A Growers Guide to Quality Potato Seed

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I dedicate this to those in my life that have helped me along the way. Thank you to my family for believing in me and pushing me to accomplish this goal. Mom and Dad, you are the reason I am driven to do and accomplish so much with my life. You gave me work ethic, confidence and most importantly, support when I needed it. Bob and Sal, thank you for your support and casseroles that seemed to end up in our fridge when Sam and I were too busy to cook meals. Finally, thank you to the biggest supporter, my Sammy. Thank you for understanding the late nights and often, little time spent together during this journey. I am grateful that I had you there by my side the entire time.

WE did it!
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I would like to thank all those that helped me through this project, it took an army and I am so grateful for each mentorship that I received. I would like to thank Wade Rehberg for mentoring me and giving me confidence to pursue this topic. Thank you to Nick Johnson for entertaining talks about potato seed and production issues for hours on end, this information really helped me go full circle with my research. Thank you to Ed Schneider of Elite Seed for letting me tour your seed cutting plant and teaching me about the process. Dan Lake, Steve Striech and Bill Skinner, thank you for answering the massive list of questions I came to you with, a seed producers’ side of the story became an important aspect of this paper and I am glad I was able to connect with you all.
Unlike traditional true seed, potato seed is a vegetatively propagated crop. A potato tuber can be uncut (single drop), cut once, twice or in some cases, three times. These seed pieces are then treated with some fungicide or pesticide, covered in a protective coating and planted into the ground. Starting with a healthy mother plant that produces daughter tubers for cutting is important because those characteristics exhibited in the mother plant will also be exhibited within the daughter tubers. For this reason there are many factors that should go into choosing the right quality of seed to utilize for commercial production. After some research, four main characteristics that affect the quality of potato seed have been determined: physiological age, seed genetics, size and seed health. These four characteristics can have a substantial effect on the vigor, health and overall outcome of a crop. These characteristics should be considered when purchasing seed to ensure growers are buying high-quality seed. Purchasing certified seed plays a large role in the seed health aspect and there will be a brief discussion on seed certification programs. The intent of this manual is to describe the importance of potato seed quality, explore the process of potato seed production from the seed grower to the commercial grower, and to define the characteristics of high-quality potato seed.
CHAPTER I

Introduction

Seed is the most important part of the production cycle of many crops, including potatoes. Seed determines important factors such as yield, quality and overall crop health. Starting with good-quality seed is the first step to a successful crop year. Seed is a large part of the input costs for a crop. According to the USDA commodity costs and returns data, the cost of corn seed in 1995 was $23.98 per acre and in 2018 it was $96.29 per acre, which is a 301% increase in 23 years ("USDA ERS - Commodity Costs and Returns", 2019). Potato seed totals up to about 11% of total input costs for a commercial potato field, only second to fertilizer (Belyea et al., 2010).

For potatoes, Washington, Idaho, Oregon and Montana grew a combined total of 46,151 seed acres in 2018 (Houser, 2019). These acres are grown in regions where commercial potato production is not present and disease pressure is low. This is done so that the disease pressure and pest pressure in commercial potato areas are not transferred to the seed. Even with these precautions, it is still important to know what quality of seed being purchased.

Although quality of seed is an important factor to consider, another important factor to understand is potato seed is different in structure from corn, wheat and alfalfa. This is due to the fact that a potato plant is propagated from a tuber, meaning that a potato is cut into pieces and these pieces are utilized as the seed. Because of this vegetative propagation process, potato seed will reflect the characteristics of the mother
plant, which ensures that traits are passed down clonally from generation to generation (Belyea et al., 2010). The average yield increase that a grower can see in a potato crop from high-quality seed is 30-50% compared to low quality seed (Wang, 2008). The overall purpose of this manual is to highlight the reasoning behind these important factors and how they can affect the commercial potato crop.
Chapter 2

Potato Seed Quality

Seed quality affects every aspect of growing a crop, so seed is the foundation of the agriculture industry. Seed quality is defined as the potential performance of a seed or seed lot ("Seed and Seed Quality | NC State Extension Publications", 1991). Seed quality depends on the requirements of the end user, but the most universal quality standard is the germination test (Matthews et al., 2012). Typically seed quality is measured by the following quality characteristics: analytical purity, other seed (seed types other than what is being certified), germination, moisture content, varietal purity, seed health, seed size, vigor and uniformity (Bewley et al., 2006). These characteristics help seed labs determine the quality of a seed lot. Potato seed is also assessed for quality characteristics. The quality of potato seed is measured in a few different ways due to the structure of potato seed.

