Chapter 4
Seed Potato Production and Certification

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Contents

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Introduction

Successful commercial potato production is highly dependent upon a consistent supply of quality seed. While the production and management of seed potatoes is very similar to commercial crop production, a major difference is that seed potato producers focus on the production of a crop that meets specific quality (purity and phytosanitary) standards. Seed production, therefore, can be considered a specialized sector of the potato industry. The vast majority of seed potatoes are produced within certification programs that define those quality standards, and most major potato production areas have laws requiring that commercial potato producers plant certified seed potatoes. This chapter will discuss seed potato production within the context of seed certification programs.

Seed Certification

Essentially, seed certification is a quality control program. Seed certification differs from private quality control programs in that it is an independent, third-party certification conducted by an official certification agency. Official certification agencies are designated by statute or regulation, and these same laws grant protection to the

terminology and indicia of official certification. Internationally, seed certification is conducted at the federal level. In the U.S., authority to conduct official seed certification resides at the state level and is conducted by state Departments of Agriculture, land-grant universities, and/or grower associations.

Regardless of the specific agency conducting certification, seed potato certification is a process that consists of the following basic elements:

1. Approved Planting Stocks Only documented planting stocks of known origin and that meet the required purity and phytosanitary standards are permitted for the production of certified seed.

2. Limited-Generation System Seed potato production is performed under a scheme in which the number of generations of greenhouse and field increase is limited. Limited-generation systems typically include a classification system based on disease levels and require a flush out of seed when disease tolerances or the maximum number of field generations has been exceeded (Table 4.1).

3. Inspections Seed potatoes are subject to inspection at all stages of production. The inspection regime will depend upon the stage of production and is performed on a visual basis according to prescribed methods. Visual inspections may be supplemented and/or confirmed by laboratory testing.

4. Post-Harvest Testing The harvested crop is subject to post-harvest testing for viruses and other factors. Post-harvest testing may consist of an off-season grow-out, laboratory testing, or some combination thereof.

5. Grade Inspection Seed potatoes are inspected at the shipping point to ensure conformity with defined seed potato grades. These grades are based on the U.S. No. 1 grade for seed potatoes.

Table 4.1 Seed potato generation sequence

Generation	Usual source material	Production facility
Pre-nuclear	In vitro plantlets	Laboratory
Nuclear	In vitro plantlets, micro-tubers, stem cuttings	Greenhouse
FG-1 (field generation 1)	Greenhouse mini-tubers	Early-generation seed producer
FG-2	Field-grown tubers	Early-generation seed producer
FG-3	Field-grown tubers	Certified seed producer
FG-4	Field-grown tubers	Certified seed producer
FG-5	Field-grown tubers	Certified seed producer
FG-6	Field-grown tubers	Certified seed producer
	Commercial potato production	

Seed Potato Production

Seed potato production consists of a series of sequential increases of approved planting stocks intended to provide the commercial potato industry with sufficient quantities of seed meeting appropriate disease tolerances and purity standards. This is accomplished through the combined efforts of public and private sources and involves laboratory, followed by greenhouse, and then field production. The terms pre-nuclear and nuclear are used to refer to laboratory and greenhouse stocks in some systems. This process may be vertically integrated and involve all stages of production from variety development to commercial production. More commonly, however, individual operations specialize in specific stages of production; e.g., laboratory and/or greenhouse production. Another common area of specialization is in the production of early-generation seed. In this case, a seed operation will perform one to two field increases before selling seed to another seed operation for further increase or to a commercial potato grower.

Introductory Materials

A basic requirement for the production of certified seed potatoes is that the planting stocks originate from pathogen-tested in vitro materials (Fig. 4.1a, b).

Thus, the first stage of production involves the introduction of parent material into tissue culture. This stage of production is performed in laboratories capable of maintaining aseptic conditions and requires the use of specialized equipment. The parent material, usually tubers, is surface-sterilized and used as a source of meristems or nodal cuttings for introduction into tissue culture. Once successfully established as in vitro material, the resultant plantlets are tested for pathogens specified in seed certification rules, typically potato viruses A, M, S, X, Y, potato latent virus, potato leafroll virus (PLRV), potato mop top virus (PMTV), potato spindle tuber viroid (PSTV), tobacco rattle virus (TRV), *Pectobacterium* spp., and *Clavibacter sepedonicus*. Tissue culture plantlets testing positive for any of these pathogens either are discarded or subjected to a combination of chemo- and thermotherapy for pathogen elimination. This cycle of testing and therapy is continued until the plantlets test free of the pathogens in question. Finally, greenhouse and/or field grow-outs are conducted to assess trueness to type and ensure that the in vitro plantlets retain the characteristics of the original parent material.

Tissue culture materials are subject to inspection and testing by the certification agency. The above-described pathogen testing is required every time any parent material is introduced into tissue culture. There is a zero-tolerance for the specified pathogens in tissue culture plantlets intended for certified seed potato production. Only when the tissue culture material tests negative for the pathogens prescribed in seed certification regulations and is approved by the certification agency, can it used for certified seed production in the greenhouse or field.

