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National Proceedings: Forest and Conservation Nursery Associations 1995



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National Proceedings: Forest and Conservation Nursery Associations 1995

**Thomas D. Landis and Bert Cregg,
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This proceedings is a compilation of 23 papers that were presented at the regional meetings of the forest and conservation nursery associations in the United States in 1995. The Western Forest and Conservation Nursery Association meeting was held in Kearney, NE, on August 7-11, 1995, and the Northeastern Forest Nursery Association Conference was held in Mitchell, IN, on August 14-17, 1995. The subject matter ranges from seed collection and processing, through nursery cultural practices, to harvesting storage and outplanting.

Keywords: Bareroot seedlings, container seedlings, nursery practices, reforestation.

Note: As part of the planning for this symposium, we decided to process and deliver these proceedings to the potential user as quickly as possible. Thus, the manuscripts did not receive conventional Forest Service editorial processing, and consequently, you may find some typographical errors. We feel quick publication of the proceedings is an essential part of the symposium concept and far outweighs these relatively minor distractions.

Acknowledgments

The professional success of this meeting was due in no small part to the willingness of many people to come and share their knowledge and experience. Many of the members of the nursery associations are government employees and as such are financially reimbursed for their time and expenses. This is not the case for private nurseries and consultants, however, and so we would like to acknowledge their unselfish contributions.

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Western Forest & Conservation Nursery Association Meeting

Nebraska

August 7-11, 1995

Sporotrichosis—An Occupational Mycosis¹

Arvind A. Padhye²

Sporotrichosis is a chronic infection usually limited to cutaneous and subcutaneous tissues. It involves all layers of skin and the subcutaneous lymphatic. The disease is caused by a dimorphic fungus *Sporothrix schenckii*. The fungus, present in nature in a variety of plants and soil, invades through a skin injury. Many times, the injury to the skin is so minor that it goes unrecognized and neglected. The fungus produces an indolent lesion which appears as a small erythematous nodule which may remain localized or spread centrally through the local lymphatics, establishing a chain of granulomatous, ulcerating nodules. Sporotrichosis generally affects the exposed parts of the body, namely, the hands, arms and legs. Pulmonary Sporotrichosis presumably results from inhalation of the fungal spores and occurs only rarely in humans with a variety of underlying conditions such as sarcoidosis, malignant neoplasms, diabetes mellitus, and chronic alcoholism. The infection may disseminate beyond lungs to become a generalized infection involving bones, joints, and the central nervous system (Goodman, 1983; Kaplan *et. al.*, 1982; Kwon-Chung and Bennett, 1982; Rippon, 1988; Scott *et. al.*, 1987). Extracutaneous Sporotrichosis shows a marked male predominance (6:1) in widely scattered geographic areas. Even though the cutaneous disease affects men and women of all ages, majority of cases observed are among males between 25-40 years of age.

The disease occurs in those who are exposed to material contaminated with *S. schenckii*. Occupations that predispose persons to infection include gardening, farming, masonry, floral work, outdoor labor, nursery workers, horticulturists, forestry workers, tree planters, orchid growers, and people involved in activities and exposure to contaminated soil, and vegetation such as sphagnum moss, salt marsh hay, prairie hay, or roses (Adam *et. al.*, 1982; Brown *et. al.*, 1947; D'Alessio *et. al.*, 1965; Goodman, 1983; McDonough *et. al.*, 1970; Padhye and Ajello, 1990; Skilling, 1983). There are more than 11 cases of laboratory acquired Sporotrichosis (Kwon-Chung and Bennett, 1992). *Sporothrix schenckii* enters the body generally through traumatic implantation or rarely from inhalation spores. In nature, *S. schenckii* has been isolated from dried edible mushrooms, *Auricularia polytricha* and *Letimus edodes* imported from Asia, and from insects that are in direct contact with the fungus. The most common form of trauma to the skin involves punctures from thorns, splinters, cuts from sedge barbs, or handling of reeds, sphagnum moss, or grasses. Other types of trauma reported include: bites from rodents, parrots, cats, dogs, and horses; pecks from hens and other birds and insect stings. In Uruguay, close to half of the recognized human Sporotrichosis cases are associated with the hunting of armadillos. Infection follows scratches from armadillos and injuries

¹Padhye, A.A. 1995. *Sporotrichosis—An Occupational Mycosis*. In: Landis, T.D.; Cregg, B., tech. coords. *National proceedings, Forest and Conservation Nursery Associations*. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 1-7.

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from the tools used to dislodge the animals from their nests and burrows. Nine-banded armadillos, (*Dasypus nevecinctus*) often used as laboratory animals in leprosy studies, were found to be infected with systemic sporotrichosis (Kaplan *et. al.*, 1982).

Several reports have described large scale epidemic outbreaks of sporotrichosis. In 1927, Pijper and Pullinger (Pijper and Pullinger, 1927) reported a sporotrichosis outbreak involving 14 gold mine workers in Witwatersrand, a town near Johannesburg, South Africa. Between 1941 and 1944 in the mines of the same area, nearly 3000 workers were infected with *S. schenckii* (Brown *et. al.*, 1947; Kwon-Chung and Bennett, 1992). The source of the remarkable epidemic in South African gold mines was traced to contaminated mine timbers over grown with *S. schenckii*. High humidity and high temperatures inside the mines provided ideal conditions for *S. schenckii* to grow on those timbers. Outbreaks of cutaneous sporotrichosis have occurred in Mississippi, Florida, Ohio, Wisconsin, Illinois, Pennsylvania, New York, Vermont, and other eastern and midwestern states of the United States (Adam *et. al.*, 1982; D'Alessio *et. al.*, 1965; Dixon *et. al.*, 1991; El-Gholl, 1986; Goodman, 1983; Grotte and Younger, 1981; McDonough, 1970; Skilling, 1983). In 1988, the largest North American epidemic of sporotrichosis occurred in 15 states involving 84 cases, with the majority of cases having associated with handling pine seedlings packed in sphagnum moss (Dixon *et. al.*, 1991). The sphagnum moss used for packing the seedlings by a nursery in Pennsylvania proved to be the source of *S. schenckii*.

The latest outbreak of lymphocutaneous sporotrichosis was at the Disney World in Florida during March to May 1994, where 9 of the 65 workers at Nursery A involved in production of sphagnum moss topiaries developed lymphocutaneous sporotrichosis (Hajjeh, 1995). Fungal cultures of some sphagnum moss samples

used in topiaries at Nursery A since January 1, 1994, and collected at different stages of topiary production grew *S. schenckii*.

NATURAL HABITAT OF *S. SCHENCKII*

Sporothrix schenckii has been isolated from soil, humus, fertilizer, the stems of beech trees, vegetable debris, moist wood, and refrigerated meat. It has also been isolated from many types of plants, such as: horsetails, rose bushes, cacti, salt meadow hay, residual packing straw, carnations, wood splinters, and most commonly sphagnum moss (Adam *et. al.*, 1982; D'Alessio *et. al.*, 1965; Grotte and Younger, 1981; Padhye and Ajello, 1990; Skilling, 1983). The fungus is worldwide in distribution, occurring in all temperate and tropical climates. Its wide distribution is illustrated by its isolation from soil and plant material from all parts of the world.

CLINICAL FORMS OF SPOROTRICHOSIS

Cutaneous Lymphatic (Lymphocutaneous) Sporotrichosis:

Infection is usually acquired by traumatic implantation with injury to the skin caused by the prick of a thorn, splinter or similar object that is contaminated with *S. schenckii*. Following such a penetrating wound, a papule may develop at the



Figure 1. An early ulcerating lesion on a finger caused by *Sporothrix schenckii*

site within two to three weeks. The papule slowly enlarges and ulcerates (Figure 1). Without treatment, secondary lesions develop along the lymphatic channels, draining the initial site of infection. The lesions form nodules, which ulcerate and drain (Figure 2). Without treatment, lesions persist for years.



Figure 2. An ulcerating, chronic lesion on a wrist caused by *schenckii*

Cutaneous Nonlymphatic Sporotrichosis:

In some cases, the lesion remains localized and does not involve the lymphatic system. Such a solitary lesion usually becomes chronic. These "plaques" and "fixed" type of lesions, as they are often referred to, can persist for years, the longest being known to persist for 26 years (Villaca-Neto *et. al.*, 1988). Although the lesion may temporarily wane, it regresses eventually, and spontaneous resolution is not common. These chronic, single lesions commonly occur on face, neck, trunk, arm or hand and can vary in appearance. They are usually erythematous papules or plaques that tend to become ulcerated or verrucous (Figure 3). In some cases, skin lesions may result from hematogenous dissemination. There are several lesions scattered over the body, not on the same extremity, or even at the site of trauma.

Extracutaneous Sporotrichosis:

This includes the following types:

- 1) **Pulmonary**, with the associated symptoms of cough, low-grade fever, loss of weight and sputum production. In some cases, hemoptysis

occurs, and can be massive, even fatal. The infection results in cavitation in the lungs. The disease is more commonly seen in males (6:1 male to female ratio) than in females. The natural course of the lung lesion is gradual progression to death, although spontaneous remission of noncavitary pneumonia has been reported.

- 2) **Osteoarticular**, which involves the bones, joints, and bursa. The majority of patients in this category present with the indolent onset of stiffness and pain in a large joint. Radiologic evidence of osteomyelitis develops slowly with diffuse osteolysis. Almost all cases of arthritis involve knee, elbow, ankle or wrist. Although fever may be present early in the illness, most patients are afebrile. Fluid accumulation in the olecranon or prepatellar bursa may occur as may Baker's cysts. In untreated patients, additional joints become involved and skin over the joint becomes erythematous and may eventually develop a draining sinus.

- 3) **Ocular**, which is caused by trauma to the eye by material contaminated with *S. schenckii* or occurs as a result of dissemination of the disease;

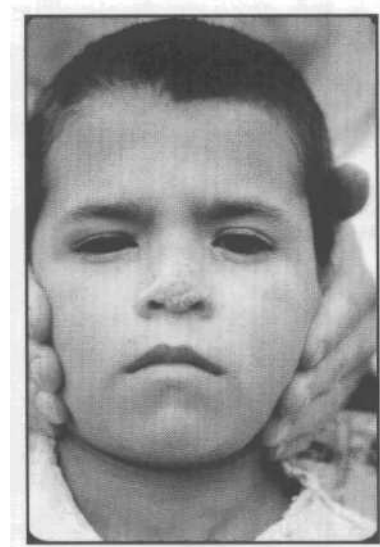


Figure 3. A solitary, granulomatous, fixed type lesion on nose caused by *S. schenckii*

4) Central nervous system sporotrichosis: a rare disease with symptoms of headaches, back pain and mental confusion, and

5) Multifocal form: patients may present with multiple skin lesions resulting from hematogenous spread, with or without lung or bone lesions. Although patients who are apparently immunologically intact may develop hematogenously disseminated, fatal infection only rarely, however, in immunosuppressed patients, the probability of hematogenous dissemination to the skin and bones increases. Patients with acquired immunodeficiency syndrome (AIDS), or other severely depressed states of immunosuppression are at greater risk of dissemination of infection.

Diagnosis:

A positive diagnosis of sporotrichosis is made by:

1) Direct examination: Although yeast form cells may be seen occasionally in a Gram-stained smear, a wet mount of pus, or a biopsy specimen, direct examination is often not helpful because of the paucity of fungal cells. By examining multiple slides of biopsy tissue stained with PAS or GMS, one can demonstrate the presence of *S. schenckii* yeast cells. These fungal yeast cells may be spherical and surrounded by a PAS-positive capsule, or have uncharacteristic elongated "cigar-shaped" cells

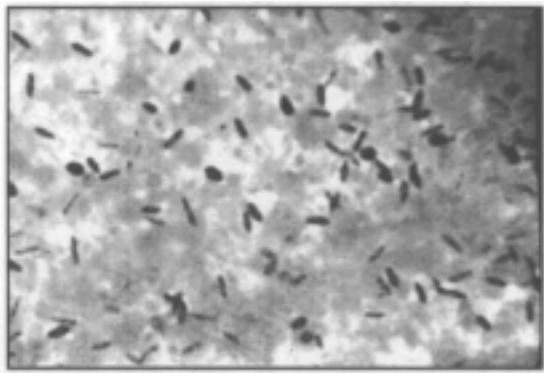


Figure 4. Cigar-shaped yeast-like cells of *S. schenckii* in spleen tissue, Gomori methanamine silver + hematoxylin and eosin X160.

(Figure 4). The fluorescein-labeled *S. schenckii* antiglobulins brightly stain yeast cells of *S. schenckii*, even when they are few in number and provide a rapid and reliable diagnostic test to diagnose sporotrichosis (Kaplan, 1982; Kaufman, 1976).

2) Isolation of *S. schenckii* from clinical

material: The causal agent *S. schenckii* is a causal fungus, that is, it grows as a mycelial fungus at room temperature and in nature. It grows on mycologic media producing moist, glabrous, white colonies, which soon become gray to black and develop radial striations

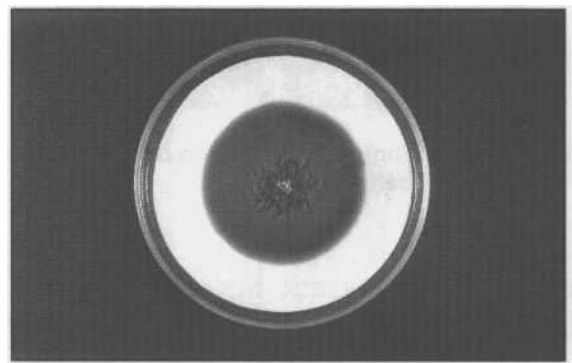


Figure 5. Two-week-old dark dematiaceous colony of *S. schenckii* on Sabouraud dextrose agar at 25°C

(Figure 5). Microscopically, hyphae are hyaline, branched, septate bearing lateral and terminal conidiophores. The conidiophores produce ovoid, spherical, pyriform conidia, 2 - 4 x 4 - 6 microns in size, borne singly on denticles in a rosette-shaped manner, or in a form of a bouquet. The conidia are also produced directly on the sides of vegetative hyphae, and are borne on small denticles (Figure 6). As colony ages, the dark color of the colony is due to dark-walled pigment produced by the conidia. In animal and human tissue, *S. schenckii* reproduces by budding like a yeast. The yeast form can be produced in vitro by culturing mycelia or conidia on rich media such as brain heart infusion (BHI) agar, or Pine's medium, or BCG agar at 37°C. The yeast form colony appears dull white, with a

dry wrinkled surface. The blastospores produced in vitro are oval, subglobose, or cigar-shaped. The conversion of the mycelial form to a yeast-like form at 37°C confirms the dimorphic nature of the fungus and serves as a confirmatory test for the conclusive identification of *S. schenckii*.

Serology:

Serological tests for sporotrichosis may be applied to sera from patients with skin lesions, subcutaneous nodules, bone lesions, lymphadenopathy, or pulmonary disease. Because of its sensitivity (94%), high specificity, and ability to provide results in 5 minutes, the LA (latex agglutination) test is used routinely in the clinical laboratory. The TA (tube agglutination) test has comparable sensitivity, but sera being tested for sporotrichosis may show false-positive reactions with 1:8 and 1:16 dilutions of sera from patients with leishmaniasis. Slide latex agglutination titers of 1:4 or greater are considered presumptive evidence of sporotrichosis. Sera from patients with localized, subcutaneous, disseminated subcutaneous, or systemic sporotrichosis may show titers ranging from 1:4 to 1:128. The test has limited prognostic value, since antibody levels may show little change during and after convalescence (Kaufman, 1976; Scott *et al.*, 1987).

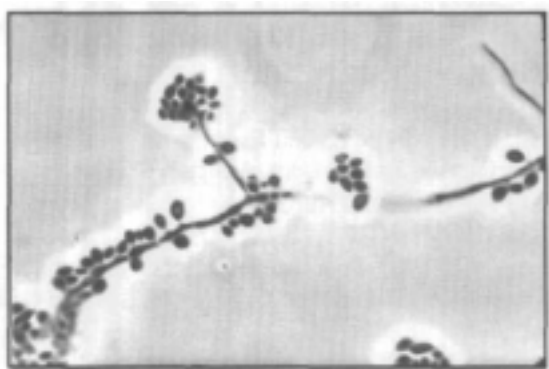


Figure 6. Lateral conidiophore bearing ovoid conidia in a rosette manner and single conidia produced laterally on vegetative hyphae X 160.

PROTECTIVE MEASURES AND CONTROL

- a) Workers handling sphagnum moss or those likely to be traumatized by objects such as thorns, splinters or sticks should wear gloves and long-sleeved shirts to protect their hands and arms. Heavy clothing or an apron should also be worn while working to prevent trauma to the body, as well as thick shoes to protect feet.
- b) After handling potentially contaminated material, individuals should thoroughly wash their arms and other exposed parts of the bodies with soap and water to reduce chances of infection.
- c) If any injury by a thorn or splinter, etc. is noticed, a disinfectant such as tincture of iodine should be applied immediately (El-Gholl *et al.*, 1986).
- d) Supplies of sphagnum moss should be stored indoors under **dry conditions**. Sphagnum moss with a high moisture content stored in a warm environment supports the proliferation of *S. schenckii*. When disturbed, the airborne conidia of *S. schenckii* may be inhaled by workers and induce pulmonary infection (El-Gholl *et al.*, 1986; Goodman, 1983).
- e) In areas likely to contain dust or aerosols from the handling of sphagnum moss, proper exhaust fans with biologic filters should be installed. In such areas, a protective mask should be used to avoid inhalation of the infectious conidia of *S. schenckii*.
- f) All storage and packing areas should be decontaminated monthly with a disinfectant.
- g) Stored sphagnum moss should be regularly cultured for the presence of *S. schenckii* (El-Gholl *et al.*, 1986).

Unfortunately there are no established methods for decontaminating sphagnum moss infected with *S. schenckii*. Chemical decontamination with formaldehyde or methyl bromide has been suggested, but has never been used on a regular basis (Padhye and Ajello, 1990). Burning of infested moss is an effective control method.

Treatment of Sporotrichosis:

Cutaneous lesions respond well to treatment with orally administered potassium iodide. A variety of side effects and the slow response to treatment require perseverance. The bitter taste of KI and the development of nausea, rumbling stomach, excessive salivation, and anorexia are better tolerated if the dose is begun small and gradually increased. A common initial dose is 10 drops of saturated KI solution given three times daily. The bitter taste is lessened if the patient drinks water or juice immediately after taking the medicine. The dose is increased once a week by about five drops per dose up to 25 to 40 drops three times daily for children under 10 years, and up to 40 to 50 drops three times daily for adults. This dose is continued till all lesions become flat and soft, a period of 6 to 12 weeks being usual. Immersing lesions in hot water for 20 to 30 minutes three times daily also helps. Heating pads or pocket warmers have been used with some success. Occasionally cutaneous sporotrichosis responds well to ketoconazole 10 mg/kg once daily, but success has been noted only in a small number of cases. Oral itraconazole 100 to 200 mg, given daily for several months has been successful in a small number of patients (Kwon-Chung and Bennett, 1992).

For pulmonary sporotrichosis involving only one lobe without any contraindication to surgery and no lesions anywhere else, the best treatment is by surgery. Although use of amphotericin B in doses totaling over 2 grams for adults has cured some patients with pulmonary sporotrichosis,

therapeutic failures are common. The combination of flucytosine with intravenous amphotericin B may be useful in refractory cases. Local injections of amphotericin B into the knee, olecranon bursa, or Baker's cyst may also be useful in refractory cases. Ketoconazole (400 to 800 mg daily) or itraconazole (400 mg daily) has improved up to half the cases of osteoarticular sporotrichosis, but the treatment may extend months or years to be effective. These drugs are less effective in cavitary pulmonary sporotrichosis (Kwon-Chung and Bennett, 1992).

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Current Developments in the Prevention and Treatment of Repetitive Motion Injuries of the Upper Extremity¹

D. Mowry²

ABSTRACT: Cumulative trauma is a condition associated with the musculoskeletal system and is due to repetitive use of that body part. There are often other aggravating factors, such as: cold environments, vibration or awkward positioning of the work site. Some cumulative disorders of the upper extremity include: carpal tunnel syndrome, DeQuervain's disease, and lateral epicondylitis. Special testing may be involved in carpal tunnel syndrome, such as Tinel's or Phalen's test and an EMG. All have similar treatment methods of using nonsteroidal medications, heat, and injections. To further treat these conditions, jobs need to be modified to decrease the risk factors, and education of the worker needs to be completed.

Repetitive motion injuries, also known as cumulative trauma disorders, are widespread in many occupational fields. Cumulative trauma is associated with the musculoskeletal system (for example cardiac arrhythmias is not accumulative trauma disorder). The parts of the musculoskeletal system includes bones, muscles, nerves, tendons and ligaments. When the musculoskeletal system is over-used, or involved in repetitive motion, then trauma can result. And this trauma is known as cumulative because it occurs over a period of time. Of particular interest are the cumulative trauma disorders of the upper extremity. These trauma disorders include: carpal tunnel syndrome, Dequervain's disease and lateral epicondylitis. The purpose of this paper is to discuss each of these three disorders, the anatomy involved, risk factors, treatment and prevention of the disorder.

Let's first look at carpal tunnel syndrome. Carpal tunnel syndrome describes a condition that is associated with compression of the median nerve at the wrist (See Figure 1). In the wrist

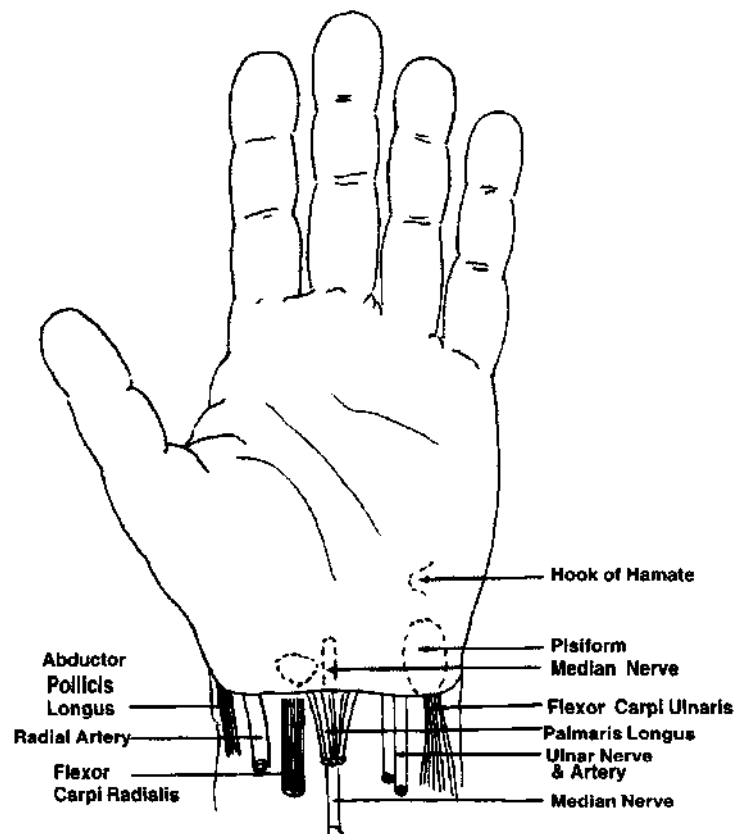


Figure 1.

¹ Mowry, D. 1995. *Current Development in the Prevention and Treatment of Repetitive Motion Injuries of the Upper Extremity*. In: Landis, T.D.; Cregg, B., tech. coords. *National Proceedings, Forest and Conservation Nursery Associations*. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 8-12.

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there are several structures. There are carpal bones which form almost a cup shape. In that cup are many tendons, known as flexor tendons. There are also some nerves. Most of these structures are held in the cup by a thick band known as flexor retinaculum. If you look at the palm of your hand and place your thumb and little finger together, then a tendon jumps out at the wrist. This tendon is known as the palmaris longus. This tendon is not held in place by the flexor retinaculum, but it is important because the median nerve lies under this tendon, so it helps us know the position of that nerve. The median nerve is held in place by the flexor retinaculum, and if compression by other components of the carpal tunnel or the retinaculum occurs, then numbness or weakness of the hand can result; this can lead to carpal tunnel syndrome. There are many etiologies for carpal tunnel syndrome. And many of these are not necessarily related to work injuries. Persons with wrist fractures are at risk for edema and swelling of the wrist which can then lead to entrapment of the median nerve and cause carpal tunnel syndrome. Rheumatoid arthritis, gout, and other inflammatory disorders can also cause carpal tunnel syndrome. Pregnancy is a great risk factor. Some studies have shown that greater than twenty-five percent of women in the their last three months of pregnancy are at risk because of overall swelling and this would include the carpal tunnel itself. Additional list of medical illnesses that can be associated with carpal tunnel syndrome include diabetes, infection, local tumors, and even possible hereditary conditions. Not only are medical issues associated but again work related injuries. There are a great variety of types of workers who have been thought to be at increased risks for carpal tunnel syndrome: the typist or computer operator, because of repetitive motion, the sign language interpreter, because of, again, repetitive motion and often not taking enough breaks during her job to rest the wrists and hands. Other jobs include the jackhammer worker because the vibration can cause local trauma and edema, the meat cutter who uses electrical knives because of vibration, and the cashier who operates

the cash register. This has lead some people to believe, because of such a diversity of types of employment has been associated with carpal tunnel syndrome, that hereditary or medical conditions are more the source of the problem. Nevertheless, there have also been many studies to indicate the syndrome is indeed associated with work injuries. And because of that thought, let's look at some of the jobs that nursery workers do and see why they could be at risk.

The tree nursery workers often are repetitively using their wrists and hands, flexing their hands to put the seedlings into holders, sorting the trees, and bundling the trees. The repetitive flexing is a great risk factor. In addition, these workers are often in a cold environment. The cold causes slowing of the nerves, and also causes any edema or inflammatory agents that have become involved in the wrist to stay in the wrist longer, causing increased pressure, and further compromise to the carpal tunnel itself. Finally, some of the workers are also involved in having the wrist in a rather awkward position that is usually not anatomically normal, and this will then cause inflammation to the wrist. Again, with the cold and repetitive trauma, the inflammation will stay and it will be a prolonged problem. When workers develop carpal tunnel syndrome there are several symptoms that they develop. Generally, there is a numbness in the median nerve distribution which involves the first three digits of the hand (thumb, second and third finger). Sometimes the worker describes it as radiating in the hand and it is often difficult to know whether it is really the first three fingers or throughout the hand. If you have ever experienced a foot, leg or arm falling asleep, you can recall how difficult it is to describe the exact region that has fallen asleep. This is the same problem that occurs when patients are asked to describe where exactly the numbness is located. Sometimes this numbness is more often present at night. This is because the person keeps the wrist in a flexed position while they sleep, further compromising the tunnel, and causing compression on the nerve,

and therefore causing symptoms. There can also be night pain associated with the hand, wrist, elbow and shoulder. If carpal tunnel syndrome is severe enough, patients can experience weakness of the hand, particularly the thumb muscles (i.e., abductor pollicis brevis). This is because these muscles are typically innervated by the median nerve.

Some simple tests that can be completed to determine if carpal tunnel syndrome is present, such as tapping on the wrist, known as Tinel's test. If tapping at the wrist causes radiation of numbness into the first three digits, then this would be a positive Tinel's test and could be indicative of carpal tunnel syndrome. Another test that can be completed, the Phalen's test, is to flex the wrist so that the dorsum of the hands are in contact. Again, there should be numbness radiating into the first three digits.

Additional testing that can be completed to determine if carpal tunnel is present, is to look for weakness, as well as sensory loss. Your physician would probably complete these tests. Additional testing that can be completed is that of electromyography better known as EMG. The purpose of this test is to look specifically at the function of the median nerve, and to determine if there is slowing across the carpal tunnel itself, which again suggests carpal tunnel syndrome. This test usually has two parts. The first part is simply stimulating the nerve or giving it an electrical shock to see how quickly the nerve will respond. The next part may involve inserting a small pin or small needle into different muscles, the abductor pollicis brevis for example, to determine if there is any evidence of nerve damage. This test may be completed by the physician prior to treatment. Often this test is completed if surgery is a consideration for treatment.

Let's look at some of the treatment options, and let's consider first the conservative treatment options. These include a cock-up wrist splint, rest or use of the opposite hand for activities, steroid

injections, nonsteroidals, ultrasound and exercises. The cock-up wrist splint is generally one of the first line treatments done for carpal treatment. They do prevent dorsiflexion of the wrist and help to stretch the carpal tunnel, thereby ideally decompressing the median nerve. The splints can be worn at work and are designed so that not to inhibit digit use. The splints are often worn at night as well, to again keep the wrist in the correct position and to stretch the carpal tunnel. Some patient's prefer only to wear these at night and not during the work period. Nonsteroidal medications such as Ibuprofen, Lodine, Naprosyn, Relafin can

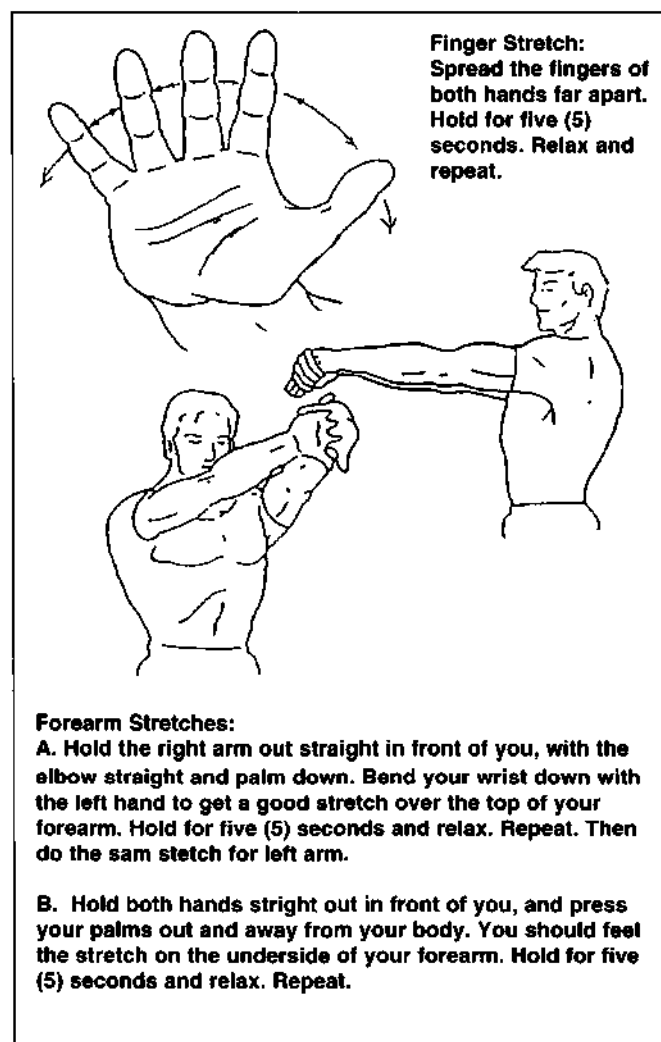


Figure 2. Exercises for Preventing Cumulative Trauma Disorders

be used. The purpose of the nonsteroidal medications used is to help decrease any inflammatory response which may also help decrease symptoms. Other treatments that have been used include exercises, (See Figure 2), which usually involve stretching of the carpal tunnel, and again, are thought to decrease compression of the median nerve. Some physicians have prescribed ultrasound. Another conservative treatment that has been included is the of injection of local steroid into the carpal tunnel.

An additional treatment that can be completed is to look at the workplace to help decrease some of the causing factors. For example, many workers in the nursery tree field often use gloves to help protect their hands, but do these gloves indeed decrease the cold? There are many other medical conditions, particularly those associated with vascular instability, in which workers also need to wear gloves to help protect them from the cold. This is well known among the patients and by the medical field. But often patients who are at risk for carpal tunnel syndrome do not think to wear gloves to help avoid this condition. Additional preventative measures that could help at work would be to rotate the job sites so that patients are not always doing the same type of repetitive job with their wrist. They also should take frequent rest breaks. In addition, they need to begin using the non-dominant arm to help rest the dominant side, and again decrease risk. Other issues that could be looked at in the work sites would be automating jobs that are highly repetitive, but may be easily operated by machinery. Finally, if the patient does fail at any conservative treatment, then surgery would be a consideration. Usually before surgery is completed, the patient has completed a good trial of conservative treatment. They may also have completed an EMG. If the EMG is ordered, and there are quite distinctive and severe signs of carpal tunnel syndrome, then conservative treatment may not be indicated.

One other condition that I would like to mention briefly is that of lateral epicondylitis, also known as "tennis elbow". Extensor tendons insert onto the lateral epicondyle, and again, with a repetitive use of the wrist, can cause irritation. The treatment is very similar to that of carpal tunnel syndrome, including local steroid injections, nonsteroidals, and ultrasound. There is also a splint that can be used for this condition, known as a tennis elbow band (See Figure 3). This band is worn a few inches distal to the insertion of the tendons. The purpose of this band is to cause compression of the extensor muscle belly itself, thereby relieving the insertion of the tendon. When the person then contracts the extensors of the forearm, most of the contraction is at the site where the band is thereby not causing further irritation, or further repetitive trauma to the tendon itself, so that decreased inflammation can occur. Over time, the symptoms of tennis elbow should resolve. Occasionally, patients do have to have surgery for resection of some of the soft tissue, and possibly even the bone around the lateral epicondyle, to allow further movement of the tendon. This again is highly uncommon.

One other condition, known as DeQuervain's tendonitis is simply a condition of three tendons involved in the movement of the thumb, and cause tendonitis usually at the anatomical snuff box, which is on the dorsum (back of the hand) at the base of the

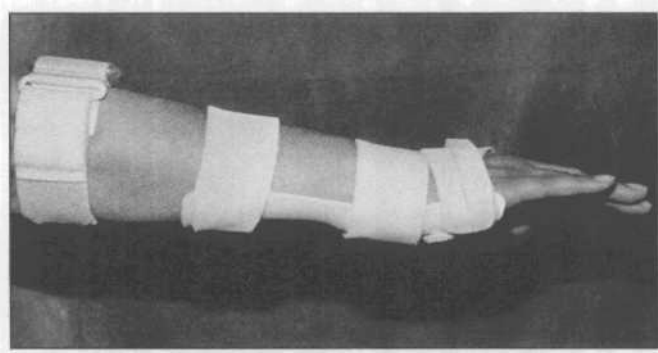


Figure 3. Cockup splint with tennis elbow cuff.

thumbs. Again, the reason for this is often trauma or even repetitive use. The treatment for this, once again, is similar to that of carpal tunnel syndrome. This involves nonsteroidal medications, injections of local steroids and ultrasound. A wrist splint, very similar to the cockup splint can also be used.

In summary then, there are at least three conditions of repetitive trauma of the upper extremity. These are often treated in a very similar fashion and also have similar risk factors. The carpal tunnel syndrome involves mostly compression of the median nerve resulting in pain and numbness. In lateral epicondylitis, there is irritation and inflammation of the extensor tendon, and in DeQuervain's disease, there is irritation of three radial innervated tendons of the thumb. Rest, nonsteroidal medications, ultrasound, local injections of steroid, and bracing are typical conservative treatments that could be tried.

Carpal tunnel syndrome can also be further diagnosed by specific maneuvers, such as the Tinel's and Phalan's test, as well as an EMG. Surgical treatment could also be considered for carpal tunnel. Again, for prevention of each of these conditions, repetitive use needs to be limited, the other non-dominant hand should be used when possible, multiple rest breaks taken, and alternate job positions. In addition, carpal tunnel syndrome is also thought to be related with vibration as well as cold, and these should be minimized. For further information concerning these conditions, I recommend that you discuss this with your physician.

Basamid® Granular Soil Fumigant:¹ Pre-Plant Soil Fumigation Update

W. Pennington²

Abstract—A seven-day program using irrigation to completely activate BASAMID®, seal the soil surface and maintain toxicant contact within the soil profile has been developed by BASF. This BASAMID® program is designed to provide nursery managers with a system to improve their success rate with BASAMID® as a preplant soil fumigant.

INTRODUCTION

BASAMID® (active ingredient: Dazomet) has been used as a soil fumigant for more than twenty years. It has been deemed by many to be a poor alternative when compared to existing soil fumigants used by forest tree nursery managers. However, BASAMID®'s ability to adequately control soil pathogens, weed and grass seeds, and nematodes has been proven by many users. Their secret: adequate moisture. Before using BASAMID®, be aware that the three most critical factors for a successful fumigation program are:

1. Soil preparation (fine tilth)
2. Soil temperature (medium to warm)
3. Soil moisture (water)

BASF developed a layman's approach to solving the critical issues associated with poor results often reported by those who inadvertently miss the soil moisture portion of the program. This system will allow the nursery manager to completely activate the BASAMID® granules and maximize the toxicant's contact in the soil profile.

SEVEN DAYS TO A SUCCESSFUL FUMIGATION PROGRAM

***This guideline is intended for use in
sandy loam soils:***

Day One

- After incorporating BASAMID®, measure soil temperature at 4 inches and record.
- Roll the soil surface.
- Irrigate with a minimum of 1 inch (or more) of water over a 4-hour time period (1 1/2" to 1 3/4" over 6 hours) .

Day Two

- Irrigate with a minimum of 3/4 " (0.75") of water in two applications; one (0.375") in the morning, one (0.375") in the afternoon.
- Keep the soil surface wet, but not waterlogged.

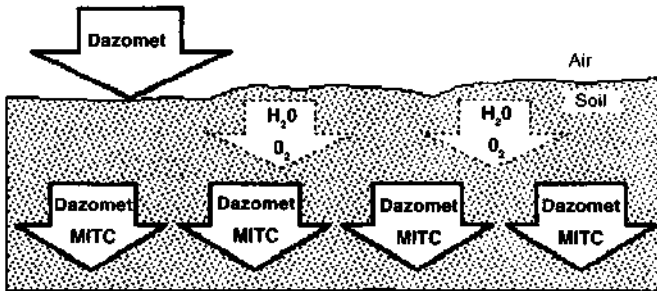
Day Three

- Irrigate with a minimum of 1/2" (0.50") of water in two applications; one (0.25") in the morning, one (0.25") in the afternoon. (This assures that

¹Pennington, W. 1995. Basamid® Granular Soil Fumigant: Pre-Plant Soil Fumigation Update. In: Landis, T.D.; Cregg, B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 13-14.

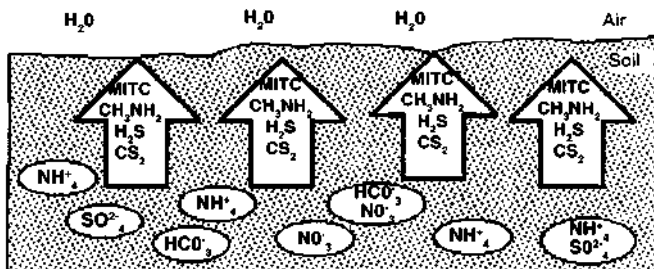
²BASF Corporation, PO Box 13528, Triangle Park, NC 27709-3528; Tel.: 1-800-878-8060.

all BASAMID[®] granules are activated and moved downward throughout the soil profile. This liquid phase will contact the soil particles throughout the incorporated profile.)



Day Four

- Irrigate with a minimum of 1/4" (0.25") of water in two applications; one in the morning, one in the afternoon.



Day Five

- Irrigate with a minimum of 1/8" (0.125) of water to ensure that the surface area has not dried out and no cracks appear in the treated area. (This assures that no gases escape as they move up the soil profile.)

Day Six

- Irrigate with a minimal amount of water to keep the surface sealed and free of cracks.

Day Seven

- Irrigate with a minimal amount of water to keep the surface sealed and free of cracks.

No additional water is needed after day seven.

To release any remaining gases, break the soil crust and aerate before planting. Please refer to product label for complete directions.

CONCLUSION

In order for fumigants to be successful, soil moisture is needed to activate the soil borne pests. It is best to have the pests active before fumigation takes place. In any planned fumigation program consider the pest being controlled, then plan your fumigation activities. Understand the pest and its habits and adjust cultural practices to economically control soil borne pests and organisms. Fumigation timing will usually determine the success rate of pests controlled. BASAMID[®]'s effectiveness as a preplant soil fumigant, when used according label directions and following the seven steps above, is a proven alternative to the gas or liquid fumigants currently used by nursery managers.

Alternatives to Chemical Fumigation Technology Development Project: Preliminary Results¹

Diane M. Hildebrand², Jeffrey K. Stone³, Robert L. James⁴, Susan J. Frankel⁵, Jill D. Pokorny⁶, Joseph G. O'Brien⁶, and Michelle M. Cram⁷

Abstract—Preliminary results indicate that each nursery requires different soil management regimes to help reduce the need for chemical fumigation. Several treatments contributed to production of seedlings with densities and morphology similar to or better than with chemical fumigation. Beneficial cultural practices included 1) Incorporation of slowly decomposing organic soil amendments, for example, aged sawdust with additional nitrogen provided to seedlings; 2) Bare fallowing, with and without periodic tilling, and with weed control; 3) Sowing of conifer seed early and shallow, and covering seed with a non-soil mulch such as aged sawdust or hydromulch.

The project, "Alternatives to Chemical Fumigation", was funded by the USDA Forest Service, Forest Pest Management, Technology Development Program, beginning in spring 1993. The overall objective is to enhance the implementation of integrated pest management at forest tree nurseries, especially by developing cropping and soil treatment regimes for production of high quality seedlings without chemical fumigation. Thirteen Federal, State, and industrial nurseries from across the United States are cooperating in the project.

CHEMICAL FUMIGATION

Many forest tree nurseries use chemical biocides for soil fumigation treatment prior to sowing. Methyl bromide (67 percent) with chloropicrin (33 percent) is one of the most commonly used fumigants, and generally considered the best for achieving a uniform, vigorous crop of quality seedlings and controlling soil-borne diseases and insects,

weeds, and nematodes. Dazomet (Basamid Granular) is also used, and its granular form is considered more safe to handle than gaseous methyl bromide mixtures.

