Bulletin No. 700

Guidelines for Russet Burbank Nuclear Seed Potato Production in Idaho

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Published and distributed by the
Idaho Agricultural Experiment Station
Gary A. Lee, Director

University of Idaho College of Agriculture
Moscow, Idaho 83843

3,500, June 1989

$1.00 per copy

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Recent technological advances in plant propagation have enabled the potato industry to rapidly increase basic pathogen-tested seed stocks. This system should minimize the transmittal of tuber borne diseases, particularly X,Y and leafroll potato viruses, bacterial ring rot and the blackleg/bacterial soft rot complex. Until recently the high cost of greenhouse space and labor-intensive practices severely limited the amount of basic seed stock increases. Advances in micro-propagation techniques now allow large numbers of plants to be produced with less space and labor requirements. This publication describes current procedures used in the Idaho basic potato seed stocks program.

Classes of Seed Potatoes

The Idaho limited generation potato seed program is based upon a 6-year generation system. The pre-nuclear stage involves the production of greenhouse tubers for field planting. These tubers, commonly referred to as mini-tubers, can be produced in two ways. The most common method uses tissue culture plantlets derived from explant stocks which are multiplied under aseptic laboratory conditions (Fig. 1) Once roots have developed and shoots have started to elongate, the plantlets are transplanted into a greenhouse for mini-tuber production. The second and less common method is to grow "mother plants" from pathogen-tested tubers.

Fig. 1. Taking cuttings from explant stock.

Stem cuttings taken from the mother plants are then rooted and transplanted into a sterile or pasteurized potting soil for mini-tuber production. This method is slower and more labor intensive.

Greenhouse-grown tubers, tissue culture plantlets and rooted stem cuttings are all classified in Idaho as pre-nuclear stocks and can be planted directly in the field for nuclear class seed production. The first generation in the field is classified as nuclear. Mini-tubers which are used most frequently because they are easier to handle and have lower susceptibility to environmental stress. Transplanting either tissue culture transplants or stem cuttings is a high risk procedure because of environmental stress. Transplanting must be done after frost danger is past. Careful management and watering are critical until after the plants are established. Hot, dry and windy weather immediately after transplanting will cause high plant mortality.

Clonal line selection is another technique used to produce nuclear seed. This involves selecting individual field plants, based upon foliage and tuber characteristics, and laboratory testing of tubers to maintain a strict pathogen-tested status for all selected material. This method is based totally upon field production technology and does not involve a step in which the nuclear plant has been completely separated from the tuber. This method does not ensure that certain seedborne diseases are absent from the tuber.

Nuclear seed is replanted the following season to produce Generation 1 seed (G-1). The subsequent field plantings are classified as G-2, G-3, G-4 and Certified for the 3rd, 4th, 5th and 6th field-increase generations, respectively.

Production of Pre-Nuclear Seed

Pre-nuclear seed (mini-tubers) for field planting is available from several commercial sources within and outside of Idaho. Tissue culture plantlets are available for purchase from the University of Idaho by individuals wishing to produce their own mini-tubers.

Greenhouses used for pre-nuclear seed production must be thoroughly cleaned and disinfected before re-

ceiving plants. If pots are to be used, they must be washed with detergent and disinfected. If an open bed system is used, the bed should also be washed and disinfected. Only sterile or pasteurized potting mix should be used. Plants should be checked regularly for insects throughout the growing season, with particular emphasis on aphids. Insecticide sprays or a fumigation program are recommended. Strict sanitation practices should be observed at all times. Entry should be restricted to authorized personnel only and footbaths should be used. Personnel should never go to the cellars or fields and then enter the greenhouse without first changing clothes, washing and disinfecting.

Greenhouse cooling is necessary during the summer months. This involves having an intake and exhaust fan system with evaporative cooling. All intake and exhaust openings must be covered with an aphid proof mesh hardware cloth. Doors must remain closed; a double-door entry system is recommended to minimize insect entry. Supplemental heat is needed during the winter months, and both heating and cooling systems will be needed to produce a fall or spring crop.

A supplemental lighting system is required during the winter and summer. Ultraviolet light deficiencies may cause leaf injury or defoliation during periods of alternating clear and cloudy skies. Fluorescent lights or lights such as metal halide over each table will reduce this problem. Once started, lights should be left on a minimum of 16 hours per day during the growing season, but they may be off during maturation. If plants are grown during the winter, high intensity (metal halide) lights should be used to extend the day length.

Many potting mixes are available for use. A standard mix is: 1 part sterile washed sand (heated for 24 hours at 240°F), 1 part sterile milled peat moss and 1 part terralite. Another option is to buy a premixed, sterilized commercial potting mix. Crops grown during the hot summer months need a higher proportion of peat and terralite or vermiculite to increase water-holding capacity, while crops grown during the cooler months need more perlite or sand. Before planting, the potting mix should be moistened and each pot or open bed should be filled about one-third full with the mix.