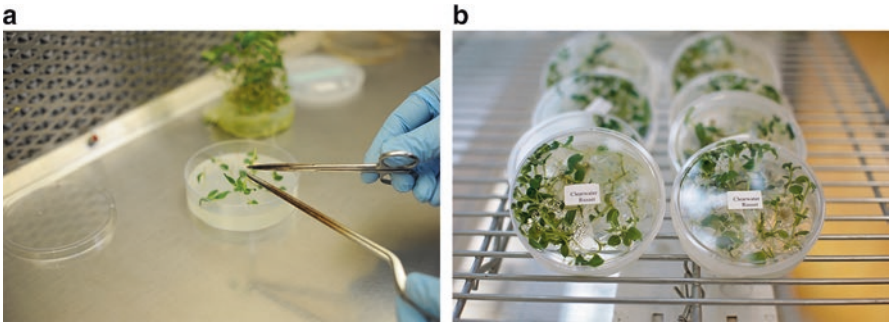

Fig. 4.1 (**a**) Dividing potato seedling into single-leaf cuttings for tissue culture production. (**b**) Tissue culture plantlets, Clearwater Russet. (Photo credit: Jenny Durrin, University of Idaho)

While the vast majority of certified seed originates from pathogen tested, in vitro planting stocks, there are instances where it is desirable to produce certified seed of material for which these planting stocks do not exist. Specific examples of this can include breeding lines, obsolete varieties, and selections made from existing varieties. Available planting stocks may be limited to true potato seed or tubers. Seed certification rules do make allowances for these special circumstances by requiring pretesting of this type of planting stock and designating its progeny in a way that differentiates it from other certified seed; e.g., the use of an "Experimental" class.

Nuclear Material

The next stage in certified seed potato production is the production of nuclear material. Most typically, this involves the production of mini-tubers in a greenhouse utilizing pre-nuclear in vitro plantlets as planting stocks. Less frequently, true seed, plant cuttings, or in vitro micro-tubers serve as planting stocks.

The amount of pre-nuclear material available is usually limited, and one or more laboratory increases of the so-called "mother" plantlets is required prior to greenhouse production. These increases are subject to inspection and testing by the certification agency. Seed certification rules typically require pathogen testing of the basal portion of a percentage (e.g., 1%) of these mother plantlets to ensure that the planting stocks are clean. These testing requirements are often less extensive than at the introductory level and usually include the following pathogens: potato viruses A, X, Y, PLRV, *Pectobacterium* spp., and *Clavibacter sepedonicus*. As with the original pre-nuclear material, there is a zero tolerance for these pathogens in the in vitro stocks used for the production of nuclear material.

After multiplication and sufficient growth, tissue culture plantlets are transplanted into the greenhouse (Fig. 4.2).

Logistically, growers are able to produce a greenhouse crop of mini-tubers every 3–4 months. However, most greenhouses typically produce one or two crops (i.e., a

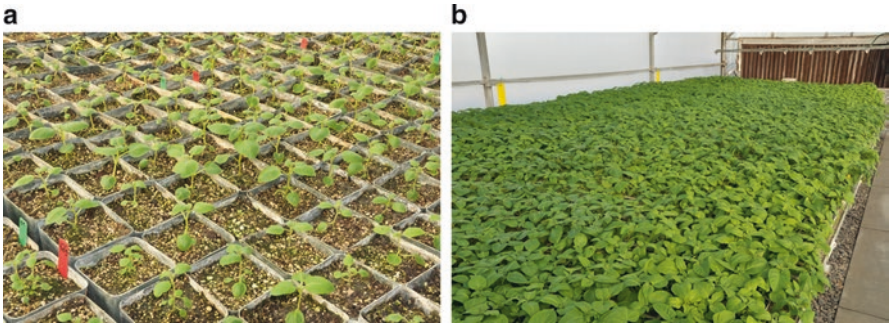

Fig. 4.2 Mini-tuber production occurs in the controlled environment of a greenhouse. (Photo credit: Jonathan Whitworth)

spring and/or a fall crop) per year because of the cost constraints and lower yields associated with winter production. The specifics of the management of the growing crop are dependent upon the system of culture used. However, because the mini-tubers will serve as the basis for future generations of field-grown seed, good sanitation and pest exclusion are critical to the successful production high-quality mini-tubers:

- Greenhouses should be insect-proofed. All intake and exhaust openings should be covered with an aphid-proof mesh hardware cloth. Doors should remain closed at all times; a double-door entry system will minimize insect entry (Fig. 4.3a, b).
- Greenhouses must be thoroughly cleaned and disinfected before planting. Organic residue; e.g., plant debris and soil, should be removed prior to washing and treatment with disinfectant.
- Pots or bedding areas should be cleaned and sanitized prior to use. A suggested method of disinfection is to wash the pots in a concentrated solution of laundry detergent (one-half cup in five gallons of water), rinse in clean flowing water, and finally dip briefly into a 2% solution of sodium hypochlorite (Clorox™ or similar product) or a prescribed solution of chlorine dioxide (Oxidate™) or quaternary amine (Sanitol™). If an open-bed system is used, growers should wash and disinfect the bed. This can be done by thoroughly steam cleaning the beds until no organic residue remains, then spraying to complete wetness with a disinfectant solution, such as those described for cleaning pots.
- Precautions must be in place to assure that the mini-tubers are produced under sanitary growing conditions:
  - Entry should be restricted to authorized personnel only.
  - Personnel entering or working in greenhouses should never do so after spending time in cellars or fields.
  - Footbaths (a shallow pan or tray containing a disinfectant solution about 1-in. deep) should be placed near the entry of each greenhouse. An effective and inexpensive alternative is to place disposable boots at each entry point for use by anyone entering the facility.
  - Tools should be sanitized between planting units and between greenhouses.