Because methyl bromide has a high potential to deplete stratospheric ozone, production and importation in the United States will be prohibited after January 1, 2001 (World Meteorological Organiza-

¹Hildebrand, D.M.; Stone, J.K.; James, R.L.; Frankel, S.J.; Pokorny, J.D.; O'Brien⁶, J.G. and Cram, M.M. 1995. *Alternatives to Chemical Fumigation Technology Development Project: Preliminary Results*. IN: Landis, T.D.; Cregg, B., tech. coords. *National Proceedings, Forest and Conservation Nursery Associations*. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 15-22.

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⁶ Plant Pathologists, USDA Forest Service, Northeastern Area, St. Paul, MN.

⁷ Plant Pathologist, USDA Forest Service, Southern Region, Asheville, NC.

tion 1995; EPA 1995). Since 1994, methyl bromide production in the United States has been restricted to 1991 levels. Reliance on any chemical biocide to maintain production is inherently risky over the long term. Such chemicals are likely to become restricted in use, due to human or environmental health hazards.

In addition to the health hazards of chemical biocides, fumigation drastically disrupts the biology of the soil system, destroying beneficial and detrimental organisms alike. The first microorganisms to recolonize the soil, through blowing dust or on equipment, may be pathogenic ones. Populations of beneficial microorganisms, especially those that limit the growth of pathogens, develop slowly while the pathogen populations are allowed freedom to increase rapidly. Fumigation tends to result in the need for continued fumigation.

Although fumigation may conveniently take care of a number of concerns simultaneously, there are other ways to achieve similar results by dealing with specific concerns at each nursery. Many nurseries cite control of soil-borne diseases and weeds as the main reasons for soil fumigation. A wide variety of herbicides are available for effective weed control. In the technology development project, "Alternatives to Chemical Fumigation" we are concentrating on management of soil-borne tree seedling diseases.

PROJECT OBJECTIVES

The overall objective of the project is to enhance implementation of integrated pest management (IPM) of soil-borne diseases at forest tree nurseries. The three facets of the project include:

1. Develop and evaluate cropping and soil treatment regimes for production of high quality seedlings without chemical fumigation;

2. Develop and evaluate combinations of biocontrol agents and application methods for suppression of soil-borne diseases of seedlings;
3. Develop accurate sampling and disease-forecasting techniques for soil-borne *Fusarium*.

COOPERATING NURSERIES

This paper presents some of the preliminary results from the first facet of the project—the seedbed treatments at cooperating nurseries. Cooperators include thirteen Federal, State, and Industrial nurseries as follows:

In the Northeast Area, USDA Forest Service (USFS) J. W. **Toumey** Nursery in Watersmeet, Michigan; and Wisconsin State **Griffith** Nursery in Wisconsin Rapids.

In the Southern Region, Florida State **Andrews** Nursery in Chiefland; International Paper Company **Supertree** Nursery in Blenheim, South Carolina; and USFS W. W. Ashe Nursery in Brooklyn, Mississippi.

In the Northern Region, USFS **Coeur d'Alene** Nursery in Coeur d'Alene, Idaho.

In the Intermountain Region, USFS **Lucky Peak** Nursery near Boise, Idaho.

In the Pacific Southwest Region, California State **Magalia** Nursery in Magalia; USFS **Humboldt** Nursery near Eureka, California; and USFS **Placerville** Nursery near Placerville, California.

In the Pacific Northwest Region, USFS **Bend Pine** Nursery in Bend, Oregon; USFS **J. Herbert Stone** Nursery in Central Point, Oregon; and USFS **Wind River** Nursery near Carson, Washington.

SOIL-BORNE DISEASE

The disease cycle revolves around interactions between the host, pathogen, and environmental conditions. Host susceptibility can depend on host physiology, anatomy, and the growing environment. Infection depends on the susceptibility of the host, the population level of pathogen (inoculum) present, and the vigor and virulence of the pathogen. Even after the pathogen infects host tissue, the expression of disease may be delayed if environmental conditions favor the host over the pathogen. Environmental conditions affect susceptibility of the host to infection, disease expression, and vigor of the pathogen.

Disease can be avoided in two ways: by preventing infection, or by preventing disease expression, that is, by manipulating the seedling environment to favor the host and suppress the pathogen. Delay in the expression of disease symptoms occurs, for example, with *Fusarium* root rot. Infection takes place quite early, soon after seed germination. For seedlings that do not succumb early to damping-off, the root rot disease is expressed later, usually by mid summer, when temperatures and moisture stress begin to favor the pathogen over the host.

The best control for disease is to prevent infection; this can be done by reducing pathogen populations, or by providing physical or temporal barriers to infection. Chemical fumigation reduces pathogen populations by killing the organisms. Without a chemical biocide, pathogen populations can be reduced by removing the available food base and encouraging competitive saprophytes. "Green manures" from cover crops incorporated into soil tend to stimulate increases in populations of pathogenic soil fungi (Stone and Hansen, 1994). Many pathogenic fungi can function as saprophytes, and their populations increase due to the greatly increased food base.

TREATMENTS FOR PREVENTING INFECTION

Strategy 1: Reduce Pathogen Populations

Treatments that reduce pathogen populations include bare fallowing, with or without tilling, and incorporation of slowly decomposing organic soil amendments. A season of bare fallow depletes the food base for pathogens, and periodic tilling continually brings pathogen propagules to the soil surface where they are exposed to dessication and lethal temperatures. Weeds provide a food base for pathogens and shade the soil surface, and thus diminish the beneficial effects of bare fallowing.

Slowly decomposing organic soil amendments, such as aged sawdust or compost, favor the growth of competitive soil saprophytes to the detriment of soil pathogens. Amendments with high carbon to nitrogen ratios are difficult for pathogens to utilize as a food base. Other soil saprophytes are able to thrive and can out-compete pathogens. The low nitrogen levels will eventually stunt tree seedlings, and they require additional nitrogen. Delay in nitrogen application until well after seedling germination may further limit the growth of soil pathogens.

Strategy 2: Barriers to Infection

Treatments that provide barriers to infection include early sowing, and shallow sowing with mulching. The barriers act to separate the germinating seedling—the most susceptible host condition—from the pathogens in the soil. Early sowing provides a temporal barrier by allowing conifer seed to germinate, and the radicle to become suberized, before the time when soil temperatures reach optimum for pathogens.

Covering the seed with mulch, rather than soil, provides a spacial barrier that partially separates the germinating seedling from the pathogen in the soil. A slowly decomposing mulch, like sawdust, may also provide a biological barrier, where competitive saprophytes displace pathogens.

PRELIMINARY RESULTS

Western Nurseries

Summary tables for western nurseries provide data from the first growing season for conifer bare root stock grown under various treatments. Pre-sow soil treatments included cover cropping, fallowing, fumigation, and incorporation of soil amendments. Mulch treatments covered seed after sowing. Seedling density and morphology data are means of measurements, taken in October 1994, from five replicates per treatment. Significant differences ($P>0.05$) between treatments were determined by analysis of variance; and are indicated by different letters following data. Where significant differences occur in seedling density, seedling morphology data may not be useful, because low densities often result in large seedlings. Seedling height was measured in the beds, while root volume and shoot length were measured in the laboratory. The Key provides explanations and definitions for recurring abbreviations used in the summary tables.

Key to Terms Used in Summary Tables

<u>Treatment</u>	<u>Explanation</u>
MBC	Fumigation with 67 percent methyl bromide and 33 percent chloropicrin at 350 lb/ac.
Dazomet	Fumigation with Basamid Granular at 350 lb/ac.
BFT	Bare fallowing with periodic tilling.
BF	Bare fallowing without tilling.
S+N	Soil amended by incorporation of aged sawdust and some form of nitrate fertilizer.
<u>Data</u>	<u>Explanation</u>
Density	Seedlings per square foot.
Mortality	Percent of seedlings with disease-caused mortality.
Fusarium	Propagules of <u>Fusarium</u> spp. per gram of soil, assayed at time of sowing.
Weeds	Weed plants per square foot, counted within a few weeks after sowing.

Bend Pine Nursery, 1-0 Ponderosa Pine

<u>Treatment</u>	<u>Density</u>	<u>Mortality</u>	<u>Fusarium</u>
Pea cover crop, MBC	21.4 a	0.06 a	170 a
BFT, S+N	22.3 a	0.11 a	618 a
BF, S+N	22.4 a	0.09 a	948 a
Peas, no fumigation	7.3 b	0.39 b	3711 b

At Bend Pine Nursery, the conventional pea cover crop without fumigation resulted in significantly greater disease-caused mortality, and lower seedling density. The bare fallowing treatments included sawdust plus nitrogen incorporated at the beginning of the bare fallowing. Bare fallowing treatments, with or without periodic tilling, were comparable to methyl bromide fumigation, resulting in similar seedling densities and low mortality.

J. Herbert Stone Nursery, 1-0 Douglas-fir

<u>Treatment</u>	<u>Density</u>	<u>Mortality</u>	<u>Fusarium</u>	<u>Weeds</u>
BFT, S+N, dazomet	19.5 ab	0.099 ns	135 a	3.3 a
BFT, S+N	16.9 ab	0.131 ns	2194 a	10.9 a
BF, S+N	14.9 a	0.157 ns	3469 b	89.5 b
BFT, No S	19.1 ab	0.117ns	1106a	4.9 a
BFT, S, delayed N	23.8 b	0.098 ns	808 a	1.3 a

At J. Herbert Stone Nursery, all treatments included bare fallow with tilling at three week intervals, except one without tilling. Sawdust plus nitrogen was incorporated as a soil amendment at the beginning of the bare fallow. In the "S delayed N" treatment, extra nitrogen was provided only after seedling germination.

Douglas-fir density after dazomet fumigation was not different from that after the bare fallow with tilling treatments. Weed density was high in the plots without tilling, with effects similar to a cover crop—Fusarium populations increased and seedling density decreased. Sawdust soil amendment with delayed application of N may tend to suppress both weed and pathogen development.

J. Herbert Stone Nursery, 1-0 Ponderosa Pine

<u>Treatment</u>	<u>Density</u>	<u>Caliper, mm</u>	<u>Shoot length, cm</u>
BFT, S+N, dazomet	19.9 a	4.8 b	12.0 b
BFT, S+N	21.4 a	4.6 a	11.8 a
BF, S+N	16.7 a	3.7 a	8.4 a
BFT, No S	20.9 a	4.7 b	12.0 b
BFT, S, delayed N	23.2 a	4.3 a	10.1 a

For ponderosa pine, all treatments resulted in similar densities. Seedling morphology was similar between the no sawdust amendment treatment and the dazomet treatment.

Coeur d'Alene Nursery, 1-0 Douglas-fir

<u>Treatment</u>	<u>Density</u>	<u>Root volume, cc</u>	<u>Shoot length, cm</u>
BFT, Dazomet	30.0 a	0.6 b	4.5 b
BFT, Bark	27.3 a	0.3 a	3.5 a
BFT	27.0 a	0.3 a	4.5 b
BFT, Pine Mulch	30.9 a	0.6 b	5.6 c
BFT, Sludge	26.4 a	0.5 b	5.8 c

At Coeur d'Alene Nursery, all treatments included bare fallow with tilling. Soil amendments incorporated before bare fallowing included composted bark chips (Bark) and sewage sludge (Sludge). The "Pine Mulch" treatment was a layer of old pine needles covering the seed. Douglas-fir density was similar after all treatments. As measured by root volume and shoot length, seedlings were smallest after the composted bark chips amendment and the bare fallow with tilling alone. Shoot length was greatest after the pine mulch and sludge amendment treatments.

Lucky Peak Nursery, 1-0 Ponderosa Pine

<u>Treatment</u>	<u>Density</u>	<u>Root Volume, cc</u>	<u>Shoot Length, cm</u>
BFT	23.3 a	3.1 b	11.0 b
BF	15.3 a	3.0 b	10.7 b
BF, Compost	15.7 a	2.0 a	8.1 a
BF, S+N	20.1 a	2.3 a	11.1 b
BF, MBC	19.3 a	2.2 a	8.1 a

At Lucky Peak Nursery, all treatments included bare fallowing without tilling except for one with tilling. Soil amendments included composted mushroom medium (Compost) and commercial sawdust with nitrogen. No significant differences in ponderosa pine seedling density were found after the first growing season.

Ponderosa pine seedling shoot length was significantly greater in the bare fallow with and without tilling, and with sawdust amendment, than in the compost and fumigation treatments. Root volume was significantly greater in the bare fallow with and without tilling, than in the soil amendments and fumigation treatments.

Lucky Peak Nursery, 1-0 Lodgepole Pine

<u>Treatment</u>	<u>Density</u>	<u>Mortality</u>	<u>Root Volume, cc</u>	<u>Shoot Length, cm</u>
BFT	17.0 a	0.18 ab	2.1 a	6.8 b
BF	20.4 b	0.16 ab	2.0 ab	6.7 b
BF, Compost	13.9 a	0.30 b	1.3 b	4.6 a
BF, S+N	16.5 a	0.21 ab	1.5 b	6.4 b
BF, MBC	20.1 b	0.11 a	2.2 a	8.1 C

For lodgepole pine at Lucky Peak Nursery, bare fallow alone resulted in similar seedling density to bare fallow followed by MBC. Root volume was greater without soil amendments, while shoot length was greater with MBC.

Placerville Nursery, 1-0 Shasta Red Fir

<u>Treatment</u>	<u>Density</u>	<u>Mortality</u>
BFT, ST, Soil, Late	18.5 a	0.41 a
BFT, ST, Hydro, Early	29.9 b	0.07 b
BFT, S, Hydro, Early	26.7 b	0.13 b
BFT, S, S, Early	27.8 b	0.16 b
BFT, Pine, Hydro, Early	26.4 b	0.10 b
BFT, Hydro, Hydro, Early	25.9 b	0.11 b
BFT, Bare, Hydro, Early	24.1 b	0.12 b

At Placerville Nursery, all treatments began with bare fallow with tilling, then an overwinter soil covering of rice straw (ST), sawdust (S), pine needles (Pine), hydromulch (Hydro), or nothing (Bare). Shasta red fir seed was sown in March (Early) or mid April (Late), and covered with soil, hydromulch, or sawdust. The conventional late sowing with soil covering the seed resulted in significantly lower seedling density, and greater mortality caused by disease. Seedling root volume, caliper, and height were not significantly different.

Humboldt Nursery, 1-0 Shasta Red Fir

<u>Treatment</u>	<u>Density</u>	<u>Root Volume, cc</u>	<u>Shoot Length, cm</u>
BF	19.3 a	0.47 ns	3.71 ns
BFT, Compost	19.6 a	0.58 ns	4.73 ns
BFT, Hydromulch	21.6 a	0.44 ns	4.25 ns
BFT, MBC	20.1 a	0.45 ns	3.87 ns
BFT, Dazomet	20.1 a	0.43 ns	4.20 ns

At Humboldt Nursery, all treatments began with bare fallow with tilling, except for one without tilling. Mulches after sowing include composted redwood chips (Compost) or hydromulch. Shasta red fir seedling density and morphology (root volume, shoot length) were not significantly different after all treatments.

Southern Nurseries

At Andrews Nursery, Chiefland, Florida, measurements were taken at the time of lifting 1-0 slash pine from four replications per treatment in January 1994. This information was reported in more detail at the Southern/Northeastern Forest Nurserymen's Conference, Williamsburg, VA, July 1994, by M. E. Kannwischer-Mitchell, E. L. Barnard, D. J. Mitchell, and S. W. Fraedrich.

Soil amendments included pinebark or composted woody yard waste (Compost), applied as a layer, 2.5 cm (1x) or 5.0 cm (2x) thick, then incorporated into the soil. No treatments was applied in the check plots. Slash pine height and density were significantly different between the MBC and check, and intermediate in the soil amendment treatments. There were no differences in caliper.

Andrews Nursery, 1-0 Slash Pine

<u>Treatment</u>	<u>Density</u>	<u>Caliper, mm</u>	<u>Height, cm</u>
Check	16a	4.6 a	19.5 a
Pinebark 1x	18 ab	4.5 a	21.8 ab
Pinebark 2x	18 ab	4.4 a	22.5 ab
Compost 1x	18 ab	4.7 a	23.6 ab
Compost 2x	18 ab	4.6 a	21.1 ab
MBC	20 b	4.9 a	25.2 b

Northeastern Nurseries

At Toumey Nursery, Michigan, the standard practice for red pine is an oak seedling crop or winter rye cover crop, followed by an oat cover crop, then MBC fumigation and sowing. Treatments compared MBC with dazomet and no fumigation (Check).

Toumey Nursery, 1-0 and 2-0 Red Pine

<u>Treatment</u>	<u>1-0 Density</u>	<u>2-0 Density</u>	<u>2-0 Caliper. mm</u>
Check	26.9	26.5	2.7
Dazomet	25.5	24.6	2.5
MBC	26.9	25.5	3.2

Between the 1 -0 and 2-0 years, there was little loss in seedling density. Seedling density was not significantly different between the unfumigated check, dazomet, and MBC. Height was more uniform in the MBC and check treatments than in the dazomet treatment.

After 2 growing seasons, seedling caliper was significantly greater in the MBC treatment, and met shipping specifications (3.0 mm). In the check and dazomet treatments caliper did not meet specifications. At the same time, none of the treatments resulted in sufficient height to meet specifications, and the seedlings were carried to 3-0. This is a fairly common occurrence in cold, upper Michigan soils. In some years red pine seedlings reach shipping specifications in the second year.

At Griffith State Nursery in Wisconsin, bare fallowing for four months resulted in lower seedling densities than fumigation with MBC or dazomet.

DISCUSSION AND SUMMARY

Preliminary results with the conifer species tested indicate that at many nurseries, modification of cultural practices can greatly reduce the need for chemical fumigation. At some nurseries current practices are sufficient and fumigation is not needed. Additional measurements—including numbers of shippable seedlings, results of repeated treatments, and testing of biocontrol agents—will be reported in future publications.

Cultural practices that can help reduce the need for chemical fumigation include:

- Incorporation of slowly decomposing organic soil amendments, such as aged sawdust with additional nitrogen provided to seedlings.
- Bare fallowing, with and without periodic tilling, maintained free of weeds.
- Sowing conifer seed early and shallow, covered with a non-soil mulch such as aged sawdust or hydromulch.

Without chemical fumigation, practices that alleviate one problem may aggravate another, for example, bare fallowing may increase wind erosion. Other soil coverings that stabilize the soil surface and wind abatement strategies are available. The solutions to growing quality seedlings without chemical fumigation will be found in each situation as the resourceful culturist recognizes the benefits of freedom from reliance on broad spectrum biocides.

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Basic Marketing Concepts for Forest and Conservation Nurseries¹

B. J. Hill²

Abstract—Basic marketing concepts can be useful for forest and conservation nurseries especially as they transition into self-sustaining financial situations. These basic marketing concepts include marketing orientation, marketing plan development, market research, target marketing, SWOT analysis, marketing mix, promotional mix, and advertising mix. These concepts are explained and applied to forest and conservation nurseries.

Basic marketing principles can be applied to nearly any for-profit or not-for-profit enterprise to increase customer satisfaction and to enhance business, or organizational, success. Sometimes, a simple outline of those basic marketing concepts is all that is needed to remind us to turn needed attention towards the customer or client. This paper seeks to provide an outline of basic marketing principles.

More than anything else, **marketing is an attitude and orientation towards your customers.** A hundred years ago, industrialized companies produced goods, like Model T's, that were purchased without a lot of hoopla. A scarcity of goods in which people bought whatever was available characterized an industrial orientation. In the past, nurseries with a fixed customer base may have been able to produce any type of seedlings the nursery desired. Fifty years ago, companies utilized dynamic salesmen to unload products, like the Edsel, regardless of their value. This approach characterizes a sales orientation. Today, businesses adjust their product, price, or pattern of

distribution to meet the needs of their customers. Businesses that characteristically put their customers first follow a **marketing orientation.**

Adjusting a nursery's product, price, or distribution to better meet customer needs and wants is the foundation of marketing. Likewise, finding customers whose needs and wants match the products and services offered by our nurseries is an important part of marketing, but not the only part. For example, a nursery that offers a new species of seedling at the request of customers, or sets the price of seed production based on species after customer complaints, or decides to deliver over a broader range of territory is involved in marketing just as much as the nursery that spends money for newspaper or magazine advertising.

Traditionally, a **marketing mix** includes these four P's of product, price, place (distribution), and promotion. Those involved in service industries have realized that the additional P's of people, packaging, programming, and partnership are also important to customer satisfaction.

¹Hill, B.J. 1995. *Basic Marketing Concepts for Forest and Conservation Nurseries*. In: Landis, T.D.; Cregg, B., tech. coords. *National Proceedings, Forest and Conservation Nursery Associations*. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 23-26.

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Deciding what you want to do to meet a customer's needs and wants for the coming months or year is called a **marketing plan**. The various stages of a marketing plan are the building blocks to marketing success. Knowing what to do comes from information you gather from your customers. Gathering and considering that information is **market research**. Understanding just who your current customers are and who your potential customers may be is identifying **target markets**. Meeting the needs and wants of different customer groups is **target marketing**.

A marketing plan is based on a formal “**vision**” of your nursery. The plan also utilizes an analysis of strengths, weaknesses, opportunities and threats, called **SWOT analysis**. Then, **broad goals and strategies** of adjustment to the marketing mix, or eight Ps, are developed. Next, an **action plan** is prepared that details how the goals will be met by describing the who, what, when and how much. The plan spells out the target market, the marketing activity, who is responsible, the time frame for the activity, and the money to be spent for each action. After **implementation**, an **evaluation** of each activity suggests whether the actions ought to continue, be adjusted, or be discontinued. Marketing planning is a continuous cycle of analyzing, strategizing, planning, implementing, evaluating, and analyzing again. Again, the steps of the marketing plan are:

1. **Creating a guiding vision of your nursery.**

For some nurseries a guiding vision is mandated by legislative, executive, or bureaucratic action. Still, nursery managers and employees have entered the field with an individual commitment to some ideal of forestry management. To gain support, build morale, and provide direction, a compelling statement of mission and ideals should be prepared. The vision materializes as questions about the reasons, objectives, themes, strategies, and profits of the nursery are

answered. Then, the vision statement can be written to crystallize the process in positive affirmations that will provide direction and build confidence.

2. **Analyzing strengths, weaknesses, opportunities and threats.**

A careful examination of the external environments that a nursery finds itself in, as well as customer-based market research, leads to a better understanding of how the nursery can meet its guiding vision. The environment, or situation, a nursery finds itself in includes: the general economy, available technologies, societal shifts, political and legal changes and regulations, available resources, and competition. A close look at these environments, and the nursery's strengths and weaknesses within these environments can give a good idea of opportunities and challenges.

Market research adds information about customers and their levels of satisfaction. Market research can be as simple as visiting with customers in the field or on the phone or as complex as a carefully designed mail survey. Market research should help to identify who the target markets are, and how their needs and wants change.

3. **Developing objectives and strategies.**

Objectives are clear and measurable statements of business intentions for a specific period of time. They can be focused on particular strategies and the effects of those strategies on growth and profitability. Major strategies should focus on each of the components of the marketing mix (the 8 Ps) that will be utilized to meet objectives and realize the guiding vision for the nursery. A description of each component within the marketing mix that might be utilized as a marketing strategy are detailed below.

Product. For forest and conservation nurseries the common products are seeds and seedlings. Other services, such as seed processing, may also be a part of the product mix. Adjusting the product mix is the first strategy that should be considered in any marketing plan.

Price. This includes not only the actual price for each seedling, seed, or service, but also the minimum order taken, discounts for bulk purchases, and unique pricing strategies for the variety of services or species that might be made available. Customer perception of value is an ongoing issue in marketing efforts.

Distribution (Place). The distribution channels used to deliver the products and services provided by nurseries may also be adjusted to better meet customer wants and needs. Sales to wholesalers, retailers, cooperatives, or directly to customers, freight by air, truck, or delivery, and use of sales representatives are all decisions that relate to distribution and are a part of the marketing mix.

Promotion. The promotional mix can include **advertising, personal selling, sales promotion, merchandising, public relations, and publicity.**

Advertising efforts are common and require careful consideration. No amount of advertising can alter a poor reputation. Only product and service changes can completely overcome a negative image. It is so easy to spend large amounts of money on advertising that any advertising expenditures should be approached with special caution. Some possible advertising media include newspaper, magazine, radio, television, outdoor (billboards), and direct mail. Cooperative advertising between nurseries is certainly an option utilized by other industries and enterprises with limited marketing budgets. Though

advertising is a tempting place to spend marketing efforts, other promotion strategies are likely to yield substantial rewards. Souvenir T-shirts and mugs with logo or slogan are examples of **merchandising**. Point-of-purchase displays, point-of-purchase demonstrations, premiums, contests, sweepstakes, games, and coupons are examples of **sales promotions**. Though these would not be commonly used by nurseries, they shouldn't be dismissed out of hand either.

Personal selling with direct contacts is certainly appropriate for bulk customers and partner agencies.

Grand opening events, new conferences, announcements or feature stories in papers or magazines, and media interviews can all play a role in nursery marketing as **publicity** and **public relations** promotions.

People. The employees of any enterprise or organization are an often overlooked marketing resource. Service industries are especially dependent on the ability of employees to serve and satisfy customers. **Internal marketing** are those efforts that help employees feel good about their work and the mission of their institution.

Packaging and Programming. These marketing strategies involve packaging and putting together various products and services in a format that meets customer needs and developing special events or activities that appeal to customers. Imagination and unique perspectives are the most important talents needed to utilize these strategies.

Partnerships. Forest and conservation nurseries have long held partnerships with various National Forests. Those nurseries may not have looked upon those as important marketing strategies, but they certainly are.

The formation of similar partnerships will continue to be an important source for increasing nursery clientele.

4. Preparing a detailed *action plan*.

An action plan describes the scheduling, resource needs and individual responsibility for each marketing strategy. The best action plans provide the greatest specific detail.

5. *Implementing your plan*.

Certainly the most important part of any marketing plan is its implementation. Without someone to carry out the marketing strategies, planning is a process of futility.

6. *Evaluating your actions and strategies*.

No marketing plan will ever be all it can be until each marketing strategy is critically examined for its effectiveness. Periodic evaluations then lead to changes and adjustments in future strategy implementation.

Marketing can be rigorous and formal or simple and casual. If an orientation towards customers is in place, anything a nursery might do to better meet the wants and needs of customers or to find those customer's who desire their products and services is marketing. A marketing plan can be a sketch of these efforts or a detailed report, but the most important activity is asking, "What can I do to adjust my product, price, place, promotion, people, packaging, programming, or partnerships to better meet customer wants and needs?"

Adventures In Marketing: California Department of Forestry and Fire Protection's Nursery Program¹

Laurie Lippitt²

Abstract — This paper discusses initial marketing efforts for a nursery program that includes a seed processing and seedling production facility. Ideas are presented on positioning products and services, factors involved in pricing, some specific marketing activities, and forms/procedures that had to be developed in response to budget constraints. While efforts to increase revenue were relatively successful, it remains to be seen if efforts were soon enough and large enough for political viability of the nursery program under increasing budget pressures.

Reorganization; it's the way of the 90's. If it hasn't already arrived, it's coming soon to an agency near you. Simply put, it means "Do lots more, with lots less, now!" Our agency is no exception. In 1993 we were told that the Nursery Program would have two fiscal years to become self-sufficient and half of the first year was already over. So, with no funds and even less time, but lots of determination, a marketing effort was started.

SEED OPERATION

Initial efforts focused on the Seed Operation. In the past, we hadn't been allowed to offer seed services or charge for them, but the private sector had wanted our services in this area and there were no large scale private processors in the state that we'd be in competition with. Since the majority of our experience and expertise was with conifers, that was the starting point. The first decisions were 1) what services to offer and 2) what to charge for them.

For conifer processing, we felt our strength was the ability to do comprehensive processing — a high quality, full-service option. This would also position us differently than the less comprehensive options available through private processors in adjoining states. We'd be giving the customers the same high quality treatment we were providing for our own seed lots and wouldn't have to think about what steps to leave out for a lower level of processing. Our comprehensive processing includes use of special collection sacks we've developed, assistance with determination of maturity and collection dates, an initial assessment of the cones at arrival, full processing, X-ray of the seedlot prior to upgrade and after the final upgrade plus testing for purity, seed/lb, moisture content and germination rate.

It was more difficult to decide on prices to charge. Price would depend on the species, the lot size, what steps were done and how long they'd take, who the steps were done by and what hourly rate applied, and provision for overhead. Even

Lippitt, L. 1995. *Adventures In Marketing: California Department of Forestry & Fire Protection's Nursery Program*. In: Landis, T.D.; Cregg, B., tech. coords. *National proceedings, Forest and Conservation Nursery Associations*. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 27-35.

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within these factors, there were more decisions to make. For example, under lot size, we felt that there would be economies of scale between very small lots, medium sized and large operational lots. But, these lot sizes needed to be more specifically defined. Once the lot size ranges were defined, the small lots were priced on a per lot basis while the operational lots were priced on a per bushel basis. Other things to be determined were; what hourly wage rate to assign to the inmate labor and what overhead rate to use. Even things we were familiar with, such as what processing steps would be involved for a given species required additional thought. There had never been a need to keep records on how long any given step took and we rarely did all the steps in uninterrupted sequence on any one seedlot. There wasn't time to collect data, so we simply did our best to make reasonable estimates with the idea that revisions might need to be made at a later time. A Processing & Testing Price Proposal Form was developed to work up the price estimates (Appendix 1) and the results were put on a handout describing our services and prices that could be mailed to prospective customers (Appendix 2). This process of deciding on a service or product, how to offer and price it, followed by development of a handout was repeated for a variety of other services.

Additional services and products we could offer in the seed arena included:

Upgrade of Previously Processed Seed Lots

We felt that we could improve the purity and germination rate on lots that had not received a full upgrade initially, especially for true fir and redwood. We chose to offer two options: 1) maximize filled seed percentage (leave in every seed that is filled, even those that appear questionable and 2) maximize potential vigor and germination by removing some seeds that appear questionable, even though they are filled. Prices were set on a per pound basis, depending on lot size.

Seed Analysis & Testing

To avoid direct competition with officially certified seed testing laboratories, we decided to remain uncertified. But this would allow us to offer services at a lower cost. Services we offer are purity, seed per pound, X-ray analysis, cut test, germination test, and determination of an appropriate seed pretreatment to break dormancy. We decided to focus on X-ray analysis which is not commonly available and provides several useful opportunities. We could make the image only and let the customer save on cost by doing their own analysis. The X-ray analysis is well suited to a rapid determination of filled seed percentage where no other testing or analysis is planned, such as many restoration projects where direct seedling is planned. The non-destructive aspect of X-ray makes it suitable for assessing small amounts of rare seed such as threatened and endangered species. A Rush Service is offered for X-ray analysis and cut tests where customers might want an immediate response in order to make a collection or seeding decision.

Since testing prices didn't depend on species, the handout developed for these services could be used on a wide array of both conifer and non-conifer species.

Seed Storage

Storage could be provided in the State Seed Bank. This service was not available within the state and most private seed was being sent out of state for storage. We decided to offer two storage options; 1) storage by the box for those with numerous small lots and 2) storage by the pound for those with larger quantities. A discount would be offered for those storing very large quantities. There would also need to be charges for entry into the system (receive, weigh, re-package, records), withdrawals and shipping.

Cones

In the past, we'd paid to dispose of cones or given them away. There was market for them, so we needed only to determine our process and price. We settled on charging a set price for a convenient volume of cones rather than using a bid process. We wanted to keep our handling and costs to a minimum, so we required vendors to come and take the cones away rather than shipping them. There was such an overwhelming response that we might consider a bid system in the future to maximize our revenues from this source.

Seed

We'd been able to sell seed before, but on a very limited basis. The purchaser had to certify that the seed, by specific source, was not available from a private vendor and we had to make a determination that it was excess to our State Seed Bank needs. Previous sales had been at the average commercial price. Now, we charge what we estimate our cost to be plus an overhead. Many of our site-specific seed lots are unavailable commercially. This, coupled with a frequently higher purity and germination rate make our seed a more specialized product that should sell for a higher price. Though we can now sell seed more freely, we still need to keep an adequate supply in the State Seed Bank.

Blister Rust-Resistant (BRR) Sugar Pine Seed Services

We'd been offering these services free of charge to fellow members in our tree improvement cooperatives. Now, a charge has been instituted. Candidate seedlot processing consists of processing a 2-4 cone lot and doing rush processing to get 150 filled seed (X-ray determination) in time to meet the USFS stratification process for the start of their resistance screening process plus upgrading the rest of the seed. We also process known BRR cones under our regular processing schedule. In our own BRR work, we'd found it necessary to pre-bag cones on some known resistant trees to exclude insects and maximize our BRR seed yield. We now sell these pre-bagging "kits" as well.

Tree Improvement Lots

We'd been doing some processing and testing of tree improvement lots for several companies under a cooperative agreement that allowed us to trade our services for supplies. Now, we can offer those services routinely. We also did a proposal and were awarded the processing and testing work for seed from a seed orchard where we are one of the members of the tree improvement cooperative. It works well for everyone- we can choose to gather extra information that will be valuable, at no cost, and the cooperators like the idea that we have a vested interest in having the highest yield and quality possible because we get a share of the seed.

Training

This is another service we'd been offering free that we needed to institute a charge for. However, after more than 10 years of offering cone and seed training, most of the conifer folks had been trained. Instead, the target market for seed workshops appeared to be restorationists. Workshops and training have been given for Society for Ecological Restoration and several agencies. Two private companies have purchased customer training sessions for their staff. This is an area with potential for future development.

Processing of Hardwood, Shrub and Other Native Species

With conifer crops so periodic in nature, we knew they couldn't be relied on to produce a steady income flow. We'd processed a number of hardwood and shrub species for use in our nursery production and felt we could process a wide array of native species. While many restoration projects involve direct seeding, there would still be a market for processing services. Still, there was a much wider range of species, lot sizes, levels of debris and differences in structure involved when compared with conifers. An entirely new pricing scheme was necessary. The system we chose is based on 1) level of debris (low, moderate & excessive), 2) lot size (small, medium, large), and 3) level of processing (basic & comprehensive). Again, we had to estimate the time that would be

involved based on trials with a limited number of species. We probably will have to revise these prices as we get more experience. Several seedlots we've processed were surprisingly time consuming. We have also successfully processed species we were completely unfamiliar with. However, in those cases, we like to see the seedlot first before agreeing to process.

Vegetable, Crop & Flower Seed Processing

In an effort to broaden our customer base beyond the traditional conifer market, we turned to a non-traditional market. Our equipment works equally well for seed of most species and we needed to keep busy in the off season for conifers rather than adding additional work at a time when we already have staffing limitations. The vegetable, crop and flower seed markets seemed an ideal extension of our current work. When we first proposed this, it met with resistance since it was "non-traditional" and non-mandated. But our compelling need to generate revenue was persuasive. The niche we focused on for this market was upgrade of previously processed seed and X-ray services. There is already a lot of commercial processing capacity for this sector, but they focus more on quantity and speed. We aren't set up to handle bulk processing on large volumes but there was room to offer an improvement in germination and/or vigor on volumes that we could handle. The service is offered on a price per pound basis with a volume discount for a large volume of business during the course of a year. This effort has been very successful, but is due almost entirely to the specialized equipment that Rich Felden, our head of processing, has designed and to his connections in the vegetable and flower seed industries.

Processing Consultation

A number of firms wanted to see what equipment we had, get processing recommendations, obtain advice on equipment and have a sample of their seed upgraded and X-rayed. We charge by the hour for consultation services and an advance appointment is required. Everyone that has paid for

a consultation has ended up bringing us additional processing and testing business, so this option has worked well.

Seed Packets and Seed Zone Maps

There have always been frequent requests for small quantities of coast redwood seed or giant sequoia seed. We now offer a seed packet with 100 seed plus instructions on seed treatment and seedling growing. A handout on growing coast and sierra redwoods outside their native range is also included. We've made sure the packaging is attractive, in contrast to the basic packaging used on our usual seed sales where larger quantities are involved. We are able to charge a high price for this relatively labor-intensive but popular product. The next step is to market these packets to nature stores, garden catalogs and other suitable outlets. We also sell the California Tree Seed Zone Maps, which used to be provided free.

We were surprised with the number of products and services that we came up with just in the Seed Operation. Other details we had to address beyond products, prices and handouts included a way to specify what was to be done for each project we accepted. A basic Project Form was a starting point and now we have a Seed Services Order Form (Appendix 3). We also needed a way to invoice and bill for services. For products like seed, we require advance payment while for services, we invoice upon completion of the work. We developed an invoice form, a seed order form and a system to track projects and revenues. It is important to attend to these details since bureaucratic interest is always high when revenue and receipts are concerned. We were audited this season and expect frequent audits in the future. While we feel fairly comfortable with all the prices and procedures we've instituted so far, it is still amazing the number of times a customer will request a quote on a custom service that we haven't determined a price for yet. We also realize we need a more detailed look at questions of liability and know we need to add additional verbiage on all our handouts to cover this area.

Revenue from the Seed Operation tripled from the first year to the second. Entering our third season, there is an almost non-existent cone crop, so we're just hoping to keep revenue comparable to last year. Trying to keep a 10 year supply of numerous species, seed zone and elevation combinations in the State Seed Bank is a large undertaking that is inherently non-economic in nature. So, it is not certain that the Seed Operation can (or should) be fully self-sufficient. Simply continuing to do this work in addition to all the revenue-generating work, with the same staffing and the same or lower budget level, is a big challenge. If we can do all this while covering most of our costs, we'll consider ourselves successful. It remains to be seen if our agency and state government as a whole will agree.

MARKETING SEEDLINGS

Here is a brief description of some of the considerations and activities we undertook to market and increase revenues on the plant production side (bareroot & container) of our Nursery Program.

We started with an assessment of our strengths and constraints. Our legal mandate still precludes us from selling seedlings strictly for landscape or give-away and this limits many markets. In terms of competition with the private sector, there is already decent coverage for conifers and our bareroot nursery is at capacity for the staff level and land under production. This suggests that conifers are not where an increase in our market lies. There are some good private native plant nurseries, so we needed to look at different species or seed sources to avoid direct competition with them. Looking at demand and the limitations of our hot climate and saline water, we felt that we could successfully produce seedlings for desert restoration, mine reclamation, pipeline projects and other harsh site environments. These areas are not well-covered by the private sector. We might be able to produce for coastal sage scrub and dune

environments if demand increases, though there is reasonable coverage by the private sector for these areas at current levels. There is considerable demand for riparian species, but our water quality precludes us from production of these species and limits our ability to produce cuttings as well. One area with good potential for future production is production of "firesafe" species where native species with erosion control, wildlife habitat and firesafe values are needed.

Following a detailed "Strengths, Weaknesses, Opportunities & Threats" analysis, we had to address the matter of pricing. For our standard species, the Board of Forestry (BOF) still sets the prices, though we are allowed to propose prices. We proposed a price increase, but didn't want to make it too drastic. Future increases will be proposed. We also changed the time of year the BOF sets the prices, so that new prices would be in effect in time to use them for contracts initiated that year. For custom species and small lots, the BOF recognized that conditions may vary and standard prices would not be appropriate. Instead, they requested that we propose a method for determining such prices and they would review and approve the method.

Again, there wasn't detailed information on costs and staff time for production of particular crops. We started with a Plant Production Price Worksheet using factors such as species, container type and size, potting mix type, quantity of plants requested and cultural practices with different levels of use that might apply to them. This process wasn't easily workable, so we went to a more simplified method involving container cost, potting mix cost, square footage charge (to cover cultural practices), length of growing period, overhead, small lot charge (if applicable) and shipping. Again, it is amazing how many different combinations there are, so that even with our method in place, we are frequently preparing quotes for requests that we haven't handled previously. We also will need to add on a charge for plants that

stay much longer than originally planned. With bureaucratic uncertainty increasing on many projects- plants were sometimes being held months and even a year or longer than originally intended. We've now developed a specific charge for this.

An analysis of our customers (mostly small, private landowners) showed that they varied by age, education, income, purpose of planting and location. They would not lend themselves to a targeted marketing approach. However, they are very loyal, with most placing orders year after year. This suggested a strategy directed towards increasing the overall number of customers, rather than doing targeted marketing to specific groups. We just needed to get the word out to likely places. Once customers heard about us and tried our services, they might be likely to remain customers. We also sought to increase the number of agencies contracting with us for plants.

A few of the marketing efforts tried were:

- 1) Putting a small, counter top handout rack/display in all of our California Department of Forestry offices and in the offices of the Rural Conservation Districts, Cooperative Extension Offices and County Farm Advisors Offices. We asked for permission to have the rack displayed and asked if they would keep the rack so that we could change the materials in it. Most agreed to our request since our display was small and didn't take up too much of their valuable counter space. In addition to our regular Price Lists & Order Forms, we've displayed notices of a Spring Sale with Discount Coupons, a Firesafe Promotional and other items. We'd like to do a nice poster as a supplement for use in these same locations, but didn't have the funds to implement.
- 2) Advertising. We placed a small ad in California Farmer for our windbreak species. We were reluctant to advertise too widely for fear of raising the specter of competition. Lack of funds also limited advertising.

- 3) Write articles for newsletters. Advantages were that this was free and got the information out without being a direct or hard sell, like an ad. Many of the projects for which we do seed work and grow plants are quite interesting and the articles also were a way to give recognition to the entities that were doing the work.

- 4) Attend meetings and conferences. Give talks, training or workshops, if possible. This gives people a chance to interact with us and our organization as a professional with information to share. Without directly mentioning it, they become aware of our expertise and services. Most people want to know who they will be working with on projects before entrusting their valuable materials with them, so personal contact is an important first step. Conferences also provide an opportunity to hear about upcoming projects and to increase expertise. Meetings and conferences can be expensive, but there are sometimes funds available to cover some costs. Otherwise, it can be looked at as professional development with the added value of the marketing aspect. Besides cost, time is a limiting factor for increasing efforts in this area. With staffing shortages prevalent everywhere, it is increasingly difficult to get away.