Plantlets from the University of Idaho are received in petri dishes (Fig. 2). Each person transplanting should be provided with a disinfecting solution. Before and after transplanting plantlets from each petri dish, the transplanters should rinse their hands in a disinfectant solution to prevent disease spread. All plants in any

Fig. 2. Cuttings in petri dish ready for transplanting in greenhouse.

Fig. 3. Trays of plants in the greenhouse 10 days after transplanting. These plants will be moved to the field at 6 weeks.

petri dishes contaminated with fungal or microbial growth should be discarded.

If possible, plant late in the afternoon or on a cloudy day to reduce transplanting shock. Pots or open beds should be moistened before planting. If an overhead mist system is used, it should be started and set to run 15 seconds every hour if the weather is sunny, less often on cloudy days. This can be adjusted as needed to ensure adequate moisture for the plants. A drip irrigation system also works well, especially during cooler months, because it reduces foliar wetting and the potential for foliar diseases. Time clocks may be installed to automate the watering. Greenhouse temperature should be maintained between 50°F minimum and 90°F maximum to promote tuberization and tuber growth (Fig. 3). Fertilizers may be applied through the irrigation system; insecticides also if a mist system is used. Only a readily water-soluble fertilizer should be used. Initial fertilizer and insecticide applications should be made immediately after transplanting.

An inexpensive and simple system can be constructed to apply both fertilizer and insecticide. A strainer similar to ones used on field sprayers can be spliced into the water delivery line. By filling the strainer cup with dye and timing how long it takes colored water to go from the initial mister through the final mister, you can calculate the quantity of fertilizer or insecticide to add to the strainer cup for each section of the greenhouse. Other options include many types of injector systems that are commercially available.

Fertilization should be minimal until stolon initiation and then increased to promote tuber development. Normal petiole nitrate-N should be near 12,000 ppm until stolon formation. Additional N is added to raise levels to about 18,000 ppm during early tuber development. The N level should then be allowed to drop slowly until tuber size reaches about ½ ounce. At this point, no further N should be applied so that the plant rapidly depletes resources. This fertilization schedule aids in vine killing, skin set and tuber storage. If early applications of nitrogen are limited, plant height can be reduced to about 14 inches.

Fig. 4. Plants growing in 6-inch pots for pre-nuclear tuber production.

Various size pots were evaluated for 3 years at the University of Idaho's Tetonia Research and Extension Center. Six-inch-diameter pots gave the optimal number of tubers, while also limiting tuber size (Fig. 4). The same results may also be achieved by using 8- to 10-inch pots with 2 to 3 plantlets per pot. In the 3-year study, average production per pot was 7 tubers ranging from ¼ to 1 ounce in size. An average of 4.3 ounces of tubers was produced per 6-inch pot. Yields varied with varieties, growing season and greenhouse conditions.

As plantlets grow, additional soil should be added to the pot. This allows for more subsurface stolon development and an increase in tuber numbers.

Certification of Greenhouse Pre-Nuclear Stocks

An application for certification must be filed with the Idaho Crop Improvement Association (ICIA). Fees to be paid include an inspection fee, membership fee and variety fee. ICIA personnel visually inspect greenhouse crops one or more times during the growing season.

Leaf samples for laboratory testing are collected by ICIA before vine killing, and tubers are sampled after harvest. Costs for laboratory analysis of tubers and leaves are the responsibility of the growers. Leaf samples from 2 percent of the plants and tuber samples from 1 percent of the plants are required for testing. The greenhouse should be divided into units, and all sampling and testing should be done on the basis of these units. There is zero tolerance for potato viruses X, Y and LR, for bacterial ringrot and for Erwinia carotovora in pre-nuclear stocks.

Harvest and Storage of Pre-Nuclear Seed

When a crop of the desired size is obtained, and with approval of ICIA, plants may be killed. This is most easily accomplished by simply shutting off the water and letting the soil dry down. The tops are then cut off and the crop is left until the tubers mature. The knife or shears used to cut off plants should be dipped into a disinfecting solution between each plant or test unit. Harvesting is done by sifting the potting soil through an expanded metal screen and picking up the tubers (Fig. 5). The potting soil should be discarded and never reused. Tubers should be stored in nylon mesh bags at 39°F and a relative humidity of 95 percent until the following spring, allowing for a normal dormancy period and aging. Dormancy is longer in mini-tubers than in normal field-produced tubers. Pre-nuclear tubers should be physiologically aged before the field planting to increase stem numbers and tuber set.