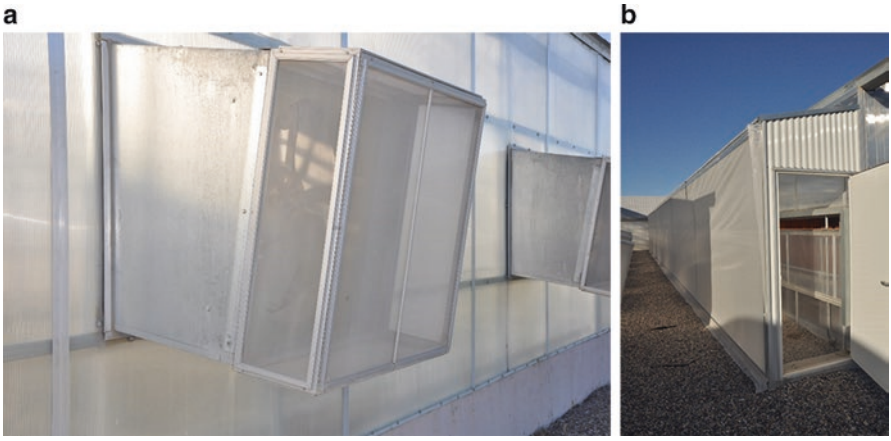

Fig. 4.3 Optimum growing conditions for nuclear seed production require screened openings (**a**) and controlled entry (**b**). (Photo credit: Jonathan Whitworth)

Production Systems

Greenhouse production most commonly involves the use of soilless potting mixes; e.g., Peat-Lite™. These mixes typically contain peat and perlite or vermiculite to aid in drainage and usually a small charge of starter fertilizer. Pots, soil bags, or raised beds may all be used in these systems. The soilless mix can be prepared by the grower and pasteurized by heating for 24 h at 240 °F. Alternatively, premixed, commercial potting mixes may be purchased. These mixes should also pasteurized before use. Some growers are moving away from organic soilless media, such as peat, because it is a potential inoculum source for pathogens. Sterilization can be a labor-intensive process, and as an alternative, pure perlite or pumice could also be used (Fig. 4.4).

To avoid the potential introduction of plant pests, soil or compost should never be used in the potting mix. Further, the potting mix should never be reused for subsequent crops.

The choice of whether to use pots, bags, or beds will depend upon a number of factors, including the design of the greenhouse. It must be noted that the choice of container does influence both yield and tuber size. In evaluations conducted at the University of Idaho's Tetonia Research and Extension Center, 6-in. diameter pots gave the optimal number of tubers while also limiting tuber size. Similar results were achieved by using 8–10-in pots with 2–3 plantlets per pot. If this system is used, additional soil should be added to the pots as the plantlets grow to allow for more subsurface stolon development and an increase in tuber numbers. If larger tubers and higher yield per unit area are desired, potato producers should consider growing transplants in raised beds. Experimentation with the potting system under a grower's own conditions is essential to allow the best use of resources to get the desired yields. For example, use of square pots reduces wasted space and water,

Fig. 4.4 Mini-tuber production using perlite as a growth media. (Photo credit: Jenny Durrin, University of Idaho)

especially if watering is done by an automatic overhead system. If size is not as important as the number of tubers needed overall, then different configurations of pot shape and size can be used to determine the best combination.

Increasingly, mini-tubers are produced using aero- or Nutrient Film (NFT) Hydroponic production systems. These systems can have higher initial setup costs when compared to conventional systems using soilless potting mixes, are technically more challenging, and require personnel with specialized training. These systems have, however, demonstrated to produce higher yields on a per-square-foot basis, because precise control over the timing of nutrient applications and the amounts administered can be achieved.

Also, because NFT systems allow for the continuous harvest of mini-tubers, tuber size can be more precisely controlled by the grower (Fig. 4.5).

Transplanting

Maintaining sanitary conditions during the transplanting operation will mitigate the risk of potential contamination of the planting stocks. Disposable gloves should be used during transplanting and should be changed frequently; minimally between varieties or lots, preferably between individual plantlet containers. Weak plants and containers that are contaminated with fungal or microbial growth should be discarded. Transplant shock can be avoided by hardening the plantlets prior to transplanting (Fig. 4.6).

If this is not feasible, transplanting late in the afternoon or on a cloudy day can help to reduce transplant shock. It is necessary to moisten pots or open beds before

Fig. 4.5 (**a**) Nutrient Film Technique (NFT) mini-tuber production. (**b**) Harvesting NFT mini-tubers. (Photo credit: Jenny Durrin, University of Idaho)

Fig. 4.6 Hardening of plantlets in the intended growth media or an alternative, such as rock wool under a dome, can decrease the chance of transplant shock. (Photo credit: Jenny Durrin)

transplanting. When transplanting is complete, the watering system should be adjusted to ensure adequate moisture for the plants while at the same time avoiding overwatering. Additionally, clear plastic cups with a ventilation hole can be placed over each transplant to provide a high humidity environment as the plant acclimates.