While our marketing efforts didn't increase our customer base as much as we'd like, we were still able to cover most of our nursery costs the first two seasons. In this third season, increased budget pressures within the Department will make it imperative that we generate even more revenue, so it remains to be seen whether our efforts have been soon enough and large enough. Many agencies determined that they want our services and plants; they just didn't have the funding approved to proceed with projects that were planned.

We face an uphill battle, both economically and politically, but are determined to continue trying to "Do lots more, with lots less, now!"

Appendix 1.

PROCESSING & TESTING PRICE PROPOSAL FORM

Species: _____

Lot Size: _____

Small Lot
5 bu.

Regular Lot
5-50 bu.

Bulk Lot
50 bu.

Processing & Testing Stage	Step To Be Done	# Reps	Est. Time	Done By	Hourly Rate	Cost This Step
Log-in						
Assessment						
After-ripen						
Pre-condition						
Dry/Kiln						
Extraction						
Dewing/Debeard						
Screen						
Preliminary Cleaning						
X-ray Assessment						
Final Upgrade						
Hand Clean						
Final X-ray						
Seedlot Weight						
Purity						
Seed/Pound or # of Seed						
Moisture%						
Germination						
X-ray Analysis						
Records						
Packaging						
Shipping						
Work-up of Price & Agreement						

Total: _____

Price Proposal Per Lot: _____

or

Price Proposal Per Bushel: _____



CONE & SEED PROCESSING Conifer Schedule

Comprehensive Processing

The Reforestation Center is able to offer comprehensive cone and seed processing, including:

- * Use of CDFs special collection **sacks**.* (improves aeration & decreases case-hardening)
- * Assistance **with** assessing **collectability** and determining maturity. A sample can be sent to the Center via mail or UPS. We can usually call you the day your sample is received with our assessment of its status. If not mature yet, we provide an estimate of when it will be ready.
- * Each lot of cones is assessed upon arrival. A copy of the initial assessment is provided.
- * Any after-ripening **and/or** pre-conditioning that is necessary.
- * A copy of the preliminary x-ray, prior to seed upgrade.
- * The highest level of seed upgrade possible. Seed upgrade is our specialty.
- * An x-ray of the completed, upgraded seed.
- * Determination of purity, seed per pound, moisture content and germination rate. Seed will be a minimum of 98% purity and is usually above 99%. Seed will be dried to storage moisture content (5-9%). The germination rate will be determined using a single test with the preferred stratification for that species.

We have experience processing numerous species. Please call to discuss your requirements and obtain a price quote on any species or special processing options of interest to you.

<u>Species</u>	<u>Operational Lots</u>		<u>Small Lots</u>
	<u>Price Per Bu</u> 10-50 Bu	<u>Price Per Bu</u> > 50Bu	<u>Price Per Lot</u> 5 Bu or Less
Ponderosa Pine Sugar Pine	\$8.75	\$8.00	\$74.00
Douglas-fir	\$9.50	\$8.75	\$80.00
White Fir Red Fir Incense Cedar	\$10.00	\$9.25	\$85.00
Coast Redwood Sierra Redwood	\$17.00	\$15.50	\$105.00
Other Species	Call for a quote.		

Seed Upgrade

Do you have seed lots with low germination and a purity of less than **98%**? These lots would benefit from further upgrade. We can improve both the purity and filled seed percent of most lots. Cost for this service will vary with lot size, species, current purity and current filled seed percent. Please call to discuss your upgrade needs and receive a quote.

* These sacks are valuable to us. In order to insure their return, a charge of **\$15** per sack will be assessed for any sacks not returned.



Appendix 3.



L.A. MORAN REFORESTATION

SEED SERVICES ORDER FORM

Ordered By _____ Order Taken By _____
 (Company name _____ Date _____
 & address) _____
 Contact Person: _____
 Phone # _____
 Species: _____ Lot# _____ Approximate Lot Size: _____
 or weight _____

SERVICES

SEED UPGRADE (includes preliminary x-ray)
 Type: _____
 _____comprehensive processing & testing
 _____maximize filled seed percentage (may leave in some seed that
 are filled, but not necessarily viable).
 _____try for maximum germination and vigor by removing
 questionable appearing seed.
 _____other _____

Instructions for upgrading fractions:
 _____save all fractions, including empties.
 _____save the final upgrade product & the next best fraction.
 _____save only the final upgrade product.

Timing of completion:
 _____regular
 _____rush (extra charge)
 If needed by a specific date, date needed _____

SEED TESTING

X-rays:
 _____x-ray only (no analysis, non-rush)
 _____x-ray only, Rush basis
 _____x-ray with analysis (non-rush)
 _____x-ray with analysis (Rush basis)

Fractions to be x-rayed:
 _____seedlot, as sent
 _____all fractions from upgrade process
 _____final upgrade product only
 _____other _____

Moisture Content: _____

Seed Per Pound:
 _____seedlot as sent
 _____final upgrade product only
 _____other _____

Purity:
 _____seedlot as sent
 _____final upgrade product only
 _____other _____

Germination test:
 _____seedlot as sent
 _____final upgrade product only
 _____other _____

Number of Seed: _____ standard 400
 _____ other _____
 Pretreatment: _____
 _____ standard
 _____ other _____
 _____ determine a suitable
 pretreatment

Shipping Instructions:
 _____ Method _____
 _____ Insured - Amount _____

Ship to: _____

Comments: _____

Benefits and Techniques for Evaluating Outplanting Success¹

Robert W. Neumann² and Thomas D. Landis³

Abstract—Although outplanting information is essential to good nursery management, many nurseries do not have the time or funds to follow the survival and growth of their seedlings after they are outplanted. The benefits of evaluating outplantings are discussed along with types of sampling plots and an example of a survey form. It is concluded that, if they don't have one already, all forest and conservation nurseries should develop a system for monitoring outplanting performance. This should be considered a normal "cost of doing business" and that for state forest nurseries, federal cost-share funds could be used to insure that this essential information is collected.

INTRODUCTION

What exactly do we mean by "success" in forest and conservation nurseries — large, healthy seedlings in the seedbeds or in the greenhouse? No, the true measure of success cannot be determined at the nursery itself but rather can only be evaluated after the seedlings are outplanted. The best-looking seedling at the nursery is worthless if it does not survive and grow after outplanting (Landis and others 1995). The goals of a nursery program should be to promote and maintain customer satisfaction, meet management objectives, and improve environmental quality. A good source of reliable information on seedling performance is essential to achieve these goals.

The purpose of this paper, therefore, is to discuss the basic concepts related to the systematic and regular evaluation of outplanting success, and suggest some ways that nurseries can implement these procedures.

WHY EVALUATE OUTPLANTINGS?

There can be several reasons for wanting to conduct evaluations of outplanted seedling success:

1. To determine if the seedlings are surviving and growing.
2. To gain feedback information to help refine the nursery cultural practices used to produce the Target Seedling.
3. To monitor compliance of planting contracts.
4. To satisfy government or company performance evaluation requirements.

All nurseries should know how well their seedlings are performing after they are outplanted. Unfortunately, this phase of the process is often overlooked because of lack of time or funding. Within a forestry organization, the responsibility

¹ Neumann, R.W.; Landis, T.D. 1995. *Benefits and Techniques for Evaluating Outplanting Success*. In: Landis, T.D.; Cregg, B., tech. coords. *National proceedings, Forest and Conservation Nursery Associations*. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 36-43.

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for performing outplanting evaluations is sometimes not well defined and so this vital task sometimes "falls between the cracks". Unfortunately, nursery managers have their hands full just growing the seedlings and often cannot afford the time to travel around and talk to their customers.

For the purposes of this paper, we were interested in whether state forest nursery managers in the 17 western states were able to perform outplanting evaluations and so we sent out a short survey. The survey had two sections: 1) Satisfaction with seedling quality and nursery services, and 2) Outplanting performance. About one-half of the respondents reported that they regularly query their customers regarding satisfaction with the services and seedlings they provide. Only 40% of the nurseries, however, indicated that they check survival in any organized manner, and only two gather data on seedling growth and this was based on comments from customers. The establishment of long-term monitoring plots to monitor seedling survival and growth is simply not done.

The second objective of an outplanting survey involves the fine-tuning of the target seedling. As nursery managers strive to perfect their craft, good data about field performance is essential. Nurseries determined their target seedlings (what species and stock type that they should be growing) when they first got started, but many never go back to review their applicability in the current market. Because outplanting performance is the only true measure of success, growers must continually review their concept of the target seedling and change cultural practices accordingly (Figure 1). Without sound data regarding seedling survival and growth, it is difficult to decide how to improve nursery culture practices. "Sound data" does not include casual visual surveys of planted seedlings to determine success because such surveys are far too subjective and impossible to adequately evaluate and document.

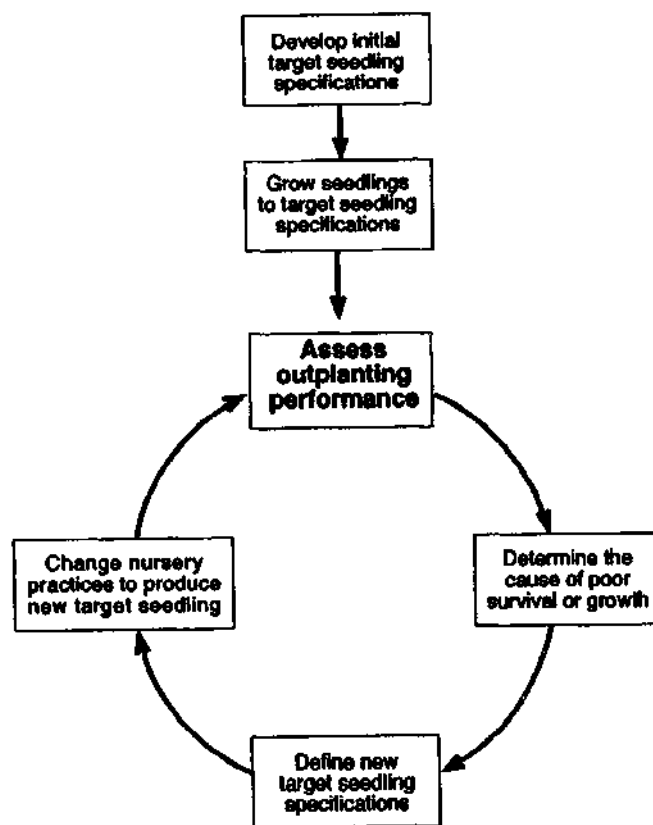


Figure 1. Nurseries must first verify their target seedling specifications and then continually revise them by monitoring performance on outplanting sites (modified from Burdett 1983)

The third reason for surveying seedling survival and growth is to check-up on how well contractors are planting the seedlings. Nurseries should be very interested in this because the performance of their seedlings critically depends on seedling planting techniques. In Texas, where they use a program of monitoring outplanting success to determine planting contract compliance, the incidence of plantation failure was more than cut in half (from 40% to about 16%) in the 10 years after an inspection program using established plots was initiated (Boggus 1994).

Finally, outplanting surveys are needed for completing government or company performance reports. The USDA Forest Service provides cooperative funding and technical support to state forest

and conservation nurseries through a program called Seedlings, Nurseries, and Tree Improvement (SNTI). A new accomplishment reporting system called the Performance Measurement Accountability System (PMAS) has just been instituted, and will significantly change the way that state forestry organizations report their accomplishments of the various cooperative programs. For the past several months, a national team in Washington, DC has been working on exactly how PMAS is going to work. Much of the PMAS discussions centered on "Outputs" vs. "Outcomes". Outputs are tangible things like "How many seedlings your nursery grew last year" and "How many acres were planted". Well, this isn't good enough anymore. The new trend in the PMAS System is to try and relate these easy-to-measure outputs to some broader "benefits" or "impacts". For example, the PMAS team has proposed that the broad outcome for SNTI programs should be "To provide quality seedlings and establishment procedures to ensure a stand of trees within 3 years". So, instead of just reporting how many seedlings were produced at a nursery or how many acres were planted each year, state foresters will be asked to report on seedling performance after outplanting.

WHAT KIND OF SAMPLING IS BEST?

As to the best type of sampling design, we recommend systematic stratified sampling. Systematic samples are located at standard predetermined distances and because of this regular pattern, plots are easy to establish and relocate. Stratification means that the entire population of seedlings in the outplanting area is subdivided into homogeneous units before sampling begins. First, strata of uniform conditions are identified, and then sample plots are located systematically within these areas. These strata could be based on species, nursery of origin, planting crew, site type, or any number of other factors that can be identified as a source of variation in seedling performance. This system combines the reduced variability among

plots within a stratum with the ease of systematic sampling (Pearce 1990).

Plot type — Staked, long-term plots are those in which individual seedlings are marked so that they can be monitored over time (Figure 2). We recommend that seedlings be individually staked because it is often difficult to locate planted seedlings after weeds and brush have grown in the plantation. Often, unstaked seedlings just seem to disappear after a few months or years especially when they are eaten by animals. When measuring seedling growth, staking is the only way to insure that the same seedling is being monitored over time. The USDA Forest Service uses a plantation evaluation system with staked row plots and monitors seedling survival and growth at one and three years after outplanting (Table 1). This procedure is detailed in the Forest Service Handbook (Section 2409), and copies can be obtained by contacting any Ranger District or Forest Supervisor's office.

The actual plots can be one of two basic shapes: *linear* or *areal*.

Linear — This type of plot is established in a straight line, and is most appropriate for sampling in long, narrow plantings such as windbreaks or



Figure 2. Staking seedlings is a simple way to insure that they can be easily found for several years after weeds and other vegetation has overgrown the plantation.

Table 1. Survival of seedlings in staked row plots for National Forests in Colorado and Wyoming during 1978 to 1983.

Species	Stock Type	Year Sampled	Staked Seedlings	No. Of Live Seedlings	No. Of Survival	
					%	Range
Engelmann spruce	3+0 Bareroot	First	11,150	9,283	83	45 to 98
		Third	5,220	2,686	51	7 to 83
	Container	First	11,755	9,532	81	20 to 97
		Third	8,208	4,417	54	9 to 94
Lodgepole pine	2+0 Bareroot	First	8,496	6,094	71	50 to 99
		Third	5,549	3,681	66	12 to 93
	Container	First	7,100	5,408	76	19 to 99
		Third	3,719	1,932	52	11 to 83

Source: Jeffers (1985)

shelterbelts. Linear plots can also be used in large area plantings where trees are planted in very well-defined rows. A systematic sample using line plots may dictate that a plot will be established every so many meters along the line of trees (Figure 3A).

Areal — As their name infers, these plots cover a discrete area and are generally circular or quadrilateral in shape. Areal plots are best for sampling large forest plantations. Circular plots are easy to establish using a known radius from the plot center (Figure 3B).

HOW MANY PLOTS ARE NECESSARY?

The number of plots to establish is generally a function of two factors:

- 1) *available resources* (time and money)
- 2) *variability* of the attributes that will be measured.

Plantation evaluation is impossible without sufficient personnel and adequate funding. Based on our survey of western nurseries, however, lack of funds was the principal reason that most nurser-

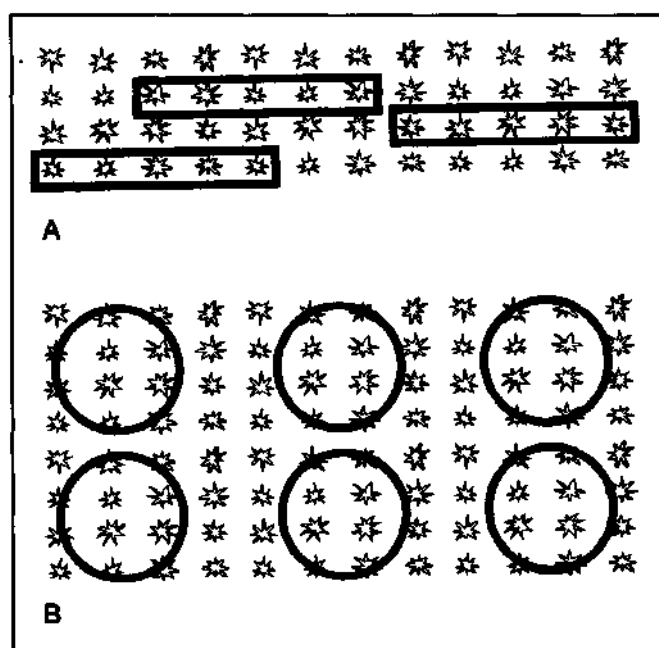


Figure 3. The best type of sampling plot will depend on whether the plantation is linear, such as a shelterbelt (A) or covers a wide area such as a forest plantation (B).

ies did not survey customers or evaluate outplantings. In the face of additional budget cuts, some creative use of existing resources will be required. If state forest nurseries do not have the staff or funds to monitor their seedlings after outplanting, then this may be an excellent use for some of the SNTI funds that are provided to State Foresters by the federal government. Some other suggestions:

- Work with others in your organization to see if outplanting evaluations can be combined with other field activities to reduce travel expenses.
- Use existing personnel like fire crews when they are in standby status.
- Require planting contractors to establish and monitor plots
- Ask customers to help. Most nursery customers will be happy to assist when they realize that the survey information will help improve the quality of their seedlings.

The second factor affecting the proper number of plots, variability of the attributes measured, is somewhat more difficult to define. In calculating the appropriate number of plots, statisticians are interested in some measure of variability - such as the standard deviation of seedling heights in the outplanting. Using this example, if a quick check on the height of seedlings varies greatly within the plantation to be sampled, then more plots should be taken. On the other hand, if the heights appear to be very uniform, then fewer plots will be sufficient. Much will depend on the type of outplanting. Shelterbelts in the Great Plains are often machine-planted which reduces planter-to-planter variation and site conditions are relatively uniform. On the other hand, there is often a wide amount of variation on mountainous outplanting sites because of differences in microclimate, soils, and planting quality. For example, seedling survival after the third year varied from as low as 9% to as high as

94% on National Forests in the Central Rocky Mountains (Table 1). To be statistically significant, there are rather complicated calculations to compute appropriate number of plots using an estimate of the variability of the attribute and the degree of statistical accuracy desired (Stein 1992).

Determining the number of plots based on variability is often a judgement call but, in most cases, a 1 to 2% sampling intensity will be sufficient. For example, if we were sampling a plantation where the seedlings were planted at a density of 2,000 per hectare (800/ac), then we would need to sample about 20 to 40 seedlings per hectare (8 to 16/ac). If we wanted the plots to contain approximately 10 seedlings each, they each would need to be about 1/200 ha (1/80 ac) in size, with a radius of about 4 meters (13.1 ft). Using these parameters, we could then specify a minimum of 2 to 4 plots per hectare (1 to 2/ac) and a maximum of 10 to 20 plots for fairly homogeneous plantations.

WHAT TO MEASURE?

During the years following outplanting, most plantations are evaluated for only a few factors: survival, general seedling condition, and shoot and caliper growth. Before beginning the survey, it is helpful to construct a data form such as that in the Appendix to make sure that the evaluation is applied uniformly and that no information is left out. This is particularly important when more than one person is doing the evaluations because there can be significant differences in procedure unless everything is strictly defined. Developing standard codes for seedling condition and cause of mortality or injury helps to describe common situations. The sample form provides space for several evaluation dates of the same plot. A plot map makes it possible to identify the location of individual seedlings by azimuth and distance from the plot center. Starting with due North (which is 0°) each seedling that falls within the plot radius can be numbered

consecutively, staked, and the location noted on the form. Accurate plot mapping is important so that the seedlings can be relocated from year to year. If trees are particularly difficult to locate, it may be necessary to also tag each tree with a numbered metal tag around the base.

HOW OFTEN TO EVALUATE?

Many people think that the first evaluation should be scheduled one year after outplanting, but they are mistaken. It is extremely important to check the seedlings within a couple of months after they are planted because stock quality problems show up quickly. Mortality or poor growth due to substandard planting stock can often be identified by evaluating the outplanting within the first few months. Some of the common problems that can be identified at this time include seedlings that had unsatisfactory or damaged root systems, those that did not generate new roots, and those which were improperly planted. Poor planting technique often can be identified by the presence of “J” shaped tap roots when an examination hole is carefully dug next to the seedling. Other sources of mortality which are often identified at the two-month evaluation include improper storage, transportation, or handling. Desiccated seedlings on a site that had adequate soil moisture might indicate freezing during storage or excessive root exposure during on-site transportation and handling. On the other hand, it is almost impossible to do a postmortem on seedlings that have been dead for a year. Many surveys done on the one-year anniversary list the cause of death as “drought” because the seedlings appear totally desiccated. This sort of misleading information is worse than none at all.

Once the two month evaluation has been completed, the customer and nursery manager can backtrack through the sequence of events prior to

outplanting and determine the true cause of the poor performance. The other advantage of an early evaluation is that plans can be made to replant quickly so that site preparation costs are not lost.

Outplanting performance plots should also be monitored at intervals of 1, 3 and 5 years. These long-term evaluations are recommended so that the effects of seasonal factors as well as site and genetic quality can be checked. The one-year measurements are useful for checking seedling tolerance to drought and frost, for example, as well as evaluating damage due to animals, insects or disease. The measurements of survival and growth at 3 and 5 years give good indications of plant adaptability and productivity - useful information when choosing future species and seed sources. Long-term plant performance also helps to evaluate site quality.

CONCLUSIONS AND RECOMMENDATIONS

The establishment of long-term plots to monitor the outplanting performance of seedlings is an essential part of nursery management. Information on seedling survival and growth has several benefits to the nursery including a way to fine-tune the specifications of the target seedling. We believe that simple monitoring plots can be established with a minimum of effort and expense, yielding a maximum of informational benefit to nursery managers. Nurseries should include the cost of monitoring outplanting performance in their normal operating budget. If state forest nurseries do not have the staff or funds to monitor their seedlings after outplanting, then this may be an excellent use for some of the Seedling, Nursery, and Tree Improvement funds that are provided to State Foresters by the federal government.

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Appendix

Site: _____
 Plot: _____

Location: _____
 Species: _____

Nursery: _____

TREE	DATE 1: _____			DATE 2: _____			DATE 3: _____			CONDITION/CAUSE CODES
	HT (cm)	CAL (mm)	CONDI/CAUSE	HT (cm)	CAL (mm)	CONDI/CAUSE	HT (cm)	CAL (mm)	CONDI/CAUSE	
										CONDITION: H = healthy D = dead U = unhealthy M = missing CAUSE: 1 = drought 2 = cattle/deer 3 = rodent 4 = insect 5 = loosely planted 6 = shallow planted 7 = spiral root 8 = deep planted 9 = "J" rooted 10 = small seedling 11 = fire 12 = vandalism 13 = shallow soil 14 = poor site 15 = other 16 = unknown INCLUDE COMMENTS WITH THESE CAUSES: PLOT MAP

The plot map shows a series of concentric circles centered on a point, representing different distances from the center. A north arrow points towards the top of the map. A scale bar indicates a distance of 1 cm.

The Basic Biology of *Juniperus* Seed Production¹

Gary Johnson²

Abstract—Junipers produce dormant seed in response to dispersal by animals and environmental conditions.

INTRODUCTION

Junipers are important species in windbreaks, wildlife, environmental and landscape plantings throughout the Great Plains and elsewhere. Dense, evergreen foliage blocks the wind year round and provides wildlife habitat. The berry-like cones are eaten and dispersed by birds and other animals. Junipers are also drought, heat and cold tolerant.

Seed dormancy hinders nursery seedling production. Often, many of the viable seed do not germinate. Understanding the basic biology of the seed production will help to find better ways to overcome seed dormancy. More work needs to be done to understand the dormancy mechanisms.

NATURAL LIFE CYCLE OF JUNIPERS

Unlike pines and most other trees, junipers are either male or female (dioecious). Seed is produced on the female trees only. Pollen from the male trees lands on a water drop at the micropyle opening and is drawn into the pollen chamber as the drop shrinks. The pollen germinates and fertilizes the egg.

Lack of pollination is not the cause of empty seed, because seed will not form unless pollen is present. One possibility for empty seed could be a

lack of compatibility after fertilization. Another possibility could be lack of fertilization. The presence of the pollen could be enough to initiate cone and seed formation.

In most junipers, including eastern redcedar, *Juniperus virginiana* L., the berry-like cones are produced in one growing season. Two growing seasons, however, are needed for cone production in Rocky Mountain juniper, *Juniperus scopulorum* Sarg. Birds and other animals eat the cones; the seed pass through the digestive system (chemical scarification), then sit in a warm, wet pile of decomposing organic matter in the late summer and fall. After passing the winter frozen, perhaps thawing several times, the seed germinates in the spring, or remains dormant through another yearly cycle and germinates the second spring. Seed dormancy is required to prevent early germination.

SEED DORMANCY

Our challenge is to understand the dormancy mechanisms and to overcome them to produce seedlings. Junipers have both seed coat and chemical dormancy. The seed coat is semi-permeable and the embryos need a period of time — called after-ripening — to produce all the chemicals in the right balance to germinate.

¹ Johnson, G. 1995. The Basic Biology of *Juniperus* Seed Production. In: Landis, T.D.; Cregg, B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 44-46.

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One of several possible models for the chemical part of juniper dormancy is Kahn's "hormone interaction model" where various amounts of gibberellic acid, cytokinins, and an inhibitor interact to promote or inhibit germination. In Kahn's model, gibberellic acid promotes germination in some seed, but if an inhibitor is present, then a cytokinin must be present to neutralize the inhibitor.

Chemical processes within the seed are dependent on many factors, including temperature and time. Some temperature regimes, such as cold stratification, favor the production of chemicals promoting germination. Time is needed for the chemicals to increase to the threshold amount needed for germination, or for the inhibiting chemicals to be neutralized.

The hormonal balance may be shifted by adding hormones to the seed by soaking the seed in a hormone solution, but the semi-permeable seed coat inhibits the uptake of the hormones. Leaching the inhibitor from the seed by putting the seed in running water for several days may also reduce dormancy in some seed, but again, the semi-permeable seed coat may impede the process. Soaking the seed in lye, as done at several nurseries, may make the seed coat more permeable (simulating a bird's digestive tract).

FACTORS AFFECTING SEED DORMANCY

1) Freshness and ripeness of the seed:

The time of collection and length and conditions of storage affect the degree of dormancy. Fresh, ripe seed are not as dormant as unripe seed or seed stored for a long time.

2) Environmental factors during formation of the cone and seed:

Climate or weather conditions during the growing and maturation of the cone and seed, such as drought, can affect dormancy.

3) Variations in genotype:

Eastern redcedar and Rocky Mountain juniper have wide geographic ranges and great genetic variability. Without this genetic variability, the species probably could not grow over such a wide area. Local populations have adapted to local conditions.

Genetic variation exists within local populations. A factor increasing this local variability is that both eastern redcedar and Rocky Mountain juniper hybridize with other junipers and with each other. The variations in genotype within the local populations and across the geographic ranges contributes to the variations in dormancy.

4) Random variation:

Seed produced by the same parents under the same circumstances of environment, time, and place exhibit variations in dormancy. This random variation in the degree of dormancy ensures that all the seed do not germinate at the same time. Spreading the germination over time increases the probability that some seed will germinate during favorable conditions for seedling establishment. We should not expect all seed produced by a tree in a given season to have the same degree of dormancy.

SINGULARIZATION

Due to flower morphology, approximately two thirds of eastern redcedar cones produce one seed, about one third produce two seeds, and about two percent produce three seeds. Often, seed from the same cone are bonded tightly together. In laboratory testing, the seed are separated, or singularized, before the tests are run. If a nursery manager plants non-singularized seed using seed per pound and germination or tetrazolium data from singularized seed, the result will not meet expectations. Depending on the number of double and triple seed in the lot, the difference could be as much as one

third greater in germination, or one third less in seeds per pound. For example, if one hundred singularized seeds germinate 80% in the testing laboratory, and the nursery manager plants one hundred non-singularized seeds with 33 double seeds (133 seeds total), then 106 seedlings will germinate in the nursery. In the same lot, 51,700 seeds per pound of singularized seed would be equivalent to 38,800 seeds per pound of non-singularized seed.

Seed testers and nursery managers need to agree on the basic question: what is a seed? Otherwise, seed testing results are not representative of the lot as the nursery manager sees the seed. Unless the nursery manager knows the percentage of double seed in the lot and compensates accordingly, the germination and seeds per pound data could be misleading.

The National Tree Seed Laboratory reports the number of double and triple seed present in the sample. The nursery manager can use this information to adjust seeds per pound and germination expectations.

Germination adjustments:

$(100 + \% \text{ of doubles}) \times \text{laboratory germination \%} =$
non singularized germination percentage

Seeds per pound adjustments:

$100 / (100 + \% \text{ of doubles}) \times \text{laboratory seeds per pound} =$
non singularized seeds per pound

CONCLUSIONS

- 1) More work needs to be done to better define the dormancy mechanisms and to develop methods for nurserymen to break seed dormancy.
- 2) Due to variation in dormancy within a lot, methods developed to break the dormancy of the more dormant seed can be expected to be harsher or greater than needed or tolerated by the less dormant seed. Many less dormant seed

may not survive the dormancy breaking treatment for the more dormant seed.

- 3) Seed testing laboratories and nursery managers need to work together and develop seed unit definitions for *Juniperus* consistent with use in the nurseries.

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Propagation of *Juniperus*: Challenges to Propagation and Opportunities for Improvement¹

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Abstract—Production of *Juniperus* in forest and conservation nurseries is often limited due to poor or erratic seed germination. Poor seed germination of *Juniperus* may be due to several factors, including a high proportion of dead, unfilled, or immature seed, seed-coat dormancy and embryo dormancy. The germination rate of seed sown may be increased through seed quality testing and treating seed to overcome dormancy. We discuss methods to separate seed, and improve seed quality and pre-treatment techniques to overcome dormancy.

INTRODUCTION

Eastern redcedar (*Juniperus virginiana* L.) and Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) are among the most widely planted trees for conservation forestry in the Great Plains. Because they are adapted to a wide range of sites, including dry or rocky soils, both species are planted for windbreaks, shelterbelts, and living snowfences. In 1990, nearly 2.7 million *Juniperus* seedlings were distributed by Great Plains tree nurseries (Moench 1993). However, due to problems associated with dormancy and seed germination, especially in Rocky Mountain juniper, conservation nursery managers often have difficulty producing a consistent crop of *Juniperus* seedlings. For example, the Oklahoma Department of Agriculture reports that typically only 16% of redcedar seed germinate during the first year after planting and the seed to saleable-seedling ratio is only 0.03 (Porterfield,

personal communication). Germination of Rocky Mountain juniper is also low at the Oklahoma nursery and other nurseries in the Great Plains. The low germination rates observed for *Juniperus* indicate that current cultural practices are inadequate to overcome dormancy.

Dormancy is the inability of a seed to germinate, even under conditions that are normally considered favorable for germination. Dormancy can be caused by the seed coat or the embryo. Seed coat imposed dormancy is due to the impermeability of the coat to water and gases which prevents inhibitors from leaving the embryo or the mechanical prevention of radicle extension (Kelly et al., 1992). Embryo dormancy is due to a lack of physiological requirements such as hormonal, temperature or light needed to break dormancy. Seed of *Juniperus* have both types of dormancy. A confounding factor in Rocky Mountain juniper is

¹ Lee, S.; Cregg, C.M.; Fleege, C. 1995. Propagation of *Juniperus*: Challenges to Propagation and Opportunities for Improvement. In: Landis, T.D.; Cregg, B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 47-51.

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that the seeds require two years to mature. Therefore, immature seeds can be inadvertently collected with the mature seeds.

Although numerous studies have been conducted on germination of *Juniperus* in the past 70 years, few have yielded consistent results. In the following discussion, we consider three ways to improve germination rates and germination uniformity of *Juniperus* seed. Seed separation techniques, treatments to overcome seed-coat dormancy and methods to overcome embryo dormancy are the methods we are currently studying, and believe may be useful to nursery growers.

SEED SEPARATION

Low rates of germination in a number of species are due to a large proportion of non-viable or non-germinating seed. Non-viable seed may be hollow, damaged, or immature. In many cases non-viable seed may be separated from viable seed relatively easily, resulting in an immediate increase in germination rates. Simple techniques for separating seed include separation by size or density and the IDS (Incubation, Dehydration, Separation) method.

Density and Size

In general, as seeds mature size and density increase. Therefore, viability and germination are often correlated with seed size and (or) density. Khademi et al. (1993) showed that as the density of *Primula acaulis* (L.) rose, the percent viability and soluble protein contents increased. The densities of the seed ranged from 1.10 to 1.18 g/cm³. The percent viability and soluble protein contents rose from 8 to 90% and from 26 mg/g to 38 mg/g, respectively, as the seed density increased. In addition to increasing germination percentage, selecting for increased size and (or) density may have the additional benefit of improving seedling vigor. Wang et al. (1994) demonstrated that as seed mass rose in black spruce (*Picea mariana* Mill.) seeds, the seedling survival rate also rose.

At an initial seed mass of 0.55 mg, survival rate was approximately 42%, while seed with an initial mass of 1.5 mg had a seedling survival rate of 75%.

A key advantage to separating seed by size or density is that it is relatively simple and straightforward. Laboratories which specialize in seed testing or seed quality improvement use specialized equipment such as density tables and air separators. However, in our current research we have found that *Juniperus* seed can be separated into various size classes using standard soil sieves. We have also found that *Juniperus* seed can be divided into density classes by floating in sucrose solutions of varying specific gravities. Presently, we are conducting trials to correlate germination rates with seed size and density for several seed lots of eastern redcedar and Rocky Mountain juniper from Great Plains nurseries.

IDS

While simple separation by size and (or) density may improve germination by removing empty or immature seeds, IDS separation provides a more physiologically-based indicator to select viable seed. The IDS technique is based on the principle that viable seeds, once hydrated, give up moisture more slowly than unfilled or non-viable seeds. The procedure involves hydrating the seeds (Incubation), drying the seeds for a specified time (Dehydration) and then placing the seeds in water and discarding the seeds that float (Separation).

Singh and Vozzo (1994) found that germination of *Pinus roxburghii* could be enhanced using the IDS technique. By immersing the seeds in solution with a specific gravity of 1.04 for 4 hours, they found that 72% of the seeds sank while 28% of the seeds floated. Of the 72% of seeds that sank, 94% of these seeds germinated. Of the 28% of the seeds that floated in the solution, only 50% of the seeds germinated. Furthermore, Simak (1984) found that for a sample of Lodgepole pine (*Pinus contorta* Dougl.) seeds that typically germinated to a 67%

capacity, almost all the 33% that did not germinate were found to be dead using the IDS technique. Increases in germination attributed to the IDS technique have also been reported for lodgepole pine (increased from 37% to 75%) (Downie and Wang 1992), white spruce (increased from 50% to 86%) (Downie and Bergsten 1991), and Scots pine (increased from 33 to 95%) (Bergsten 1988).

OVERCOMING SEED DORMANCY

Although seed separation techniques will remove dead and non-viable seeds, the remaining seeds may still be dormant. As indicated earlier, dormancy may be due to seed-coat dormancy, embryo dormancy or, in the case of *Juniperus*, both.

Seed Coat Dormancy

In order to overcome seed coat dormancy, the seed coat must be broken or conditioned to permit the seed to imbibe water and allow inhibitors to leach out. Seeds may be scarified by soaking in acid or bases, or by mechanical means. Masamba (1994) found that germination of three species of *Acacia* seeds known to have seed-coat dormancy increased to at least 80% by treating the seeds using a hot wire method. This basically burns the seed coat to scarify the seeds. The best germination from the hot wire method came from a duration of 5-10 seconds. Cutting the seed bases (hilum) of eastern redcedar and Rocky Mountain juniper seed resulted in epicotyl development within 3 to 9 days (Djavanshir and Fechner, 1976). Sulfuric acid treatments of 35 minutes for ERC and 120 minutes for RMJ produced a hole in the hilum which led to similar types of germination rates. Seeds of West African Laburnum (*Cassia suberiana* DC.) germinated best when they were immersed in 98% sulfuric acid for 45 minutes, plus a one-hour water soak or nicking, and scarifying the seed coat in a commercial mill for 4 minutes (Todd-Bockarie et al. 1993). The acid and mechanical scarification resulted in 93% and 85% germination, respectively, as compared to 5% for the untreated controls.

In a separate study done by Todd-Bockarie and Duryea (1992), seeds of velvet tamarind (*Dialium guineense* Willd.) were treated with concentrated sulfuric acid or nicking the seed coat to overcome seed coat dormancy. Nicking the seed coat surface with a scalpel produced the highest germination of 96% while a germination rate of 55% was obtained by soaking seeds in concentrated sulfuric acid for seven minutes. These two treatments are very promising as the germination rate for the control seeds was only 10%. In our current research with *Juniperus* seed we are investigating the effectiveness of wearing down the seed coat with a rock polisher as a simple method to mechanically scarify seed.

Embryo Dormancy

Embryo dormancy or physiological dormancy in *Juniperus* is controlled by a complex series of hormonal interactions that are poorly understood. Presently the most reliable method of overcoming embryo dormancy is by a combination of warm and cold stratification. Exogenous applications of chemicals, mainly hormones, may also overcome embryo dormancy.

Stratification

In a study by Young et al. (1988), different stratification techniques were performed on seeds of western juniper (*Juniperus occidentalis* Hook.) and Utah juniper (*Juniperus osteosperma* [Torr.] Little). Stratification in aqueous solutions with near saturation of the solution with oxygen increased germination of western and Utah juniper to around 50%. Similar treatments using aqueous solutions of 0.289 mol L⁻¹ gibberellic acid (GA₃) improved germination of western juniper to better than 80%. Jones (1989) found that East African pencil cedar (*Juniperus excelsa* M. Bieb.), subjected to cold stratification (5°C) for 60 days increased germination to 63% over controls grown in the greenhouse (53%) and in a growth chamber (47%). Extended H₂SO₄ (1 hour) and hot water treatments resulted in very low germination rates. Jones also found that significant differences in

germination percentages between seeds from different maternal parents with a final germination percent ranging from 18 to 60%. The most accepted method for breaking dormancy in eastern redcedar and Rocky Mountain juniper is a warm moist stratification (6 weeks) followed by a cool moist stratification (10 weeks) (Van Haverbeke and Comer 1985, Johnson and Alexander 1974).

Chemical Treatments

Soaking spruce (*Picea smithiana* [Wall.] Boiss.) seed in GA₃ increased germination by around 19% (Singh 1989). Applying GA₃ (50 mM) and Ethephon (50 mM) increased germination of eastern redbud (*Cercis canadensis* var. *canadensis* L.) seeds to 28% (± 4.8) and 60% (± 4.5), respectively, compared to 2% (± 1.7) for the untreated controls (Geneve 1991).

In a study done by Persson (1993), seeds of ornamental plants of 16 species were infused with 1mM or 1mM gibberellic acid or with a concentration of 1mM gibberellic acid, 0.5 μ M kinetin and 1mM Ethrel(2-chloroethanephosphonic acid) dissolved in acetate. Infusion of these growth regulators improved germination in 10 of the experimental species. In all cases, germination rates were increased. Final germination was higher in treated than in control studies. The most effective treatment for increasing germination percentage was gibberellic acid at a concentration of 10 μ M.

OSMOTIC PRIMING

Osmotic priming using polyethylene glycol (PEG) has been demonstrated to improve seed germination and uniformity of germination in a number of species. Seeds are imbibed in aerated solutions of PEG to a point right before germination occurs. Then the seeds are hydrated with water and the germination process is rapidly initiated. Hallgren (1987) found that germination of

loblolly pine (*Pinus taeda* L.) could be enhanced from 53% to 79% for unstratified seeds. In a separate study by Hallgren (1989), it was found that osmotic priming increased final germination and rapidity of germination for loblolly and shortleaf pines (*Pinus echinata* Mill.), but was generally detrimental to germination of slash pine (*Pinus elliottii* Engelm.) seeds with one exception. At 15°C germination temperature, Hallgren found that unprimed slash pine seeds that were not stratified would not germinate but when primed they would germinate to 29%.

SUMMARY

Researchers in the Great Plains and elsewhere have studied the problem of germination in *Juniperus* for over 70 years with limited results. From this research it is clear that poor germination stems from the seeds being doubly dormant (seed coat plus embryo dormancy) and may also be due to a relatively high proportion of immature or otherwise non-viable seed. Given this situation, it seems unlikely that a 'magic bullet' will be found that will dramatically increase germination of eastern redcedar and Rocky Mountain juniper. However, we believe our integrated research approach combining seed quality testing and a combination of stratification, scarification, and, perhaps, chemical treatment may increase rates and uniformity of germination.

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Rocky Mountain Juniper Production at the Colorado State Forest Service¹

Randy D. Moench²

Abstract—Seed dormancy limits Rocky Mountain juniper production. The Colorado State Forest Service has found summer sowing and "natural stratification" to be beneficial. Seed stratified in this way follows a "natural" soil temperature regime over a seven month period. Seventy percent or better germination is achieved using this method from Great Plains and Northern Colorado seed sources.

INTRODUCTION

Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) is Colorado's most important evergreen for conservation plantings. Rarely do Great Plains' nurseries produce adequate numbers to meet customer demand. Problems with consistent production of Rocky Mountain juniper include: overcoming seed dormancy, uniform and predictable germination, and frost damage to new seedbeds.

Production of juniper at the Colorado State Forest Service Nursery consists of 2-0 bareroot production, 2-1 container transplants and greenhouse grown stock. The addition of greenhouse production is new. The success is due to using "natural stratification"—following the temperature range achieved with a summer sow date used for bareroot stock.

BAREROOT PRODUCTION

2-0 bareroot production method for conifers is not unique. An unusual factor at Colorado State is the summer sowing date. We sow bareroot seedbeds the last week of July. Soil temperatures are

around 70°F, and remain quite warm until late September (Figure 1).