Potatoes are vegetatively propagated. This means that a tuber is planted as a seed, rather than a true seed like most vegetable crops (Belyea et al., 2010). In contrast to a true seed, potato seed goes a different certification processes due to the nature of the seed. The state certification agencies’ primary purpose is to provide assurances that seed stocks have varietal purity and are relatively free of disease causing organisms (Belyea et al., 2010).

High-quality seed, which is most likely certified, will have low levels of disease and pest infestations. As a result, growers will not need to apply as many pesticide
sprays, which saves passes across the field, man hours, tractor hours and chemical costs that accompany each application. One example of the economic impact of seed quality is for alfalfa hay. If non-certified seed were purchased and planted for the export hay market, presence of any plant matter other than alfalfa in the bales could lead to price discounts when the hay is sold. Certified seed with minimal amounts of weed seed is important here because the end user requires the hay to be below a certain percentage of weeds. On the other hand, if a grower produces hay for his own dairy, he might not necessarily need certified seed, but nevertheless might want to consider the benefits of buying to maximize yield. Benefits from using quality seed include less disease and insect contamination, high vigor, high and predictable yield, genetic trueness to type, rapid emergence, uniform stands, and uniform timing of maturity.

Seed quality is an important factor in most agriculture operations. The quality of seed that is purchased will set the stage for the remainder of the growing season, but not all seeds are created equal. As discussed, potato seed is vegetatively propagated, so the need for health seed is very important because those health characteristics will be transferred to the next generation. Ensuring that quality seed is purchased in the beginning is one of the best decisions a farmer can make.
The beginning: Potato seed

Healthy potato seed starts with a healthy mother plant. This is achieved through optimization of in vivo conditions, which are natural conditions, or in vitro conditions, which are in a sterile laboratory (Struik and Wiersema, 2012). The in vivo process requires breeders to repeatedly propagate potatoes in the field, starting with plants that are free of pathogens and true to their variety. This system is called clonal selection (Struik and Wiersema, 2012). In vivo produced tubers have a higher chance of containing pathogens harmful to seed stock; therefore, an in vitro approach is commonly used to ensure quality as well as speed up the lengthy process. The in vitro process requires multiplying the disease-free plants in a sterile environment via nodal cuttings, which are stem pieces with one axial bud and one leaf or with microtubers, which are small tubers produced in laboratory conditions (Belyea et al., 2010). Nodal cuttings are used in instances where high volumes are needed in a short amount of time and microtubers are produced using plantlets that typically produce only a single tuber (Belyea et al., 2010). During the time that the plantlet is growing in the lab, it is extensively tested for many pathogens. Once the lab has produced the number of plantlets needed to increase seed stock, the cultivar is further multiplied in a controlled field area until the G3 stage. The G3 Stage can mean different stages of the production
cycle depending on which state it is produced. In Idaho, Washington and Montana, G3 means that the potato has been reproduced for four years (Belyea et al., 2010).

**Field production of potato seed**

Field production of potato seed is done in hills or ridges, just as for conventional production ("The potato: Cultivation - International Year of the Potato 2008", 2008). A hill of soil is formed during planting in order to prevent the daughter tubers from poking out of the ground and greening. When a potato turns green, it is the result of sun exposure or heat ("Green Potatoes: The Problem", 2019). The field will go through an entire growing season with irrigation, disease management, and pest management monitored closely. The seed grower will let the crop go until physiological maturity, when it will either senesce naturally or be sprayed with defoliant. The manner in which this is done can impact physiological age of the tubers at harvest, which will be discussed later. The first step to harvesting the tubers is skin set. Skin set is the development of the periderm that protects the tuber from moisture loss and diseases (Nolte and Olsen, 2019). Once the skin is set, the potato will be harvested and stored until next year. The next year the seed grower will plant the seed lots from the previous year to increase their tuber count and start the next year of seed production. Most of our growers purchase G3 seed, which means it has been multiplied for four years, including the time in the lab.
In the Potato Association of America Handbook, a table clarifies the field planting equivalency of seed grown in different states or countries.