Fertilization

Fertilizers that contain both macro and micronutrients are necessary to maintain good growth of the transplants. Production systems utilizing soilless potting mixes typically use a combination of a slow-release fertilizer; e.g., Osmocote™, applied at soil mixing and a readily soluble fertilizer applied through the irrigation system. A standard formulation is 26–16–8 (NPK), plus micronutrients and calcium. The need for fertilization is minimal until stolon initiation, after which the fertilizer requirements increase because of demands on the plant associated with tuber development. Fertilizer applications should be scheduled based on petiole nitrate-nitrogen (N) levels. Normal levels of petiole nitrate-N in the greenhouse are lower than what is normal in the field. Optimal levels are near 12,000 ppm until stolon formation. During early tuber development, the petiole nitrate-N levels can be raised to about 18,000 ppm but should then be allowed to drop slowly until tubers are about 1/2 oz. in size. At this point, no additional fertilizer should be applied. This fertilization schedule aids in vine maturation, skin set, and tuber storage. If early applications of nitrogen are limited, plant height can be restricted to about 14 in. Careful attention to plant size can also help reduce large canopies that favor high humidity and greater chance for fungal disease establishment. See Chaps. 9 and 11. Seed certification standards for nuclear material are extremely stringent. The maintenance of an insect-free environment in the greenhouse, especially aphids, is critical in preventing the introduction and spread of viruses, such as potato virus Y (PVY). Plants should be inspected regularly for insects, and the placement of "sticky traps" can be useful in monitoring greenhouses. A preventative insect control program, including the application of a systemic insecticide during soil mixing or just after planting is recommended. Foliar diseases can also be an issue in greenhouse production. Disease scouting and the regular application of protectant fungicides are recommended. If foliar diseases are of concern, a drip irrigation system should be considered. These systems work well, especially during cooler months, because they reduce foliar wetting and the potential for foliar diseases.

Harvest and Storage of Pre-Nuclear Tubers

To prepare for harvest, greenhouse-grown plants are often artificially killed. Vine kill may be performed chemically or mechanically, and watering schedules may be manipulated to accelerate vine maturity while controlling tuber growth. Whatever method is used, the timing of the vine killing procedure is based on tuber size and is done after certification inspections are completed. If vines are killed before harvest, growers should remove the tops and leave the crop in the pots until the tubers are mature. Instruments used to remove vines should be dipped into a disinfecting solution between each plant or test unit. The harvesting process can be simplified by dumping pots onto an expanded metal screen, sifting through the potting soil, and separating the tubers.

Tubers can be stored in any kind of open mesh bags at 39 °F and a relative humidity of 95% until the following spring. If mini-tubers are green dug, they should be cured for 2 weeks at 55–60 °F before cooling to the final storage temperature. Seed from late fall or winter greenhouse crops and those from later harvests of aeroponically produced mini-tubers may express dormancy beyond planting time. Pre-warming of this seed to 55–60 °F for several weeks before planting and/or treatment with gibberellic acid may be required for dormancy break and proper stands in later field plantings.

Certification of Greenhouse Crops

Greenhouse crops are subject to inspection and testing during production and after harvest. Normally, two inspections are performed while the crop is actively growing in the greenhouse. The first inspection is usually performed when the plants are at least 12-in tall; the second shortly before vine kill. Factors that are considered during these inspections include identification and isolation of individual seed lots; overall condition of the crop; and the presence of insects, weeds, and disease. It is common to collect leaf samples during the second inspection; typically 2% of the plants in the crop are tested for potato virus X, Y, A and PLRV (Fig. 4.7).

After harvest, inspectors gather a sample of tubers, equivalent to 1% of the crop, that are tested for *C. sepedonicus* (bacterial ring rot) and *Pectobacterium* spp. (bacterial soft rot). Finally, mini-tubers to be sold are subjected to inspection at the shipping point to ensure conformity with seed potato grades. Mini-tubers meeting the requirements prescribed in the certification standards are eligible for further production of certified seed potatoes.

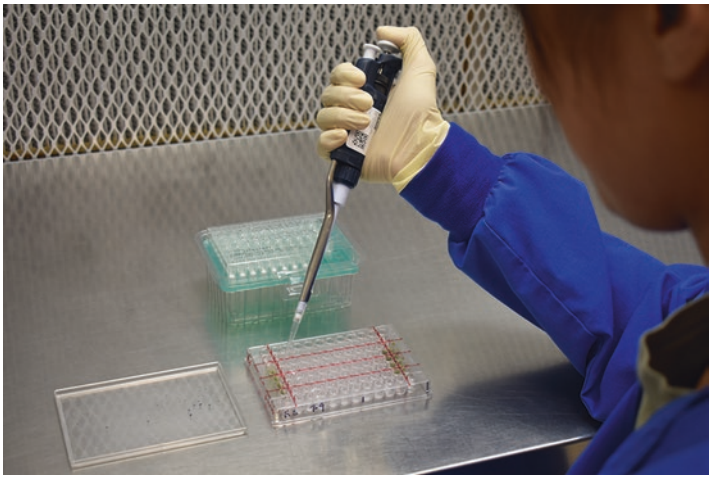

Fig. 4.7 Laboratory testing for potato virus X, Y, A, and PLRV. (Photo credit: Phillip Nolte)