Goal 1.6E herbicide is used for pre-emergent weed control. We apply mulch to the seedbeds. In the last few years a "frost fabric" has been used instead of our traditional straw mulch (Moench, 1994). This fabric raises the soil surface temperatures by 5°F, increasing frost protection for newly emergent seedlings.

Another unique factor in our bareroot production is winter irrigation. Colorado's arid and windy climate frequently requires that we irrigate established crops and new seedbeds in the dead of winter, without this irrigation, seedlings can suffer from extreme moisture stress during Chinook wind events.

Seedlings emerge in April. Production follows common bareroot nursery practice from then on.

CONTAINER PRODUCTION

Traditional container production of Rocky Mountain juniper at this nursery is transplanting 2-0 seedlings into a tarpaper container for one

Moench, R. 1995. Rocky Mountain Juniper Production at the Colorado State Forest Service. In: Landis, T.D.; Cregg, B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 52-53.

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growing season. Container seedlings are preferred in the Rocky Mountain region for its improved survival over bareroot.

Greenhouse production was always limited due to poor germination. That all changed after Allen Hackleman of our staff suggested a more "natural" approach. Seed for greenhouse production is stratified in a way duplicating our practice of summer sowing. We bag and bury seed lots in a newly sown summer juniper seedbed. We then extract the seed in February for greenhouse sowing. The seed undergoes the same soil temperature regime as the bareroot (Figure 1).

Of the extracted seed, 70% of the seedcoats are cracked, and the tip of the radical is evident. Upon sowing, germination is rapid and uniform.

The growing regime is the same one we use for all of our conifer production. With the February cycle, the seedlings are moved outdoors in late July for finishing. The Rocky Mountain juniper continues to grow, particularly during the cool months of September and October.

CONCLUSION

A long "natural stratification" period works best in overcoming juniper seed dormancy in Colorado. The warm soil temperatures of summer may be a critical factor. This procedure has allowed the nursery to begin efficient and consistent greenhouse production of Rocky Mountain juniper.

Seed testing before any treatment is essential. We use tetrazolium staining to show viability.

Finally, using frost fabric mulch can reduce the damaging effects of spring frost. Application and removal are much more efficient than hay mulches.

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Soil Temperatures

At CSU Main Campus Station

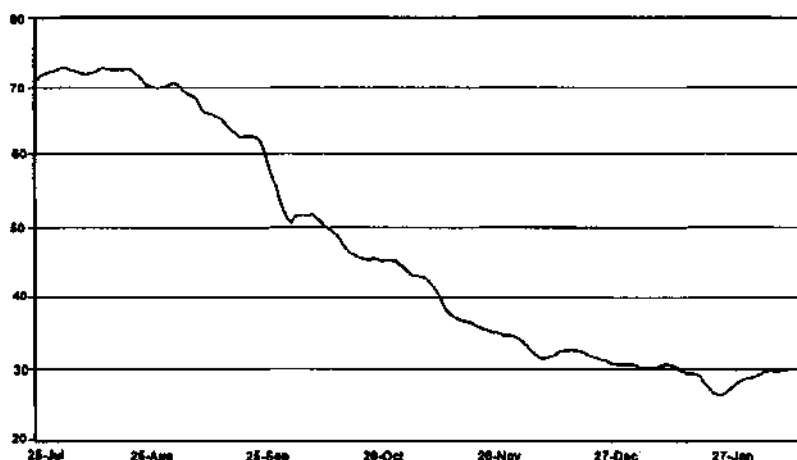


Figure 1. Four inch depth soil temperatures recorded at the Colorado State University weather station. This data should approximate temperatures experienced in summer sown seedbeds.

Pregermination Treatment of Eastern Redcedar Seed¹

William L. Loucks²

INTRODUCTION

Eastern redcedar (*Juniperus virginiana*) is a major component of windbreaks and wildlife habitat plantings throughout the Great Plains. This species is notorious for inconsistent germination with results varying with the seed source and crop year.

Great Plains nursery managers have found that seeding redcedar in mid to late summer provides fairly consistent germination. However, late spring frosts occasionally kill new germinants resulting in inconsistent supply of seedlings. It has been suggested that planting pre-ripened seed after danger of frost may be a solution to this problem.

The author stumbled onto a procedure to pre-treat redcedar which gives consistent results in a container-grown seedling nursery. His procedure is described in this paper.

PROCEDURE

Our first attempt to grow redcedar in a greenhouse was with freshly collected seed. After studying the seed manual (Schopmeyer 1974), a 60 day moist-cool treatment was used with excellent results. Our education began the next year when

we used the same seed and treatment only to have nearly zero germination. It was apparent that seed which had been dried for storage required different treatment than freshly collected seed.

The author has forgotten who to give credit for the suggestion that he should try to duplicate the treatment that bare-root nursery managers were in effect using by planting in late summer. He will be forever thankful for the suggestion. He found that a 30-day moist-warm period followed by a 90-day moist-cool period gives consistent germination. This treatment has been used successfully on seed from Kansas, Nebraska and South Dakota seed sources.

We treat the seed in five gallon plastic buckets with holes in the bottom to ensure drainage. Before placing the seed in stratification, the seed is soaked in water for 24 hours. Peat and seed are alternated in 1.5 inch layers. The seed is placed in fiberglass net (window screen) bags so that it can be easily separated from the peat. The peat and seed are kept moist, but well drained. The warm period is at room temperature—usually 70 to 80 degrees F, and the cool period is 33 to 35 degrees F.

Van Haverbeke and Comer's (1985) research suggests that these results can be improved with a 96 hours soak in citric acid (10,000 ppm), 6 weeks

¹Loucks, W.L. 1995. Pregermination Treatment of Eastern Redcedar Seed. In: Landis, T.D.; Cregg, B., tech. coords. *National Proceedings, Forest and Conservation Nursery Associations*. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 54-55.

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in moist-warm (24 degrees C) and 10 weeks moist-cool stratification (5 degrees C). There is a need for continued research to develop a quick, reliable method to pretreat redcedar seed.

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Growing Conservation Seedlings by the Square Foot: Making it Pay¹

David L. Wenny²

Abstract — In your nursery, do you really know which species and stock types are making or losing money? I have developed an exercise to help nursery managers check their species/stock types and determine if the resulting plants are yielding profit or loss. A computer spreadsheet can quickly provide information on how changes in cell density (changing container types) affect seedling price and nursery income, and rank the contribution each species or stock type makes toward financial objectives.

BACKGROUND

The University of Idaho has served as Idaho's state nursery, providing reforestation and conservation seedlings since 1909. The University of Idaho nursery has roles in teaching, research and service. Our nursery facility serves as a classroom/laboratory for forestry students and offers practical work experience for graduate students interested in nursery management and regeneration projects. Research in seedling production technology and in vegetative propagation by students, research associates and faculty are essential to our mission and we work closely with the nursery industry to pass on the benefits of our research program. We continuously seek methods to improve production technology, seedling quality and outplanting performance. Our service role involves technology transfer, various outreach and continuing education activities and, importantly, seedling sales. Sales must provide funds for operating expenses.

Recently, we placed a greater emphasis on providing relatively few seedlings to each of many landowners, a niche not occupied nor sought by

regional private nurseries. This emphasis required us to change stock types from smaller seedlings suitable for reforestation to larger seedlings better able to survive and grow under harsher conditions, especially in the hands of good-intentioned, poorly-trained seedling handlers and planters. Although seedling shipments include handling and planting instructions, seedlings may not receive the best care. Many of our conservation seedlings are shipped to southern Idaho where planting sites are hot and dry, heat girdling is a concern, site preparation is often poor and shipping and storage conditions are less than ideal. A larger, tougher seedling was required better to survive under these conditions.

INTRODUCTION OF SUPERSTOCK

Plug size of our conservation stock has evolved and increased over the years from 4 cubic inches to 20-cubic-inch capacity (45/340 (615 A)) copperblocks. We call seedlings grown in this

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larger container “SuperStock” to differentiate them on our order form from smaller stock of the same species. Introduction was gradual, taking several years as we slowly built up sales by creating demand. Our marketing focused on benefits of bigger seedlings: larger calipers withstand heat stress, bending, trampling and other mechanical damage better; larger stock are more visible so they are less likely to be run over with mowers; larger stock survive better and grow faster meeting planting objectives sooner; and chemically root pruned stock eliminate many root-related planting problems. We also found that with higher seedling prices, better pre- and post-planting care was taken, further increasing survival and growth potential. Landowners began with small orders for SuperStock seedlings, found they did survive and grow better on harsh sites (and on mesic sites) and as word has spread, demand has increased each year. This past season we provided 10 conifer and 27 hardwood SuperStock species (Table 1).

The conversion of stock type to larger seedlings reduced the total number of seedlings produced. With reduced production it became increasingly important that each species and stock type be analyzed for its contribution to financial objectives.

PRICING CONSIDERATIONS

Expenses for owning and operating a nursery must be matched or exceeded by income from the seedling production area. If this expense is expressed on a unit area of production, such as per square foot of bench space, then different container types and species can be readily compared. I use total bench area rather than floor area since bench surface area is the actual production area. A spreadsheet makes comparison an easy task. First sum all costs (salary, benefits, labor, travel, operating, capital outlay, taxes, profit etc.) that must be covered by seedling sales income and divide by total bench area to determine a "target return". If production is effectively increased by growing multiple crops, count that bench area multiple times. Target return varies among nurseries due to the nature of expenses and the economics of scale. I estimate the target return for a 2 million capacity nursery in the Intermountain Northwest to be about \$11 per square foot, and that a 5 million capacity nursery would have a target return reduced to about \$9. The Research Nursery has a target return of over \$17 due to high research and service expenses, and a small (< 12,000 ft²) production area.

Table 1. Species grown as SuperStock.

Ponderosa pine	Sugar maple	Wild apple	Black locust
Western white pine	Serviceberry	Western syringa	Rugosa rose
Austrian pine	Sagebrush	Hybrid poplar	Golden willow
Scotch pine	River birch	American plum	Arctic willow
Western larch	Siberian peashrub	Sand cherry	Buffaloberry
Western redcedar	Redosier dogwood	Black cherry	White lilac
Blue spruce	Russian-olive	Nanking cherry	Purple lilac
Norway spruce	Autumn-olive	Chokecherry	
Engelmann spruce	Honeylocust	Bur oak	
Rocky Mt. juniper	Amur honeysuckle	English oak	

Once target return is established, set up a spreadsheet by container type. Enter the number of trays per table or bench, and calculate actual density per square foot of bench area, where:

$$\text{density} = (\text{trays per bench} \times \text{cells per tray}) / \text{bench area.}$$

Then divide target return by density to determine the equivalent seedling price. For example, to generate \$11.00 per square foot of bench space, Ray Leach pine cell seedlings (PRL 200/66) would cost \$0.11 each (Table 2). A PSB 160/90 seedling would have to cost \$0.16 to generate the same income per square foot and a PSB 45/340 seedling would cost \$0.59. These are the minimum prices to charge for each container type to pay its "fair share".

The above density per square foot of bench space assumes all cavities sown will yield seed-

lings available for sale. Unfortunately, this is not the case. Nurseries, however, can easily adjust the density factor and produce an equivalent price by species, as well as by container type. Adjusted density is the density of cells per square foot of bench space times the yield expressed as a percentage. Yield percentage for a species is the number of seedlings meeting specifications divided by number of cells sown. Species equivalent prices may illustrate where improvements need to be made. For example, Table 3 shows river birch should cost \$5.24 per seedling to pay its way. Since this is far more than the actual selling price, we are losing opportunity income by devoting space to this species. We must either determine ways to increase the yield factor, raise prices or suffer the loss.

Table 2. Equivalent seedling price determination (target return = \$11 / Bench Ft²).

<u>Container Type</u>	<u>Tray Dimensions</u>	<u>Trays / Bench (6' x 16' Bench)</u>	<u>Density / Bench Ft²</u>	<u>Equivalent Seedling Price</u>
PRL 200/66	12" x 24"	48	100.0	\$0.11
PRL 98/1 64	12" x 24"	48	49.0	\$0.22
PSB 160/90	14" x 24"	40	66.7	\$0.16
PSB 1 1 2/80	14"x 24"	40	46.7	\$0.24
PSB 77/1 70	14" x 24"	40	32.1	\$0.34
PSB 45/340	14" x 24"	40	18.8	\$0.59

Table 3. Species equivalent seedling price (target return = \$11 / Bench Ft²).

<u>Container Type</u>	<u>Species</u>	<u>Yield %</u>	<u>Adjusted Density / Ft²</u>	<u>Equivalent Seedling Price</u>
PSB 160/90	Ponderosa pine	98 %	65.4	\$0.17
PSB 160/90	Grand fir	63 %	42.0	\$0.26
PSB 45/340	Ponderosa pine	99 %	18.6	\$0.59
PSB 45/340	Juniper	72 %	13.5	\$0.82
PSB 45/340	Rugosa rose	33 %	6.2	\$1.77
PSB 45/340	River birch	11 %	2.1	\$5.24

Table 4. Species profit or loss with a target return of \$17.63.

Container Type	Species	Equivalent Seedling Price	Market Price	Profit or (Loss)
PSB 160/90	Ponderosa pine	\$0.27	\$0.28	\$0.01
PSB 160/90	Grand fir	\$0.42	\$0.28	(\$0.14)
PSB 45/340	Ponderosa pine	\$0.95	\$1.50	\$0.55
PSB 45/340	Juniper	\$1.31	\$1.50	\$0.19
PSB 45/340	Rugosa rose	\$2.84	\$1.50	(\$1.34)
PSB 45/340	River birch	\$8.40	\$1.50	(\$6.90)

Last year the target return for the Research Nursery was \$17.63, substantially higher than the factor illustrated in Table 3. Table 4 shows the yield adjusted equivalent seedling price for a target return of \$17.63. The spreadsheet has been expanded to include a "Market Price" and the "Profit or Loss" which is the difference between "Equivalent Price" and "Market Price". Our market price for conservation seedlings was adjusted in consideration of the extra costs involved in dealing with small lots and individual landowner customers. Larger SuperStock seedlings are priced at \$1.50 each for all species in order to, on average, cover increased operating costs.

CONCLUSIONS

Each square foot of bench space must contribute to nursery income. Once a minimum target is established, a spreadsheet can enable managers to compare container types or species by establishing equivalent seedling prices. No attempt is made to account for varying costs of seed or labor required to grow different species. No extra charges are made to larger seedlings that use more of the facility, utilities or fixed costs. The spreadsheet does show how each species is distributed about the minimum income needed to cover all expenses (target return). This information is of benefit in establishing minimum prices by container type and/or species.

History of Bessey Nursery¹

Clark Fleege²

Welcome to the Nebraska National Forest. The notion of having a planted forest on the treeless Sandhills of central Nebraska was first proposed by Dr. Charles E. Bessey, a professor of botany at the University of Nebraska. The idea of planting trees in Nebraska was not new. On the first Arbor Day in 1872, over one million seedlings were planted in Nebraska. Trees had been planted in the Sandhills through the Timber Culture Act (1873) with limited success and on a limited scale. In 1890, Dr. Bessey joined forces with Dr. Bernhard E. Fernow, Chief of the USDA Division of Forestry to grow trees in the Sandhills of Nebraska. The site they selected was in northeast Nebraska, near Swan Lake in Holt County.

After considerable opposition from local ranching and farming interests, in the spring of 1891, several species of conifers were planted. These included jack pine, red pine, Scotch pine, Austrian pine, ponderosa pine, douglas-fir and arborvitae. After ten years those species with the highest rate of survival were jack pine, Scotch pine, and ponderosa pine.

The success of this tree planting effort led to the establishment of three "Forest Reserves" for tree planting purposes. On April 16, 1902, by Presidential Proclamation, President Theodore Roosevelt created the Dismal River, and Niobrara River Forest Reserves. These Reserves contained 90,000 and 124,000 acres respectively. In

1906, the North Platte Forest Reserve was established. It contained 347,000 acres. The total area set aside for tree planting purposes was over one-half million acres.

Local legend has it that Teddy Roosevelt not only created the Dismal River Forest Reserve, but also visited the Forest Headquarters and planted a Colorado blue spruce seedling on site. Though the official designation is the "Dismal River Forest Reserve" (because the southern boundary is the Dismal River), the Headquarters was located on the Middle Loup River (the northern boundary), because it was a more-suitable nursery site.

The Dismal River Forest Reserve is located in the heart of the Nebraska Sandhills. The Sandhills region encompasses approximately one-quarter of the state. The Sandhills are rolling sand hills, with the principle vegetation being grasses, and the principle land-use being ranching. The purpose of the "planted forest" that Bessey and Fernow envisioned was to provide timber to homesteaders under the Kinkaid Act, and to provide timber for the railroad. In time, the forest became a laboratory of challenge and a training school for many foresters.

On September 6, 1902, the location of the first seedbed was staked. The bed was 136 feet by 136 feet. It was surrounded by five-foot woven picket fencing, and roofed with four-foot picket fencing.

¹Fleege, C. 1995. *History of Bessey Nursery*. In: Landis, T.D.; Cregg, B., tech. coords. *National proceedings, Forest and Conservation Nursery Associations*. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 60-63.

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The first seed sown on November 13, 1902. The species was ponderosa pine, with seed collected from the Pine Ridge region of northwestern Nebraska. The seed collection costs were \$1.36 per pound. The first out-planting of conifer seedlings produced at the Nursery was 1904. These were 1-0 yellow pine (ponderosa pine), and did not fare well, as they were too small.

In the early days of the Nursery, each task was extremely labor-intensive. The implements were either horse-pulled, or man-operated. Early seedbeds were cultivated with teams of horses, and then seedbeds were prepared with side-boards, rulers and levels for exactness. Bird and rodent predation was discouraged with the use of horizontal overhead snow-fencing known as "Pettis frames" (Figure 1). Along with hand seeding, mechanical seeders were used. Planet, Jr. seed drills, still used by many nurseries today, were used to sow conifer seed in 1906 (Figure 2).



Figure 1. Horizontal overhead snow-fencing, "Pettis frames".



Figure 2. Planet, Jr. seed drill.

Following seeding, sand was used as a mulch. After the application of the mulch, a wheelbarrel of sulfuric acid was pulled by hand and applied over the conifer seedbeds to prevent "damping off" (Figure 3).



Figure 3. Wheelbarrel of sulfuric acid pulled by hand over seedbeds.

The success of the early plantings was 5 to 10 percent survival; seedling survival attained in 1911 was 85-90 percent. This dramatic increase is due largely to improved methods in the nursery. The most important improvement was the use of transplant seedlings. The first transplanting was done in May, 1906. A transplant crew consisted of five men: two men would dig the trench; one man would place the seedlings in the transplant board; and then two men would set the transplant boards in the open trench, fill the trench with soil, and remove the transplant board from the seedlings. The average production per day for a crew of five men was 6000 seedlings.

Along with the practice of transplants, root pruning was a cultural practice that greatly increased out-planting survival. An L-shaped bar undercutting the seedlings at approximately eight inches was pulled by a block-and-tackle. This was a standard practice as early as 1905 (Figure 4).

It was extremely important to supply water to the growing seedlings. The earliest irrigation sources were from windmills located adjacent to the seedbeds. Later, as more acres were under

cultivation, irrigation was pumped from the Middle Loup River. This water was then used to "flood irrigate" the nursery seedbeds. In time, flood irrigation was replaced by overhead sprinklers; first with the "Skinner system" to our current system of ground irrigation lines, risers and oscillating watering heads (Figure 5).



Figure 4. Horse-drawn L-bar used to undercut seedlings.



Figure 5. Skinner irrigation system at Bessey nursery.

A two-horse team hooked to a capstan bar tightened a cable that pulled the horizontal underground bar that "lifted" or harvested the seedlings. A crew then field-packed the seedlings immediately behind the bar. When the seedlings were packed, they resembled a "jelly-roll" (with the roots all to the center of the roll and seedling tops all to the outside end). The seedlings were then stored in a shed until spring planting. An ice-pond was created on the nursery for the sole purpose of

cutting large blocks of ice out of the pond during the cold winter months. The harvested blocks were then stored until use in the spring to maintain seedling dormancy.

Once the seedlings were harvested, it was time for out-planting. Five tree planting camps were established on the Dismal River Forest Reserve (Figure 6). The field planting camps moved every two years, and would accommodate fifty men and thirty horses. The seedlings were transported to the field planting camps via flat-bed truck, buck-board wagon or pack trains. One pack horse could carry two one-thousand tree seedling packs.

The standard planting procedure was to plow a furrow, have the seedlings inserted into the planting trench, and close the furrow. Three men and six horses were needed to plow the furrow. One man holds the furrow plow while one man drives



Figure 6. Tree planting camp in sandhills (Compare to established forest in background of Figure 5).

the team, and the third man operates the trencher. Two teams of three men and six horses worked together, plowing open the same furrow. In time, mechanization replaced the horses. Bulldozers pulled tree-planting machines that made tree planting much more efficient. With this mechanization 10,000 to 20,000 trees could be planted per day. Of the 90,000 acres were available for tree planting well-over 20,000 acres planted to trees. Many species were planted (eg. red pine, Afghan

pine, Austrian pine), but three species were proven to be most successful. These were ponderosa pine (currently 16,000 acres), jack pine (currently 2000 acres), and eastern redcedar (currently 2000 acres).

Seedlings produced at the Bessey Nursery were used for more purposes than simply foresting the Dismal River Forest Reserve. Seedlings were shipped via the railroad for reforestation purposes on various federal "Forest Reserves" throughout the Rocky Mountain region (Figure 7). For example, in 1905, one-year red fir seedlings were shipped to the Pike's Peak Forest Reserve; and in 1906, fifty thousand two-year bull pine were shipped to Wyncote, Wyoming. During the Prairie State Forest Program of the mid-thirties, the Bessey Nursery was one of two nurseries supplying conifer seedlings for windbreak plantings on the Great Plains.



Figure 7. Trains were used to ship seedlings to surrounding states.

The Civilian Conservation Corps made many important contributions to seedling production and seedling planting during the 1930's. The CCC's had maintained a camp for over two years. In 1935, a swimming pool was constructed by the CCC that is still in use today. The swimming pool is the only pool managed by the Forest Service.

What does the future hold for the Bessey Nursery? The Nursery is the bareroot and container seedling production facility for the Rocky Mountain Region of the USDA-Forest Service. The Nursery is also the home of the Regional Tree

Seedbank and Extractory. In addition, the Nursery produces approximately three million seedlings annually for the Nebraska Forest Service for distribution to rural landowners in Nebraska. Due to its abundant source of good water, highly desirable production soils, and favorable climate, the Charles E. Bessey Nursery is poised to remain in the forefront of seedling production in the Great Plains and Rocky Mountain region.

What does the future hold for Dismal River Forest Reserve? Over time the Dismal River Forest Reserve became the Bessey Ranger District. Tree planting is no longer the dominant activity on the District, though seedlings continue to be planted on a limited scale (eg. to enhance wildlife habitat). As the District is a natural prairie, trees will give way to grass where no woody revegetation occurs. The only natural pine regeneration occurs on north-facing slopes, in depressions, in thinned tree stands, or in narrow bands between the plantation and the native grass. Eastern redcedar is the only conifer extending beyond its planted bounds. It is felt the long-term composition of the hand-planted Forest will be dominated by eastern redcedar. With less than two percent of the land base in Nebraska in the public domain, recreation on the District continues to grow. Some of the recreation activities include hunting, hiking, horseback riding, wildlife viewing, camping in developed sites and dispersed areas.

The spirit and vision of Charles E. Bessey extends far beyond the boundaries of the original Nebraska Forest Reserves of the early 1900's.

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Nursery and Reforestation Programs at the Missoula Technology and Development Center¹

Dick Karsky and Ben Lowman²

Abstract—The Missoula Technology and Development Center (MTDC) evaluates existing technology and develops new technology to ensure that nursery and reforestation managers have appropriate equipment, materials, and techniques for accomplishing their tasks. Work underway in 1995 is described and recent publications, journal articles, and drawings are listed.

INTRODUCTION

The Missoula Technology and Development Center has provided improved equipment, techniques, and materials for Forest Service nurseries and reforestation programs for more than 20 years. The Center has worked to improve efficiency and safety in these areas, and throughout the Forest Service. The Center evaluates existing technology and equipment and develops new technology and equipment. Projects are funded by the Washington Office Timber Management Staff. The Center's program of work in reforestation and nurseries is selected by the National Forest Regeneration Committee, which is made up of representatives from various levels of the Forest Service. The following summaries describe the Center's current projects.

REFORESTATION TECHNICAL SERVICES

(Project Leader — Ben Lowman)

Through this continuing project, Center personnel provide a variety of services to field units. Surveys are conducted to determine current refor-

estation field problems. Those problems are translated into projects in the reforestation program. The Technical Services project allows us to investigate promising new techniques and equipment that may, after evaluation, become part of the Forest Service inventory of equipment. In addition, Technical Services provides a forum for answering inquiries from field personnel concerning equipment, material, and techniques applicable to reforestation activities.

Papers presented at professional meetings, technical reports, and drawings are also funded through this project.

Recent Accomplishments:

- Adapted a Pacific Northwest Region (6) tree climbing guide into a Forest Service guide. The guide will be available in the fall of 1995.
- Modified the Salmon Blade. The drawings were updated and sent to interested commercial manufacturers, including Weldco-Beales, for commercial production.

¹Karsky, D.; Lowman, B. 1995. Nursery and Reforestation Programs at the Missoula Technology and Development Center. In: Landis, T.D.; Clegg, B., tech. coords. *National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-365*. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 64-74.

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- Worked with Doug Basford, Northern Region (1) to produce his natural regeneration and timber stand release video. Loan copies are available from MTDC.
- Completed work on the Loblolly tree seed collection system and the power platform. Reports were published to close out these projects.
- Responded to numerous field inquiries for information on tree girdlers, feller bunchers, and excavators.
- Worked with Washington Office Timber Management to revise the wording on timber management posters. These revisions have been recorded on AUTOCAD for easy transfer to potential commercial manufacturers.

Center representatives meet with the National Forest Regeneration Committee each year to review the status of ongoing projects and new projects. Project proposals are welcome. They may be submitted to Ben Lowman at MTDC. Write a summary of the problem and the desired action. The information will be used to determine priorities, and to link you with others with similar problems or to those who may have solutions to your problem.

POLLEN EQUIPMENT

(Project Leader — Debbie O'Rourke)

Thirty years ago the Forest Service launched an expanded tree improvement program. A network of genetically superior tree seed orchards was created in an effort to produce top-quality seed. These trees are now in the cone-bearing stage. Protecting the genetic quality of their seed is of prime importance.

Stands of timber surrounding Federal orchards are sources of "inferior" pollen that threatens the decades of work done by tree breeders to upgrade

seed quality. About 40 percent of the tree seed now produced by these orchards is the result of fertilization by outside "inferior" pollen. Equipment and methods to control orchard pollination are essential to the seed improvement program.

The Center has been working with orchard personnel and Forest Service Research organizations to develop equipment for mass collection and mass application of pollen. A vacuum collection system developed by the Center gives orchard managers a means of collecting a large supply of pollen from the crowns of designated trees in a quick and efficient manner. This pollen is cleaned and stored for future application to target trees during their receptive period.

For application, the Center has developed a modified tractor-mounted air duster that can blow the collected pollen high into the crown of orchard trees. Dry pollen application was tried first, but "blow-by" was very high. Subsequent tests used pollen in water suspension. Monitoring of the effectiveness of this method will be completed by Don Copes, PNW, this year.

This equipment can help protect the quality of seed and increase orchard productivity by ensuring that an adequate amount of genetically acceptable pollen is available. Systems for both West Coast Douglas-fir, and North Carolina loblolly pine have been developed. A final report, complete with drawings and specifications, is being prepared (Figures 1, 2).

ANIMAL REPELLENTS

(Project Leader — Debbie O'Rowke)

The survival and growth of seedlings planted on National Forests has improved dramatically in the past 20 years. Primarily because better quality seedlings are being produced in Federal nurseries and because increased care is being used in planting and handling these seedlings. One major problem remains—animal predation of planted stock.

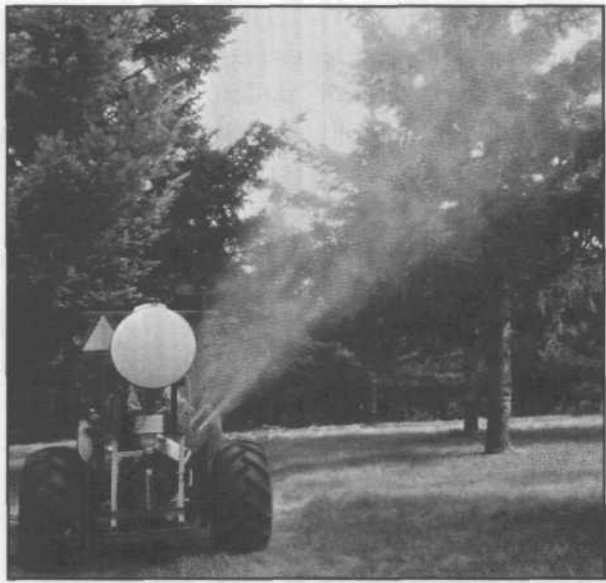


Figure 1. Wet pollen applicator.

Although livestock, rodents, and other animals take their toll, deer and elk are the primary browsers. By nipping off buds and shoots, elk and deer restrict the growth of some seedlings and kill others. Fencing can reduce this damage, but it is expensive and impractical in most field situations. Chemical sprays, powders, and systemics have been tried for years with only limited success.

The Center has teamed with the USDA, Animal and Plant Health Inspection Service (APHIS) under a cooperative agreement covering animal pest control research. In 1993 a steering committee including representatives from the Center, APHIS, and the Pacific Southwest and Pacific Northwest Regions (5 and 6) was formed to outline the project's objectives. The steering committee decided that APHIS and MTDC should enter into a contract covering three services: testing repellents and barriers on penned animals; publishing a comprehensive catalog of currently available animal repellents and barriers; and publishing a Tech Tip reporting the results of a field evaluation of repellents intended to keep animals away from certain areas. The tests have



Figure 2. Poly-mix applicator.

been completed. The catalog and Tech Tip will be published in 1995.

MTDC will also publish a Tech Tip on pocket gophers and gopher control based on a comprehensive report written by Ron Bonar. Both will be available in 1995 (Figure 3).



Figure 3. Deer nip off buds and shoots from unprotected seedlings.

NATIVE PLANT SEED COLLECTOR

(Project Leader — Debbie O'Rourke)

As part of the Forest Service's shift into ecosystem management, land managers are paying more attention to plant diversity. Management plans focus on all plants on a site, not just the commercial tree species. Shrubs and non commercial trees will be part of the planning package.

Because of the previous emphasis on commercial tree species, little work has been devoted to the techniques and equipment necessary for collecting various native plant seeds. This project will determine the needs in this area and find equipment or methods to meet these needs.

The Center is surveying Forest Service personnel to determine what equipment is needed to adequately collect plant seed from native shrubs and non-commercial species. MTDC will also conduct a market and literature search. Results will be reported to the Forest Regeneration Committee.

STUMP APPLICATOR FOR FELLER-BUNCHERS

(Project Leader — Dick Karsky)

MTDC has designed and fabricated a tank and spray system that can be attached to feller-buncher tree harvesters for applying stump treatments during thinning operations. This system will be used to prevent annosum root rot in thinned conifer stands.

Heterobasidion annosum is the most common disease of thinned pine plantations in the Southern Region (8). Thinning opens a stand to colonization by *H. annosum* through the freshly cut stump surfaces. The fungus spreads to adjacent trees through root grafts. Treating stump surfaces with a solution of TIM-BORTM, or a solution of a competing fungus, *Phlebia gigantia*, can control this disease. However, stump application by hand is labor-intensive. The MTDC system allows the feller-buncher operator to treat the stump when it is cut.

The system consists of a 40-gallon tank, a diaphragm pump, a timer, and a full cone nozzle. The nozzle is mounted behind the saw head where it can be seen by the operator and still be protected from debris. A 3-second spray burst fully covers a stump.

The prototype system was tested at the Savannah River Forest Station in September 1994. The unit proved to be a practical, easily attached stump applicator system. It can easily be adapted to different models of feller-buncher harvesters. Minor improvements incorporated into the prototype design will be tested at Savannah River in 1995. Results of the test will be reported.

NURSERY SOIL FUMIGATION

(Project Leader — Dick Karsky)

Growth of young trees is affected by the levels of pathogenic organisms present in the nursery environment. Certain cultural practices, such as crop rotation, have been used to reduce these levels in nursery seedling beds, but chemical application has been the preferred method. Basimid and Methyl Bromide were two fumigants used to sterilize beds in the past.

Methyl Bromide has been found to be environmentally harmful. The Environmental Protection Agency has proposed banning its use by 2001. MTDC was asked to find an economically and environmentally acceptable way of sterilizing nursery bed soils.

Both microwave and steam sterilization methods will be investigated. A cooperative agreement or contract will be arranged to determine the feasibility of microwave technology.

The Center has acquired a portable diesel-fired steam generator and will configure it for nursery operations. The Center is working with Bob James,

Northern Region (1) pathologist and the Coeur d'Alene Nursery to develop a test plan for the steam sterilization machine. A preliminary test will take place in late summer at the Coeur d'Alene Nursery.

SPOT SITE PRE-MIXING

(Project Leader — Dick Karsky)

Most site preparation equipment developed for forest applications has been designed with a scalping action. Scalping moves much of the topsoil to the side of the planting spot, or casts it even farther away. Foresters wanted better techniques that allowed the soil treated in spot site preparation to be left in the spot.

This requires a mixing action rather than a scalping movement. This technique is frequently used in agriculture and nursery work to cultivate and rototill. However, rocky soils in forestry applications have made mixing difficult. This project's goal is to provide equipment to Forest Service reforestation personnel that will enable them to prepare planting sites by mixing rather than scalping.

The Center contacted personnel from the Francis Marion National Forest in South Carolina (Eastern Region 8) to define the problem and establish requirements for a mixing action site preparation machine. The Center will contact other Regions and conduct a literature and equipment search to determine if existing products meet these needs.

SMART TOOLBAR

(Project Leader — Dick Karsky)

Nursery equipment operators have experienced problems in maintaining toolbar height at a consistent level above the seedbed during various cultural operations. This capability is essential for such tasks as root wrenching, root culturing, and top pruning.

With current technology, a system can be designed to automatically sense toolbar height and manipulate the tool to maintain that height. MTDC is working with Forest Service nursery personnel to perfect such a system. Essentially, this project tested various distance-sensing devices, determine the most applicable, and design a system for automatic height control.

Both mechanical ground sensors and ultrasonic devices have undergone preliminary tests. The ultrasonic sensor seems most promising. However, for lateral control, the mechanical sensor is still necessary. A prototype smart toolbar will be evaluated at the Coeur d'Alene nursery in 1995. Results will be reported (Figure 4).



Figure 4. Smart toolbar.

STEEP SLOPE SITE PREPARATION

(Project Leader — Dick Karsky)

Mechanical site preparation is generally restricted to slopes of less than 35 percent. With the emphasis on ecosystem management in the Forest Service, more residual material is being left after timber harvests. New methods are needed to adequately treat brush and logging debris and to prepare planting sites on slopes steeper than 35 percent with heavy slash.

The Center conducted a market and literature search to seek equipment and techniques available for work on steep slopes. All applicable equipment—from large excavators to small four-wheel-drive ATV's—was considered. Results of the MTDC investigation revealed a variety of equipment that would meet Forest Service needs. The report, "Site Preparation Equipment for Steep Slopes" (Proj. Rep. 9224-2839-MTDC), was published. The project has been terminated.

MACHINE VISION

(Project Leader — Dave Gasvoda)

Forest Service tree nurseries tailor their seedlings to specific Forest and District needs. To do so, these nurseries must have an effective quality control system.

Currently, lifted seedlings are delivered to packing sheds for grading and packing. Graders sort seedlings by hand, cull the unacceptable plants, and sort the others by stem diameter, top length, root area, and overall quality. They place the acceptable seedlings on a packing belt for final processing and packaging. Quality control checkers monitor this operation, picking samples and overseeing grader performance. This process is labor intensive and expensive. The Center was asked to automate the quality control and grading in an effort to reduce these costs.

Under contract to MTDC, Glenn Kranzler and Michael Rigney at Oklahoma State University delivered a machine vision quality control inspection station to the Forest Service's J. Herbert Stone Nursery (Central Point, OR) in February 1994. The system utilizes high-resolution line-scan camera technology and a personal computer. Ten tree seedling morphological features are measured at rates of up to 10 seedlings per second. Initial performance tests demonstrated measurement precision equal to or greater than manual measurements.

The seedling inspection station can be expanded to automate production line grading. Several related aspects of defect detection and seedling handling still must be addressed to achieve a comprehensive automated system.

Investigation of color detection of defects such as chlorotic foliage and stripped root laterals showed promising results. A positioning and sorting mechanism for handling the seedlings after grading was found to be marginally suitable to support automated root pruning.

During fiscal year 1995, MTDC will continue to work with OSU to develop a fully functional automatic grading system. The problem of seedling sorting and handling after grading will be more completely examined. Progress will continue to be reported under a new project, Seeding Grading Machine (Figure 5).

SMALL AREA FORESTRY EQUIPMENT

(Project Leaders —

Bill Kilroy and Keith Windell)

In this project, MTDC will determine the needs of field personnel for small area forestry equipment. During fiscal year 1995, initial contacts will be made and site visits arranged. After initially determining what is needed in small area opera-



Figure 5. Machine vision quality control inspection station for tree seedlings.

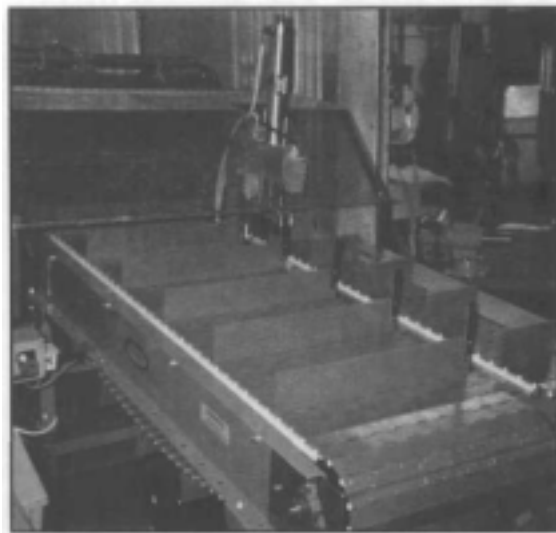


Figure 6. MTDC root pruner.

tions, the center will make an extensive market search to identify commercially available equipment that fills these needs. A catalog of this equipment and appropriate sources will be published, along with recommendations of further work to be presented to the Regeneration Steering Committee.

ROOT PRUNER

(Project Leader — Debbie O'Rourke)

During seeding, grading, and packing operations at the nurseries, seedlings are pruned in the packing shed to provide seedlings with a uniform root length. This is currently done by hand with paper cutters similar to those found in many offices.

This system has a number of problems. Hand cutting is difficult. Workers tire quickly, and are subject to injuries such as carpal tunnel syndrome and finger lacerations. The work is slow and typically requires additional personnel and equipment to keep up with production. Finally, contractors have difficulty meeting Forest Service root length specifications.

The Center was asked to develop a root pruner to automate the pruning process and increase packing shed safety and efficiency. The prototype accommodates up to an 8-inch diameter seedling bundle, carrying it to the cutting area on a plastic conveyor chain. When these bundles enter the cutting area, the shear is activated and the seedlings are pruned to the correct length. The bundles are transported to the end of the unit and packed in boxes. The cutting area is completely enclosed with a Lexan guard, which provides a barrier between the operator and the cutting mechanism, yet still allows the necessary visibility. The system has been refined based on field tests. Fabrication drawings and a report will be prepared terminating the project (Figure 6).

MULCH FOR SEEDLINGS

(Project Leader — Keith Windell)

Ground mulch is commonly used in the ornamental and landscape business to reduce vegetative competition and improve soil moisture around newly planted trees and shrubs. Forest Service researchers determined that ground mulch could

significantly improve seedling survival and promote early growth.

As part of a nationwide cooperative research effort, MTDC collected data on various types of mulch material and current techniques and equipment used to place the material around newly planted trees. The Center has also helped collect the final data on a cooperative mulch test project with the Lolo National Forest.

Results will be published in an MTDC report intended to serve as a reference for field foresters. The report will include information on commercial mulches currently available, suggested installation techniques, a quick overview of the results of past mulch studies and of the cooperative mulch test, recommendations, and a comprehensive bibliography. Forest Service employees from the Southern Research Station, the Forest Products Laboratory, Pacific Northwest Region (6), and Northern Region (1) are cooperating with the project. (Figure 7)

PEOPLE IN TREE TOPS

(Project Leader — Tony Jasumback)

For many years equipment has been needed to gain access to the tops of trees for various cultural work such as pollination, cone collection, and insect and disease surveys. Tree climbing equipment is commonly used, but it is dangerous and provides only limited access to the entire crown.

Mechanical equipment such as lifts require frequent moving to reach all sections of a tree and are limited in the heights they can reach. The Center conducted a search of new commercial technology and determined that equipment already existed to meet Forest Service needs. The results were published in the Tech Tips, "Aerial Lifts for Working in Tree Tops" (Tech Tips 9424-2314-MTDC). The project has been terminated.

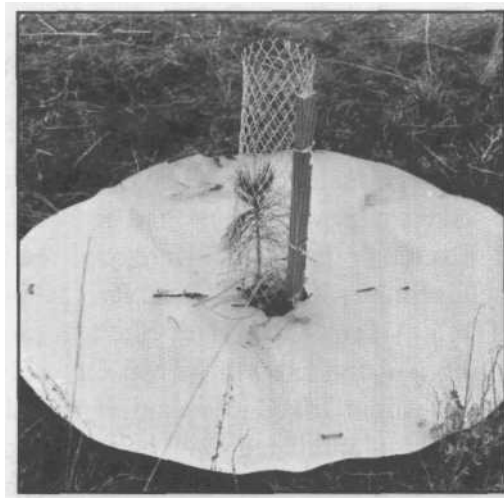


Figure 7. Mulch mat.