![Field planting equivalency table](image)

**Figure 1:** *Field planting equivalency table* (Belyea et al., 2010)
Although each seed-potato-producing state has different classifications for the age of seed stock, Idaho, Washington and Montana all have the same classifications. Physiological age is important because it can help a grower determine what kind of quality they will see in the field. This is helpful to our local growers because they purchase seed primarily from these four states. The seed generation is determined by the number of years that a plant has been multiplied. Year 1, which is referred to as N is the year in the greenhouse. Each year after that is G2, G3, G4, etc. for seed produced in Montana, Idaho and Washington. During each year of this process, potato seed is tested to prove its health, and grow outs are conducted to ensure true to type seed is being reproduced.

Potato seed is grown mostly in regions where there is little commercial potato production. This is done for several reasons, but mainly to keep the seed away from common diseases and pests that commercial production experiences. States that produce potato seed follow somewhat similar certification processes. Despite minor variations among states, most states apply basically uniform standards and approaches that had led to quality seed available for commercial growers to purchase (Belyea et al., 2010).

**Destination: Commercial production**

Most of the growers typically use a potato seed broker to secure their seed. They let the broker know how much seed they need and how much they plan on planting so that the broker can find a source for them. Once a source is found, the potato seeds are
shipped by truck to the seed cutting storage shed where it is stored under humidity and temperature controlled conditions, until it is needed. The seed is kept divided by seed lot and variety, so that the seed can be traced if any issues arise. The ability to track the origination of seed can help a grower determine a root cause if there are any issues in the field. If the issues can be traced back to the seed lot, it is important that the seed lots were kept separate and planted separate for these purposes. Next, the growers will order seed from the seed cutting facility when they are ready to start planting. When this seed is ordered, it is conveyed to the building where sizing tables and knives cut the seed.

Potato seed is produced from a tuber that is cut into 1, 2 or 3 different pieces. Preferably, a grower would want their seed to be single drop or 1-2 cuts because each cut exposes potato matter to diseases and pests (Belyea et al., 2010). Limiting the number of these cuts per tuber can limit the exposure to these outside threats, which in turn gives the seed piece a better chance at thriving. Seed that is larger is cut multiple times and seed that is smaller is cut once or not at all (single drop). Each piece should have 2 to 3 “eyes”, which are the little notches in the potato where a sprout will grow (Belyea et al., 2010). Different varieties have varying numbers of eyes per potato, so knife set ups can vary
between varieties to ensure the seed is being cut in an efficient manner. After the cutting process, the seed pieces go on to a conveyor that leads to a bar of spray nozzles that applies a pesticide/fungicide combination, then to a barrel that coats the seed in alder bark. The alder bark acts as a shield from pest and disease while the seed piece “heals” the skin on the cut side. The seed is then loaded onto trucks and sent to a field or sent to storage for several weeks until needed.

When the seed is sent to the field it is loaded into a planter and planted into a prepared seedbed. This seedbed contains two bands of fertilizer to give nutrients to the seed. The planter has cups that use air to grab the seed, it is dropped into the “shoe” and simultaneously disks around that dropped seed form the hill once the potato is put into the ground. This is the final destination for the potato seed.

![Planting Potatoes](Image)
CHAPTER 4

Characteristics of Quality Potato Seed

Four key characteristics have a major impact on the harvest quality of a potato field: physiological age, seed genetics, size and seed health. Physiological age refers to the physiological condition of the seed tuber, which is directly related to its production capacity (Struik, 2007). Seed genetics is closely related to physiological age, refers to the traits from the mother plant inherited by the seed tuber. The size of the seed tuber is determined by growing and cutting operations and potato seed health is determined by state seed certifying agencies and primarily derives from the seed growers’ processes and farm location.

Physiological Age & Genetics

Physiological age is defined as the developmental state of a potato seed tuber. (Struik, 2007). The Physiological age affects the number of stems produced by the seed tuber, which relates directly to the size distribution of the harvestable crop, the time before emergence and tuber set (Nepal et al., 2016). Older generations of seed pieces produce more stems, which in turn produces more tubers. Most of my growers use a G3 seed (see figure 1), which would be tubers that have reproduced for four years. Physiological age is likely to be the most important aspect of a quality seed lot.

