Table 3. Results of double stratification treatments on *Pseudotsuga menziesii* and *Abies procera*.

Final Germination Test - Percent germination based on 200 seeds.

Abies procera (noble fir)

Treatment		Days in Germinator 7	14	21	28
Normal strat. only	A	29.5	62.0	63.0	63.0
Strat. + post-strat.	B	27.0	62.5	63.0	63.0
Strat. + post-strat. + strat.	C	*63.0	63.0	63.0	63.0
Strat. + dry-freeze + strat.	D	41.0	52.5	53.0	53.0

Pseudotsuga menziesii (Douglas fir)

Treatment		Days in Germinator 7	14	21	28
Normal strat. only	A	33.0	76.5	83.0	86.0
Strat. + post-strat.	B	56.0	79.0	81.0	82.0
Strat. + post-strat. + strat.	C	70.5	84.5	84.5	84.5
Strat. + dry-freeze + strat.	D	66.0	85.5	86.0	86.5

* Approximately 0.5% of the seed germinated in the cooler and was removed before the seed was tested.

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NEW IDEAS IN THE USE OF PLUG SYSTEMS

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The development of the seedling plug is one of the major advances in the bedding plant industry in the last decade. As more growers have recognized the potential of plugs, demand has been created for improved seeding equipment, higher quality seed, and more advanced environmental controls, as well as more efficient methods of handling plug flats and plugs. This is a brief overview of those advances.

Skagit Gardens is a 155,000 square foot glass bedding plant range located in Northwestern Washington. Among other things, we produce over 80,000 flats of annuals and vegetables, 1,000,000 flowering perennials, 500,000 4 in. flowering annuals, and 300,000 primroses. Ninety-five percent of these plants are grown from plugs. As little as four years ago, all this seed was hand broadcast on open flats and transplanted bareroot into the finished containers. In the winter of 1982, we purchased our first automatic seeder and quickly converted to a plug system.

There are a number of automatic seeders now available. We use a Hamilton seeder which was developed in England. It is a pneumatically operated vacuum seeder, capable of sowing up to 80,000 seeds per hour. It drops a single row of seeds at a time, with a maximum of 18 seeds per row. The brass tipped nozzle-bars are available with 1, 2, or 3 holes per nozzle, allowing multiple seeds to be sown in a single pass. The seeds are discharged down nylon tubes to funnel-shaped seed cups, which slow them down before they hit the plug tray. The seed cups can be spaced to fit a large number of different plug trays.

The Hamilton needs a separate compressor which can supply at least 2 CFM of clean air at 60 PSI. Various accessories include a dibbler, a vibrating seed tray to aid in seed pick up, self-cleaning nozzles, a percussion singulation hammer to remove excess seed from the nozzle, and a vermiculite dispenser that, under the control of an electric eye, will cover the seed flats as they emerge from the seeder.

The electrically driven Blackmore Transplanter Company's automatic seeder uses a self-contained vacuum pump/compressor to supply the air for the machine. Using any one of four plug trays, the Blackmore can sow up to 62,400 seeds per hour. Like the Hamilton, it uses a vacuum to pick up seeds from a vibrating tray and a positive burst of air to discharge them, one row at a time.

The Blackmore uses rubber nozzles rather than brass to pick up the seed and has a slotted seed tray. This feature, not found on other seeders, positions seeds for pick-up even when there are few seeds left in the tray. At this time, the Blackmore is limited to using specially designed plug trays. The Waffle Tray® can be used in conjunction with Blackmore's mechanical transplanter.

Similar in principle to the Hamilton and Blackmore, but somewhat less expensive, is A. E. Nichols Little Seeder®. It has a built-in vacuum supply, can handle seed size from petunias to peppers, and will sow about 43,000 seeds/hour.

JVK of Canada has introduced somewhat of a hybrid of the Hamilton and Blackmore seeders called the Niagara Seeder®. It has many features of both machines and is adaptable to nearly any plug tray.

Growing Systems of Milwaukee, Wisconsin, manufacturers two seeders. The Vandana #400® is of simpler design than the Hamilton or Blackmore. The seeds are manually distributed over a drilled seed plate and are held in place by vacuum at each of the holes. The holes are spaced to conform with the cells of the plug tray. The seed plate is then tilted so that excess seed that is not held by vacuum can slide off. The seed plate is then inverted over a series of tubes, the vacuum released, and the seeds dropped into the plug tray.

The Vandana Direct Seeder® follows the same principles as the Model #400 but rather than having discharge tubes, the seed plate inverts directly onto the plug flat. This is an advantage with large or coarse seed that will not fit down small diameter discharge tubes. A Vandana seeder can be very accurate because the operator has the opportunity to visually inspect the seed plate for misses before sowing it, but such accuracy does cost time. The position of the discharge tubes of the Model #400 limits the types of plug flats that can be used with this seeder, but Vandana has developed an adaptor which allows it to fit more trays.