Fig. 5. Harvesting pre-nuclear tubers.

Nuclear Seed Production from Mini-Tubers

Nuclear seed potatoes (first field generation) can be produced from mini-tubers, tissue culture transplants, stem cuttings or clonal line selections. The most common method, and the one used by the University of Idaho, is to plant mini-tubers. These are planted as early as possible to lengthen the growing season. Ground prepared for nuclear seed production must not have been in potatoes the previous year. Fields are prepared in the usual manner for potato production.

Fertilizer applications are based upon a soil test and the management plan for the field. If additional N is to be applied later in the season, preplant N should be reduced accordingly. Herbicides should be applied as well as a systemic insecticide.

Uniting (establishing discrete, identifiable groups of plants) is important in nuclear production. This arranges the field to minimize physical contact between plants during the various field operations. These discrete units help to isolate disease and to prevent the spread of disease within the field. Units can be maintained from pre-nuclear production or arbitrarily assigned at planting if mini-tubers are purchased. The size of the unit will depend on the individual grower and the degree of risk he is willing to assume. If disease is detected in any plant(s) in the unit, the whole unit must be removed.

In nuclear fields planted from greenhouse tested stocks, the likelihood of disease is relatively low, and harvesting strategy is an important consideration in planning the size of the unit. Generally 1- to 4-row units are recommended, with a blank row between units. The length of the unit down the row depends on the grower's decision, but 100 feet is adequate. Leaf samples for PVX testing can then be picked based upon row and unit numbers down the row.

Growers must leave adequate walkways for roguing, ICIA inspections and leaf sampling. Leaving a blank row every 5th row (4 planted rows, 1 blank) provides adequate access to the field and keeps plant contact to a minimum. The grower may want to leave more than one blank row so the unplanted rows can be cultivated more easily. A solid set irrigation system should be used to minimize plant contact with irrigation equipment and personnel.

If dormancy has been properly broken, tubers planted 4 inches deep will emerge in 3 to 5 weeks, depending on the size of the mini-tuber. A 12-inch plant spacing keeps weed growth low and tuber size moderate. Mini-tuber sizes of ¼ to 1 ounce produce acceptable results (Table 1).

Mini-tubers can be planted by hand or by mechanical planters. In either case, strict sanitary measures must be practiced. Periodic disinfecting of equipment is essential. Personnel handling tubers must wash periodically and wear clean clothing each day.

Table 1. Tuber size vs. emergence and yield, Tetonia R&E Center.

Tuber size	Emergence	Yield/plant
¾ to 1 oz	20 days	22 oz
½ to ¾ oz	22 days	14 oz
¼ to ½ oz	31 days	9 oz
less than ¼ oz	37 days	1.4 oz

Nuclear Seed Production from Transplants

Pre-nuclear transplants (greenhouse plants) must be hardened before being planted in the field. Plants rooted in a 2 × 2 cell pack should be dried to a slight wilt and then watered until completely rehydrated. This procedure is repeated 2 to 3 days before transplanting. The plants are removed from the cell packs and layered into a holding tray. Care should be taken to minimize root damage, and hands should be washed between each tray. The plants should be hardened before they are taken to the field, but they should be well hydrated for planting. While being transplanted, plants should not be allowed to desiccate. Keep plants moist and covered until planted.

While the plants are being hardened in the greenhouse, the fields can be worked, fertilized and pre-irrigated. Irrigation pipes, if properly spaced, can be left in the field during planting for irrigation immediately after transplanting each day. This aids in cooling the soil, firming the soil around the roots and lessening transplant shock. No herbicide or systemic insecticide should be used with transplants to avoid the possibility of plant injury. After the plants are established (2 to 3 weeks), side dressing and chemigation can be used as necessary.

The first 2 weeks after transplanting are extremely critical. Adverse environmental conditions can result in extremely high plant mortality. Plants must be protected from frost and hot, dry wind.

The most successful transplanting method involves 6- to 7-inch tall plants that are planted about 5 inches deep, just leaving the top leaves out (Fig. 6). If totally

buried, the plant dies; if planted too shallow, it is easily desiccated, and the wind may break off the top.

Light, frequent irrigations should be applied to keep the root zone damp and the soil surface cool until plants become established. This normally takes 10 days to 2 weeks. The same unit field arrangement is used that was discussed for mini-tubers.

After transplants are established or plants from mini-tubers have emerged, the field is cultivated and hilled. To minimize disease spread, no further mechanical operations are used. The crop is managed as any other seed potato crop in terms of irrigation timing and frequency.