Physiological age affects apical dominance and the number of stems produced per plant or seed tuber (Knowles and Knowles, 2015). This means that the potato goes
through different stages as it ages, and each stage can correlate with how vigorous the plant will be. Dormancy is a stage during which no sprouts emerge. Apical dominance is the next stage; this stage yields only one sprout per tuber. The next stage is normal or advanced sprouting, at which the tuber produces many sprouts per tuber (see figure 2). After this sprouting stage, the quality of seed goes down. The next stage is senility where the tuber has many sprouts, but the sprouts are very weak, and the final stage is incubation where the tuber sprouts little tubers and the quality is very poor (Struik, 2007).

![Figure 2: Potato eyes. (Photo courtesy of Emily Merk)](image)

The physiological age of the seed progresses chronologically, but there are many factors that play into how mature the seed is, including size, timing and method of the kill down of the plants, conditions in the field and in storage, and any possible treatments.
that may have had an impact on the tubers (Struik, 2007). Even with tubers coming from the same stem, there can still be some physiological variation between the tubers (Struik and Wiersema, 2012). Several of the characteristics that potato exhibit are based upon the environment in which the potato is grown (Struik and Wiersema, 2012). If the plant is stressed in any way from temperature or water stress, it might exhibit undesirable characteristics that a non-stressed plant might not express. Though there are several factors that accelerate physiological age, the most important of these factors is the temperature at which potato seeds are stored (Belyea et al., 2010). In a study conducted with Ranger Russets and Russet Burbanks, it was found that seed aged physiologically when stored at high temperatures. This aged seed produced more stems per plant but also progresses towards a smaller size profile due to high stem counts (Nepal et al., 2016).

Storage temperatures above 40º F will promote premature sprouting and storage temperatures below 37º F will increase respiration and age the seed. Ideal storage temperatures for seed are 38ºF to 40ºF (Belyea et al., 2010).

The physiological age of the seed plays a large role in the potato plant’s ability to grow and thrive but seed genetics also important. Physiological age and genetics go hand in hand because of the relationship they both have to plant vigor. The potato, a vegetative, propagated crop, is subject to genetic degeneration due to a decrease in health status from virus concentration (Struik and Wiersema, 2012). This means that viruses can be easily transferred from generation to generation because of propagation.
Starting with a healthy mother plant is possibly the most important step in potato seed production.

Potato Seed growers have different ways of getting seed stock, Montana for example has an excellent program. The state seed certification program is a voluntary program where all seed flows through Montana State University so that the University’s laboratory can verify that the tubers are disease- and pest-free before they reach commercial seed growers. This is in an effort to encourage the production of top quality potato seed ("2019 Garden Seed Directory - potato seed Certification Program | Montana State University", 2019). They have very strict rules about this process and pride themselves on being able to deliver the highest quality because they start with early generation seed that requires rigorous testing to prove it is of high quality. Purchasing certified seed is one way to ensure that the genetic package of the potato seed is of high quality.

Having a strong relationship with the seed grower and knowledge of their practices can also help a grower determine the quality of the seed coming from that specific seed grower. Through purchase of seed that is in the normal or advanced sprouting stage, which has different names depending on state, and minimally stressed, the grower has a higher chance of having a successful growing season.
Size

Seed size plays an important role in potato growth because the seed piece is the energy source for the growing plant until it reaches the surface of the soil and can produce its own energy. The size of the seed piece is a significant quality factor because the bigger the tuber is, the more eyes it can possible have (Struik and Wiersema, 2012). Ideally, the seed piece should be approximately 1.3 to 3.0 oz (Belyea et al., 2010). Each seed piece should have several “eyes”. The eyes produce stems that shoot to the soil surface, and from each stem tiny hairs underground grow that eventually turn into shoots that swell with a tuber. potato seed plants with many stems it will produce many tubers, but overall the size will be smaller than from seed pieces with fewer stems. The amount of space in the seed field hill also has an impact on size, as well as the total canopy cover.

Figure 5: Cut potato seed. (Photo courtesy of Emily Merk)
and the ability of the plant to photosynthesize (Bohl et al., 2011). The size of the tuber can be manipulated during the growing seasons, but seed piece size can also be adjusted during seed cutting.