HAWK SCARIFIER

(Project Leader — Keith Windell)

This project will develop a safer digging head for a commercially available multiple-use chain saw attachment. This attachment will be used for scarifying a tree planting site, clearing a fire line, or constructing a trail. The Center is developing an alternative digging head that will do all these tasks and be safer to use than the currently available commercial design. An electrically powered test stand was constructed to simulate a gasoline chainsaw.

Several prototypes have been fabricated and tested. Additional field tests are planned for fiscal year 1996. Safety is the primary concern at this time. (Figure 8)

SEEDLING PROTECTION

(Project Leader— Keith Windell)

MTDC has been working with Southern Region (8) timber management to evaluate commercially available devices that can protect seedlings from animal damage and promote growth. Seedling protectors have been successfully used in Europe and in some areas of the United States for years. Along with protecting the young plant from animal

browsing, these devices can create a microclimate around the seedling that will improve survival and promote its early growth.

The Center conducted an extensive literature search to see what previous work had been done in this field. Results of that search were reported in "Tree Shelter Survey Results" (Proj. Rep. 9424-2822-MTDC). A Tech Tips, "Tree Shelters for Seedling Survival and Growth" (Tech Tips 9324-2315-MTDC), summarized information published in the larger report and listed new shelter designs and information on manufacturers and distributors. A fact-finding trip to England allowed the center to monitor shelter development there and discuss current uses of the shelters. The findings were summarized in "Seedling Protection in England (Proj. Rep. 9324-2845-MTDC).

MTDC will assist in a National Tree Shelter Workshop to be conducted in June at Harrisburg, PA. Center personnel will discuss the durability of tree shelter materials. Jim McConnell, who retired from the Southern Region (8) timber management staff, Jim Barnett, Project Leader at the Southern Research Station, and Dave Haywood, Research Forester at the Southern Research Station are helping to guide this project.



Figure 8. Hawk scarifier.

PRUNING EQUIPMENT

(Project Leader—Keith Windell)

The Center is beginning a project to determine what pruning equipment currently available is best for timber stand improvement. MTDC has surveyed field personnel for current methods and equipment used. Results are available in an MTDC publication. Researchers were contacted to determine the best and most efficient pruning methods. The Center purchased equipment for a comprehensive field evaluation. Field testing is underway in the Pacific Northwest Region (6). (Figure 9)



Figure 9. MTDC will evaluate pruning techniques and equipment.

NURSERY TECHNICAL SERVICES

(Project Leader — Ben Lowman)

This continuing project allows MTDC to provide technical services to Forest Service Nurseries and to respond to requests from State agencies and private individuals. New technology is continually monitored under this project. Center personnel disseminate this information by presenting papers at professional meetings and symposiums. The Center also answers inquiries from field personnel,

visits various Forest Service nurseries, and provides drawings and publications on request.

The Center personnel attended the Western Nursery Conference in Moscow, ID, visited the Georgia Forestry Commission to view modifications to the acorn planter, and presented a summary of MTDC work at the Great Plains Reforestation Workshop in Nebraska during fiscal year 1994.

Your nursery project proposals are welcome. They should be submitted to Ben Lowman in writing or over the DG (B.Lowman:R01 A). Write a summary that clearly states the problem and proposes your desired action. The information is used to determine priorities, to link you with others with similar problems or with solutions to your problem, or to establish a project to solve the problem with appropriate equipment or techniques.

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Publications and drawings may be ordered in single copies. If you need additional information, contact:

USDA Forest Service
Missoula Technology and Development Center
Building 1, Fort Missoula
Missoula, MT 59801
(406) 329-3900
Data General mtdc.pubs:r01a
E-Mail: /s=mtdc.pubs/ou1=s22a@mhs-fswa.attmail.com

RECENT DRAWINGS

Orchard Seed Harvester MTDC 851

Pollen Collector Head MTDC 856

Progeny Seeder MTDC 858

110 VAC Field Storage Unit MTDC 865

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Cyclone Pollen Collector MTDC 876

Seedling Box Pickup MTDC 880

Pollen Injector MTDC 893

Root Pruner MTDC 901

Salmon National Forest Scarifier MTDC 924
Sand Spreader LPN 8

Acorn Planter MTDC 908

Woods Cutting Planter MTDC 909

Machine Vision Development and Use in Seedling Quality Monitoring Inspection¹

David B. Davis and John R. Scholtes²

Abstract— Seedling processing costs have increased in proportion to overall seedling costs in part because of lack of automation. A PC-based machine vision seedling inspection station has been developed for packing—house quality monitoring as part of a program to develop an automated seedling grading and packing system. This inspection station is being evaluated for incorporation into the quality monitoring inspection program at J. Herbert Stone Nursery. The station has been evaluated for accuracy of measurements of seedling morphological features with favorable results. Machine vision grading criteria are being developed from comparisons of machine vision with current manual methods of measurement. Further studies will be made into developing grading criteria using features measured by machine vision which were not obtainable with manual methods. A fully functional machine vision based seedling grading and packing system remains the goal of the program.

INTRODUCTION

J. Herbert Stone Nursery is in Southwestern Oregon near the city of Medford. It is a USDA Forest Service nursery and produces conifer seedlings and other plant materials for publicly owned lands only. The major clients are the USDA Forest Service and the USDI's Bureau of Land Management and Bureau of Indian affairs. The capacity is approximately 24 million seedlings per year. More than 275 million seedlings have been shipped since 1979 to planting sites throughout Oregon, Washington, Northern California, Northern Idaho, and Western Montana.

LIFTING AND PROCESSING

One and two-year-old seedlings are lifted from seedling beds during the dormant season. The lifting window established for the J. Herbert Stone

Nursery is between December 1 and March 1. Lifting begins with undercutting with a blade spanning the 4-ft wide seedling bed. Shaker tines attached behind the blade shake the seedlings and soil up and down, loosening the soil from the seedlings.

Seedlings are hand lifted out of the loosened soil with any soil remaining removed from the roots by a gentle shaking motion. The bareroot seedlings are packed into field containers and loaded onto specially designed field trailers. Seedlings are then taken to storage facilities to await processing.

Seedlings are transported from storage to the processing shed using a forklift. The seedlings are placed on a moving conveyor that delivers them to the grading stations. Grading is accomplished by individuals taking a hand-full of seedlings and visually inspecting them by passing the seedlings

¹Davis, D.B., Scholtes, J. 1995. *Machine Vision Development and Use in Seedling Quality Monitoring Inspection*. In: Landis, T.D.; Clegg, B., tech. coords. *National Proceedings, Forest and Conservation Nursery Associations*. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 75-79.

²J. Herbert Stone Nursery, 2606 Old Stage Rd., Central Point, OR 97502; Tel.: 541/858-6180; Fax: 541/858-6110.

from one hand to the other. Groups of five or 10 shippable seedlings are placed back onto the same moving conveyor. This conveyor moves the shippable seedlings to where the seedlings are gathered, root pruned, and placed into their final storage and shipping containers. We have five of these grading conveyors with the potential of processing up to five different lots simultaneously.

Inspections for quality are made throughout the process. As a minimum, 1% of all seedlings are inspected for sorting, root trimming, accuracy of count, etc. Samples of culls are also inspected for shippable seedlings before disposal.

THE CASE FOR MACHINE VISION

Unlike advances made in seed handling and seedling culturing, very little has changed in the lifting and processing of tree seedlings for decades.

Ten years ago, the cost of seedling production was two-thirds of the total direct cost of our program. Today, two-thirds of our direct cost is in lifting and processing. Most of this change is our lack of mechanization while facing steadily rising labor costs. Quality monitoring also requires heavy use of labor while yielding only pass/fail information. Our personnel only have time to determine if grading, pruning, etc. meets our standards.

Our clients have expressed interest in having actual data on various attributes for each seedling lot they receive. They would use this information in making final plans for the seedling use such as reserving lots with heavier root systems and/or larger calipers for the more harsh sites. Having nearly 100 clients and more than 650 individual seedling lots each year would require an automated data processing system.

MACHINE VISION DEVELOPMENT

Machine Vision has progressed through several stages of development beginning with discussions about grading criteria and various technologies available for sensing seedling attributes and computing data. One major decision was to use a line scan instead of an area scan system. The project developed along with new technologies including faster computer CPU speeds, larger memory, and more accurate camera devices. At times, the project was slowed awaiting availability of new equipment developed, but not manufactured and released on the market.

THE CURRENT MACHINE

In Feb. 1994, the Machine Vision Seedling Inspection Station was delivered to J. Herbert Stone Nursery. This station has been described in detail by Rigney and Kranzler (1994). The station consists of two 18-inch-wide conveyors mounted end-to-end on a single frame. The first (inspection) conveyor is 74.5 inches long and the second (sorting) conveyor is 39 inches long. These conveyors operate at the same speed and have a variable speed control that allows operating at speeds of one to three m/sec. The distance between the inspection conveyor and the sorting conveyor is 1.5 inches. This allows for the high-intensity fluorescent back-light mounted below the conveyors to shine up between them. A line scan camera is mounted above the conveyors directly above the light.

No supporting equipment to feed seedlings onto the inspection conveyor or to process the seedlings from the sorting conveyor has been developed. Seedlings are placed on the inspection conveyor top first with their long axis running parallel with the direction of conveyor travel. As they cross the gap between the conveyors, the camera "sees" the

shadow cast by the seedling against the very bright back-light. This camera image is then digitized by a line-scan digitizer and sent to a 50-MHz 486 computer.

The computer uses the OS-9000 operating system (Microware Systems Corp., Des Moines, Iowa). A combination of commercial and custom software is required to run the station. Oklahoma State University holds the copyright to the custom software written in the C programming language. Algorithms developed for inspecting the seedlings are the intellectual property of Oklahoma State University and are considered a trade secret.

Operational speeds vary depending upon the average total length of the seedlings. The station is designed to handle seedlings with tops ranging from seven to 91 cm and with roots up to 36 cm.

The seedling features measured include stem diameter, top height, maximum root length, root mass length, percentage of root area outside the user defined root zone, percentage of fine roots, projected root area, and projected shoot area. From these measurements are calculated the sturdiness (top height/stem diameter) and shoot to root ratios.

SEEDLING FEATURES MEASUREMENT

Initial testing showed the station had some difficulty in finding the exact location of the root collar. It also had difficulty finding the terminal bud on species such as ponderosa pine where the terminal bud may be obscured by needles. Because of these difficulties, the calculated top heights and root lengths varied from actual measurements. Modifications were made to the software to allow user defined adjustments on how the root collar and terminal bud are found and to allow for adjustments as needed. These adjustments have allowed for top height and root length measurements to

compare more favorably with manual measurements of Douglas-fir and ponderosa pine.

Machine vision measurements comparable with manual measurements have been made on stem diameter of Douglas-fir and ponderosa pine.

The fine root percent measurements appear accurate when the root mass is not so heavy that it appears as a large solid mass to the camera. When the root mass appears solid to the camera, a low percent of fine roots is recorded. This might make it difficult to use this measurement on some species and age classes.

Root area comparison with root volume measured using the water displacement method shows a general correlation with 2-0 Douglas-fir (fig.1). This suggests that shoot to root ratio based on the shoot and root area has a tendency to be comparable to the volume method. Further investigation is needed to clarify this relationship with other species and age classes.

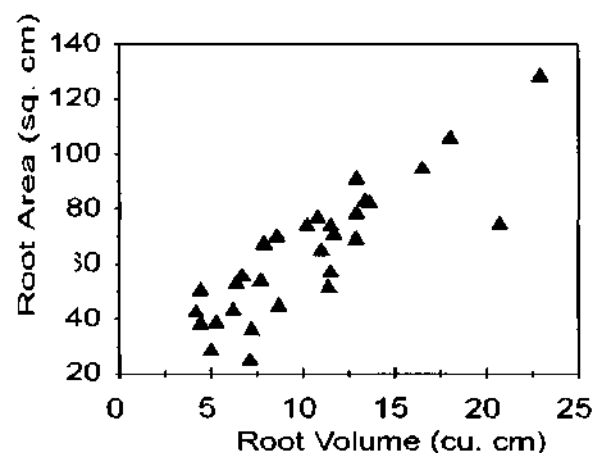


Figure 1. Comparison of root volume and root area in 2-0 Douglas-fir.

Root zone percentages as measured by machine vision appear from observations to correspond to the percent of roots outside the user defined root zone.

Table 1. Sample Summary and Data Reports produced by the Machine Vision Seedling Inspection Station.

Summary Report — Measurement Statistics

<u>Feature</u>	<u>Mean</u>	<u>STDEV</u>	<u>Min</u>	<u>Max</u>	<u>Units</u>
Diameter	6.59	0.05	6.51	6.75	mm
Height	33.1	0.1	32.7	33.5	cm
Shoot/Root	4.3	0.1	4.1	4.5	ratio
Sturdiness	5.0	0.06	4.8	5.1	ratio
Rt Max Length	19.4	0.2	19.1	20.0	cm
Rt Mass Len	19.4	0.1	19.1	19.7	cm
Out Root Zone	7.0	2.3	4.7	14.6	%
Fine Roots	11.2	0.4	10.7	12.2	%
Root Area	46.7	1.0	44.9	48.1	sq cm
Shoot Area	201.4	2.6	194.5	204.6	sq cm

Seedling Measurement Data

<u>Diameter</u> <u>(mm)</u>	<u>Height</u> <u>(cm)</u>	<u>Shoot/root</u> <u>(ratio)</u>	<u>Sturdiness</u> <u>(ratio)</u>	<u>Root Max</u> <u>(cm)</u>	<u>Root Mass</u> <u>(cm)</u>	<u>Root Zone</u> <u>(%)</u>	<u>Fine Root</u> <u>(%)</u>	<u>Root Area</u> <u>(sq cm)</u>	<u>Shoot Area</u> <u>(sq cm)</u>
6.61	33.0	4.1	5.0	19.6	19.6	5.3	11.5	47	197
6.51	33.2	4.5	5.1	19.2	19.2	4.8	11.7	44	200
6.56	33.0	4.4	5.0	19.1	19.1	5.8	11.5	45	202
6.54	33.2	4.3	5.1	19.5	19.4	7.0	10.9	47	201
6.61	33.3	4.3	5.0	19.6	19.6	7.1	11.3	47	202
6.54	33.1	4.4	5.1	19.3	19.3	6.8	12.2	46	202
6.60	33.2	4.4	5.0	19.2	19.2	5.3	11.0	46	204
6.59	33.2	4.3	5.0	19.4	19.4	5.4	11.0	46	201
6.54	33.1	4.3	5.1	19.7	19.7	5.2	11.7	46	201
6.59	32.8	4.4	5.0	19.7	19.7	8.7	11.2	46	202
6.61	33.3	4.4	5.0	19.5	19.5	7.7	11.1	46	204
6.55	33.2	4.5	5.1	19.4	19.4	6.0	10.9	45	203
6.75	32.7	4.4	4.8	19.5	19.5	14.6	11.2	46	204
6.62	33.1	4.3	5.0	19.4	19.4	8.3	11.1	47	201
6.52	33.4	4.3	5.1	19.5	19.5	5.7	10.9	46	202
6.64	33.3	4.2	5.0	20.0	19.7	6.9	11.0	48	200
6.64	32.9	4.1	5.0	19.7	19.7	10.9	11.1	47	194
6.60	33.2	4.3	5.0	19.2	19.2	7.8	10.7	46	201
6.52	33.3	4.3	5.1	19.3	19.3	4.7	10.9	46	198
6.57	33.5	4.2	5.1	19.6	19.6	5.3	10.9	47	197

GRADING CRITERIA

The machine vision seedling inspection station produces classification reports based on up to eight user defined grading criteria classes using the seedling features it can measure. Stem diameter, top height and root length grading criteria correspond closely with the same measurements manually. These criteria need modification to compensate for the discretion allowed by manual observation where looking at the seedling in a three-dimensional perspective is possible.

Grading criteria for the other features measured will be developed as more experience allows us to translate visual evaluation of these features to a form usable by the station.

ALGORITHM PARAMETERS

The machine vision inspection station uses various parameters in the algorithms to distinguish seedling features. These parameters must be modified depending on the morphology of the seedling being inspected. Currently parameters have been developed for 1-0 and 2-0 ponderosa pine and 1-0 and 2-0 Douglas-fir. Due to variations within species and age classes these become default settings which may require modifications for a given lot.

SUMMARY AND DATA REPORTS

Summary and seedling measurement data reports may be created by the inspection station at the users request (Table 1). The summary report displays the measurement statistics and the data report displays the measurement data for each seedling graded. The data summary is stored as ASCII text in a DOS partition on the hard disk and is easily used by many commercial software packages for further analysis.

FUTURE DEVELOPMENT

Further refinement of the algorithm parameters and grading criteria for various combinations of species and age class is the next step. New grading criteria will be analyzed and outplanting survival checked. Current grading processes depend entirely upon human ability to judge sizes and amounts. This places a significant part of the decision as to the plant being acceptable upon the easier to visualize and describe attributes such as top height, root length, and stem diameter. The current equipment will gather more dependable information on other attributes such as shoot to root ratio, percentage of fine roots and shoot and root areas. The use of new combinations of grading rules such as stem diameter and total root mass may be better indicators of survival and initial growth than those currently in use.

Evaluation will be made of the use of color and shades of grey in detecting off-color foliage and recognizing damage such as stripped roots or other wounds.

Development of a complete system is the final goal. This will include equipment capable of singulating and feeding seedlings to the station, separating out two, three, or more grades of seedlings, performing root trimming and other final preparation of the seedlings, and packaging the seedlings.

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Herbicide Program at the PFRA Shelterbelt Centre¹

W.R. Schroeder and L.K. Alspach²

Abstract —The PFRA Shelterbelt Centre is a major supplier of conservation tree and shrub planting stock in Canada. Testing of herbicides for nursery weed control has been under way for over thirty years. The result of this research has been the development of a comprehensive herbicide program that has supplemented conventional weed control methods that has significantly reduced nursery labour requirements. Herbicides currently used operationally are linuron for poplar and willow cuttings, choke cherry and green ash sowings, conifer transplants, all 1-0 deciduous crops and nursery shelterbelts; sethoxydim for barnyard grass control in conifer transplants; and trifluralin for caragana and Siberian elm sowings. Herbicide treatments being tested for operational use include: oxyfluorfen for conifer sowings; napropamide for villosa lilac sowings; trifluralin for buffaloberry and sea-buckthorn sowings; trifluralin/metribuzin tank mix for pre-emergent weed control in shelterbelts; and clopyralid for control of Canada thistle in shelterbelts.

INTRODUCTION

The Prairie Farm Rehabilitation Administration (PFRA) Shelterbelt Centre at Indian Head, Saskatchewan was established in 1902. The Centre is located at Indian Head, Saskatchewan and occupies an area of 640 acres. Current production ranges from 8 to 10 million tree seedlings annually. Seedlings are used for farmstead and field shelterbelts, wildlife habitat, reclamation and agroforestry plantings. Currently the Centre produces four coniferous and 22 deciduous species. Since its inception in 1902 the Centre has distributed over 500 million tree seedlings to prairie tree planters.

Fifty years ago the Shelterbelt Centre established a research unit that conducted studies on nursery practice, tree breeding, and pest control in

addition to providing technical support to nursery production operations. The unit has undergone several changes over the years. Its current mandate is to solve problems associated with growing trees on the prairies and more recently to investigate tree related activities that have a role in sustainable rural development. Research is being conducted in the following disciplines: tree improvement, propagation, entomology, weed control, pathology, agroforestry and shelterbelt effects. Along with the research mandate the section remains responsible for overseeing most technical operations at the Centre. This includes herbicide, insecticide, fungicide, fumigant, defoliant and fertilizer applications.

The Shelterbelt Centre has a long history of herbicide research. The program was initiated through a need to establish herbicide recommenda-

¹ Schroeder, W.R. and Alspach, L.K. 1995. *Herbicide Program at the PFRA Shelterbelt Centre*. In: Landis, T.D.; Cregg, B., tech. coords. *National proceedings, Forest and Conservation Nursery Associations*. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 80-83.

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tions that could safely be used in nursery crops. Weed control is an important factor in nursery production. Prior to the use of herbicides considerable labour was required for weed control. Alspach (1988) reported that herbicides reduced the labour requirement for weed control in Siberian elm sowings by 92 percent and poplar cutting beds by 63 percent. This paper outlines herbicide practices currently in use at the PFRA Shelterbelt Centre.

SEEDBED FUMIGATION

Conifer seedbeds are routinely fumigated using dazomet. Dazomet (Basamid 98% granular) is applied to seedbeds using an applicator designed and fabricated at the Shelterbelt Centre. The applicator applies the dazomet at 425 kg/ha and incorporates to a depth of 20 centimetres in one operation. The seedbeds are irrigated daily for five to seven days following application. After the necessary treatment time has elapsed the soil is rotovated to allow any remaining gases to dissipate. Dazomet is currently used for disease and weed control in white spruce (*Picea glauca* (Moench) Voss), Colorado spruce (*Picea pungens* Engelm.), Scots pine (*Pinus sylvestris* L.) and Siberian larch (*Larix sibirica* Ledeb.) seedbeds as well as deciduous shrub seedbeds.

CONIFER SEEDBEDS

Conifers grown at the Shelterbelt Centre include white spruce, Colorado spruce, Scots pine and Siberian larch. White spruce and Siberian larch are fall sown whereas Scots pine and Colorado spruce are spring sown. Oxyfluorfen (Goal 19% EC) is applied at 2.6 litres product per hectare (38 oz/acre) immediately after sowing white spruce, Colorado spruce and Scots pine. This treatment is applied before conifer or weed emergence. The herbicide is incorporated with light irrigation (0.5 centimetres) following application.

CONIFER TRANSPLANTS

Conifers are transplanted in beds after two years in seedbeds. Transplanting is carried out during June using modified celery transplanters. Weed control is provided by linuron application at 4.7 litres product (48% Liquid Suspension) per hectare (68 oz/acre) immediately after transplanting when seedlings are dormant. The herbicide is incorporated by light irrigation (0.5 centimetres). In the fall, linuron is applied at a rate of 3.5 litres product per hectare (50 oz/ac) as an overall spray when seedlings are dormant. This treatment provides residual weed control in the following growing season. Barnyard grass (*Echinochloa crusgalli*) is controlled by applying sethoxydim (Poast 18% EC) at 1.0 litres of product per hectare (14 oz./acre). For optimum control the barnyard grass should be in the 2-3 leaf stage and irrigation must not be applied within one hour of herbicide application.

POPLAR AND WILLOW HARDWOOD CUTTINGS

Poplar and willow hardwood cuttings are rooted in nursery fields. Cuttings are planted in late May using a mechanical planter developed at the Shelterbelt Centre (Schroeder 1984). Following planting but before budbreak, linuron (48% Liquid Suspension) is applied at a rate of 3.5 litres of product per hectare (50 oz/acre). The herbicide is incorporated using light irrigation (0.5 centimetres).

DECIDUOUS TREES AND SHRUBS

The Shelterbelt Centre currently produces 18 deciduous species. Major species include caragana (*Caragana arborescens*), green ash (*Fraxinus pennsylvanica*), choke cherry (*Prunus virginiana*), villosa lilac (*Syringa villosa*), Siberian elm (*Ulmus pumila*), Manitoba maple (*Acer negundo*), silver buffaloberry (*Shepherdia argentea*) and sea-

buckthorn (*Hippophae rhamnoides*). All species except for caragana, Manitoba maple and Siberian elm are fall sown. These species are spring sown and germinate soon after sowing. Western snowberry (*Symphoricarpus occidentalis*) and Arnold hawthorn (*Crataegus arnoldiana*) are summer sown and do not germinate until the following spring.

Caragana and Siberian elm are sown in late spring. Prior to sowing, fields receive a pre-seeding treatment of trifluralin (Treflan 48% EC) at a rate of 2.35 litres product per hectare (33 oz/acre) in 18 gallons of water per acre. The herbicide is applied no more than seven days prior to sowing and incorporated to a depth of 8 to 10 centimetres (3 to 4 inches) with a tandem disc.

Choke cherry and green ash are sown in late fall. Occasionally stratified seed will be sown in the spring. Linuron (48% Liquid Suspension) is applied immediately after sowing at rate of 3.5 litres of product per hectare (50 oz/acre). Precipitation during the fall and winter provide incorporation of the herbicide. For spring applications the herbicide is incorporated with a light irrigation (0.5 centimetres).

Testing of herbicides for weed control in villosa lilac has been under way for many years with little success. The most promising treatment appears to be application of napropamide (Devrinol 50% WP) prior to sowing lilac. The recommended application rate is 5.0 kilogram of product per hectare (70 oz./acre) followed by incorporation to a depth of 5 centimetres.

Summer sown species such as snowberry and hawthorn require weed control prior to germination the following spring. This is accomplished with applications of paraquat (Gramoxone 20% solution) at a rate of 5.6 litres of product per hectare (80 oz/acre). Paraquat application is repeated as often as required, prior to shrub emergence.

Most deciduous species are in nursery fields for two years. Weed control during the second growing season is provided by application of linuron the previous fall. Linuron is applied as an overall spray at a rate of 3.5 litres product per hectare (50 oz./acre) to fields of dormant seedlings. This treatment is particularly effective for control of winter annuals such as flixweed (*Descurainia sophia*), stinkweed (*Thlaspi arvense*) and shepherd's-purse (*Capsella bursa-pastoris*).

CHEMICAL DEFOLIATION

Late defoliation of Siberian elm, villosa lilac and willow species delays nursery lifting operations. Lifting of these species prior to defoliation often results in proliferation of mould during winter storage. Defoliation of Siberian elm can be initiated by application of a tank mix of ethephon (Cerone 48% SN) at 3.4 litres of product plus potassium iodide (KI) at 1.62 kilograms in 90 gallons of water per acre. Thorough coverage of foliage is important. An operating pressure of 100 PSI is maintained while spraying. The defoliation of willow and villosa lilac requires application of ethephon (Cerone 48% SN) at 1.86 litres of product per acre plus endothal (Des-i-cate 6.2% SN) at 14.4 litres per acre. Seedlings can be safely defoliated once they are vegetatively mature. Vegetative maturity is determined by removing the terminal bud on a seedling and monitoring the development of lateral buds for seven days. When mature, the lateral buds remain dormant. Within two weeks of chemical application leaves turn brown and seedlings defoliate.

NURSERY SHELTERBELTS

Nursery fields are separated by shelterbelts. These tree rows provide microclimate modification and also are used as seed sources for nursery production. Weed control is necessary in these tree

rows so that tree growth is maximized and the hedges do not become a source of weed seed that will infest adjacent nursery fields. Prior to planting new shelterbelts a tank mix of 5.2 litres product per hectare of trifluralin (Treflan 48% EC) and 600 millilitres product per hectare of metribuzin (Sencor 50% Liquid Suspension) is applied. After application the herbicide is incorporated to a depth of 8 centimetres using a tandem disc. This treatment is currently being evaluated. Results to date indicate there is little to no toxicity to most tree and shrub species. Each fall linuron is applied to tree rows at a rate of 5.0 litres product per hectare (70 oz./acre).

For Canada thistle (*Cirsium arvense*) control a directed application of glyphosate (Roundup 36% Solution) is used. The herbicide is applied avoiding contact with tree foliage as contact can cause severe damage. An alternative treatment being tested is clopyralid (Lontrel 36% EC) at a rate of 0.8 litres product per hectare (12 oz./acre) applied as an overall spray. Caragana and other legumes are very sensitive to clopyralid, most other tree and shrubs species are tolerant.

CONCLUSION

Weed control practices at the PFRA Shelterbelt Centre have been described. The use of herbicides has significantly reduced labour requirements for nursery production of tree and shrub species. New herbicide treatments are routinely being evaluated to increase the weed control options available to the nursery. Registration of new treatments is a long process requiring many years of testing. This process is essential, however, to ensure the safe and effective use of herbicides.

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Fertilization Practices and Application Procedures at Weyerhaeuser¹

Mark E. Triebwasser² and Steve L. Altsuler³

Abstract — Fertilizer practices used in nine Weyerhaeuser nurseries are compared. Each nursery has developed a unique reliable process for fertilizer application based on soil properties and climate. These processes have evolved over time with changes in other cultural processes. Our application technology also has evolved. Use of computer controlled spray equipment to give precise application is becoming our standard.

INTRODUCTION

Weyerhaeuser Company grows over three hundred and fifty million seedlings of seventy species each year. The species include Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), loblolly pine (*Pinus taeda*), along with additional true firs (*Abies spp.*), cedars (*Thuja spp.*, *Chamaecyparis spp.*), pines (*Pinus spp.*), and cypress (*Taxodium spp.*). We also grow a variety of deciduous seedlings. Red alder (*Alnus rubra*) is grown in the West, and a variety of oaks (*Quercus spp.*) and other deciduous seedlings in the South. The stock types include one and two-year old seedlings and transplant crops of bareroot and container seedlings. In the West we also produce two million rooted cuttings of Douglas-fir.

Four nurseries are located in the Pacific Northwest, one in central British Columbia, Canada, and four in the Southeast. With so many nurseries, species, and stock types there is a wide diversity of fertilizer prescriptions. This brief overview will comment on our practices and contrast the differ-

ences in fertilizer practices in these nurseries. The evolution of our application technology will also be discussed. Weyerhaeuser also has several greenhouse operations but fertilization practices at these facilities are not included in this summary.

FERTILIZATION PRACTICES

Each of our nursery sites has developed a unique fertilization regime based on the soils and climate of the site. Natural soil fertility, soil texture, structure, organic matter, pH, and other soil properties have shaped the regimes that each facility has developed. The importance of each of these factors has been reviewed by van den Driessche (van den Driessche, 1980, 1984). These regimes have been modified over time based on the growth and development of the seedlings. The color of the seedlings is used as a major indicator of their nutrient status. We use tissue analysis periodically to monitor nutrient levels as we make changes in other cultural practices. Tissue nutrient analysis is also done where nutrient problems are suspected.

¹Triebwasser, M.E.; Altsuler, S.L. 1995. Fertilization Practices and Application Procedures at Weyerhaeuser. In: Landis, T.D.; Cregg, B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 84-88.

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All of our facilities use a pre-sow or pre-transplant application of fertilizer. The nutrients used and the rate to apply is determined after a soil nutrient test. Nutrients applied may include triple super phosphate, Sul-Po-Mag, potassium sulfate, ammonium sulfate, ammonium phosphate, lime and/or sulfur. The southern facilities are primarily concerned with levels of potassium and sometimes phosphorous in their pre-sow applications. Lime may also be used. In the West our primary concern is for phosphorous and to a lesser degree potassium. One western nursery occasionally applies lime, while the remainder of our western nurseries are more concerned with high pH and may use sulfur or other means to lower pH. All facilities in the South and some in the West also include a blend of micro-nutrients in their pre-sow application.

On the ground to be sown no nitrogen sources are used, except at our Canadian facility. No nitrogen is applied because we have found that high nitrogen levels in soils when seedlings are just germinating increases the level of disease (Sinclair et. al., 1975). Nitrogen will be applied to some of these seedlings later in the growing season. In the Canadian nursery ammonium phosphate is used in the fertilizer mix. Only about 15 pounds of nitrogen is applied per acre and then no subsequent growing season applications of nitrogen are made during the first year.

Several months after germination, fertilization begins. The growing season applications are primarily for nitrogen. In the West the source may be ammonium sulfate, urea, calcium nitrate, or N-32, a solution of ammonium nitrate and urea. One to four low rate applications may be made over the next three months. Rates are typically about 15 pounds of nitrogen per acre per application. Only 30 to 60 pounds of nitrogen may be applied during the growing season.

In the southern nurseries, the nitrogen source is ammonium sulfate, which is applied at a weekly rate of 10 pounds/acre. Total nitrogen applications

during the season may be 100 to 130 pounds per acre. In the South they may also make one or two applications of potassium either as potassium chloride or Sul-Po-Mag (Sulfate of potash-magnesium).

On western seedlings that are to be grown for two years little or no growing season nitrogen is used during the first year. Application of nitrogen causes too much growth the first year and makes it difficult to control growth during the second year. No growing season applications of nitrogen are needed on red alder. This three to four-foot tall, one-year-old seedling is produced without nitrogen. This species has a symbiotic bacterium, *Frankia*, that fixes nitrogen from the atmosphere. We inoculate the beds with ground *Frankia* nodules to ensure infection.

Fall fertilization is desired to allow for good nutrient status when the seedlings enter dormancy (Thompson, B, 1983). The fall application also promotes good bud development. Fall fertilized seedlings have a dark green color and can be more frost hardy than seedlings that have not been fertilized. Once again the primary nutrient for the fall application is nitrogen. One or two applications may be made. In Canada the fall application is made in late August, using ammonium phosphate or ammonium sulfate. Calcium nitrate may be used for the fall application in our Washington nursery. The other Pacific northwest nurseries use their normal nitrogen sources. In the South, ammonium sulfate is the nitrogen source for fall fertilization. In all facilities the rate is between 15 and 30 pounds per acre.

In the West many seedlings are grown as two-year-olds. The seedlings receive much the same nutrient regime as the one-year-old seedlings although the rates are increased and the application time is earlier in the year. Prior to bud break an application of ammonium phosphate is made followed with two or three applications of nitrogen prior to early July.

In the West the desired stock type for reforestation is a transplant seedling. These seedlings are generally larger in height and caliper than the 2+0 stock. They have more branches and buds, and a heavier, mop like root system. These seedlings receive much the same fertilizer regime as the 1 +0 seedlings except that sixty pounds of nitrogen is included in the pre-plant application. Nitrogen applications during the growing season are approximately twice the rate of the one-year-old seedlings. Total amount of nitrogen applied will be from 120 to 180 pounds per acre.

APPLICATION PROCEDURES

Most of the nutrient sources used in the pre-plant applications are of low solubility. This necessitates the use of a fertilizer spreader that can apply granular material such as a rotary spreader. Many of our facilities contract with a commercial applicator to apply the pre-plant applications. These contractors use the same type of equipment but can apply fertilizer to large acreage much more efficiently than we can using smaller tractor mounted equipment. The variation in rate of application is large using this type of equipment. The distribution of the commercial applicators is only slightly more uniform than with nursery equipment.

A rotary spreader can also be used for growing season applications. A major disadvantage is the lack of uniformity of application. Many times the appearance of yellow stripes in the field will be apparent from the variation in application when using this type of equipment. Also, almost 40% of the area fertilized is in tractor wheel paths. For a more uniform application a drop or box spreader may be used. The advantage of this type of spreader is that it produces a much more uniform application. Wheel paths are not fertilized. The disadvantages are that they are slow and require

frequent filling. Most of our southern nurseries still use drop spreaders. The use of gangs of spreaders that allow them to fertilize three beds with each pass speeds up the application. In the Pacific Northwest we still use this type of equipment for special applications and for fertilizer experiments. Canada has added drop tubes to their spreader to allow placement of the fertilizer between the rows of seedlings. This prevents fertilizer from lodging in the foliage and causing fertilizer burn.

In the West about thirteen years ago we began using our spray equipment to apply fertilizer. Applications could be made that were very uniform with great accuracy. Our sprayers are capable of applying fertilizer to a full section of trees, either 6 or 7 beds at one time. When we first began this type of application we simply took the granular fertilizer material and poured it into the spray tank. The agitation in the tank dissolved the fertilizer before spraying. There were several disadvantages to this process, including: safety of moving 80 pound fertilizer bags on small, awkward platforms; length of time to get all the material to dissolve in the sprayer; impurities in the mix may not dissolve and can plug the nozzles and screens of the sprayer.

The next improvement at one facility was to move the dissolving operation to a separate tank with mechanical and jet agitation. The tank was situated on a raised platform with ample work area. The heavy fertilizer bags still had to be picked up, but there was less risk from climbing and moving bags in a restricted area. The mixing was done unattended while the operator was out spraying the previously mixed batch. There was also the ability to screen out impurities as the solution was pumped into the sprayer.

The next improvement came when we converted from the bagged granular material that needed to be dissolved to a liquid formation. The fertilizer is delivered in bulk tanks of 250 gallons. When adding fertilizer to the sprayer a forklift

raises the bulk tank and simple gravity feed delivers the material to the tank. The desired quantity of fertilizer is decanted into the sprayer. The tanks are calibrated for easy measurement. Water is added to get the desired concentration. Although we are using the sprayer for application, the solution is not for foliar feeding. The fertilizer is washed off the foliage and into the soil with irrigation immediately after spraying. We have done some experiments with foliar applications but to date have not found any real advantage of using these more expensive materials.

COMPUTER CONTROLLED SPRAY INJECTION SYSTEM

Although it is not required for application of fertilizer through the spray system, all of our Pacific northwest nurseries have converted to computer controlled injection systems on our sprayers. The southern nurseries are considering making this change. The system consists of a 500 gallon tank containing water or fertilizer solution, two tanks to hold pesticide concentrates, a tank to collect rinseate, and a tank of clean water for emergency washing. The ground speed is monitored using radar. The on-board computer then calculates the rate of injection of pesticide and the flow rate for the water. Electronic controls on the pump and solenoid valves deliver the desired application rate per acre of both carrier and product. Tractor speed is not critical. The system can adjust for variation in ground speed.

Another advantage of using computer controlled injection systems is that since the material is not diluted, only five or ten gallons of pesticide concentrate are placed into the chemical tanks. Thus, only a limited amount of chemical is being transported instead of 500 gallons of diluted mix. This usually is enough for a full day of spraying. Additional water can be obtained from many locations on the site. In the event of an upset or spill the environmental damaged would be much easier to cleanup.

There is no concern for preparing the exact amount of chemical solution to use. The chemical is not diluted so it can be left in the chemical tank for use another day. If left in the chemical tank it must be labeled. The chemical can be decanted back into the original labeled container if desired. The same is true if weather conditions become unacceptable and you must stop spraying before the project is complete. Any rinse water generated when emptying containers is placed in a special tank, and then pumped out as part of the chemical application at very low rates. The system also has the ability to fully rinse the chemical tank and all booms while still in the field. This rinse water is then applied as part of the spray operation to the crop, thus there is no rinse water to deal with later. All of the valves necessary for spraying, rinsing, or pumping are controlled electronically from the control panel located on the tractor. The operator does not need to get off the tractor for any reason.

For fertilizer applications we do not use the injection system but simply mix the solution in the spray tank. The desired rate of fertilizer solution in gallons per acre is loaded into the controller and it accurately delivers the desired rate of material per acre. If we are also applying a fungicide at the time of fertilizer application this can be put into the chemical tanks and it will be metered into the solution as it is sprayed on the crop.

FUTURE RESEARCH

Weyerhaeuser Company continues to do research in fertilization practices. As an alternative to frequent applications of fertilizer the use of slow release fertilizer is being tested. Although we have not found benefits we continue to investigate the use of foliar applications of nutrients. Other studies are exploring the role of fertilizer in development of frost hardiness and production of improved root fibrosity.

SUMMARY

Each facility must develop its own reliable process for fertilization of seedlings. Each nursery will develop a unique nutrient prescription based on climate, soils, and species grown. Careful monitoring of results will allow improvements in the process. Use of sprayers allow for the greatest accuracy in application of fertilizer.

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Nursery Waste Water: The Problem and Possible Remedies¹

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Abstract — We found between 49 and 72% of the water applied to a production crop of container-grown conifer seedlings was discharged from the nursery. The amount discharged varied by species and by seedling growth stage. Our results showed between 32 and 60% of all nitrogen was also discharged, again influenced by species and growth stage. In another study, Douglas-fir and western white pine seedlings were grown using relative addition rate fertilization and 60% less nitrogen than our conventional crop. Based on our results and the literature, we feel a combination of improved greenhouse efficiency, irrigating crops based on container capacity, using intermittent irrigation, and applying fertilizers with a relative addition rate can improve irrigation and fertilization efficiency and reduce nursery runoff.

INTRODUCTION

Producers of container-grown seedlings use large volumes of water because nearly all fertilizers and pesticides are applied through irrigation systems. Our earlier work also showed large volumes of water are discharged from container nurseries during the first 15 weeks of growing reforestation stock (Dumroese and others 1992). Within the discharged water are appreciable amounts of nitrogen (N). One study found nitrate levels greater than 1700 lbs per acre (2000 kg/hectare) in the top meter of soil below commercial greenhouses (Molitor 1990). The potential, negative environmental impact from runoff from nurseries producing container-grown stock is serious from a water quality standpoint. However, public perception of container nursery runoff is probably more important in dictating regulation (Johnson 1992). Nonetheless, increasing levels of

nitrate in drinking or surface water will force political action to control nitrogen fertilizer (Newbould 1989) or its discharge from nurseries, as in Oregon (Grey 1991).

At the University of Idaho Forest Research Nursery, we decided to evaluate our water usage and the quality of water discharged to ascertain environmental impacts. Our objective was to determine the efficiency of irrigation applications and the quality of water being discharged. Results from the first 15 weeks of the growing cycle were previously reported (Dumroese and others 1992). In this paper we will only highlight the results of N and water used and discharged from three species over one growing season (The Problem) and some possible remedies, including some best management practices for water use and a pilot study examining the effects of relative addition rate fertilization as a means to reduce N discharge.

¹Dumroese, R.K.; Wenny, D.L.; Page-Dumroese, D.S. 1995. Nursery Waste Water: The Problem and Possible Remedies. In: Landis, T.D.; Clegg, B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-365. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 89-97.

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PART I. THE PROBLEM

Methods

At the time of this study (1991), the University of Idaho Forest Research Nursery grew about 850,000 conifer seedlings annually in Ray Leach® pine cells filled with a 1:1 peat:vermiculite growing medium (Grace/Sierra, Portland, OR). Seed was sown during the first week in April. Seedlings were grown on rolling benches and 86% of the greenhouse area was in production. Water was supplied by an on-site well. Crops were watered and fertilized with an overhead, traveling-boom irrigation system. Fertilizer was applied via a 1:100 Smith injector.