Field Production of Certified Seed Potatoes

As noted above, field production of certified seed potatoes involves many of the same practices employed in the production of commercial potatoes. Certified seed potato production practices differ in that they must take into account the necessity of meeting seed certification requirements. In general, successful production of seed potatoes requires increased attention to detail and higher inputs than does the production of commercial potatoes. Good seed potato production practices generally require a sacrifice of total yield to produce a crop of the required quality and tuber size. Key areas in which differences between seed and commercial potato production occur include:

1. Identity Preservation The basic unit of certification is a seed lot. A seed lot is usually comprised of a single generation of each variety of seed potatoes produced. Seed lots may range in size from a few plants to 100 acres or more. Each seed lot is given a unique identifier; i.e., a certification number, which is used to track the results of inspection and testing and to establish a pedigree. Certification standards require proper identification and strict physical separation of seed lots at all stages of production to prevent admixture and mitigate the spread of disease. Degradation or loss of identity at any stage of production can result in a significant financial loss due to downgrading or rejection of a seed lot from certification.

2. Planting Stocks Only planting stocks that meet the minimum requirements of certification rules are eligible for the production of certified seed potatoes. Typically, planting stocks are limited as to maximum tolerances for disease and admixture, maximum generation, and grade requirements. Eligibility of planting stock is documented by official tags or certificates issued by a certification agency. This documentation must be provided to the certification agency when application for certification is made.

3. Sanitation Sanitation is of paramount importance to the production of quality seed potatoes. All surfaces with which seed potatoes come in contact must be cleaned and disinfected using recommended practices and products to mitigate the potential for disease spread. Ideally, all handling equipment is disinfected between each unit, lot, or variety of seed. At the beginning and end of each operation, all harvesters, truck beds, storages, cutters, planters, and handling equipment should be thoroughly cleaned and decontaminated. The practice of frequently cleaning equipment will help control the spread of bacterial and fungal diseases and may also help control spread of some virus diseases.

4. Field Restrictions and Rotation Requirements In order to prevent disease spread and admixture, certification rules place restrictions on the choice of fields used for planting certified seed. Minimally, certified seed production is not permitted in fields that were planted to potatoes in the previous season. In cases where specific diseases are found on farms, the rotation requirement may be increased to as long as 3 years (e.g., bacterial ring rot), or may be prohibited entirely (e.g., Columbia root knot nematode, corky ring spot disease).

There are isolation requirements placed upon fields used for certified seed production. When more than one seed lot is planted in a field, the seed lots must be physically separated by a blank row or a crop other than potatoes. Also, restrictions are placed on the proximity of seed and commercial potato fields. Usually a minimum distance between seed and commercial fields is specified; an extreme example occurs in Idaho, which has designated seed production areas where commercial potato production is prohibited.

5. Storage Requirements Certification standards place restrictions on the storage of seed potatoes. It is common for certification rules to include sanitation inspections and preapproval of storages prior to harvest. These rules also prohibit the use of storages in which sprout inhibitors have been used, the storage of certified seed with commercial potatoes, or the storage of seed lots that are infested with specified diseases; e.g., bacterial ring rot, Columbia root knot nematode.

6. Inspection and Testing of the Seed Crop In addition to routine scouting of the crop performed by the grower or crop consultants, seed potatoes are subject to inspection and testing by the certification agency. A typical inspection regime will include a minimum of two field inspections and inspection of the harvested crop, post-harvest storage inspections, post-harvest testing, and a grade inspection at the shipping point.

7. Field Inspections are performed according to prescribed procedures, including minimum plant counts, and are intended to assess conformity with seed certification field standards. Although the focus of each field inspection may differ, they will each include examination for varietal identity and purity, virus diseases (leafroll and mosaic), bacterial diseases (bacterial ring rot, blackleg), and other miscellaneous factors. Field inspections may be supplemented by laboratory testing; examples of supplemental testing include confirmatory testing of suspect plants and routine screening of early-generation seed lots for potato virus X (PVX) (Fig. 4.8).

Fig. 4.8 (**a**) Field inspection of certified seed potato field. (**b**) Plants with suspected disease are flagged. (Photo credit: Phillip Nolte)

8. Storage Inspections are performed at harvest or shortly thereafter. These inspections focus on proper storage conditions, including required lot identification and physical separation. Other factors that may be considered during these inspections include admixture and diseases, such as bacterial ring rot.

9. Post-harvest testing is required prior to final certification and may include a post-harvest grow out (field or greenhouse), laboratory testing, or some combination thereof. Currently, most certification programs conduct post-harvest grow outs of grower-submitted samples in FL or HI. Post-harvest testing is used to estimate virus disease (mosaic and leafroll); varietal mixture; and other factors, such as herbicide damage. The estimates obtained in the post-harvest test will determine eligibility of a seed lot for both additional seed production (recertification) and certification for commercial seed sales.