An earlier version of the Vandana Seeder is now marketed under the name Vanloon 288 Direct Seeder®. There is also a direct seeder called the Seed-Rite® which is similar to the Vandana Direct Seeder.

The Old Mill Company of Maryland has developed a line of seeders which differ from the others in that they use electronic and optical systems for supervision of the seeding process, rather than the observation of a human operator. Old Mill uses the same concepts used in mechanical seed counters. Seeds are placed in a circular bowl mounted on top of a vibratory feeder. The bowl adjusts for various seeds by a knob narrowing the width of the track so that they feed from the unit one at a time. The seeds travel by gravity to a drop head. An electric eye insures that the machine will not advance until a seed has been dropped into each cell. Flats move through the unit on the indexing conveyor belt. Guide and dropping assemblies can be adjusted to run a flat either direction on the conveyor. A plug tray can be handled having up to 14 cells in a row. The seeder will direct seed into any cell pack or tray.

Although the Old Mill seeders are relatively costly and not as fast as some of the other mechanical seeders, they are

highly accurate. The Old Mill Company is currently using its technology in the development of a combination extractor/ sorter/transplanter that will mechanically lift seedling plugs from the plug tray and pass them through a seedling inspection station, where they are inspected for size and form. If acceptable, they continue on to the transplanter unit and are planted.

Williames High Tech International of Australia manufactures a high speed rotary seeder capable of sowing row seeds ranging in size from lobelia to peas, at a rate up to 400,000 seeds per hour. Although very expensive, this machine could be very practical in the vegetable seedling industry.

Williames has also developed the Cell Chain, a system in which seeds are sown into a cell built into a link chain. When the seedlings are transplantable, that chain can be fed through a machine which selects only viable seedlings of a predetermined size and mechanically transplants them at high speed.

A relatively new concept developed in England is fluid drilling, in which seeds are "pre-germinated" in an oxygenated water tank that can be heated to precise germination temperatures. As soon as the radicle emerges, the seeds can be sown with a specialized vacuum seeder, or even stored for several days by immersing the seeds in oxygenated water at a temperature close to freezing. Between the germination and sowing stages, it is possible to separate the germinated from the ungerminated seed by using a sugar solution. Seeds from the germinator are placed in this solution, where most of those that have germinated will float, and those that have not will settle to the bottom.

Along with advances in seeder technology have come various related equipment for handling plug flats. Still rather unique is the Blackmore Transplanter, which according to the manufacturer, allows growers to increase transplanting rates 400 percent or more. Designed exclusively for the Blackmore 648 Waffle tray, the transplanter uses moveable pins to push seedlings through the pre-cut waffle bottom into the flat below. One drawback of this transplanter is that it will punch out a cell whether there is a seedling in it or not. Blackmore has also developed a pin-type extractor to loosen plugs from its other sized plug trays.

The system used at Skagit Gardens is centered around a 512 cell plug tray. An Antal® pin-type dislodger is used to break the surface tension between the root system and the cell wall of the tray. The dislodged plugs can then be easily lifted from the tray without damage. We have mounted our dislodger on a stand and added a foot pedal for increased leverage.

Dislodged seedling plugs are the main ingredient of our assembly line transplanting system. We use a Granterplanter® transplanting belt to move flats past the transplanting crew. As the flat moves by, plugs are inserted into pre-dibbled holes. The transplanted flat leaves the belt and is automatically irrigated with fertilizer by a series of mist nozzles. The flow volume of the nozzles is totally adjustable.

The flats can be conveyored directly to greenhouse benches or stacked on pallets and transported to the growing area by a forklift.

The success of any plug system relies on a high percentage of useable plugs per plug tray. As important as accurate seeding equipment is, the environmental factors which influence germination must be optimized. Methods of controlling soil temperature range from Agritape® root zone heaters, which use heat from electrical resistance in Mylar covered copper strips, to time-proven skirted heat benches. Fairly new are the hot water root zone heating systems sold as Biotherm®, Root Zone® or Ball Seed's Bench-Mate®. All three use synthetic rubber tubes through which heated liquid flows, radiating heat as it goes. The tubes are installed parallel to one another, on or directly below the bench, and are spaced according to heat distribution required.

Moisture control is also critical for germination. Intermittent mist systems in conjunction with capillary mats, are probably the most widely used system. Mists are often uneven or leave the soil too wet, and dripping water from suspended mist lines can wash out plug cells below them.