During the seed cutting, as previously mentioned, the potatoes can be cut once, twice, three times or not at all. Most growers prefer uncut seed pieces (i.e., small, intact tubers) because of reduced wounding and thereby less exposure to outside threats (E. Schneider, personal communication, interview, 2018). Seed tubers that are large require many cuts and can be less productive due to uneven eye distribution over the tuber (Belyea et al., 2010).

It is important to do inspections in the seed cutting facility to determine that the seed pieces being cut have good eye distribution. The eye distribution can vary by variety. Varieties such as the Russet Burbank or Umatilla Russet have many eyes while a Shepody variety can have very little in comparison. This is an important determination because the number of eyes per seed piece affects the plant vigor, which in turn affects the plant emergence in a field (Struik and Wiersema, 2012). If a variety has low eye count, the seed pieces might tend to be larger in an effort to obtain enough eyes for proper plant growth (E. Schneider, personal communication, interview, 2018).
Seed Health

The health of a seed depends on the absence or presence of pathogens, which are disease-causing organisms (Bewley et al., 2006). One way to ensure that the seed being purchased is of good health is to buy certified seed. It is important to understand that certified seed can still contain small amounts of disease. That being said, growers who utilize certified seed could see a 30-50% increase in yields as opposed to self-saved seed (Wang, 2008).

Certified seed is inspected in the field, in storage and at the shipping points (Belyea et al., 2010). During these inspections the potato seed is tested for viruses and assessed for varietal purity. Varietal purity is determined by visual inspections, according to tolerances based on state regulations. Each state has seed classes with tolerances set forth by the certifying agencies. The seed is sold as certified seed if it is below these tolerances. If it does not meet these tolerances, the grower has the option to sell the seed on the fresh market. All the information gathered during the inspection process is included with seed information so that the grower is aware of the overall health of the seed lot. Buying certified seed helps reduce the chance that the issues will be found in a field that are seed borne.

When there is an issue in a field, it is important to understand whether the infection in a field is primary or secondary. Primary infection would be an infection attained in the current growing season, whereas secondary infection would be infection obtained from already infected seed tubers (Struik and Wiersema, 2012). Some examples
of situations in which primary infection often occurs include fields with high aphid counts, heavy infestations of late blight (caused by the Oomycete *Phytophthora infestans*) or early blight (caused by the fungus *Alternaria solani*). Secondary infections can include viruses, bacteria, fungi and nematodes (Struik and Wiersema, 2012). Determining whether the issue came from the seed or the field is the first step to figuring out what happened in a field that is diseased.

Certifying agencies might publish their findings in a seed lot book that is distributed to commercial growers. This book includes all seed growers that have gone through the certification and what the disease level of each lot. This information is also available upon request from the seed grower before seed is sold. When a grower knows what kind of seed is being bought and what kind of disease to watch out for, the management of that seed lot is more efficient, therefore the health of a seed lot can be monitored and managed with the use of certified seed.
Seed quality is an important part of the Agriculture industry. As discussed, potato seed quality is important due to the fact that a potato seed is vegetatively propagated. The four characteristics of quality potato seed physiological age, seed genetics, size and seed health. The physiological age genetics and seed size all impact plant vigor and the health of the seed impacts the overall crop. Buying certified potato seed is the best way to ensure that the seed being purchased is of high quality and four characteristics should be considered when growers are looking to buy seed.
REFERENCES


Figure 2: Potato eyes. (Photo courtesy of Emily Merk)
Figure 3: Tuber shoots (Photo Courtesy of Emily Merk)

Figure 4: Seed cutting knives. (Photo courtesy of Emily Merk)
Figure 5: Cut potato seed. (Photo courtesy of Emily Merk)

Untreated seed  

Treated seed

Figure 6: Untreated cut seed vs. Treated cut seed. (Photo courtesy of Emily Merk)
Figure 7: Planting potatoes (photo courtesy of Nick Johnson)

Figure 8: Potato rosettes. (Photo courtesy of Emily Merk)
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Figure 10: Rows of potatoes. (Photo courtesy of Emily Merk)
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Figure 12: Potato field to row closure. (Photo courtesy of Emily Merk)
Figure 13: Potato field towards the end of the season. (Photo courtesy of Emily Merk)

Figure 14: A senescing potato field. (Photo courtesy of Emily Merk)