10. Shipping Point Inspection A grade inspection at the shipping point, usually performed by the Federal-State Inspection Service, is the final step in the certification process. Seed potato grades are based on the USDA-Agricultural Marketing Service standards and focus on quality issues, such as size and specified defects. The final grade is indicated by tag color, with blue tags representing the highest grade (Fig. 4.9).

Fig. 4.9 A tag attached to a container of seed potatoes assures the buyer that the contents meet quality standards. Colors represent different grades. (Photo credit: Phillip Nolte)

Cultural Practices for the Field Production of Seed Potatoes

Cultural practices specific to seed potatoes are implemented to ensure seed quality, including minimizing disease, appropriate size profile, and meeting grade requirements. The following are practices that are routinely used to meet these requirements.

Isolation

As noted above, there are minimum physical isolation requirements mandated by seed certification rules. However, there are also several other recommended forms of isolation that can be employed by seed growers to mitigate disease risk.

- *Temporal isolation* of seed crops can be achieved by following the standard recommendation to "plant early and kill early." In this case, the goal is to limit the total potential exposure to insects that vector disease, especially aphids, which are vectors of PVY and PLRV. This form of isolation necessarily involves a tradeoff between limiting potential disease exposure and obtaining proper seed size and maximum yields.
- *Physical isolation* beyond that required by certification rules can be useful in controlling the spread of viral diseases, including PLRV, PVY, and PVA. Isolation of seed fields from other potatoes using a distance of at least 1/4 mile will mitigate risk of infection with PVY and PVA. Isolation for control of PLRV may require distances of one mile or more. The use of green border crops, such as spring-planted winter wheat, has been shown to be effective at slowing spread of viruses into seed fields. Mesh row covers have also been effective when conditions permit their use (Fig. 4.10).
- *Intergenerational isolation*, both in the field and in storage, is often overlooked as a disease control strategy. When possible, plantings should be grouped by generation. Early-generation seed should be isolated from all other potato fields by the greatest distance possible (two or more miles is best). This is especially critical for controlling the spread of PVY and PVA in varieties that are susceptible to those viruses. Similarly, field operations, such as roguing and spraying, should begin with early-generation fields and proceed in order of increasing generation. Proper sanitation practices should be employed when moving from one generation to another.

Where feasible, potato growers should store each generation of seed or at least early-generation seed in a completely separate facility. Storage of several generations of seed in any building with a common air system may result in failure to break the disease cycle and may also result in contamination of early-generation seed with fungal and bacterial pathogens.

Fig. 4.10 Insect-proof mesh row cover can prevent spread of viruses into valuable early-generation seed potatoes. (Photo credit: Jill Randall)

Selection of Planting Stocks

True seed, tissue culture plantlets, mini-tubers, and field-grown tubers can all serve as planting stocks for field production of certified seed potatoes. Planting stocks are selected based on the intended purpose or market of the resultant crop; e.g., early-generation seed, recertification, or commercial seed production. Regardless of the type of planting stock used, care must be taken to select the highest quality stock that is available. Identifying a source of quality seed for multiplication is paramount for success, as any disease problems present in early generations of seed likely will be magnified in later generations. Planting seed with disease problems can result in failure to meet certification with that particular lot and can also jeopardize an entire seed operation. Certification records, including a North American Certified Seed Potato Health Certification (Fig. 4.11), should be obtained to ensure that the generation and disease status of the planting stocks are suitable for the intended purpose. If possible, the buyer should also inspect the field and storage facility of the source of seed to be purchased.

NORTH AMERICAN CERTIFIED SEED POTATO HEALTH CERTIFICATE - CROP YEAR 2019

	Grower		Importer
Name	Seed Potato Producer		
City, State/Prov.	Anytown, ID		
Variety	Russet Burbank	**Acres** 85	**Quantity Shipped**
			Size

Lot Certification					
Certification #	19-101	**Lot origination from tissue culture**	No		Yes X
Seed Class/Gen.	FY4		Year micropropagated for planting		2015
Certifying State/Prov.	ID	by	Tissue Culture Lab		

Production environment pedigree: Fill 1 column per production year, use different initials in Greenhouse and Field boxes for different farms (e.g. JSF for John Smith Farms); indicate a tuber-united lot with a '+" after farm initials; describe other footnotes in notes below.

2012	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	Year of Production		
			Pre-nuclear					Greenhouse (insect excluding) & sterile soil		
				FY1	FY2	FY3	FY4	Field (note special measures below)		
			PN-15-10	16-150	17-189	18-200	19-101	Certification No.	Number of years produced	
			ID	ID	ID	ID	ID	Certifying State	in field soil	4

				Post harvest readings		
Summer Field Readings					Location	N/A
1st	2nd	3rd	Final	FINAL		
0.0000%	0.0000%	N/A	N/A	%LEAF ROLL	0.75%	Sample No. 19-101
0.0000%	0.0000%	N/A	N/A	%MOSAIC	0.00%	Plant Count 400
			N/A	%VARIETAL MIXTURE	N/A	
		Less Than	N/A	%BLACKLEG		**Winter ELISA Test Results**
		Less Than	N/A	%VERT + %FUSARIUM + %EARLY BLIGHT		%PVY N/A %PVX N/A
						BRR Test Results NEGATIVE

Other Diseases	Not known to occur in growers area	No. of years since last found on this grower's farm, or NONE ON RECORD if free > 5 years	Not found this year during normal certification field inspections
Bacterial Ring Rot		NONE ON RECORD	
Late Blight			X

Notes: An official (ICIA) sample of 400 tubers tested negative for Clavibacter michiganensis subsp sepedonicus using CelA primers described by Gudmestad et al (Plant Disease 93:649-659).