Three species were evaluated for N and water use efficiency: Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*) and western white pine (*Pinus monticola*). Our initial growth phase started three weeks after germination. We fertilized seedlings twice each week with Peters' Conifer Starter® (N:P:K = 7:40:17) at 42 ppm N and micronutrients. Each application supplied about 14 ml of water/fertilizer solution to each seedling (0.36 gal/ft²). After four weeks for the pines and six weeks for Douglas-fir, we switched to an accelerated growth phase. Again, seedlings were fertilized twice each week but with Peters' Conifer Grower® (N:P:K = 20:7:19) and micronutrients (see Wenny and Dumroese 1987a,b, 1992) alternated with calcium nitrate (14 ml per seedling (0.36 gal/ft²)). Ponderosa pine received 50 ppm N for four weeks, Douglas-fir 120 ppm N for six weeks, and white pine 192 ppm N for nine weeks. To promote budset and hardening, seedlings received lower amounts of N, in alternating forms of Peters' Conifer Finisher® (N:P:K = 4:25:35)(24 ppm N), calcium nitrate (46 ppm N), and micronutrients when the growing medium became barely moist (about 75% saturated block weight). Application rates ranged from 14-21 ml per seedling (0.36 - 0.55 gal/ft²). Four weeks after initiating buds, seedlings received finisher at 24 ppm N and micronutrients alternated with 92 ppm

N calcium nitrate when the growing medium became barely moist (about 75% saturated block weight). Seedlings were also foliar fertilized (2.5 ml per seedling (0.06 gal/ft²) with Peters' Foliar Fertilizer® (N:P:K = 25:15:12) about once every two weeks at 972 ppm N (3 lbs/100 gal (3.6 g/l)) until lifting. Douglas-fir received only one foliar application.

To determine the quality and quantity of errant spray (the combination of water dripping through the trays, leachate from containers and water being sprayed directly onto the floor) entering the drains, we placed a series of gutters beneath the tables. Two 10-foot sections of plastic gutter were connected with wing-nuts and the entire assembly held beneath the benches with bungee cords. Gutters were positioned under the tables to intercept all errant spray, including that sprayed directly onto the floor. The gutter assembly drained into a plastic bucket. Three assemblies were used per species for each sample collection. The buckets were emptied about 1.5 h after irrigation ceased. The gutters sampled all errant water. Surface area of the gutters was determined so the volume of water per square foot being discharged could be calculated.

The amount of water applied per irrigation event was determined by directly measuring output from each traveling boom. The output delivered by each nozzle during one minute was measured so an average volume per nozzle per minute could be determined. We also timed the boom as it made one pass over the greenhouse. By recording the time the system was irrigating the crop, we then calculated gallons of water applied per irrigation

At lifting, three replications of ten seedlings from each of the three species were oven dried (60°C for 24 h) for dry weight measurements. Whole seedling nutrient concentration was determined by Grace/Sierra Testing Laboratories (Allentown, PA).

RESULTS

During irrigation, our traveling boom system sprayed 12.5% of the water directly onto the floor, the walls, or through openings in the tops of the containers, indicating 87.5% of the applied water reached the crop.

Water use varied by species and so did water discharged (Table 1). For the growing season, 49% of the water applied to ponderosa pine was discharged from the nursery. For Douglas-fir and white pine, 67% and 72%, respectively, was discharged. Discharged amounts also varied by seedling growth stage. For ponderosa pine, 73% of the water applied during the initial growth stage was discharged, but the value dropped to about 45% for the rest of the growing season. Water discharged from Douglas-fir during the initial growth phase was 71 % of applied, and interestingly, was 72% during hardening. White pine discharge was highest during initial growth (88%) but declined to 79% during the accelerated growth period and 69% during hardening.

As might be expected with this much discharged water, and the bulk of it having passed through the growing medium, N was also observed departing the site. Ponderosa pine was the most nutrient thrifty — only 32% of the applied N was discharged and it did not vary much by seedling growth phase (Table 2). Douglas-fir, however, was poorer at assimilating N. Nearly 50% of the N applied during the initial growth phase was discharged and an incredible 70% was lost during the accelerated growth period. Even after budset, 60% of all applied N was discharged. We expected more N loss with white pine and we found that to be true. White pine is notoriously slow-growing and seemingly large amounts of N are required to reach target heights. However, during the initial growth period, 80% of the applied N left the nursery. This value dropped to 67% during accelerated growth and eventually dropped to a more respectable 50% during hardening.

PART II. POSSIBLE REMEDIES

Best management practices (BMP's) for nursery managers are voluntary measures taken to reduce the potential for agricultural contamination of surface or ground water. BMP's include source controls and practices designed to reduce inputs into the nursery production system. BMP's also include practices designed to mitigate any potential harm from waste generated within the nursery production system. For container nurseries, this means a structural control, either containing and treating waste water before release, or containing and recycling water within the nursery. For the scope of this paper, we will focus on source controls [see Landis (1992) for several papers discussing other BMP's]. Regarding N in the nursery production system, we have two source controls: fertilizers, and the volume of water used to carry them.

Water Source Controls

There are several ways to reduce the amount of water discharged during seedling production. Obviously, maximizing the amount of greenhouse area in production allows more applied water to be intercepted by seedlings. Rolling benches can minimize aisle space while still allowing access to all seedlings. The type of irrigation system is also important.

As discussed earlier, 87.5% of the water applied with our traveling boom reached the crop. This efficiency is high compared with other fixed overhead systems (Weatherspoon and Harrell 1980). Traveling boom irrigation systems may have other advantages over fixed systems. Fare and others (1994) report better irrigation efficiency, less leachate volume, and fewer nitrates in leachate when the total volume of water applied to plants was divided into two or three spraying cycles rather than one cycle. Further, plants irrigated in two or more cycles grow similarly to plants irrigated in a single cycle, but with less water (Whitesides 1989; Daughtry 1990; Lamack and Niemiera 1993; Karam and others 1994). Traveling

Table 1. Water applied to three conifer crops and amount and percentage discharged. All values normalized to 100,000 pine cell containers.

	Ponderosa pine			Douglas-fir			Western white pine		
	Applied (gals. ¹)	Discharged (gals.)	Discharged (%)	Applied (gals. ¹)	Discharged (gals.)	Discharged (%)	Applied (gals. ¹)	Discharged (gals.)	Discharged (%)
First soak ²	655	260	40.0	655	260	40.0	655	260	40.0
Germination misting ³	800	100	12.5	800	100	12.5	920	115	12.5
Fertilization ⁴ - Initial	3660	2675	73.0	3370	2385	70.0	3735	3300	88.0
Fertilization - Accelerated	3400	1495	44.0	5485	3535	64.5	9980	7865	79.0
Fertilization - Hardening	12420	5395	43.0	6955	5010	72.0	11540	7990	69.0
Leaching ⁵	1375	1215	88.0	1100	995	90.0	0	0	0.0
Foliar fertilization ⁶	475	60	12.5	60	8	12.5	325	40	12.5
Total	22785	11200	49.0	18425	12293	67.0	27155	19570	72.0

¹gals. = 3.785 liters.

²Water applied initially to bring medium to field capacity.

³Mists applied during the heat of the day to keep the seed zone moist.

⁴All water applied during fertilization, including plain water used to pre-moisten foliage and rinse foliage after fertilizer application.

⁵One long application of plain water to leach salts and excess fertilizer from medium.

⁶Low volume applications of foliar fertilizer — applied until runoff from foliage.

Table 2. Nitrogen applied to three conifer crops and amount discharged.

	Ponderosa pine			Douglas-fir			Western white pine		
	Applied (lbs. ¹)	Discharged (lbs)	Discharged (%)	Applied (lbs. ¹)	Discharged (lbs)	Discharged (%)	Applied (lbs. ¹)	Discharged (lbs)	Discharged (%)
Growth phase									
Initial	4.0	1.10	27.5	1.20	0.58	48.3	2.13	1.71	80.4
Accelerated	4.4	1.5	34.1	5.71	3.92	68.7	30.73	20.72	67.4
Hardening	19.6	6.34	32.3	2.16	1.30	60.2	23.37	11.41	48.8
Total	28.0	8.94	31.9	9.07	5.80	63.9	56.23	33.84	60.2

¹lbs. = 0.4536 kg.

boom systems epitomize cyclic irrigation. In our nursery, the boom travels about 10 ft/min (3 m/min) so plants receive less than a one second application every 10 minutes. Growers with fixed overhead systems could realize some benefits of cyclic irrigation by dividing the total amount of irrigation water to be applied into two or more parts, allowing a 20-60 minute resting phase between irrigations.

Irrigation frequency has an impact on irrigation efficiency. Timmer and Armstrong (1989) and Langerud and Sandvik (1991) found seedlings grew best when irrigated after containers lost 8-10% of the liquid held at container capacity. Timmer and Armstrong (1989) found better seedling nutrient uptake and Langerud and Sandvik (1991) noted less total fertilizer was needed at this irrigation frequency. Langerud and Sandvik (1991) concluded frequent irrigations with small volumes would reduce both drought and drowning stress on seedlings, thereby yielding a more uniform crop. Developing a container weight scale (using container capacity), which is sensitive to water loss and relatively easy to apply operationally (Timmer and Armstrong 1989), is explained in Landis and others (1989). Besides irrigating sufficiently to saturate the root plug completely, applying enough water to keep salts from accumulating is also important. Landis and others (1989) recommend irrigating the necessary amount to saturate the rooting medium, and an additional leachate fraction of 10% more (based on container capacity) to complete this objective. For example, if seedlings were growing in a 70-ml capacity container and allowed to lose 10% of its liquid at container capacity, it would take 7 ml to saturate the medium and another 7 ml more to leach away salts (14 ml total). As the leachate fraction increases from 10%, the total amount of nitrate leached from the medium increases (Fare and others 1991; McAvoy and others 1992; Yelanich and Biernbaum 1993, 1994).

Once seedlings reach target size and bud initiation commences, less frequent irrigation will help induce buds and begin hardening. Seedlings

preconditioned to water stress are known to exhibit a greater decrease in transpiration rates in response to dry soils than seedlings grown without prior moisture-stress (Unterscheutz and others 1974). Seedlings exposed to drought-stress can show increased drought resistance (Zwiazek and Blake 1989) which can translate into improved survival on dry sites (van den Driessche 1991). Langerud and Sandvik (1991) found Norway spruce (*Picea abies*) seedlings irrigated when containers lost 10% of the water held at container capacity transpired significantly more (32%) than seedlings grown in medium allowed to lose 30% of container capacity. During irrigation in this experiment, we checked medium saturation by extracting sample seedlings and feeling the moisture content of the plug. Of course, finding a dry sample seedling dictates the need for continued irrigation until dry plugs are no longer found. This means, however, those seedlings whose medium saturated early in the irrigation yield larger leachate volumes, and although nitrates may be less concentrated, total nitrates discharged also increase (McAvoy and others 1992). This problem becomes more pronounced with larger seedlings and more moisture stress (70-80% container capacity) because of the hydrophobicity of dry peat moss.

FERTILIZER SOURCE CONTROLS

Using controlled-release fertilizers (slow-release fertilizers) intuitively seems like a viable way to decrease N runoff from greenhouses. However, Hershey and Paul (1982) and Cox (1993) found leachate nitrate could be as high or higher than with water-soluble fertilizers. Split applications and top-dressing applications of controlled-release fertilizers did reduce nitrate leachate better than single applications or medium-incorporated applications (Cox 1993). The rate of nitrate leaching from controlled-release fertilizers is also dependant on species (Brand and others 1993).

At the Research Nursery we have traditionally used water-soluble fertilizers. For this study, we

fertilized twice each week, on schedule to avoid weekend watering, during the initial and accelerated growth phases. Most growers apply fertilizer during these growth phases; it is usually at a standard rate, or at least a rate consistent through that particular phase. Ingestad and Lund (1986) developed a method to control relative growth rates by controlling nutrient supplies. Essentially, they found that matching available nutrients with optimum seedling uptake over time is more important to seedling growth than the nutrient concentration in the growing medium. The optimum nutrient supply rate varies by species (Ingestad and Kahr 1985; Burgess 1990, 1991). In a study on red pine (*Pinus resinosa*), a species that grows very slowly like western white pine, researchers using relative addition rates successfully grew a crop with 75% less fertilizer than typically used to grow seedlings to a similar size (Timmer and Armstrong 1987). Obviously, growers could reduce their N discharges if they apply nutrient rates to seedlings at a rate that matches optimum seedling uptake.

This spring, we put in a trial testing relative addition rates on Douglas-fir and western white pine. The basis for relative addition rate fertilization is the equation described by Ingestad and Lund (1979):

$$N_r = N_s(e^r - 1)$$

where r is the relative addition rate required to increase N_s , the initial nitrogen level when fertilization begins, to a final level $N_T + N_s$, where N_T is the total amount to be added over t , the number of fertilization applications. For this study, we knew the N concentration and seedling biomass at bud initiation from previous work so we could calculate N content ($N_T + N_s$) per seedling. We assumed N_s for these species was similar to that used by Timmer and Armstrong (1987) for red pine. We also knew how many weeks we fertilized the crop conventionally (twice per week) which gave us our t value. The equation was then solved for r .

To determine how much N to apply at fertilization, the above equation was modified to account for N previously applied:

$$N_T = N(e^r - N_{(t-1)})$$

where $N_{(t-1)}$ is the cumulative amount of N added.

Noting we used two different formulations of fertilizers for this experiment is important. Conventionally-fertilized seedlings received conventionally-applied water-soluble fertilizers following our current regimes (Wenny and Dumroese 1987b, 1992) but seedlings grown with relative addition rates were fertilized with a liquid fertilizer applied with a watering can. A similar volume was applied to each treatment. A liquid fertilizer was used because extremely low ppm's of nutrients were required during the early fertilizations, and that, coupled with needing only small quantities of solution, made measuring and/or diluting water-soluble fertilizers impractical.

Two weeks after sowing, the conventionally-grown Douglas-fir seedlings received 42 ppm N twice each week for four weeks and then 120 ppm N twice each week for six weeks. Seedlings receiving relative addition rate were also fertilized twice each week, but they started at 4 ppm N and by week 12 the final application was only 62 ppm N. At this point budset was initiated and all seedlings were fertilized the same. Heights and calipers (root collar diameters) of Douglas-fir when budset was initiated and one month later are shown in Table 3. There were no differences in caliper growth, but seedlings grown with relative addition rate were shorter. However, since caliper is a better indicator of stock viability than height (Chavasse 1977; Duryea 1984; Ritchie 1984; South and others 1993), the shorter height may be beneficial. Basically, we grew the same seedling by applying 7.4 mg N with relative addition rate and 25.7 mg N traditionally (60% less fertilizer). One month later, seedling sizes were still similar. It is important to note several other indices of seedling viability

Table 3. Heights and calipers of Douglas-fir and western white pine seedlings grown with relative addition rate fertilization and conventional fertilization.

	Douglas-fir		Western white pine	
	Bud initiation	One month later	Bud initiation	One month later
Height				
Conventional	20.5 a	24.7 a	9.1 a	9.8 a
Relative Addition Rate	17.3 b	21.2 b 8.8 a	10.1 a	
Caliper				
Conventional	1.43 a	2.24 a	2.03 a	2.65 a
Relative Addition Rate	1.42 a	2.25 a	1.72 b	2.30 b

Means for heights and calipers within columns followed by different letters are significantly different at $p < 0.05$ using Tukey's HSD.

were not tested (seedling biomass, shoot-root ratio, N concentration and content).

Western white pine height growth for conventionally-grown seedlings was similar to those grown with relative addition rates but caliper in the relative addition rate seedlings was significantly reduced. The difference may be partially attributable to the reduced amounts of calcium delivered to seedlings fertilized with relative addition rates since calcium is important in cell wall formation and promotes sturdiness during hardening. Our western white pine grown conventionally receive appreciable calcium (184 ppm) once each week during the accelerated growth phase.

MANAGEMENT IMPLICATIONS

After examining water and nitrogen discharged from our nursery under operational conditions, it is apparent resources are not being used efficiently. Growers of reforestation and conservation seedlings can improve their water use efficiency by strict adherence to container capacities for deter-

mining irrigations, irrigating only enough to restore container capacity and leach excess salts (10% extra), and using some form of cyclic irrigation, either a traveling-boom system or breaking fixed overhead irrigation events into two or more cycles with a 20-60 minute rest between cycles. Besides improving irrigation efficiency, these steps should also reduce nitrate leaching from containers. It also appears that relative addition rate fertilization is a viable, if not better, alternative than applying fertilizers at a constant rate. Growing seedlings with significantly less fertilization coupled with less leaching of the fertilizer in our containers should have a significant impact on the quantity and quality of water our industry discharges.

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Late-Season Nitrogen Fertilization: Application in Southern Nurseries¹

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Abstract—Production of high-quality seedlings is the goal and responsibility of the nursery manager. Applying nitrogen fertilizer late in the season is a cultural regime that will improve seedling quality without adverse effects to seedling morphology at lifting. Research in southern production tree nurseries has shown late-season N fertilization to increase seedling N content and concentration, and improve survival and growth. Implementing a late-season N fertilization program is simple and economical.

INTRODUCTION

Successful reforestation begins with the production and planting of high-quality seedlings. Therefore, as the nursery manager and responsible for seedling production, your goal is to produce a crop of high-quality seedlings at a minimum cost. A high-quality seedling is one that demonstrates acceptable levels of performance (survival and growth) on a given site (Duryea 1985). Cultural activities applied in the nursery like top clipping, root wrenching, seedbed density, irrigation, and nutrient management directly effect seedling quality. How effective cultural activities are at improving seedling quality can be measured by evaluating **material attributes** (bud dormancy, water and carbohydrate status, morphology, mineral nutrition, and levels of growth regulators, enzymes, etc.) and **performance attributes** (vigor, root growth potential, frost hardiness, and seedling temperature) (Ritchie 1984). Evaluating the quality of a seedling by its "grade" alone is still valid, but

technology and science has gone beyond this. I'm sorry, but the rules have changed!

To obtain specific production objectives it may involve some sort of change. Research is the driving force behind most changes, and lessons learned by "trial and error" in the nursery are just as important, particularly when it comes to the applied side of things. Changes in the technology and science of tree nursery production result in changes in the quality of seedlings produced. Nevertheless, the status quo of seedling production is no longer an option! Examples of change in nursery production may be the purchase of a new precision sower for greater control of seedbed density; development of a new protocol for seed collection, handling, and treatment to complement genetic gains; or adoption and implementation of a cultural regime that has been shown to improve seedling quality. Cultural practices applied to seedlings in the nursery bed influence seedling morphology and physiology at lifting, and ulti-

¹Irwin, K.M. 1995. Late-Season Nitrogen Fertilization: Application in Southern Nurseries. In: Landis, T.D.; Cregg, B., tech. coords. *National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-365*. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 98-101.

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mately a seedling's ability to grow and survive after outplanting. The availability of nitrogen (N) to the seedling crop is of particular importance. Foliar N content and concentration are quantifiable indices of quality, and are directly related to the physiological status of a seedling (Duryea and McClain 1984; Landis 1984). This paper will describe a fertilizer regime that can effectively increase seedling N levels at the time of lifting, and make recommendations to help southern nursery managers evaluate its effectiveness.

NUTRIENT MANAGEMENT

Production of quality seedlings begins with nursery soil management. Before initiating actions to alter nursery soil composition, the soil should be tested to determine baseline macro and micro nutrient levels. Management decisions regarding how nutrient level adjustment can then be based on hard data, not on intuition. A range of recommended nutrient levels, pH, and organic matter values for southern pine nursery soils are presented in Table 1 (May 1984). Keep in mind, that these values represent optimum levels at plow down and will not be applicable to every nursery soil.

Depending on nursery soil characteristics, precipitation, and genetic quality of seed, the amount of N fertilizer applied during the growing season of 1-0 pine seedlings will typically range from 150-200 pounds per acre for most nursery

soils (May 1984). It is important to control the availability of N to insure an adequate supply is available during the various stages of seedling growth. Nitrogen can be supplied from both organic and inorganic sources. However, for economic reasons, inorganic forms of N are used most often. For example, it takes 145 pounds of horse manure, compared to three pounds of ammonium nitrate to provide one pound of N (Pritchett 1979). The key to successful N fertilizer management is knowledge of: (1) the properties of the specific fertilizer used; (2) the nursery soil characteristics; and (3) the seedling response to frequency, rate and timing of fertilizer applications. At this point, I want to focus on the third item above, particularly the timing of fertilizer application.

LATE-SEASON N FERTILIZATION

Implementing a late-season N fertilization program is based on the following objectives: (1) to increase seedling N content and concentration prior to lifting, while not adversely effecting seedling morphology; (2) to "prime" the seedlings for a fast start once outplanted; and (3) to increase survival and growth. This concept is not new by any means. Wakeley (1948) was aware of this and felt that increased levels of seedling N at time of planting may improve the ability of a seedling to initiate vigorous root and shoot growth after planting.

Table 1. Recommended soil organic matter, pH, and nutrient levels for pine nursery soils. Adapted from May, 1984.

<u>Soil Texture</u>	<u>OM%</u>	<u>N%</u>	<u>pH</u>	<u>P</u>	<u>K</u>	<u>Ca</u>	<u>Mg</u>
Sands & light loamy sands	1.5	0.07	5.3-5.8	50-100	75-125	400-600	50-60
Loamy sands & sandy loams	2.0	0.10	5.3-5.8	75-100	125-175	600-900	60-90
Loams, silt loam & clay loam	>3.0	0.15	5.3-5.8	75-125	150-250	>900	>90

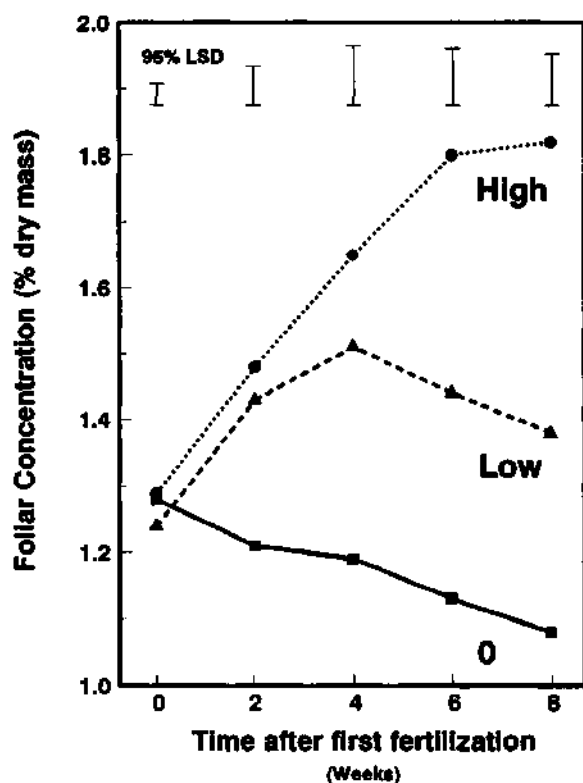


Figure 1. Foliar N concentrations of slash pine seedlings during the 8-week sampling period as affected by soil application of ammonium nitrate only: Low N—one application 57 kg N ha⁻¹ on November 15, 1989; High N—three applications at 57 kg N ha⁻¹ on November 15 and 29, and December 13, 1989.

Researchers have evaluated the effects of late-season N fertilization on southern pine species. Late-season N fertilization in the nursery was found to increase seedling N concentration from 1.08 percent to 1.20 percent in slash pine (*Pinus elliottii* var. *elliottii* Engelm.) (Duryea 1990). In another study, foliar N concentration of slash pine seedlings (Figure 1) decreased under normal cultural practices, while those receiving late-season N fertilization treatments increased (Irwin 1991). And, in the same study, there were no significant morphological changes at the time of lifting. Other studies have shown mixed results regarding growth and survival after outplanting. Growth of loblolly pine (*P. taeda*) after outplanting has been positively correlated to foliar N concentration (Switzer

and Nelson 1963; Larsen *et al.* 1988). Late-season N fertilization studies of southern pine by Ursic (1956) and Shoulders (1959) found reduced survival, whereas Gilmore *et al.* (1959) found no effect, and Switzer and Nelson (1963) reported an increase.

MAKING A DECISION

Operationally, a late-season N fertilization program is simple. The actual application is no different than any other. The difference lies in that it is just applied late in the season — 6 to 8 weeks prior to lifting. Nitrogen fertilizer should be applied at a rate of around 50 pounds of N per acre after seedlings have entered the quiescent stage and winter buds appear. Ammonium nitrate has been found to perform best when top dressed and watered in to prevent "burning" of the seedlings. At this rate, the possibility of initiating bud burst and top growth is minimized, but the seedlings are capable of active absorption of the additional N.

Economically, a late-season N fertilization program represents minimal cost. What would be a reasonable amount to spend on a cultural practice that could improve seedling quality and increase survival and growth? Is \$0.03 to \$0.05 per thousand seedlings too much? This is the approximate cost for one application of N (ammonium nitrate). Nursery managers should find this economically justifiable considering the potential benefits of improving seedling quality.

RECOMMENDATIONS

Implementing a late-season N fertilization program requires more than just the application of fertilizer. The nursery soil should be tested in the spring prior to any other activities, and provide the following: macro and micro nutrient levels; pH; and organic matter content. This information will provide the nursery manager with the appropriate decision making tools to determine the range of critical and acceptable levels of soil fertility.

The next step is to establish small trial plots in the nursery and a planting site to monitor field performance. If in-house expertise is not available for developing the experimental design, contact a USDA Forest Service Nursery Specialist for assistance.

As part of the nursery trial, seedling tissue will need to be sampled throughout the trial and analyzed to determine N content and concentration. From this, the effectiveness of the late-season application can be evaluated, as well as the efficiency of recovery by the seedlings.

Late-season N fertilization is a cultural practice that will improve seedling quality in southern pine nurseries. It has been demonstrated to improve survival, and if growth of those seedlings is vigorous, the stocking density is maintained and the value of the stand at harvest will be increased. Therefore, one application of 50 pounds of N late in the season is a cultural practice well worth the investment.

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Lessons Learned From the USDA Forest Service Reforestation Improvement Program¹

Richard W. Tinus²

Abstract—The Reforestation Improvement Program gave the USDA Forest Service nurseries and reforestation specialists new tools to track progress of the growth and condition of their crops, including electronic-age capability to collect and analyse data in real time to support management decisions. It developed an information and help network among Forest Service Research, National Forest Systems, and State and Private Forestry to promote successful reforestation.

In 1985 the USDA Forest Service instituted a major Reforestation Improvement Program (RIP) with the goal of making reforestation more predictable and successful by applying the latest knowledge and technology (Owston et al. 1990). It involved setting up an intensive monitoring system of environmental conditions, seedling biology, and nursery and field operations for several test lots of several important species at all 10 Forest Service nurseries. The nursery phase of RIP terminated in 1991 after producing three crops of 2+0 seedlings. Monitoring of the field planting sites continued for two more years.

Now that this program is officially terminated, it behooves us to identify its lasting benefits and make them available to the nursery industry at large. The following list represents some of the outstanding accomplishments, but is by no means exhaustive.

ADP EQUIPMENT

Each nursery was equipped with two automatic recording weather stations for a "base" and a "seedbed" location, plus a portable computer with software for downloading and processing the data. This gave the nurseries the most complete local weather information they had ever had, and provided documentation of any microsite differences from one part of the nursery to another. The nurseries were given the tools to manipulate the data to correlate important aspects with growth in the nursery, and performance in the field. Electronic recording meant less manual handling of the data, fewer mistakes in translation, and the ability to analyse large volumes of data in real time to supply information to support management decisions.

For instance, they could easily calculate growing degree hours, which could be correlated with height growth, making it possible to have comparisons of growth in one year to that of previous

¹Tinus, R.W. 1995. *Lessons Learned From the USDA Forest Service Reforestation Improvement Program*. In: Landis, T.D.; Cregg, B., tech. coords. *National proceedings, Forest and Conservation Nursery Associations*. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 102-107.

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years. Calculation of cold hardening degree hours may yield important information about when the seedlings are ready to be lifted, whether they are fully dormant, and how well they will store.

To calculate growing or hardening degree hours, it is necessary to establish a zero-effect baseline temperature. In the past, these have been "best guesses" supported by very little data. However, the data generated by RIP, and the ease with which it could be manipulated, enabled us to try a series of different base temperatures in search of the best one. In addition, as a member of their Scientific Analysis Team, I was stimulated to re-analyze some growth chamber data on optimum growing temperatures (Tinus and McDonald 1979), and calculate a base temperature mathematically by extrapolating height growth to zero (Fig. 1). The remarkably good correspondence between this method and the empirical method used in RIP gives us confidence in the base temperatures we have found.

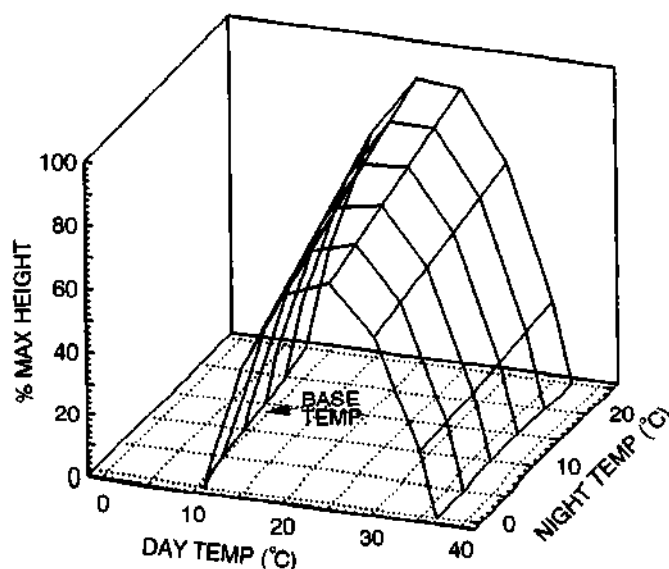


Figure 1. Height growth of ponderosa pine (Ruidoso NM provenance) as a function of day and night temperature. Extrapolation of height growth to zero yields a base growing degree day temperature of 8-11°C with a small positive effect of increasing night temperature.

Another possible use of the weather data is to calculate potential evapo-transpiration on a daily basis and use it to manage the irrigation regime efficiently by adding only the water needed to replace what has been lost (Papadopol 1990). This has not been implemented at Forest Service nurseries, but is coming into use in places such as the New Mexico State University horticultural farm at Las Cruces.

Probably equally important, the instruments and computers introduced the nurseries to electronic data collection and processing, and suggested more ways to use them in other aspects of the nursery business. Whereas the Forest Service as a whole had committed itself to a centralized mini-main-frame computer with limited proprietary software (the Data General system), the nurseries were given a system that was much more flexible. It also was more expandable in terms of capability for data storage and processing (the personal computer).

HISTORY PLOTS

For each of the seedlots used in the program, history plots were installed in the seedbeds. A history plot is one that tracks the life history of a population of first seeds, then seedlings, from sowing to lifting, and documents the losses at each stage of growth and production. These plots were observed and measured intensively and repeatedly, giving a detailed life history of establishment, growth, and the effect of cultural treatments, so that actions could be taken to keep the crop on a trajectory that would yield the expected number of seedlings in the right condition when they were needed (Landis and Karrfalt 1987).

For example, one observation might be to dig up a sample of the seed immediately after sowing to confirm that the drill actually placed the seed at the expected spacing and uniformity. In addition to supplying detailed information about the crop that the nursery manager can use immediately to change the course of growth, history plots focus

the attention of nursery personnel on the biology of the seedlings, and many of them will notice things that were not noticed before.

History plots can be used to establish growth curves that will be useful as benchmarks in future years. By comparing growth during the current year with growth in previous years the nursery manager can tell whether the current crop is on schedule to reach its target size and condition, or whether conditions need to be changed to increase or slow down growth.

SEEDLING QUALITY TESTING

For decades nurseries have used size, shape, and visible damage as grading criteria, and thus have been able to increase outplanting success considerably. However, the physiological condition of seedlings is at least as important as their morphology in determining quality. By 1985 several physiological tests had been developed and were in use in research, but not many considered them practical as operational nursery tools (Duryea 1985). When RIP mandated the use of cold hardiness, root growth potential (RGP), and drought stress tests, it was necessary to come up with convenient and affordable equipment, along with simple procedures for running these tests. As a result, we now have the root mist chamber for RGP tests (Rietveld 1989, Rietveld and Tinus 1987a, 1990) which is a conveniently sized, moveable box, that requires only electricity and a well lighted room to operate. Roots need not be measured, just counted (Burr et al. 1987) to determine RGP. Good root growth potential has been demonstrated to be important to survival and growth after outplanting (McTague and Tinus, in press), and is beginning to be specified in Forest Service growing contracts.

Whole plant cold hardiness measurement usually requires a programmable chest freezer, but can be run with an ordinary household freezer and some ingenuity (Rietveld and Tinus 1987b). The

test can be completed in a day, but it generally takes a week for the damage symptoms to show up. However, with practice, someone with a good nose can smell the damage after one day. More recently, practical quantitative instruments based on this principle have been developed (Templeton and Colombo 1995).

Freeze induced electrolyte leakage of foliage can measure cold hardiness with very good precision in less than three days. The test requires more expensive equipment, and some software to process the data collected, but it can also handle more samples in a single run (Burr et al. 1986, 1990).

Cold hardiness tests are now in use for a variety of purposes. They can indicate when bareroot stock is ready to lift in the fall, and when it is sufficiently dormant to store well. In the spring they can track emergence from dormancy, and supply important information about how to handle the seedlings and the prospects for outplanting success (Rose et al. 1990).

For example, some years ago I was asked to test some ponderosa pine that had been delivered to Flagstaff in a truck in which the refrigeration system had malfunctioned and frozen the trees. RIP had provided the nursery with small electronic temperature recorders, one of which was contained in one of the bags of trees. As a result, we knew the temperatures to which the trees had been subjected, and they were indeed cold enough to have damaged them. A root growth potential test of these trees and others that had been shipped in a different truck (which did not freeze), quickly showed that most of the root systems of the frozen trees was dead and that outplanting would be futile (Table 1). That was bad news, but it saved the Forest Service about \$30,000 in direct costs by not planting them and probably a lot more in indirect costs. Before this equipment and tests were available, the dead trees would probably have been planted anyway because managers would not have been willing to take responsibility for dumping them without good evidence that they were not viable.

Table 1. Root growth potential of ponderosa pine seedlings shipped frozen to Mormon Lake and Tusayan or unfrozen to Panguich and North Kaibab.

District	Frozen	New roots/seedling	Mean % of root System dead
		Mean $\pm$ Std. Error	
Panguich	No	18.4 $\pm$ 2.9	0
North Kaibab	No	10.2 $\pm$ 2.5	0
Mormon Lake	Yes	1.3 $\pm$ 0.7	66
Tusayan	Yes	0.0 $\pm$ 0.0	86

In a more recent case I was asked to examine a shipment of container ponderosa pine received by a nearby District. There was concern that the trees were not dormant as specified in the contract, and they wondered whether they should accept them. The trees did appear to me to be post-dormant, but the “budbreak” that the District staff was concerned about looked to be a combination of normal prolepsis growth and inadequate time for bud formation in the nursery. We took samples, and I ran RGP and cold hardiness tests on them. The latter showed the trees to have about half of the maximum hardiness, and the shape of the curve suggested that they were coming out of dormancy (Figure 2). However, with the RGP so high, my recommendation was to keep them refrigerated to preserve their current condition and consider them plantable.

ADVANCING NURSERY SCIENCE

One of the objectives of RIP was to collect a large volume of data that could be used to generate hypotheses to be tested. However, there also had to be enough year-to-year variation in weather or management practices to produce differences in results that needed to be explained. Most of the RIP plantings were highly successful in terms of survival and growth, which was a nice validation of our current best practices, but offered few suggestions for further improvement.

One exception was the plantings on the San Juan NF which varied considerably in performance among the three years (Table 2). Examination of all of the data collected at Bessey Nursery and at the planting sites suggested that high survival and growth were due to early undercutting in the second year at the nursery that produced short stocky seedlings with large buds in 1987 (Table 3).

A study was initiated to test this hypothesis and reproduce the different seedling morphologies produced in RIP, and see how they performed in the field. Unfortunately, 1993 was unusually wet, and the undercutting seemed to have little effect on the morphology, although it did increase the uniformity of RGP somewhat. When outplanted, the height and caliper of trees from the three undercutting treatments were not different, but first year height growth and survival of trees undercut with a stationary bar was less than that of trees undercut with a reciprocating blade, or trees not

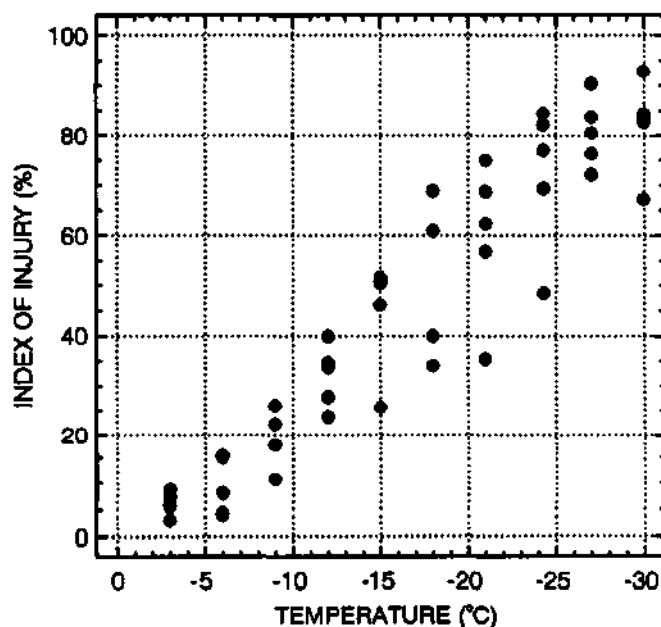


Figure 2. Cold hardiness of a Southwestern seedlot of ponderosa pine by the freeze induced electrolyte leakage test. The shape and position of the curve indicates that the trees are about half of maximum hardiness and probably coming out of, rather than entering into, dormancy.

Table 2. Survival and growth of ponderosa pine from Bessey Nursery planted in three consecutive years on the San Juan NF. See table 3 for characteristics of the seedlings.

Year Planted	Precip.	Survival (%)			1 st Year Ht. growth (cm)
		1988	1989	1990	
1988	normal	88	76	69	6.3
1989	drought	—	40	26	2.9
1990	normal	—	—	41	2.8

Table 3. Morphology of ponderosa pine produced at Bessey Nursery in three consecutive years.

2nd Year	Height (cm)	S/R*	HT/CAL*	Bud Length* (mm)	Date of Budset* (JD)
1988	17	2.3	25	21	137
1989	29	2.9	41	15	187
1990	23	4.0	33	16	155

*Shoot/root ratio (S/R) is an indication of drought resistance, height to caliper ratio measures stockiness, and bud length indicates height growth potential next season. Budset was induced by undercutting, and the Julian date of budset explains the morphology.

undercut at all (Figure 3). However, because of the weather and some practical difficulties in the execution of the experiment, it needs to be repeated before the results can be considered definitive.

INFORMATION EXCHANGE

During the seven years that RIP was underway, nursery managers and technicians, and the researchers associated with the program, met annually to discuss progress and exchange information. These meetings brought together nursery-related people who were working on the same, or similar, problems to network among themselves and trade

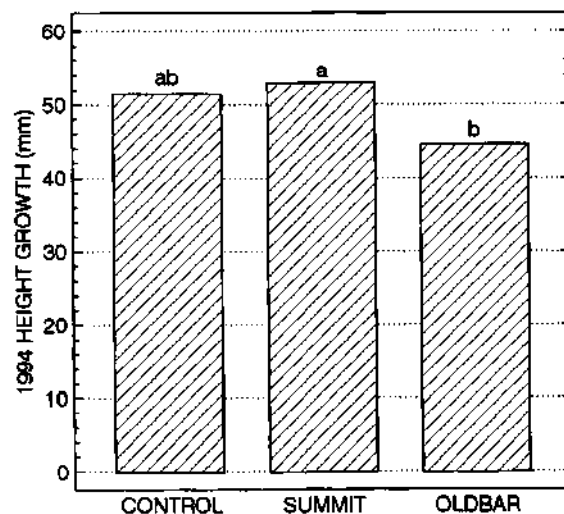
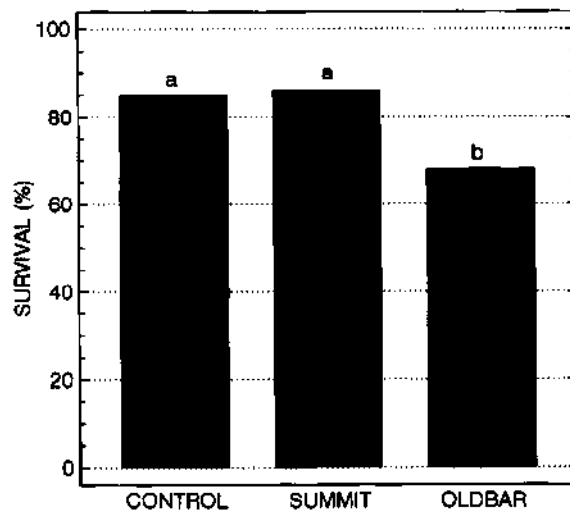


Figure 3. First year survival and height growth of ponderosa pine after outplanting on the San Juan NF. The stock (100 trees per treatment) was not undercut (control), undercut with a reciprocating blade (Summit) or with a stationary blade (oldbar). Bars not having the same letters are significantly different ($P = .05$) by the Chi Square test (survival %) or Tukey's multiple range test (height growth).

ideas, observations, and solutions. This included not just the top echelon, but also the people who actually did the work, and who might not have had a chance to join their counterparts at other nursery meetings. The result was a strengthened professional network, and an enthusiasm that raised the level of nursery practice and reforestation to a higher plane throughout the country.

