerical value on the overall appearance of plants (amount of dead tissue and presence of characteristic spots). Learning about these difficulties has been very beneficial to my understanding of scientific research in general. Previously, I had no experience by which to evaluate the methods used in data collection in the scientific papers I read. Now I read the “Methods” section with much more scrutiny. I have a better understanding of how the authors actually carried out their study and the difficulties they may have faced when designing the experiment.

Perhaps the most important message I took home from my experiences over the summer is that a single scientific study requires immense quantities of time and labor. College courses cannot adequately explain the time dimension behind a scientific paper. Dr. du Toit told me about her years of graduate study, and how working hard in the field or in the lab, day after day, had given her a better perspective from which to work. The hours spent planning, tilling, planting, cleaning, weeding, dissecting, counting, plating, pouring, harvesting, weighing, and analyzing add up. Research experiments may span weeks, months, or years. I will never read a scientific paper quite the same way as before, having participated in the process of scientific research. Time is required to produce accurate data, and the insights a good study can provide are well worth it.

While interning at the research station and gaining experience working in a biological field, I was able to reflect on where I would like my education at WWU to take me after graduation. Biology encompasses a broad range of fields, and I’ve found it difficult to narrow my focus down to a specific interest to pursue as a future career or area of graduate study. My undergraduate education has been a very valuable chance to take a wide variety of Biology classes and learn about a broad range of subjects. Vegetable seed pathology was a research field with which I was not familiar prior to my internship, and seeing the kind of dynamic, exciting work environment and important research taking place at WSU's NWREC made me realize that I am not ready to narrow down my career path just yet. After talking to Dr. du Toit and the other employees at the station, and realizing how much this internship has taught me, I decided that after graduating in the spring of 2008, I will take a few years off of school. This will be a time for me to gain more work experience in Biology and broaden my horizons before I enter graduate school. I would like to pursue graduate studies in some field that eventually leads to work in agricultural research. I have always found plant biology fascinating, and this area of science provides so many opportunities to ask- and begin to answer- questions that have the potential to help resolve environmental problems, as well as improving production of food, fiber, fuel, and other agricultural products. A good base of work experience in the field will help me enter graduate school with a deeper perspective on the purpose and value of my education. I am thankful to have been able to work at WSU's NWREC as an intern this summer, and undoubtedly the knowledge I gained while employed there will prove invaluable to my future work and educational pursuits.

Susceptible female spinach plant- dried and ready to be cut.

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Photographs are courtesy of Dr. Lindsey du Toit.