The above information is accurate to the best of our knowledge:

Program official / title — Date 2/3/2020

Agency — Telephone 208-522-9198

FAX 208-529-4358

Approved for use by the Certification Section of the Potato Association of America

Fig. 4.11 North American Certified Seed Potato Health Certification https://cvp.cce.cornell.edu/submission.php?id=253

Planting Stocks for Early-Generation Production

Mini-tubers are the most common type of propagative material for the production of first field generation seed potatoes. Mini-tubers may be planted by hand or with mechanical planters. In either case, it is critical to use strict sanitary practices, and disinfection of equipment between seed lots is essential. Mini-tubers tend to have longer dormancy than field-grown tubers and will tend to emerge slowly; therefore, mini-tubers are planted as early as possible to take advantage of the full growing season. Dormancy issues can be mitigated by prewarming and/or treatment with gibberellic acid. If dormancy has been properly broken, tubers planted 4 in deep will emerge in 3–5 weeks, depending on the size of the mini-tuber. Mini-tuber sizes from 0.25–1.0 oz. produce acceptable results. When mini-tuber size is larger, they can be still be planted as whole mini-tubers. Seed cutting should be avoided to mitigate the potential for disease spread.

True seed (TPS) and tissue culture plantlets are much less frequently used as planting stocks for field production. Both may be planted directly in the field. However, TPS is difficult to plant because of its small size, and a so-called "field plantlet introduction" using tissue culture plantlets entails greater risk due to the potential for high plant mortality. In both cases, better results are obtained when the materials are started in the greenhouse; e.g., in 2 × 2-in cell packs. When the plants have reached 6–7 in, they should be hardened and can then be hand or mechanically transplanted in the field. During transplanting, care should be taken to minimize root damage, and appropriate sanitation measures should be taken. A suggested transplanting method involves 6–7 in tall plants that are planted about 5 in deep, leaving just the top leaves out. Irrigation should be applied immediately after transplanting, followed with light, frequent irrigations until the plants become established. No herbicides or systemic insecticides should be applied during planting because transplants may be susceptible to chemical injury. Row covers can be used to provide added protection from both wind and freezing temperatures for transplants (Fig. 4.10).

After the transplants are established, potato producers may cultivate the field and create hills. At this time, applications of fertilizer and insecticides can be made using side dressing or chemigation. Weed control should be done by hand, with cultivation, or with light amounts of herbicides that are safe for post-emergent use. Once the plants are completely established and 8–10 in tall, further mechanical operations should be avoided to minimize disease spread. The crop should be managed as any other seed potato crop in terms of irrigation timing and frequency.

Later Generation Increases

Tubers harvested from first-year production serve as the basis for subsequent seed increases. Although seed potatoes may be increased for five or more field generations, increases typically cease after the fourth field year, at which time the seed is

sold for commercial potato production. Regardless of the generation produced, proper seed health and grade, including size profile, are important in the selection of these planting stocks. Except as noted below, the handling and planting of this seed is similar to that of commercial potatoes.

Units of Production

Uniting; i.e., establishing discrete, identifiable groups of plants is important in seed production. Beyond the minimum requirements specified in seed certification rules, it may be advantageous to further subdivide seed lots to minimize risk of disease spread. Although uniting may result in more expense during certification, in cases where disease is present, a lack of uniting may result in the loss of an entire crop. The size of the unit largely depends upon the size of the seed lot and the degree of risk the grower is willing to assume. Minimally, units from the previous generation should be maintained; i.e., planting stocks should never be mixed.

For field year one production, growers should maintain units from nuclear production. Depending on the size of the seed lot, it may be advantageous to divide the lot further into so-called "family" units of 1–4 rows each. A blank row left between units will facilitate roguing, certification inspections, and leaf sampling. The family units should be harvested and stored separately, and a post-harvest test sample submitted for each family unit. If disease is detected in any plant(s) in the unit at any time, the entire unit should be removed.

In later generations planted with field-grown tubers, the size of the seed lot will determine the degree of uniting that is practical. Smaller, earlier generation lots may benefit from the planting of family units and, when cut seed is planted, tuber uniting. As lots become larger in size, family uniting becomes impractical. In the case of very large lots that are planted in more than one field, benefit may be realized from treating each field as a separate certification unit. This is especially the case when fields are separated by large distances and have different exposure to potential risk; e.g., proximity to commercial potato fields.

Planting and Nutrition

In general, the practices employed in planting and fertilizing a seed potato crop mirror those of commercial plantings. In addition to the recommendation for early planting, the following important differences apply to seed potato production:

- *Seed cutting* is a very effective method for spreading bacterial, fungal, and some viral diseases. Therefore, a standard recommendation is for seed growers to avoid, when possible, cutting seed. When seed cutting is necessary, proper sanitation must be practiced. Minimally, seed cutters should be cleaned between seed lots.