Plastic tents provide a near ideal environment for most seedlings, but tents tend to be labor-intensive when they must be opened and closed frequently to irrigate or control temperature. Some growers are using a plastic covering directly on the flats to maintain high humidity. Sub-irrigation with capillary mats keeps soil moist under the plastic. Often plug flats are simply hand misted by a vigilant grower, although there can be much room for error in this method.

Fog Systems, such as the Mee II Cloudmaker® or the Baumac Micro Mist System®, have been used by a few growers for seedling germination. The tiny droplets (about 10 microns) provide the high humidity around the seed without overwetting the soil. The flats still need to be irrigated occasionally.

Once germinated, the irrigation of plugs becomes more complex. Growers who produce large quantities of a single crop can take advantage of boom watering systems, such as Growing Systems' Travelling Irrigator® or the Andpro Spray-rite® boom. Both irrigators provide fairly sophisticated control

of irrigation functions. In situations where many different plant cultivars and sizes are mixed, a skilled person with a hose is still an intricate part of the system.

Nutrition of plugs is a matter of some research. Generally, it is being found that early feeding of plugs does not produce "stretched" plants as it would in crowded open seed flats, but actually promotes stronger, more compact seedlings. Sierra Chemical has developed a down-sized version of Osmocote, called Micro-Fertilizer®, that can be incorporated into plug mixes. It appears that when used with a liquid feed program, the Micro-Fertilizer improves seedling development over the use of liquid feed alone.

The popularity of plugs has created a demand for high germination seed. Some seed producers are using breeding and selection for more uniform and higher germination, while other companies are improving germination by refining the seed cleaning and sizing techniques. The exact processes used are closely guarded secrets. In any case, the term "High Tech" seed can mean anything from a pelleted begonia seed to a marigold with the tassle removed.

Improved cleaning processes can now eliminate the small or misshapened seed from a lot, leaving only the larger and heavier seeds, which generally have higher germination. Marigolds are extremely difficult to sow raw, but with the tassles removed, sowing marigolds is within the capabilities of many mechanical seeders. These refining processes significantly add to the cost of the seed so growers expect high yields from their seed.

Pelletizing seed is still controversial because it is said to decrease germination; however, the use of pelletted seed is convenient. Pelleting seed allow accurate singulation and gives uniform size to the seeds. Seeder operators can easily visually inspect their work for skips even when sowing begonia seed.

Harris-Moran Seed Company is now experimenting with the effects of immersing seed in a solution of ethylene glycol. The process, called "priming" allows the seed to inbibe enough moisture to begin germination. Before emergence, the seed is removed from the solution and dried and it remains viable in short term storage already well into its germination cycle. Priming has already been successful with direct seeded field peppers and may have applications in plug culture.

Improvements in equipment, environmental control, and seed technology have already begun to revolutionize the bedding plant business. Increased mechanization using plugs will insure that it remains a healthy industry in the future.

®Denotes registered trademark

VOICE: What temperatures do you use for initial seed stratification, post-stratification, and your second stratification?

SHARON DELONG: We use 36° F, but the seeds are soaked first in water at about 60° or 70° F. They are taken out after stratification, dried, and then put back at 36° F.

VOICE: In your hydrogen peroxide test do you leave the seeds in the hydrogen peroxide until the radicles emerge?

SHARON DELONG: Yes, you soak the seeds before you cut the tip off — the tip of the radicle may be cut without damage. The rest of the radicle will elongate. Then the seeds are put back in the hydrogen peroxide in the dark.

MIKE EVANS: Sharon, when would you use the quick, tetrazolium or hydrogen peroxide seed viability test rather than the standard germination test?

SHARON DELONG: When you have thousands of pounds of seeds that look good inside and out, but they will not germinate. You need these other tests to determine viability.

MICHAEL SMITH: Dr. Moore, has any research been done on the possible effects of the PGPR (Plant Growth Promoting Rhizobacteria) bacteria on seed germination — by way of hormones, or breaking down the seed coats, etc. — which might suggest their commercial use of difficult seeds?

LARRY MOORE: If there is, I am not familiar with it. The work was initiated primarily with things like potatoes and then it spread to other plants that would respond, which response was measured by increased mass or yield.

WESTERN REGION QUESTION BOX

Bruce Briggs and Charles Parkerson, Moderators

QUESTION: What time of year is best to take cuttings of Colorado blue spruce?

DICK BUSH: We take current season's growth — one year old growth — taken in February. If they still are not rooted by mid-summer, we put them in a coldframe and they root in the fall.

QUESTION: What is the advantage of a rooted conifer cutting over a grafted conifer?

VERL HOLDEN? A grafted conifer might break off in a strong wind. I would much rather have a conifer on its own roots.

QUESTION: How do you get cutting-grown conifers to grow straight?