Clonal Line Selection

Clonal line selection is a system of selecting individual plants in the field for nuclear production. The University of Idaho does not use tubers from hill selections directly for nuclear production. This technique is accepted by ICIA and is used by some growers, however. A grower needs to have in mind specific plant and tuber characteristics that is considered desirable. For example, leaf size, shape and color and plant growth pattern may be important. Tuber characteristics such as tuber shape, color, size, depth of eyes and uniformity are important.

Clonal selection is a long term process. Selection and re-selection over a 3- to 4-year period of individual plants, hills and hill-units are intended to produce a seed lot that typifies the desirable characteristic of the variety or of the particular mutation/genetic trait being propagated. Early generation (G-1 or G-2) seed stocks should be used for initial selections. This will increase the probability that selected plants will be free of viral and bacterial pathogens.

Fig. 6. Plants are transplanted about 5 inches deep in the field, leaving just the top leaves out of the ground.

All tubers from each chosen plant are bagged together and each bag is given an identification code. During the winter, one tuber from each bag (hill) is submitted to ICIA for laboratory testing. Each of those tubers is tested for PVX, PVY, PLRV, bacterial ringrot and Erwinia carotovora. If any tuber tests positive for any of these pathogens, the bag from which the tuber was selected will not qualify for nuclear planting.

Each bag from which the selected tuber tested free from the five pathogens is designated as pre-nuclear and can be planted in a nuclear class seed plot the next growing season. All tubers from each bag must be planted into an identifiable hill-unit in the nuclear clonal selection plot. Tubers within each bag may be cut before planting to help increase the numbers of plants grown from each hill selection. Cutting knives must be disinfected between each bag.

Each hill-unit (all plants produced from one bag) will be visually inspected and PVX tested independently of other hill-units in the clonal selection plot. The grower must carefully examine each plant in each hill-unit during the growing season and rogue any plants that fail to exhibit the desirable characteristics being selected. If disease is detected in any plant(s) in the unit, the whole unit must be removed. At harvest, tubers from hill-units will be examined, and the final hill selections will be made for the pre-nuclear hill-units to continue the system the next season. Any hill-units not selected are bulk harvested for planting in a second generation (G-1) increase plot. All tubers in selected pre-nuclear hill-units must again be individually bagged and coded with a representative tuber submitted for laboratory testing during the winter. The following year these bags are once again planted as hill-units for increase, continued evaluation and further selection.

Maturing the Crop and Vine Killing

Vine killing is an essential element of early generation seed potato production. Late-season virus spread into seed fields by aphid vectors can be reduced by this practice. Early vine kill also ensures plenty of opportunity for tubers to mature (set skin) before harvest. Early generation seed must be harvested before there is any danger of frost injury. The vines on early generation seed are difficult to kill because of their vigor and lack of senescence at the early vine-killing dates.

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. The grower should select a vine-killing product, such as sulfuric acid, that kills vines rapidly. If satisfactory vine killing can be achieved with the application of the vine-killing agent alone, mechanical treatments should not be used.

Because it is physiologically young, nuclear class seed matures much slower after vine killing than later field generation seed. Tubers commonly require 20 to 30 days to mature. This before-harvest maturing process is essential so the tubers will have a good skin set that will enable them to maintain quality during storage.

Harvesting and Storing

Harvesting should be done in identifiable units. Units can be as small or as large as the individual grower chooses, but bulk harvesting of nuclear fields is not recommended. The best strategy is to harvest in units that are as small as possible and then bulk one or more of these units during the next year's planting. The amount of bulking would depend upon the outcome of winter testing. The process of uniting ensures that virus or other problems are restricted to a small identifiable portion of the total seed lot. During harvesting, all tubers from a block of plants (unit) are kept together in sacks or bins (Fig. 7). Each of these units is given an identification code that is maintained through storage. This code should also be used for the winter test sample identification. Planting, harvesting and all other field operations should proceed first from the earliest field-generation to the later generations.

Storages used for early generation seed potatoes should be thoroughly cleaned and disinfected before any tubers are placed in them. Generations should be stored separately if possible. At most, only the 1st, 2nd and 3rd year field increases should be stored in the same storage since later generation seed possibly could serve as a source of contamination to the earlier generation seed. Of particular concern is blackleg/soft rot contamination.

Pre-nuclear and nuclear seed should be stored off the cellar floor in mesh bags. Once in storage, the temperature should be lowered to 45° to 50°F for 30 days with 95 percent relative humidity to promote suberization and healing of tuber injury. Then the storage should be lowered to about 38°F and maintained until spring. Fluctuations in temperature should be avoided. Before planting, the cellar should be warmed so the tubers will break dormancy.

By following these guidelines of management and sanitation, growers can produce early generation seed and assure themselves of having the highest quality seed stocks possible.

Fig. 7. Harvesting nuclear seed in 50-pound mesh onion bags. This provides the basic unit for G-1 production.