- *Seeding rates* may be higher for some varieties than in commercial plantings. Higher plant populations are used to maintain yields while achieving the smaller tuber size profile desired for a seed crop. Higher plant populations are usually achieved by decreasing plant spacing on standard-width rows. Higher plant populations can also be achieved by planting seed potatoes in beds with narrow rows; e.g., 30 in. Seeding rates in these systems can be up to twice the normal rates typical of commercial potato production.
- *Fertilization rates*, particularly nitrogen, may be lower than those recommended for commercial production. Seed potatoes generally are not grown to full season and, therefore, will not require the full nutrient rates of a commercial crop. Additionally, reduction of nitrogen aids in vine killing and in a more fully mature plant and tuber crop. Tuber diseases can enter through wounds when immature tubers are subject to skinning during handling at harvest and storage.

Disease and Insect Control

Control of diseases and insects, particularly aphids, is necessary to prevent the introduction and spread of disease and, thus, to meet certification requirements. Routine scouting of the crop, plus the use of a preventative insecticide and fungicide program is a cornerstone of a good management program. See Chaps. 11 and 9. This will minimize early infestations and mitigate risk as the season progresses. It should be noted that the actionable threshold for some potato pests may be lower in seed potatoes than in a commercial planting.

- *Roguing*, a term used to describe the physical removal of undesirable plants from a field, can also be an important component of a comprehensive disease control strategy. When admixtures or off-types are present, roguing is also necessary for maintaining the varietal purity of seed. Roguing should be performed "early and often." In the case of virus diseases, roguing usually begins when the plants are 8–12 in tall, or as soon as symptoms are observed. Rouging for varietal mixtures may require additional plant growth, up to and including flowering, to allow proper identification of admixtures. Fields are commonly rogued twice; additional roguing may be done in early-generation seed and seed lots with more issues. When roguing, all vines and tubers should be removed from the field.

  While roguing can be an effective tool in disease management, it is not a substitute for purchasing planting stock with low disease levels. It may be difficult or impossible to rescue a seed lot due to cost and time constraints. It should also be borne in mind that, if the initial disease levels are high enough, the rate of current season spread of virus may outstrip the ability of the roguing crews to remove diseased plants. Finally, roguing for disease after row closure is of limited value, as many diseased plants will be hidden, and current season spread is likely to have already begun

Vine Killing

Early vine killing is recommended for seed potato production. Vine killing should be performed as soon as possible after target yield and size profile have been achieved in order to avoid late season aphid flights and the resultant spread of viruses vectored by them. Early vine kill also ensures plenty of opportunity for tubers to mature before harvest. Proper skin set will help to prevent the spread of diseases, such as soft rot, that may impact the quality of the seed crop.

- Early vine kill on seed crops may be difficult to achieve because of vigor and lack of natural senescence. Since most vine-killing chemicals act slowly and vines are vigorous, killing vines usually requires repeated chemical applications or some type of mechanical vine treatment before the chemical is applied. Growers need to be cautious in using mechanical treatment, however, because the use of machines increases the potential for virus movement into the tubers. A vine-killing product that kills vines rapidly, such as sulfuric acid, should be selected. If satisfactory vine killing can be achieved with the application of the vine-killing agent alone, mechanical treatments should not be used.
- Despite the difficulty, potato growers must take steps to ensure that the vines are killed as quickly and completely as possible without damaging the tubers. Early-generation seed fields should be killed earlier than surrounding fields so they do not become an "oasis" for late-season aphid vectors. Any green within killed fields should be eliminated as soon as possible for the same reason.

Harvesting and Storage

Other than the restrictions placed on storage by certification requirements, seed potato storage recommendations are similar to those of commercial potatoes. Storage temperatures are generally lower; however, proper conditioning, airflow, and humidity all are important to prevent disease spread and maintain the grade of the crop. Seed potatoes should be harvested before any danger of frost injury occurs. Tubers that are damaged by frost or exhibiting other signs of breakdown should be removed to prevent the potential spread of disease in storage.

During harvest, the units established at planting may or may not be maintained, depending on logistics, availability of storage, and other factors. Whenever possible, the original planting units should be maintained. Bulking of units, especially during harvesting of early-generation fields, is not always the appropriate course of action. Often, the best strategy is to harvest in units that are as small as possible and then, if necessary, units can be combined after the outcome of post-harvest testing is known. The process of uniting ensures that virus or other problems are restricted to a small, identifiable portion of the total seed lot.

During harvest of the first field generation seed, all tubers from a family unit should be kept together in sacks or bins. Each of these units should be given an

identification code that is maintained throughout storage. Units should be stored off the cellar floor in mesh bags or slatted boxes to ensure good air flow. Immediately after harvest, the storage temperature should be held at 50–55 °F and 95% relative humidity for 2 weeks, which will promote wound healing. After 2 weeks, the storage temperature should be lowered as quickly as possible (without causing condensation) to about 38 °F and maintained there until spring. Fluctuations in storage temperature should be avoided.