It is also worth noting that RIP was a joint venture of all three branches of the Forest Service: Research provided the latest scientific information and packaged it in ready-to-use form, while State and Private Forestry contributed technology-transfer services, and National Forest System nurseries and Forests implemented the Program. RIP has been a good model of close cooperation among the three branches, which is one reason it was successful. Another key reason for success is that nursery managers and staff embraced RIP enthusiastically. It is not easy to take on an extra workload that means learning to use new tools and techniques and bringing them into practice, but they did, and did it well.

In summary, the Reforestation Improvement Program accomplished many of its original goals. It gave the nurseries new tools to track the progress of the growth and condition of their crops. It brought them to the cutting edge of the electronic age with tools to collect large quantities of data and analyse it soon enough to support management decisions. It put everyone in contact with each other, so that solutions would only have to be invented once. Finally, it showed that, on the whole, the Forest Service is indeed doing a very good job of reforestation.

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An Overview of Forest Diversity in the Interior Low Plateaus Physiographic Province¹

Edward W. Chester²

Abstract—The Interior Low Plateaus Physiographic Province includes parts of six states and is centered in the Ohio, Cumberland, and lower Tennessee River drainage systems. Four sections and numerous subsections are included. The diversity of topographic, geological, climatic, and drainage patterns results in innumerable microenvironments and consequently, the botanical diversity also is great. Floristic diversity includes elements of great geological age, disjuncts, endemics, and many groups with great genetic complexity. Also, the province is at a botanical crossroads and receives elements from many migratory pathways and from adjacent provinces, resulting in numerous floristic-vegetation themes. The results of anthropogenic influences, mostly over the past 200 years, also are great. In addition, evidence indicates a flora of diverse origins and interesting relationships.

INTRODUCTION

Biodiversity (biological diversity) has become a widely used term in both popular and scientific literature. Although often used synonymously with species richness, numerous authors (e.g. Wilson 1994), have pointed out that diversity has various components and may be addressed in several ways. McMinn (1991) notes that biological diversity encompasses the "diversity of life, including the diversity of genes, species, plant and animal communities, ecosystems, and the interaction(s) of these elements."

It is not the purpose of this paper to discuss biodiversity and the all-important need to preserve as much of the remaining biodiversity as possible. Excellent discussions on these topics can be found in various sources (e.g. the authors cited above, and the first issue of *Nature Conservancy* for 1994

is devoted entirely to biodiversity). Instead, I will discuss here the Interior Low Plateaus Physiographic Province, diversity of forest communities within the Province, and some of the reasons for that diversity.

THE REGION

Physical Features

The Interior Low Plateaus Physiographic Province, as described by Quartermann and Powell (1978), includes central Kentucky and Tennessee and smaller areas in Alabama, Illinois, Indiana, and Ohio (Figure 1). The Province, drained by the Cumberland, Ohio, and Tennessee rivers and some of their tributaries, includes a complex of level to rolling plains, dissected uplands, and hilly outliers of adjacent provinces. Elevations range from about 109- 400 meters. Provincial boundaries are the Appalachian Plateaus (east-south), the Gulf

¹Chester, E. W. 1995. *An Overview of Forest Diversity in the Interior Low Plateaus: Physiographic Province*. In: Landis, T.D.; Clegg, B., tech. coords. *National Proceedings, Forest and Conservation Nursery Associations*. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 109-115.

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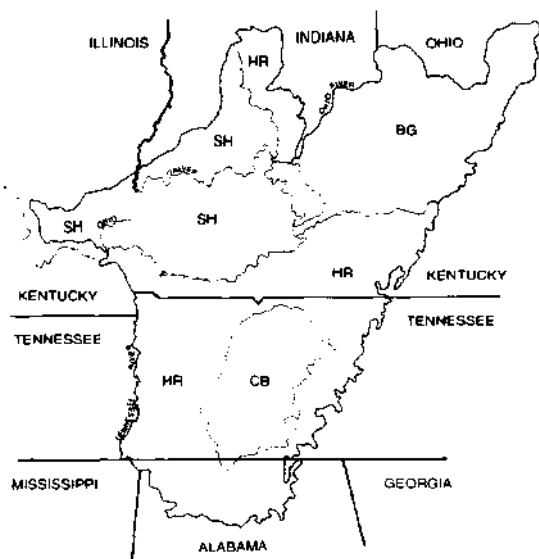


Figure 1. The Interior Low Plateaus Physiographic Province, after Quarterman and Powell (1978); Sections are: BG = Bluegrass, CB = Central Basin, HR = Highland Rim, SH = Shawnee Hills.

Coastal Plain (southwest-west, except for a narrow interface with the Ozark Plateau in southwestern Illinois), and the Central Lowland (north).

Geologically, the Province is dominated by Mississippian age limestones and shales; these carbonate rocks result in the most extensive area of karst topography in the United States. The Shawnee Hills Section in the west is a southern extension of the Pennsylvanian- aged sediments of the Illinois Basin. A regional uplift, the Cincinnati Arch, extends from northern Kentucky into Middle Tennessee; erosion of this uplift has exposed limestones and shales of Ordovician age. The region is not generally considered glaciated, but small parts (extreme north) have been, and the entire northern boundary is along the Till Plains Section of the Central Lowlands Province.

Four Sections (Highland Rim, Shawnee Hills, Bluegrass, and Central or Nashville Basin; Figure 1), each with named Subsections, comprise the Province (Quarterman and Powell 1978).

Vegetation

The Interior Low Plateaus is within the extensive Deciduous Forest Formation, first studied in its entirety by Braun (1950), who divided the Formation into nine regions. One of these, the Western Mesophytic Forest Region (WMFR), occupies the Interior Low Plateaus. The WMFR lies between the more mesic Mixed Mesophytic Region to the east and south, the more xeric Oak-Hickory Region to the west, and the glaciated Beech-Maple Region to the north. The WMFR includes vegetational and floristic elements from these surrounding Regions, as well as from the Mississippian Embayment to the south. Thus Braun considered the WMFR to be a transition region and without a combination of characterizing dominants. Within this broad transition zone, local climatic, topographic, and edaphic factors determine vegetational features of a given area within the broad mosaic of types.

Some have mapped the vegetation of the Interior Low Plateaus differently. For example, Küchler (1964) included the area in his Oak-Hickory Forest, with some Beech-Maple in southern Indiana, with prairie outliers in Kentucky and Tennessee, and with cedar glades in Alabama and Tennessee. Others (e.g., Bailey 1976) included the Plateaus under the broader Central Hardwood Forest Region.

The following brief vegetational summary of the Interior Low Plateaus looks at each of the four major physiographic Sections of Quarterman and Powell. For details, and especially for conditions in the Subsections and/or specific areas, the reader is referred to the following references (from whence my summaries were taken), and the extensive bibliographies cited by these authors: Braun (1950), Baskin et al. (1987), Chester (1989), Martin et al. (1993 - especially the included paper by Bryant et al.), and Quarterman and Powell (1978).

Sections of the Interior Low Plateaus Physiographic Province

1. Bluegrass (BG) Section. There are five Subsections (Quarterman and Powell 1978), with considerable diversity in substrate, topography, and vegetation. The Inner BG (30% of the BG) is a rolling, fertile, mildly karst plain that is ideal for agriculture and was early- settled. Scanty historical records of the plant life and existing remnants indicate savanna- woodlands characterized by bur, chinquapin, Shumard and white oak, blue and white ash, sugar maple, hackberry, Kentucky coffee tree, and several others, including shellbark hickory. Cane occurred in extensive stands, and meadows were prominent. The Outer BG (40% of the BG) is similar, but includes outwash from Pleistocene glaciations in the extreme north, more floodplains, and glades and glade-like habitats. Forests are mixed hardwoods in various combinations depending upon local conditions. The Northeastern BG and Eden Shale Belt Subsections are oak-hickory dominated, especially on drier sites. The same is true for the Knobstone Escarpment and Knobs Subsection, although deep ravines there support more mesophytic forests. Important species of these more mesic sites are American beech, tulip poplar, sugar maple, northern red oak, and white ash.
2. Central Basin (CB) Section. This Section, sometimes referred to as the Nashville Basin, is unique with its cedar glades and endemic or near-endemic taxa and has received much attention elsewhere (e.g. Somers 1986). In regard to forests, only fragments of original conditions remain; most of the area has been cleared for decades. Earlier references refer to the abundance and enormous size of trees growing on deeper soil in the Basin, especially species of ash, cottonwood, walnut, hickories, beech, maple, buckeye, hackberry, Kentucky coffee tree, red cedar, and others. Red cedar, winged elm, and hackberry are most common on shallow soil in glade areas. Knobby Highland

Rim outliers include species similar to those of the Rim.

3. Highland Rim (HR) Section. Vegetational diversity is great in this Section and I must at least mention the major Subsections. The Eastern Highland Rim, lying east of the Central Basin and adjoining the Cumberland Plateau on the east, provides a rich and diverse group of habitats and elements. Dry slopes and ridges produce oak-hickory forests, although chestnut was important before its virtual elimination in the first half of this century. White, scarlet, blackjack, southern red, black, post, chestnut, and southern red oak are significant, as are mockernut, pignut, and shagbark hickories. More mesic slopes add sugar maple, American beech, northern red oak, white ash, and tulip poplar. Mixed mesophytic conditions, with American beech, sugar maple, tulip poplar, white oak, and sporadically, yellow buckeye, basswood, and cucumber and umbrella magnolia are found in some mesic sites. Oak swamps occupy some wet sites, with pin, swamp white, willow, and swamp chestnut oaks, and sweet gum, red maple, black gum, and beech. These upland swamps provide habitats for a number of Coastal Plain herbs and shrubs. Some barrens, especially on the southeastern Highland Rim, are grass-dominated and numerous rare species occur there.

The Western Highland Rim, lying between the Central Basin and the Tennessee River, is slightly lower in elevation than the Eastern Rim, and mixed mesophytic conditions are much more circumscribed and rare. Ridge and slope forests are oak-dominated (white oak is most frequently seen), but composition varies with aspect and elevation. American beech, sugar maple, white ash, wild black cherry, and tulip poplar are important on more mesic sites and in ravines. Forests are mostly hardwood but white and yellow pine occur sporadically and Virginia pine communities occur on dry promontories

about the Tennessee River and along breaks to the Central Basin. Most rivers are impounded by Tennessee Valley Authority and U.S. Army Corps of Engineers dams. Flooding and dewatering regimes result in several kinds of wetland communities, ranging from dewatered flats to marshes and swamps. Bottomland forests are limited (most removed early or now flooded by impoundments). Several site studies are available, especially from the northwestern section (Montgomery Bell State Park, Cross Creeks National Wildlife Refuge, Land Between The Lakes).

The Pennyroyal Plain and Elizabethtown Subsections include areas historically referred to as the Big Barrens (Baskin et al. 1994). A wide variety of landtype associations occurs on these limestone karst plains of Kentucky (mostly) and Tennessee. Although now mostly agricultural, plant communities include limestone cedar glades, prairies dominated by native perennial grasses and forbs, and forests of dry, mesic, and wetland sites which are not unlike those of the adjacent Rim. Forests of upland depressions and karst fens are of interest, and are now the subject of some study.

The Southwestern and Southern Subsections are primarily upland hardwood types, but yellow and loblolly pine types are locally abundant. Ravines and moist slopes support types not unlike that of the adjacent Rim. Several other smaller Subsections of the Highland Rim are addressed by the cited authors, especially by Quarterman and Powell (1978).

4. Shawnee Hills (SH) Section. This Section, also known as the Western Coalfields in Kentucky, in general is a rolling upland plateau with broad, alluvial plains bordering the major rivers. The Dripping Springs Escarpment lies to the south and east, forming an area of bluffs, cliffs, and generally rugged terrain. Agriculture, and especially surface mining for coal, has had

devastating effects on much of the natural vegetation. Remaining forests are secondary (apparently) and scattered. Slopes, ridges, and ravines are dominated by mixtures of mostly hardwood species. Slopes are oak-dominated (black, white, red) but hickories (pignut, shagbark, mockernut) are common. More mesic slopes and ravines will have American beech, sugar maple, tulip tree, white ash, and wild black cherry, while more xeric sites (upper slopes, ridges) will have more typical dry-land oaks (black, blackjack, post), red cedar, even some Virginia pine. Floodplains of major rivers include such southern species as bald cypress, water locust, and water tupelo, along with typical bottomland hardwood species of birch, cottonwood, elm, hickory (shagbark, shellbark, pecan), maple, oak (cherrybark, overcup, pin, swamp chestnut, willow), sycamore, and sweetgum. In the deep gorges of the escarpments may be found several species with Appalachian affinities, e.g., American holly, eastern hemlock, magnolia (bigleaf and umbrella), mountain laurel, white pine, and yellow birch. A few barrens, glades, and relict hill prairies also occur.

FLORISTIC AND VEGETATIONAL SIGNIFICANCE OF THE PROVINCE

The flora of the Province is relatively large, e.g., more than 3000 taxa in Kentucky (Browne and Athey 1992) and 2900 in Tennessee (Wofford and Kral 1993). This floristic richness may be accounted for in a number of ways. Most importantly, the Province is at a botanical crossroads and receives elements from many migratory pathways, as well as various spill-over elements from adjacent provinces. For example, the Tennessee River has provided a migratory pathway for a small but significant Appalachian element, and the Cumberland River, originating in highlands of the Cumberland Plateau to the east, contributes elements from there. Likewise, prairie elements from the north and west, and Coastal Plain elements

from the south and southwest, are significant. Massive reservoirs, destructive mining, and other major anthropogenic perturbations have destroyed significant habitats and community types, but also have resulted in new habitats and as a consequence, allowed for the introduction of new species and the expansion of old ones.

Other factors explaining the floristic richness include the diversity of substrates and soils, the various slope aspects (direction and degree of slopes), the temperature, wind currents, precipitation, and the drainage systems. These highly variable factors have produced innumerable microenvironments which provide for the ecological requirements of many species. Also of significance is the great age of the Province, or time that the area has been available for plant occupancy; most of the Province has not been under marine waters for millions of years, nor acted upon by glacial ice during the geologically-recent ice ages. Collectively, and along with numerous other (many yet unknown) factors, an interesting flora has developed, one with (1) geologically old elements, (2) disjuncts (with other Provinces and even other continents), (3) numerous endemics, (4) groups with great genetic complexity, and (5) a highly significant, but not always desirable element that is the result of anthropogenic activity.

The factors given above not only help to explain floristic richness, but also offer some explanations for the intricate mosaic of vegetation types present in this Province. Foremost, this region is transitional in a vegetative as well as a floristic sense, with major influences from the more xeric Oak-Hickory Region to the west and the more mesic Mixed Mesophytic Region to the east. It is no surprise that the Province includes numerous floristic-vegetational themes. For example, forest types include mixed mesophytic, mixed hardwoods, oak and oak-hickory, pine, cedar, bottomland hardwoods, and swamp forests. Also, upland swamps, karst fens, cedar glades, barrens, prairie relicts, and several dozen other minor community-habitat types occur.

Ideas on the origins and relationships of this diversity also might be mentioned. Nearly 30 years ago evidence was summarized for origins and relations of the southern highlands floras that include at least part of the Interior Low Plateaus [i.e., by A. J. Sharp, first heard by me in a 1966 lecture - see literature cited, and later (1970) became available in print], and by Alan Graham (1965) for Southeastern North America. They found the uniqueness and diversity of eastern North American Cretaceous floras to be primarily due to diverse origins, including:

1. A portion of the species comprising the modern flora evolved more or less in place from older Mesozoic vegetation. Examples include species of genera known, from the fossil record, to have been present in eastern North America during the early period of angiosperm evolution, including species of maple, birch, walnut, oak, cottonwood, willow, and others.
2. During the Eocene and Early Oligocene, land connections and climates were favorable for the introduction of tropical vegetation (early Tertiary). Once these species were introduced, later Tertiary trends toward colder times produced one of two responses in this area: (A) the tropical species were eliminated and are no longer represented in the flora, except as fossils; (B) some species evolved into types capable of existing under temperate conditions. These species exist today, usually represented only by one or a few species, although there may be numerous relatives in the tropics. Examples are persimmon and pawpaw.
3. A second interchange occurred between our biota and that of Europe and Asia during the Tertiary, via migration across land bridges. These are remnants of the well-documented Arcto-Tertiary Geoflora and probably include species of such genera as yellow-wood, sweetshrub, sycamore, oak, maple, walnut, elm, and others.

4. During the Pleistocene Period many boreal elements were introduced. Most of these were eliminated by warming conditions but some notable northern disjuncts (e.g., arbor vitae and a type of yellow birch, among others) still occur.
5. The last and perhaps most significant modification has occurred during the last 200 years as a result of anthropogenic activity. These include the accidental introduction of weedy species (many grasses and forbs), escape of planted species (fescue, kudzu), the elimination of taxa due to human activity (American chestnut), and perhaps most importantly, elimination of entire landtypes due to urban sprawl, reservoirs, strip mining, and other major land-changing activities.

SUMMARY

The Interior Low Plateaus Province is a place of topographic, floristic, and vegetational transition, and therein lies its beauty, and in many cases its worth. From the blue grass to the hill country, from river bottomlands to glades and barrens, floristic diversity is great, and the number of plant community types and combinations almost innumerable (and in many cases undocumented). For those of us who seek truths of and about the biota of an area - its origins, composition, distribution, community types, interactions, and relationships, this is a great place to be. For those of us who seek to preserve and conserve the biota and natural beauty of an area, our work is at hand.

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Quality or Quantity: Stock Choices for Establishing Planted Northern Red Oak¹

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Abstract—A northern red oak plantation was established in 1988 in a recently clearcut mixed oak stand to evaluate outplanting performance relative to the type of planting stock (1-0, 2-0, 1-1, 2-1, 2-year-old containerized, and direct-seeded) and impositions of other cultural factors (undercutting in the nursery, raising stock in an extended growing season in Alabama vs a local Pennsylvania nursery, top-clipping at planting time, and tree shelters). Twenty different treatments were compared, each with at least 33 replications. To minimize potential genetic bias among treatments, the same seed source was used to produce all but four of the treatments. For the first 3 years after outplanting, the plantation was enclosed by an electric fence to minimize deer damage and competing vegetation was controlled.

Six years after outplanting, seedlings grown from 2-year-old containerized stock were tallest (averaging 3.3 m) and had excellent survival, but were costly to produce and plant. The 2-0 bareroot stock, especially if undercut in the nursery and top-clipped at planting, performed best of the remaining treatments with 100% survival and an average height of 3.0 m. Other treatments, especially 1-0, were smaller and had lower rates of survival. Seedlings from direct-seeding were as tall as most 1-0 treatments. Undercutting, top-clipping, nursery transplanting, raising stock in different nurseries, and tree shelters marginally affected the height or survival of most seedlings. However, undercutting was particularly useful on the 2-0 stock not only by increasing outplanting performance but also by making the seedlings easier to lift and handle in the nursery and plant in the field. Seedlings that were above-average in height after 3 years, when deer fencing and weed control were withdrawn, were most likely to survive over the subsequent 3 years. All treatments produced at least some seedlings that were above-average in height (245 cm) and in a superior competitive position 6 years after planting. However, to reach plantation stocking goals on an operational basis, results suggest that choosing high quality and more intensively cultured stock should require considerably fewer seedlings (up to 1/3 less) to be planted initially compared to less intensively cultured stock.

¹Zaczek, J.J.; Steiner, K.C.; Bowersox, T.D. 1995. *Quality or Quantity: Stock Choices for Establishing Planted Northern Red Oak*. In: Landis, T.D.; Cregg, B., tech. coords. *National Proceedings, Forest and Conservation Nursery Associations*. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 116.

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Oak Regeneration — Why Big Is Better¹

Paul P. Kormanik², Shi-Jean S. Sung³, Taryn L. Kormanik⁴ and Stanley J. Zarnock⁵

Abstract—It is generally accepted that large preharvest advanced oak regeneration is required for maintaining a significant oak component in future stands. However, developing advanced oak regeneration on productive sites has been difficult because stand prescriptions encouraging oak regeneration are the same conditions that favor development of potentially faster growing competitor species. It is now practical to produce in the nursery oak seedlings that duplicate the sizes suggested for natural advanced oak regeneration. These large Northern red oak seedlings have been successfully established in small research plantations and in harvested stands where they have shown good to outstanding growth. However, they have preformed poorly when used as underplanting stock, where the understory has insufficient overhead sun to maintain stem elongation or root growth.

INTRODUCTION

This paper does not review the hundreds of articles written about oak regeneration. Instead, it reviews the research done, since we first proposed the first-order lateral root (FOLR) competitive ability hypothesis at the Institute of Tree Root Biology (ITRB) USDA Forest Service, Athens, GA. This hypothesis states that regardless of the phenotypic attributes of mother trees, their progeny can be stratified by number of first-order lateral roots (FOLR) and those with the greatest number will be the most competitive in the nursery and after out-planting in a forest environment (Kormanik and Muse 1986). We have examined at least 30 species in various nursery locations and have never found a single exception; i.e., those seedlings with the greatest number of FOLR are always the largest in stem caliper and height. We

followed survival and growth of sweetgum (*Liquidambar styraciflua* L.) and loblolly pine (*Pinus taeda* L.) in the field for several years and found a positive correlation between the number of FOLR at the time of outplanting and the growth several years after outplanting. Limited research with Northern red oak (*Quercus rubra* L.) and white oak (*Q. alba* L.) shows a similar correlation.

Initially, our research was concentrated on improvement of nursery planting stock, emphasizing seedling developmental morphology. We later concentrated on developing a fertility level in nursery soils to ensure that all fields in a nursery are comparable. This latter research eliminated the field to field variation in seedling sizes that severely limited developing grading standards for seedlings in general and hardwood seedlings in particular. Subsequently, we concentrated on

¹Kormanik, P.P.; Sung, S.S.; Kormanik, T.L.; Zarnock, S.J. 1995. Oak Regeneration — Why Big Is Better. In: Landis, T.D.; Clegg, B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-365. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 117-123.

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growing season management practices that allowed us to produce seedlings of specific sizes. This ability has enabled us to introduce larger-size oak plantings to our basic biological research on species physiological requirements for optimum development. The concept that large seedlings provide better oak regeneration is not new, however, the concept of producing this advanced regeneration as nursery stock is new. Large seedlings even show promise in regenerating Northern red oak on highly productive sites.

This paper discusses "**Why Big is Better.**" This approach appears to be working in the South and may be equally effective in other oak growing regions.

WHERE WE ARE

Practically all oak stands regenerated on the better quality sites have developed after clearcutting of existing stands or developed after chestnut blight (*Crythronectria parasitica*) decimated stands once dominated by American chestnut (*Castanea dentata* (Marsh.) Borkh). In most cases, we know little about specific stand conditions before oaks became an important component. However, because of their biological requirements for reproduction and regeneration, oak probably did not dominate the previous stands. Furthermore, unless we alter future stand development by proper management, oak is not likely to be a significant component in the future (Clark 1993).

However, when many of the more productive oak stands have been harvested, regenerating these stands back to oaks has been difficult. On the good sites, various methods of natural and artificial regeneration have experienced varying degrees of limited success (Johnson 1993). Regenerating oaks is not a problem on the least productive oak sites where they can readily dominate a stand. Currently, no regeneration procedure is widely adaptable or acceptable throughout the range of a single oak species. The situation is discouraging for

species like Northern red oak and white oak where extensive study has not resolved the problems associated with regeneration. Recently, these two species have been the focus of our basic and applied oak research. We strive to understand the metabolism requirements of these species and use this knowledge to increase regeneration success.

WHAT WE FOUND

The absence of successful regeneration on the most productive oak sites is a complicated silvicultural matrix that can no longer be viewed as a single species problem. Mensurational aspects of stand development have been emphasized in order to develop what appears to be a single viable oak regeneration prescription (Burns and Honkula 1990; Sanders and Grancy 1993; Sanders 1990). However, most oak species have such a broad geographic range or are so site specific that a single management protocol for even one species is probably impossible. Research emphasizes the importance of advanced regeneration but does not adequately define "advanced regeneration" and does not describe how much and how best to obtain it (Sanders 1990). However important advanced regeneration may be, the reproductive and establishment requirements of the oak species may render total reliance on natural reproduction a questionable endeavor, because the problems associated with oak regeneration start with the acorn (Cecich 1993; Cecich 1994; Barber 1994).

The silvical requirements of 25 different oak species as we currently understand them, are well covered in Agricultural Handbook 654 (Burns and Honkula 1990). The 1992 Oak Regeneration Proceeding which describes the current status of oak regeneration is a second source of our review (Loftis and McGee 1993). These manuals document that good oak seed years in nature usually occur at 2-5 year intervals. After predation by insects, diseases, rodents, birds, large and small mammals and unfavorable weather conditions during acorn drop, virtually no sound seed are

available for regenerative purposes during the "off seed" years. In a good seed year, producing a single seedling probably requires 500 viable acorns because over 80% of the acorns are damaged or may be nonviable for a number of reasons (Sanders 1990).

This single seedling faces a bleak future because virtually all 25 important oak species require more than 35% of full sunlight to become established. However, even when only 28% of the canopy remained, light intensity was inadequate for successful oak regeneration (Clark 1993). Few naturally regenerated oak seedlings will obtain 35% of full sunlight and in a few years, they will dieback and disappear. This may well be the reason in the words of Kellison (1993) that there is danger of the Northern red oak becoming the "California Condor" of the Eastern deciduous forests.

WHAT HAPPENS

Examination of oak regeneration in the South before and after harvesting or selective cutting was revealing and directly affected how we approached potential oak regeneration. Similar observations have also been reported for other areas of the United States (Johnson 1993; Sanders 1990). If 10-30 cm tall seedlings of unknown age are sufficient for potential reproduction then many oak stands have enough oak seedling for future stand development. After a good seed year, many such seedlings are normally present but their numbers decline over a few off seed years. This decline in seedling numbers was especially prevalent in white oak stands where a literal carpet of seedlings practically disappeared in a few years. Northern red oak seedlings seldom develop in such abundance. Advanced natural oak reproduction in excess of a meter in height is rarely observed in fully stocked stands in most regions.

Post harvest vegetation on productive oak sites results in lush sprout and seedling reproduction of shade tolerant species, as well as seedling repro-

duction of yellow poplar (*Liriodendron tulipifera* L.) from the abundant seed stored in the duff and litter layers (Beck 1990). Within a short period of time sprout and vigorous yellow poplar seedling development results in a uniform canopy and oak is unable to become dominant because of its low preharvest position. This is so commonly known that a reference source is not required, however, this fact is often overlooked when discussing regeneration options.

When stands are selectively harvested or thinned to encourage growth in small oak seedlings or underplanted to establish advance reproduction where natural reproduction is lacking, long-term success has been questionable. Conceptually, these practices will result in vigorous root systems that will provide the growth potential for the seedlings when the mature trees are removed (Clark 1993; Johnson 1993). The success of these practices is questionable because the first ignores the effect of partial thinning on potential competitors and the second ignores the amount of sunlight needed by oak seedlings.

WHAT WE HAVE DONE

Over a period of years, we developed a nursery management protocol that permitted 4-7 growth flushes by most oak species with 1 -0 nursery stock (Kormanik et al. 1994a; Kormanik et al. 1994b). For most oak species, heights of the best 50% of the seedlings can easily reach 1-1.5 meters. We found that multiple flushes and large stem sizes resulted in significant increases in root development of the most competitive seedlings (Ruehle and Kormanik 1986; Kormanik et al. 1989). We also found that large multiple flushes were accompanied by distinct "growth" rings in the tap roots which alternated with stem growth flushes.

We then began to study transplanted and non-transplanted seedlings in the nursery. With small non-transplanted seedlings we found that root development did not improve the second year in

the beds and that their relative crown competitive position declined in relationship to larger individuals. When transplanted into adjacent nursery beds where lateral root development could be observed, the development of the individuals with low FOLR numbers remained intermediate or suppressed and did not compete with transplanted seedlings with higher FOLR numbers. Invariably, new root development occurred in abundance not only from the severed tap root of the large seedlings but also from the severed end of the FOLR. For seedlings with 0-4 FOLR, few new lateral roots developed from severed ends of FOLR and new roots from the severed tap root were few and appeared less vigorous. We found the lower the FOLR number at lifting, the poorer the root development on the smaller transplanted seedlings.

In 1989, we established our first Northern red oak plantation, using 866 graded 1-0 seedlings from 8 half-sib seedlots in a traditional plantation configuration with 3.3 x 3.3 m spacing. At age 3, the plantation was vigorous and apparently disease free, with 60% of the individuals taller than 3.0 m tall (Fig. 1). The plantation was developing well and showed promise of being one of the most productive Northern red oak plantations in the South if not in the country. At that time, the survival was 88%, and the number of seedlings in height classes 3.0~3.4, 3.5~3.9 and > 4.0 meters were 182, 118, and 159, respectively. Mortality occurred primarily in seedlings with the lowest FOLR numbers or when voles (*Microtus* spp.) consumed the roots during the initial outplanting year. Interestingly, the vole damage was almost entirely limited to large individuals with high numbers of FOLR while normal mortality was usually restricted to individuals with the fewest numbers of FOLR.

In 1992, we observed dead branches on the upper third of the crown, of two good-looking seedlings. From these dead branches we isolated a fungus *Botryosphaeria* spp. and decided to follow its progress for a year or two before reporting on

the plantation. The following year, significant cankers developed on branches and main stems of many other individuals. Cankers on the main stems resulted in dieback affecting up to 50% total height. By age 5, the entire plantation was affected with this fungal pathogen which resulted in dieback and mortality of many individuals.

In 1995, at age 7, dieback, resprouting and mortality continue to occur. However, individuals that show no dieback are 7.5~9.0 m tall even though the mainstem may have several cankers. This plantation demonstrates that large Northern red oak seedlings can be established and show significant growth on a high quality stream bottom.

While this plantation was developing, a second outplanting was undertaken in North Carolina, on the Grandfather district of the Pisgah National Forest in cooperation with the North Carolina Division of Forestry. The site index (50 years) was 100 for yellow poplar which comprised a

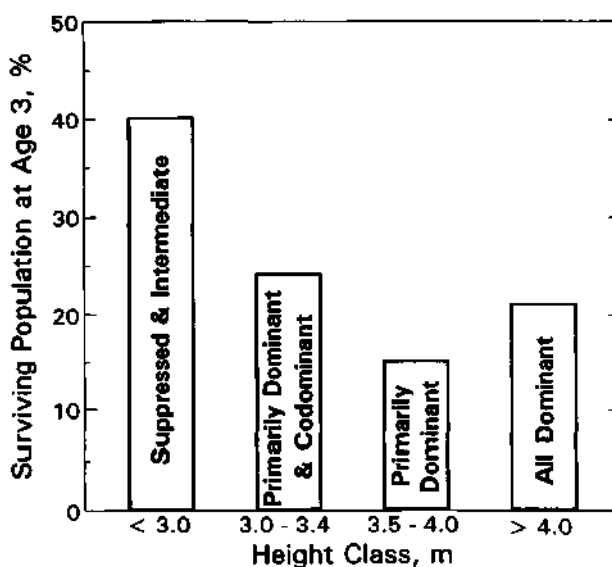


Figure 1. Percentages of surviving Northern red oak seedlings by height classes: suppressed, intermediate, codominant, and dominant canopy three years after outplanting.

significant component of the preharvested stand. We established this outplanting simply to compare seedling development in the understory planting with plantings in an adjacent clearcut, across the road using seedlings of different heights and FOLR numbers.

No post harvest treatment occurred in the clearcut. The underplanting site was thinned leaving a residual basal area of 70 sq. ft with understory vegetation removed before the seedlings were planted. Seedlings were classified as good, medium or poor based on FOLR numbers of > 12, 7~11, and 0~6, respectively. Heights of the seedlings were directly related to FOLR numbers (Ruehle and Kormanik 1986). In both areas, seedlings were planted in rows at a specific spacing regardless of potential competition from sprout origin materials or overhead shade. In both cases, all good and medium seedlings initially exceeded 1.25 m in height when outplanted. The poor ones, depending upon FOLR numbers, were 30~70% smaller.

First year mortality was insignificant in both planting situations with almost all seedlings surviving. As previously observed, little first-year height growth occurred in either situation as the roots became established and individuals recovered from transplanting shock. In the clearcut, few if any of the large seedlings were overtopped by competing sprout and seedling reproduction but many of the small seedlings and most of the small, naturally regenerated seedlings fell behind sprout growth. None of the seedlings in the understory planting experienced direct competition from competing understory growth.

The second year growth in the clearcut was good, with many of the large seedlings almost doubling in height. In the understory planting, few individuals grew more than 10~20 cm and seldom produced more than 10 leaves. In the fall following the second growing season, a severe epidemic of 17 year locusts occurred and severely impacted

over 90% of the individuals in the clearcut plantings but no seedling damage occurred in the understory planting. Early in the third growing season, seedlings in the clearcut that had not died back almost to the ground were severely damaged along their entire length.

In the third through the fifth year, the seedlings in the understory began to dieback and the number of leaves that developed decreased each year. At the end of the fifth year, these seedlings were essentially the same size as when outplanted. Survival of the understory planting remained relatively good with only 3.8, 3.8, and 18% of the good, medium and poor individuals dropping out of the planting.

A number of seedlings had been established in the underplanting to evaluate root development as our underplanted "advanced" regenerated material developed. In February, 1995 some of these seedlings were excavated after 5 years in the understory. We unexpectedly found that almost the entire original lateral root system had atrophied and was replaced by a few poorly developed new roots that had developed where the taproot had been severed before outplanting. The taproot had essentially the same diameter it had when it was planted. In our plantation and other trial plantings where we routinely excavate seedlings to follow FOLR development we have never observed similar reductions in root mass. A more extensive lifting of more seedlings is planned for fall and winter 1995-1996.

In the clearcut, competition at the end of the fifth year was extensive with approximately 30,000 stems per acre present. The poor seedlings with low numbers of FOLR experienced 65% survival, but only 6% were free to grow. The survival rate for the medium and good seedlings was 66% and 70%, respectively. However, 52% of the good seedlings were free to grow and 28% of the medium seedlings were so classified. In most cases, the free to grow oak seedlings were the same

height (3~4 m) as the better naturally regenerated yellow poplar seedlings. The sprout material of some species were up to 5 m but were not impacting the free-to-grow Northern red oak seedlings. Unlike the root systems from the understory planting, those from the clearcuts were making root growth commensurate with their impressive height growth.

A detailed report of this co-operative study is being prepared. Based upon its performance to date and the performance of other smaller studies, the ITRB, Region 8 and the University of Tennessee have undertaken an extensive region wide study to test the effect of large Northern red oak seedlings on both timber and mast production. The seedlings from 78 different half-sib seedlots were grown at the Georgia Forestry Commission Flint Nursery in 1994 and were out planted on 18 different ranger districts from Virginia, south to Georgia, and west to Kentucky in February 1995. At each location 1,250 seedlings from 25 different families were planted in small 3~5 acre clearcuts.

In this region-wide planting, at 18 different sites, we have had preliminary reports of total deer browse on 18 plantings, gypsy moth on one and 17 year locust damage on two. Early reports indicate the majority of the large seedlings are not being overtopped by competing natural vegetation. However, the extended drought during the 1995 season may be impacting survival.

SUMMARY AND CONCLUSIONS

In the South, underplanting of any oak may not result in development of advanced regeneration whose root system is developed well enough to permit a significant number of seedlings to compete after the stand is harvested. The small (5~30 cm) oak regeneration characteristically present in the understory of mixed hardwood-oak stands have little chance of competing on high quality sites because they quickly become overtopped by the dense canopy of woody sprout and herbaceous

material. Large 1-0 seedlings with suitable FOLR development have one or two years to become established before intensive competition for sunlight and root growing space occurs. This may be sufficient time to permit the planted seedlings to act like true advanced regeneration and become part of the newly developing stand. This concept is new, and we can now produce advanced regeneration in our nurseries and identify the most competitive ones.

Plantation performance of these large Northern red oak seedlings has been outstanding even though the oldest plantation has been essentially destroyed by *Botryosphaeria* spp. Even in this plantation, the largest individuals have attained heights of 7~9 m which is outstanding by any standard. We are constantly monitoring our other Northern red oak outplantings to evaluate this disease. Several seed orchards were established at the Georgia Forestry seed orchard adjacent to the Flint Nursery complex using these large seedlings. These orchards have also been having outstanding seedling development.

Because acorn predation is high and seed years are infrequent natural regeneration will probably not provide ample material for consistent success on the better quality sites. Moreover, small seedlings, even those with good root development, will probably not overcome transplanting shock and become established before sunlight is limited. Large seedlings, however, have demonstrated an ability to overcome transplanting shock and become established before they are overtopped by competing vegetation. After 5 years, these seedlings attain heights commensurate with sprouts and other competing regenerated vegetation.

Successful Northern red oak regeneration on the more productive bottomland, mesic and cove sites may ultimately depend upon nursery production of large competitive seedlings and using only the best for artificial regeneration prescriptions. The silviculture prescriptions must in turn be dictated

by biological not political considerations. If this does not occur, Northern red oak may indeed become the "California condor" of the Eastern deciduous forest (Kellison 1992).

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The Target Seedling Concept: Implementing a Program¹

Robin Rose and Diane L. Haase²

INTRODUCTION

The Target Seedling Symposium in 1990 (Rose et al) covered a range of topics surrounding the target seedling concept. The usefulness of stock type designations was found to be less than worthy where there is a necessity to set criteria for reforestation success. Height and stem diameter were found to be useful target traits in seedlings, but these traditional measures of quality require support from other seedling traits in order to be useful. Root growth potential was not found to be quite as useful in pinpointing reforestation success as perviously thought. Root system size was clearly shown to greatly enhance the ability to quantitatively assess quality. Mycorrhizae play an important role in reforestation success in some areas and their presence or absence can have subtle impacts on how seedlings perform. Bud dormancy and cold hardiness in temperate tree species can have profound impacts on seedling field performance. Seedling moisture status is key to lifting seedlings in spring and ensuring their ability to survive the first few weeks after outplanting when new roots are being formed. And lastly, mineral nutrition is a vital link with reforestation success. Seedlings sent to the forest with nutrient imbalances are likely to suffer growth set backs even when environmental conditions are good. Seedling quality testing using the above mentioned traits is an integral part of all

of this and forms the basis for discovering which traits will work best as successful reforestation criterion.

The purpose of this paper is to put the target seedling concept in the context of an on-going program coordinated between nursery activities and a reforestation planting program. Time and time again it has been learned that a reforestation program depends on the successful integration and coordination of all activities from seed collection to planting the seedling in the field. The purpose here is to discuss how to get a target seedling based reforestation program into existence.

DEFINITION

What is the target seedling concept? The concept is defined as targeting specific physiological and morphological seedling characteristics that can be quantitatively linked with reforestation success. There are two adjectives in this definition that carry a great deal of weight in terms of understanding the fundamental basis of the definition. The first adjective is 'specific', namely those characteristics at specific levels that are to be developed in seedlings to make them perform best on a given site. The second adjective is 'quantitative', namely

Rose, R.; Haase, D.L. 1995. *The Target Seedling Concept: Implementing a Program*. In: Landis, T.D.; Cregg, B., tech. coords. *National Proceedings, Forest and Conservation Nursery Associations*. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 124-130.

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those characteristics that can be statistically correlated with successful seedling performance on a given site. Overlooked, but implied, in this definition is the term, *target site*, which means that each target seedling is being cultured to grow under the known environmental field conditions of a specific site, i.e. ecotype, slope, aspect, brush competition (Dr. Mike Newton, personal communication).

Carrying out the objective of the definition is a daunting task, especially when it is fully realized how little is known about how various species of differing characteristics perform. Few nursery operations are set up to deal with culturing more than a few stock types. Even within a single stock type designation seedling attributes such as height and stem diameter can occur over a wide range of values. It is common knowledge that one nursery's 2+0 stock can be much larger than the 2+0 stock of a nursery 50 miles away.

The reforestation industry long ago settled on height and caliper as grading criteria for seedlings because it was quick and easy. But, as costs have gone up, reforestation success has been mandated by law in some places and public responses have been negative regarding poor quality reforestation, and more attention has been shifted toward seedling quality. Every year private forestry operations strive to increase growth in the first few years, not only to improve long term economics, shorten rotations, and maintain sustainability, but to improve short term economic gain by capturing the site quicker in hopes of using fewer chemicals.

Running a target seedling program is less science than just good coordination and management. Where programs have been successful, such as at Weyerhaeuser Company and the Oregon Department of Forestry, upper management was in full support of the program. The seedling is seen as a product of the organization with a set of characteristics and quality control standards for manufac-

ture. Quality control is maintained via the cultural practices such as genetics, seed quality, planting density, fertilization, irrigation, and storage. Wrenching and undercutting play a key role in some bareroot nurseries in developing the target root system.

LIST OF TARGET CHARACTERISTICS

To most nursery managers and reforestation supervisors there are a bewildering array of characteristics for seedlings. Over time it has been overwhelming for some operational managers to deal with the ever-increasing array of stock type designations. There are nurseries that advertise that they have over 160 seedling stock types. This is not hard to do if one is in the containerized seedling business with seed from 12 different species being sown to 12 different container sizes and shapes. This alone would make 144 stock types. Additionally, the cultural practices can be altered in 16 different ways (i.e. light regime, fertilization, hardening off schedule, nutrient levels). This could result in a huge factorial with seemingly endless combinations of stock types!

However, these stock type designations are unimportant if the actual characteristics of the seedlings do not yield predictable reforestation success under most circumstances. For all 160 stock types, however derived, it is still vital to ensure that they have enough roots to supply the top with water, sufficient cold hardiness to withstand long term storage and survive outplanting, and a workable nutrient balance.

There are many characteristics to examine. The point here is only to list them and briefly describe their usefulness. The target seedling concept uses all of these parameters in an integrated way.

MORPHOLOGICAL PARAMETERS

Height. This parameter is the most common in use. Evidence has shown that height is not always a reliable indicator of success without taking into account stem diameter and root volume. The height/diameter (mm/mm) ratio has been useful to understanding the ability of the plant to withstand stress. The higher the ratio the more out of balance it is (e.g. > 60) and the less it is able to compete with brush. Where herbicides are not allowed most managers prefer tall seedlings with big supporting root systems to outcompete the brush.

Stem Diameter. Diameter at ground line is also one of the most common characteristics looked at in seedlings. Some work has shown that there is a good correlation ($r^2 = .68$) between stem diameter and root volume of newly lifted seedlings. However, depending on lifting techniques in the nursery a large diameter seedlings can go to the forest without a lot of roots. Therefore, it is important to look beyond stem diameter when determining the target seedling.

Root volume. This characteristic is one of the newer traits to be linked with reforestation success. Unlike height and stem diameter this trait takes a little more time and effort to measure. The most common method of measuring trees for root volume is by water displacement on an electronic balance. It has been clearly shown that the greater the root volume the better the seedlings tend to survive and grow. Prior to the use of root volume, root length was sometimes used but length has little to do with root mass, although it can be important to get roots down to where the soil moisture is. Root volume says nothing about fibrosity. In some species the number of first order laterals can be quite important. Shoot volume can also be measured and used with root volume to calculate shoot:root ratio.

Other morphological characteristics like stem, needle or leaf, and root weights have been mostly looked at by researchers. Number of branches has been used. Bud size or appearance has been used in some species. Needle length may be useful if the seedlings transplanted shocked in the nursery. Forking due to insect or disease is something to avoid. L-rooting of seedlings by undercutting or wrenching can create very undesirable characteristics.

By looking at these characteristics as part of a target seedling program it is possible to fully realize how close or how far a nursery manager is from producing optimal seedlings whether called target seedlings, ideal seedlings or archetype seedlings. The goal of the target seedling program is to seek the **optimization of all of these traits for the greatest** gain after outplanting (Figure 1).

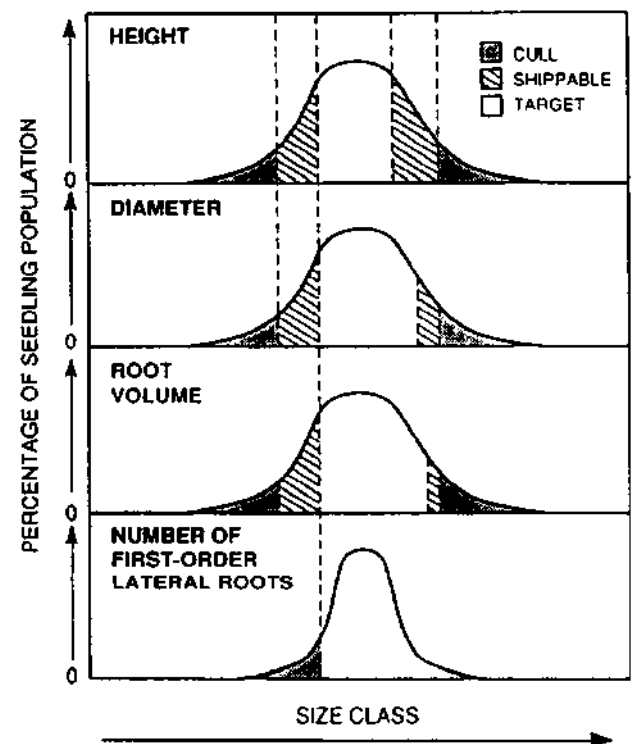


Figure 1. Normal population distributions for several morphological traits of tree seedlings.

PHYSIOLOGICAL PARAMETERS

Few if any physiological parameters are used by nursery managers and this needs to change if real progress is going to be made. Many known physiological or biochemical techniques are best suited for use by researchers, who then translate their findings into operational practices.

Plant Water Potential. The measurement of plant water potential or plant moisture stress using a pressure bomb has been used successfully in some nurseries for years to determine watering schedules to meet growth targets, to determine when best to lift, and to trouble shoot handling procedures between lifting and cooler storage.

Cold hardiness. Some nurseries send their seedlings to a cold hardiness testing service to determine if their seedlings are ready to be lifted and long term freezer stored. It can be very surprising to learn that lots within the same species are no where near (-10°C) as hardy as others (-20°C).

Nutrients. Given the fact that there are so many labs able to do seedling foliage testing for nutrient levels, one would think more managers would avail themselves of this service. Few seem to bother at all and basically put on 'recommended' fertilizer rates and if the seedlings look green proceed from there. It is only when chlorosis shows up mysteriously do most nurseries want to run foliage tests. But then, they have nothing for data comparisons. Chlorotic foliage is yellow because it is missing nutrients and all the test will do is confirm that the nutrient levels are clearly wrong. Nutrition levels need to be tracked yearly in order to determine acceptable ranges at each nursery and for each species.

Other physiological techniques such as starch analysis, chlorophyll fluorescence, and photosynthesis belong to the domain of the researcher. The role of the researcher is to improve our understanding of how plant processes can be manipulated to

best advantage. For instance, net photosynthesis (production of carbohydrates) is known to be adversely impacted as plant water potential decreases beyond -15 bars. Knowing this aids the nursery manager in setting irrigation regimes, knowing if there is plant stress prior to storage, and knowing how best to harden seedlings off without doing physiological damage. This illustrates the fact that not all physiological characteristics can be used in a target seedling program, but a conceptual understanding of physiological mechanisms can greatly aid in the production of target seedlings.

IMPLEMENTING A PROGRAM

Starting a target seedling program is not particularly difficult, but it does take a high degree of commitment and in some instances a reallocation of resources. Some steps (Figure 2.) that might be followed to get started are as follows:

1) *Inventory and Characterization*

Set about finding out what kind of stock are currently grown. For each stock type collect information on height, stem diameter, shoot volume, root volume, and number of first order laterals. From these data calculate height / diameter ratio and shoot /root ratio on a volume basis. These data on approximately 100 seedlings of each stock type should then be analyzed to produce means, standard deviations, range in values, and a coefficient of variation. Of added benefit is to break the data down into different stem diameter classes and look at the distribution. How many seedlings fall within each of the classes? How many fall within a given root volume class? There are innumeral ways to look at these data and derive an operational understanding of what a particular stock type looks like based on a particular cultural regime. Some state and corporate operations have more than one nursery. In this case it can be eye opening to compare the same stock types from different

Coordinated Target Seedling Action Plan.

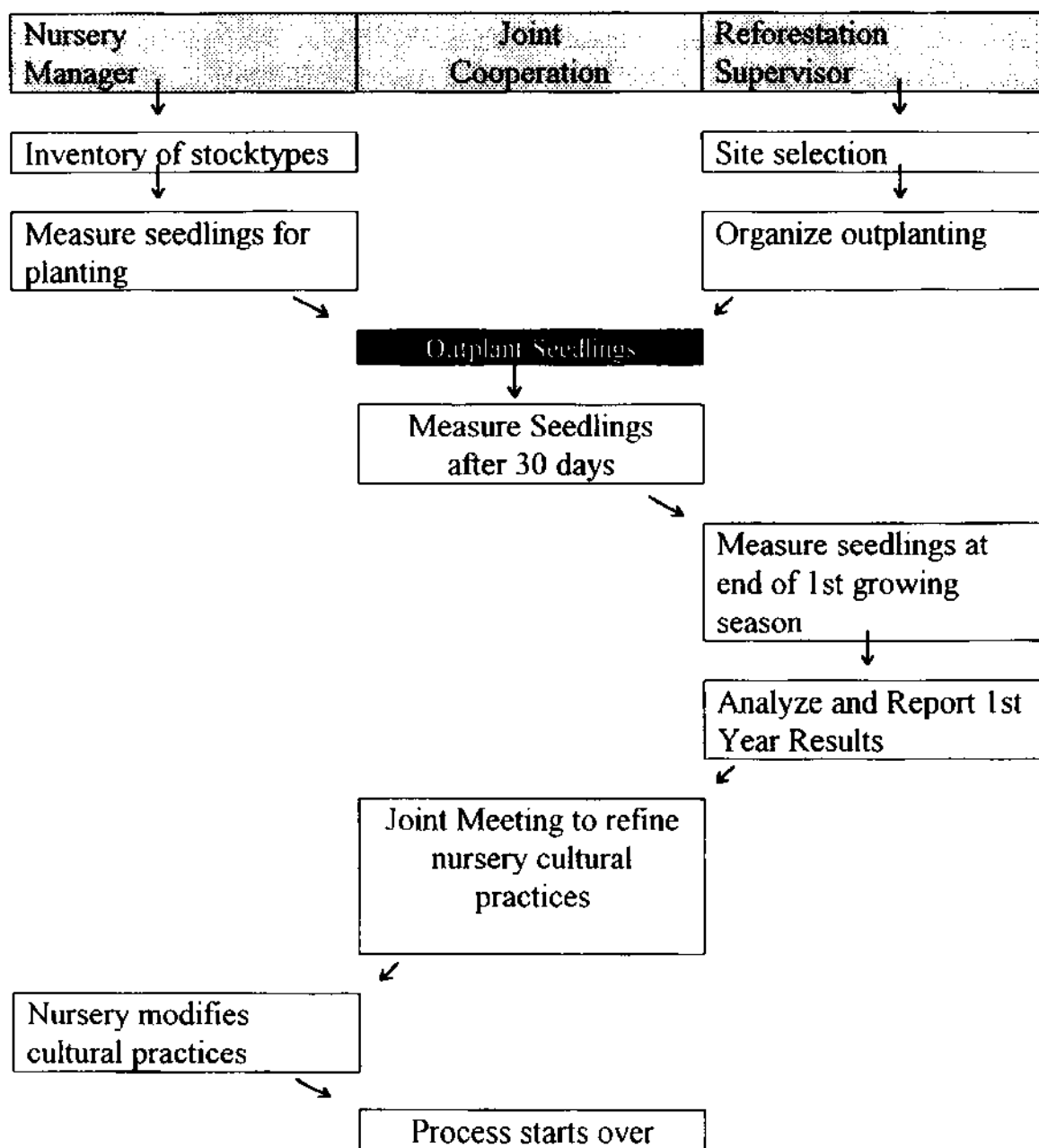


Figure 2. Schematic diagram showing a generalized schedule for the coordination of a target seedling program between the nursery manager and the reforestation supervisor.

nurseries. Physiological tests like root growth potential, cold hardiness, and nutrients can also be measured.

2) Field Testing

The non-destructive nature of this data collection is very useful toward the purpose of developing an on-going target seedling program. A minimum of three sites should be chosen representing an array of typical field conditions. A minimum of six replicated plots containing 10-15 seedlings of each stock type should be established. Single tree plots also work very well and a minimum of 100 seedlings should be used in this instance. Usually it is a good idea to test no more than six stock types in any one test so the experiment does not get too unwieldy to plant and measure.

This results in a replicated study where the initial height, stem diameter, shoot volume, and root volume are known along with the other values that can be calculated. Following planting the seedlings should be measured for field height and stem diameter within 30 days after planting and checked for signs of stress or mortality. At the end of the first growing season the seedlings should be measured again.

Some organizations with a real commitment to target seedling work repeat this same experiment with each year's nursery crop for two or more years, planting the seedlings in the same immediate area. In this way crop year is also a source of variation. There is great statistical power in doing this and it helps to confirm any other trends which may show up.

Why do the measurements and then plant the trees? Knowing the root volume, for instance, at planting allows a statistician to use this variable as a covariable, accounting for differences in growth attributable to initial root volume. A key to success is knowing what the seedlings actually look like prior to planting in a way that a stock type designation such as 2+0 never could.

Assuming the seedlings have been cultured, handled and planted correctly, trends in these planting trials are likely to show up within the first three years. It is critical to success that the handling and planting be the best ever done. It serves no purpose to handle and plant an expensive trial with inexperienced or poorly motivated planting crews. This is not a trial designed to study operational planting. It is a study to determine those characteristics that contribute the most to outplanting success, given that each seedling is well planted.

SOME ESSENTIAL QUESTIONS

How can an operational target seedling program be initiated in a nursery or reforestation effort? Fundamental to success is commitment on the part of the organization at all levels. Attempts to create an artificial need for such a program is doomed to failure if various managers simply do not think it is necessary and that "things" are fine as they are. Too often what instigates a whole new look at reforestation are numerous unexplained failures that have many managers grasping for explanations. Eventually meetings are called and it becomes apparent that the nursery needs more funding to meet operational targets, weather has been less than optimal for planting, and the planting supervisors question the quality of the seedlings coming from the nursery. After all of the verbal exchanges are over everyone gets down to the fact that they have a problem and it is time to work more closely in order to improve reforestation success. This is where the target seedling program comes into play.

What are some of the common concerns? Initially there are often many concerns about funding and changing what seems successful now. Nursery managers often operate right at the margin of meager budgets so when it is suggested that they provide some labor and measure trees, set up meetings with field foresters, and visit plantations

there is a lot of concern about where the time and money are going to come from. Training people to do this kind of operational research is also a concern since most have no idea how to set up a crew to go forth and measure seedlings, much less know how to analyze and interpret the data. This is where upper management needs to step in and organize the support to make things happen with outside help.

What are some of the constraints? Money is a big constraint. The old adage that "it takes money to make money" is very true in this case. Money to buy small items of equipment and money to hire extra people is important, especially in those operations that depend a great deal on seasonal help. Money for extra travel is important so that communication among responsible parties can be maintained.

What are some of the important linkages that need to be made between the nursery and the field managers? It is surprising to some upper level supervisors how few of their nursery managers actually go into the field to see the results of their work. It is also surprising that reforestation supervisors seldom set foot inside of a nursery - most have seedlings delivered! These two entities form the most critical link in producing target seedlings because they must develop a trusting feedback mechanism to relay what is working and what is not working in the forest. Sometimes field foresters will want to see a particular type of seedling they think will do well, but soon discover it is impossible to grow in the nursery. On the other hand there are nursery managers who think their 6" seedlings are workable in high brush areas, having never actually seen or even heard that their seedlings die under such conditions. Upper management must be involved in this process from time to time in order to keep the goals realistic and keep everyone oriented toward functional outcomes, i.e. finding target seedling characteristics that work.

CONCLUSION

Implementing a target seedling program is really nothing more than an extension of the job most managers are already paid to do. That job is to improve product quality in order to better meet customer needs and minimize costs. Nowhere has it been shown that planting failures save money. The primary objective of a reforestation program is to get the seedlings up and growing the first time, often to meet legal, environmental, and economic goals simultaneously. There is an old saying, "if you can not get it right the first time, when will you have time?" A target seedling program is a good step toward getting it right the first time.

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Biological Control of Fusarium Diseases of Conifer Seedlings¹

Cynthia A. Buschena², Cynthia M. Ocamb³, and Joseph O'Brien³

Abstract—An alternative to soil fumigation with methyl bromide is needed for control of Fusarium root rot and damping-off of conifer seedlings. Studies with eastern white pine (*Pinus strobus*, L.) and red pine (*P. resinosa*, Ait.) are underway to develop biological control microorganisms for application to conifer seed. Preliminary results show an ectomycorrhizal fungus, as well as bacteria derived from the rhizosphere, suppress Fusarium root rot of eastern white pine.

INTRODUCTION

With the loss, in the year 2001, of methyl bromide as a soil fumigant, reduction of seedling growth and vigor, as well as increased seedling mortality, is anticipated. Because conifer seedlings are susceptible to root rot and damping-off, caused by *Fusarium* species, an alternative is needed to control *Fusarium* in bareroot nurseries. The application of a mixture of biological control agents is a promising and necessary alternative.

Many, but not all *Fusarium* species are pathogenic. *Fusarium* species may cause seed decay and damping-off early in the growing season. Later damage usually consists of root necrosis and some chlorosis. The damage is usually clustered in the nursery beds as evidenced by brown patches of seedlings. Fusarium root rot and damping-off are among the most important soilborne diseases of eastern white pine (*Pinus strobus*, L.) in bareroot nurseries.

Seedborne *Fusarium* Species

Fusarium may be introduced into nursery beds on seed. These *Fusarium* species can decrease seed germination or seedling emergence (James et al. 1991, Kelley & Oak 1989). Nine seedlots of eastern white pine, collected from the Lake States, were tested for the presence of *Fusarium* species. The proportion of seeds infested with *Fusarium* ranged from 40 - 100 % of seeds tested, with the majority of seed lots being nearly 100% infested (Figure 1). To try to reduce seedborne *Fusarium*, various methods were evaluated for effective seed disinfestation. Washing eastern white pine seeds for 48 hours or treating seed in 0.05% NaOCl for 40 minutes decreased the percentage of seeds with *Fusarium* species. Immersing seed in hydrogen peroxide for three hours resulted in the greatest reduction in percent seed with *Fusarium* species (Figure 2).

¹Buschena, C.A.; Ocamb, C.M.; O'Brien, J. 1995. Biological Control of Fusarium Diseases of Conifer Seedlings In: Landis, T.D.; Clegg, B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-365. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 131-135.

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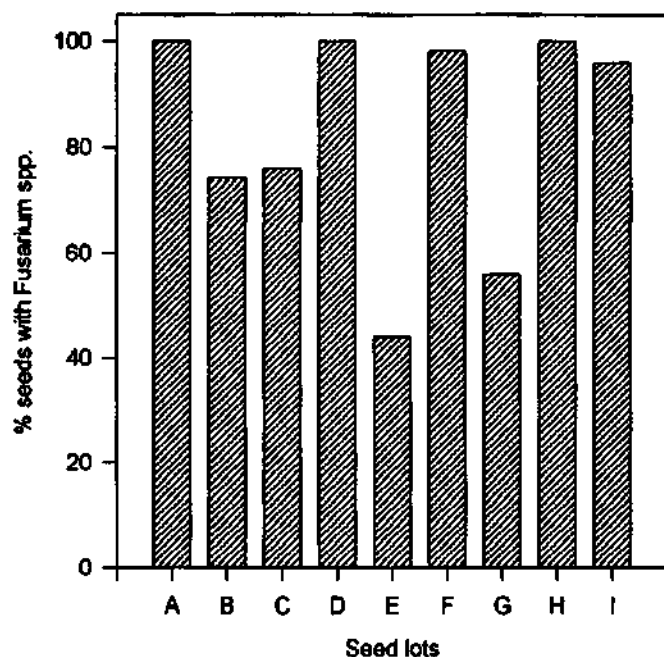


Figure 1. Percent of eastern white pine seeds from which *Fusarium* spp. were isolated. Nine seed lots (A-I) collected from the Lake States region were examined.

Soilborne *Fusarium* species

Even when soil is fumigated, *Fusarium* species still can be present in nursery soil, perhaps surviving in plant debris (Juzwik and Ocamb, unpublished). An analysis of plant debris from different soil depths revealed that *Fusarium* species were found on the majority of plant debris, greater than 1 mm in diameter in soil, one month after fumigation with methyl bromide--chloropicrin (MC-33) (Ocamb, unpublished). Clearly, even when methyl bromide is used, *Fusarium* diseases can be present in nursery beds.

Rhizosphere-derived biological control candidates

Numerous soil organisms have an inhibitory effect on soilborne pathogenic *Fusarium* species. A technique was used to isolate microbes to be used as biological control candidates (Ocamb 1994). Rhizosphere soil from a variety of sources was mixed with media and incubated in petri plates for 48 hours. An isolate of *Fusarium* was minced

with agar, then layered on top of the rhizosphere soil dilution plates. Microorganisms were then isolated from the center of zones free of growth by *Fusarium* species. Using this technique, more than 500 candidate organisms were obtained. These biological control candidates were challenged with combinations of pathogenic *Fusarium* species and candidates that were judged to be the most suppressive to *Fusarium* growth were further tested in greenhouse evaluations.

Mycorrhizal fungi

We wanted to include ectomycorrhizal fungi in our mix of biological control agents. Ectomycorrhizae are not only necessary for conifer survival and health but have been shown to inhibit development of some soilborne pathogens (Chakravarty &

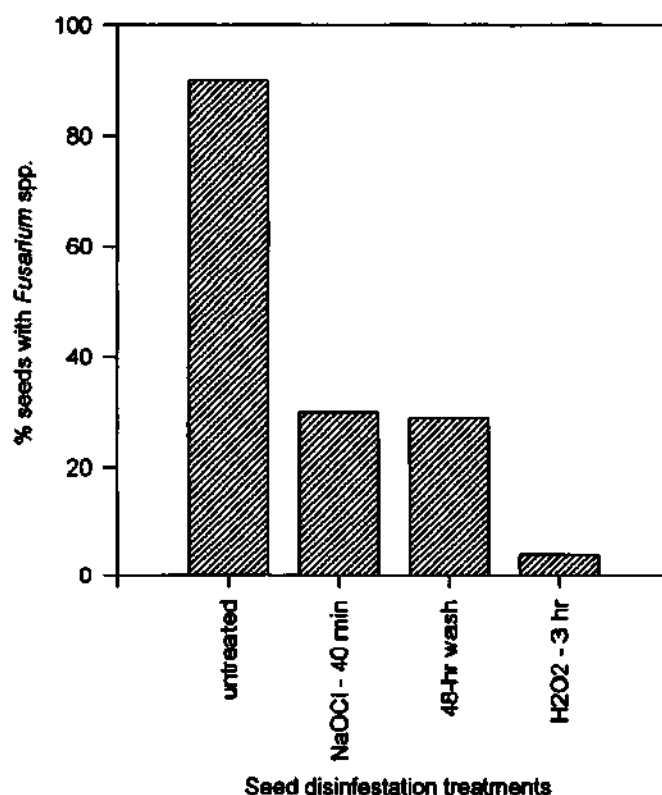


Figure 2. Percent of eastern white pine seeds from which *Fusarium* spp. were isolated. Seeds were disinfested in 0.05% sodium hypochlorite (NaOCl) for 40 min, hydrogen peroxide (H₂O₂) for 3 hr, running tap water (48-hr wash), or left untreated.

Hwang 1991, Sinclair et al. 1975, Duchesne et al. 1988, Farquhar & Peterson 1991). Isolates of two species of ectomycorrhizal fungi obtained from sporocarps associated with white pine nursery seedlings, were tested separately with and without *Fusarium* present in the soil in a series of growth chamber experiments. On average, seedlings inoculated with isolate #2 had 70% mycorrhizal roots and isolate #1 had approximately 45% mycorrhizal roots, without *Fusarium* present in the soil (Figure 3). With *Fusarium* present, mycorrhizal colonization by isolate #1 dropped off to approximately 10%, while mycorrhizal colonization of seedlings inoculated with isolate #2 did not greatly drop off. In addition, root rot was reduced when isolate #2 was present (Figure 4). Isolate #2, which forms a thick mantle around each short root, appears promising as a biological control agent against pathogenic *Fusarium* species.

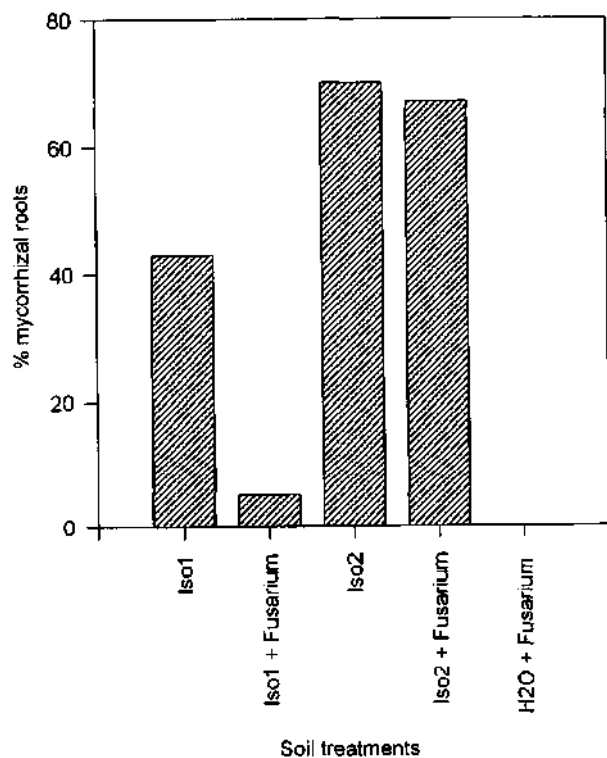


Figure 3. Percent of eastern white pine seeds with mycorrhizal associations. Two mycorrhizal fungi, Iso1 and Iso2, were applied to seedlings growing in pasteurized field soil with and without artificial infestation of pathogenic *Fusarium* spp.

The growth chamber trials were conducted with a relatively small number of seedlings. In January 1995, 480 containers were inoculated in a greenhouse at George W. Toumey Nursery in Watersmeet, Michigan with two ectomycorrhizal fungi, other biocontrol candidates collected from the rhizosphere of white pine, and Mycostop[®], a commercial formulation. The seedlings at Toumey were treated the same as other seedlings grown for production except they did not receive any fungicide applications. Trees treated with the mycorrhizal fungi showed evidence of sporocarp production by seven months of age. Seedlings will be evaluated for percent mycorrhizal colonization, size and root health.

In addition to the greenhouse study, three field studies have been installed at Toumey Nursery, testing the rhizosphere-derived biological control

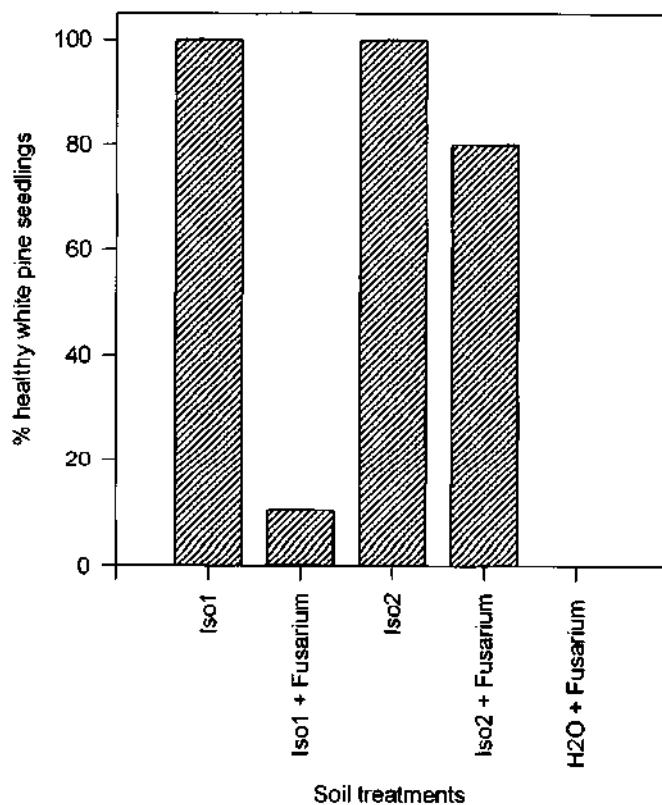


Figure 4. Percent healthy eastern white pine seedlings when two mycorrhizal fungi, Iso1 and Iso2, were applied to seedlings growing in pasteurized field soil with and without artificial infestation of pathogenic *Fusarium* spp.

candidates and ectomycorrhizal fungi. Two studies are on eastern white pine and the other is red pine. The experimental designs are a randomized complete blocks. The treatments were blocked over the length of the nursery bed. Seed treatments included non-treated seeds and seeds disinfested with hydrogen peroxide. Disinfested seeds were coated with the biological control candidates. Ectomycorrhizal fungi inoculations were coupled with all seed treatments.

Approximately 450 white pine seeds were sown in each plot. Stand counts were made approximately 10 weeks after sowing. Seedling numbers were greater in plots treated with some biological control agents than in the control plots. Figure 5 illustrates some of the preliminary results with eastern white pine. In general, dazomet-treated beds had a greater seedling stand count than that found in MC-33 treated plots. Disinfesting seed alone did not improve the stand count relative to that found with untreated seeds. Application of BCA 1 and Mycostop® increased the stand counts. An evaluation of ectomycorrhizal colonization is underway.

CONCLUSION

Our research with biological control agents looks very promising. Preliminary data suggests that by integrating three components: (1) seed disinfestation, (2) soil fumigation with dazomet, and (3) treatment with a mix of biological control candidates, we can control *Fusarium* root rot and damping-off of conifer seedlings in the nursery. Future direction includes looking for a practical and economical delivery system, application rates, and secondary effects.

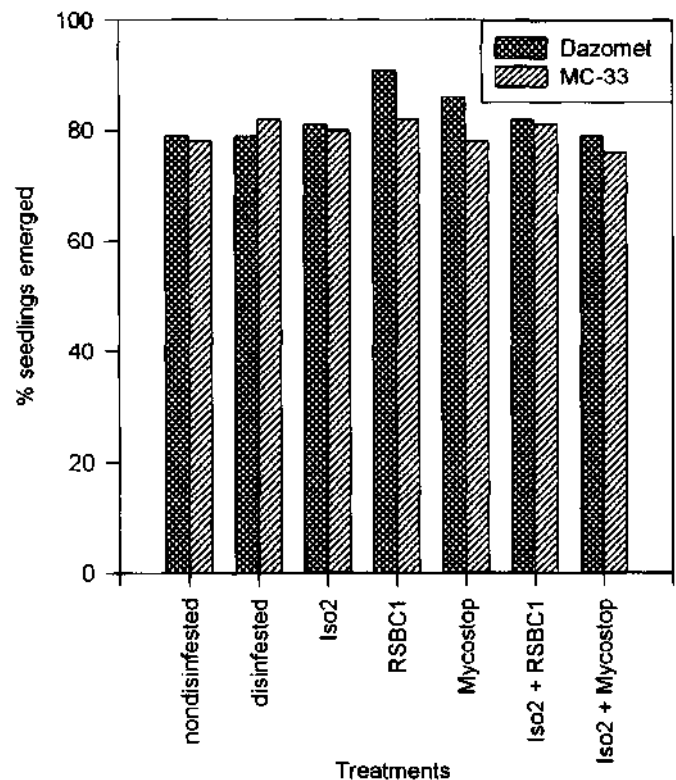


Figure 5. Percent emergence of eastern white pine seedlings when a mycorrhizal fungus (Iso2), a rhizosphere-derived biocontrol agent (RSBC1), or Mycostop were applied to disinfested seeds sown in the field.

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Business Meetings

Western Forest and Conservation Nursery Association

MINUTES FROM THE 1995 BUSINESS MEETING

The business meeting was called to order by Tom Landis at approximately 12:45 PM on Thursday, August 10. He explained that, based on the Association Charter, everyone who attends the annual business meeting becomes a member and has full voting privileges.

Old Business:

- 1. Minutes from the Previous Meeting.** Tom Landis announced that the minutes from the 1994 Business Meeting in Moscow, Idaho, are published in the Proceedings from that meeting. The minutes were approved by a voice vote.
- 2. Report on reorganization into Western Forest and Conservation Nursery Association.** Tom Landis reported that he had presented the proposal to combine the Western Forest Nursery Council and the Intermountain Forest and Conservation Nursery Association into one organization—the Western Forest and Conservation Nursery Association (WFCNA) at the meeting last year, and it was passed unanimously by voice vote. The new charter is published in the minutes of last year's Proceedings.
- 3. First National Nursery Proceedings Published.** After approval of members at last year's meeting, the first National Nursery Proceedings was published in May, 1994, as General Technical Report RM-GTR-257. This publication contained papers presented at the two nursery meetings from 1994: The combined Southern

and Northeastern Forest Nursery Association Conference, which was held in Williamsburg, Virginia, on July 11-14, 1994, and the combined Western Forest Nursery Association and the Forest Nursery Association of British Columbia meeting which was held in Moscow, Idaho, on August 15-19, 1994. Tom reminded members that this technology transfer service was paid for by USDA Forest Service, State and Private Forestry funds with the technical assistance of the Rocky Mountain Research Station. Free copies of the Proceedings will be sent to anyone who did not receive one.

There was no other old business, and so the floor was opened for New Business.

New Business:

- 1. Proposed Amendments to Charter.** Tom Landis proposed an amendment to the Charter that would allow the Association to pay for the travel expenses of the host nursery manager for next year's meeting. He explained that this is necessary because most nursery managers do not have adequate travel funding, especially for out-of-state meetings:

"The vice-chairperson of the Association, who will be the host nursery manager for the coming year's meeting, should be able to attend the current year's meeting at the Association's expense. This will be good training for the vice-chair, and will provide better continuity from year to year."

A move to accept this amendment was seconded, and it passed by a voice vote.

2. Location of Future Meetings

As specified in the Charter, the WFCNA meets on even-numbered years on the West Coast and then in the Great Plains/Intermountain area on the odd-numbered years.

1996 - Tom announced that the meeting will be held at the Quality Inn Conference Center in Salem, OR on Aug. 19 to 22. These dates were chosen so that attendees would have the benefit of attending the Far West Show of the Oregon Association of Nurserymen which will be held at the Portland Convention Center on Aug. 22-25. Our host will be Mark Triebwasser of the Weyerhaeuser Aurora Nursery. The agenda and focus topics are still being developed, but field trips are planned to several local nurseries including the Aurora and Weyerhaeuser Turner Nurseries. We also plan to visit some local ornamental nurseries to see their latest technology.

1997 - The meeting will be held at the USD A Forest Service, Lucky Peak Nursery in Boise, ID during the week of August 17-21. Our host will be nursery manager Dick Thatcher and his staff.

1998 - The group decided to ask the Forest Nursery Association of British Columbia if we could meet jointly with them at some nursery in that province.

1999 - The meeting will tentatively be held in Manhattan, KS where the Kansas State Forest Nursery will be our hosts.

2000 - The Association should plan a special meeting for this millenium year, any suggestions should be sent to Tom Landis. One proposal already has been received to have the meeting in the Corvallis, OR area.

Western Forest and Conservation Nursery Association Record of Past Meetings

<u>Year</u>	<u>Dates</u>	<u>Location</u>	<u>Host Nursery</u>	<u>Joint/Special Meetings</u>	<u>Proceedings</u>
1995	Aug. 7-11	Kearney, NE	USDA Forest Service Bessey Nursery Clark Fleege		USDA Forest Service GTR-PNW-365
1994	Aug. 14-18	Moscow, ID	Forest Research Nursery University of Idaho Kas Dumroese, Dave Wenny	Forest Nursery Assoc. of British Columbia	USDA Forest Service GTR RM-257
1993	Aug. 2-5	St. Louis, MO	G.O. White State Nursery Licking, MO Bill Yoder	NE Forest Nursery Association	USDA-Forest Service GTR RM-243
1992	Sept. 14-18	Fallen Leaf Lake, CA	L.A. Moran Refor. Ctr. Davis, CA Laurie Lippitt		USDA-Forest Service GTR RM-221
1991	Aug. 12-16 Draper, UT	Park City, UT	Lone Peak State Nursery Glenn Beagle, John Justin		USDA-Forest Service GTR RM-211
1990	Aug. 13-17	Roseburg, OR	D.L. Phipps State Nursery Elkton, OR Paul Morgan	Target Seedling Symposium	USDA-Forest Service GTR RM-200

Western Forest and Conservation Nursery Association Record of Past Meetings

<u>Year</u>	<u>Dates</u>	<u>Location</u>	<u>Host Nursery</u>	<u>Joint/Special Meetings</u>	<u>Proceedings</u>
1989	Aug. 14-18	Bismarck, ND	Lincoln-Oakes Nurseries Bismarck, ND Greg Morgenson		USDA-Forest Service GTR RM-184
<i>(A complete summary of past meetings of the Intermountain Forest Nursery Association for 1960 to 1989 is contained in the GTR- RM-184).</i>					
1988	Aug. 8-11	Vernon, BC	BC Ministry of Forests Victoria, BC Ralph Huber	Forest Nursery Assoc. of British Columbia	USDA-Forest Service GTR RM-167
1987	Aug. 10-14	Oklahoma City, OK	Forest Regeneration Center Washington, OK Al Myatt, Clark Fleege		USDA-Forest Service GTR RM-151
1986	Aug. 12-15	Olympia, WA	Webster State Forest Nursery Ken Curtis IFA-Toledo Kevin O'Hara Weyerhaeuser-Mima Jim Bryan		USDA-Forest Service GTR RM-137
1985	Aug. 13-15	Ft. Collins, CO	Colorado State FS Nursery Marvin Strachan		USDA-Forest Service GTR RM-125
1984	Aug. 14-16	Coeur d' Alene, ID	USDA-FS Coeur d' Alene Nursery Joe Myers		USDA-Forest Service GTR INT-185
1983	Aug. 8-11	Las Vegas, NV	Tule Springs State Nursery Pat Murphy, Steve Dericco		USDA-Forest Service GTR INT-168
1982	Aug. 10-12	Medford, OR	USDA-FS J.H. Stone Nursery Medford, OR Frank Morby		S. OR Community College Unnumbered Pub.
1981	Aug. 11-13	Edmonton, ALB	Alberta Tree Nursery Edmonton, ALB Ralph Huber		Canadian Forest Service N. Forest Res. Centre Info. Rep. NOR-X-241
1980	Aug. 12-14	Boise, ID	USDA-FS, Lone Peak Nursery Dick Thatcher		USDA-Forest Service GTR INT-109
1979	Aug. 13-16	Aspen, CO	USDA-FS, Mt. Sopris Nursery Carbondale, CO John Scholtes		USDA Forest Service, S&PF Unnumbered Publication
1978	Aug. 7-11	Eureka, CA	USDA-FS, Humboldt Nursery McKinleyville, CA Don Perry		USDA-Forest Service, S&PF Unnumbered Publication
1977	Aug. 9-11	Manhattan, KS	Kansas State FS Nursery Bill Loucks		USDA-Forest Service, S&PF Unnumbered Publication
1976	Aug. 10-12	Richmond, BC	BC Ministry of Forests Surrey Nursery Bayne Vance		BC Ministry of Forests of BC

Western Forest and Conservation Nursery Association Record of Past Meetings

<u>Year</u>	<u>Dates</u>	<u>Location</u>	<u>Host Nursery</u>	<u>Joint/Special Meetings</u>	<u>Proceedings</u>
1975	Aug. 5-7	Missoula, MT	Montana State FS Nursery Willis Heron		USDA-Forest Service, S&PF Unnumbered Publication
1974	Aug. 26-29	Denver, CO	Denver, CO	North American Containerized Forest Tree Seedling Symposium	Great Plains Agric. Council Publication No. 68
1974	Aug. 5-7	Portland, OR	USDA-FS, Wind River Nursery Jim Betts		Unnumbered Publication
1973	Aug. 7-9	Watertown, SD	Big Sioux State Nursery Don Townsend		Unnumbered Publication
1972	Aug. 8-10	Olympia, WA	Webster State Forest Nursery/ H. Anderson IFA-Toledo/ R. Eide Weyerhaeuser-Mima/ J. Bryan		Unnumbered Publication
1971	Aug. 3-5	Edmonton, ALB	Northern Forest Research Center, D. Hillson		Unnumbered Publication
1970	Aug. 4-6	Coeur d' Alene, ID	USDA Forest Service Bud Mason		USDA Forest Service Unnumbered Publication
1969	Aug. 5-7	Bismarck, ND	Lincoln-Oakes Nurseries Lee Hinds/Jerry Liddle		Unnumbered Publication
1968	Aug. 6-8	Salt Lake City, UT	Green Canyon Tree Nursery Clyn Bishop		Unnumbered Publication
1967	Aug. 1-4	Indian Head, SAS	PFRA Tree Nursery Sandy Patterson		Unnumbered Publication
1966	Aug. 30- Sept. 1	Ft. Collins, CO	Colorado State FS Nursery John Ellis		Unnumbered Publication
1965	Sept. 14-16	Carbondale, CO	USDA FS, Mt. Sopris Nursery Sidney H. Hanks		Unnumbered Publication
1964	Aug. 19-20	Boise, ID	USDA-FS, Lucky Peak Nursery Leroy Sprague		Unnumbered Publication
1963	Sept. 11-13	Missoula, MT	Montata State FS Nursery Don Baldwin		Unnumbered Publication
1962	Sept. 13-14	Monument, CO	USDA FS, Monument Nursery Ed Palpant		Unnumbered Publication
1961	Sept. 14-15	Halsey, NE	USDA-FS, Bessey Nursery Red Meines		Unnumbered Publication
1960	Aug. 20	Watertown, SD	Big Sioux Nursery Marvin Strachan		Unnumbered Publication

Northeastern State, Federal and Provincial Nursery Association Minutes of the August 16, 1995 Meeting

On August 16, 1995 the following persons were present at Spring Mill State Park Inn, Mitchell, Indiana for the Annual Meeting of the Northeastern State, Federal, and Provincial Nursery Association:

Dave McCurdy	John Ayton
Bill Yoder	Greg Hoss
Roger Hendershot	Dan DeHart
John Solan	Jerry Grebash
Chuck Bathrick	Marty Cubanski
Calvin Gatch	Spencer Stone
Randy Klevickas	Fred Rice
Fred Prince	John Borkenhagen
Tom Hill	Jim Storandt
Ron Overton	Trent Marty
Alan Peaslee	Mike Mason
Don Houseman	Dave Horvath

The meeting was called to order by Chairman Peaslee at 5:45 P.M. The minutes of the July 13, 1995 meeting in Williamsburg, Virginia were presented. On a motion by John Borkenhagen, second by Jim Storandt and approval of the members present, the minutes were accepted.

Mike Mason was appointed to review the Association's financial records for the past year. Mike reported the books to be in order. On a motion by John Solan, second by John Borkenhagen and approval of the members present the Treasurer's report was approved as presented. The balance as of July 31, 1995 was \$6,307.10 .

OLD BUSINESS

John Solan noted that he would see to it that Larry Ehlers from Ohio and Jean Paul Campanga from Quebec received retirement plaques. It was

also noted that Vermont's State Nursery was closed. Bill Baron who had managed that facility was now working for Vermont.

Park Division

A committee made up of Al Stauder, Spencer Stone and Fred Rice reported on their research into changing the name of the Association. Most of the membership evidently felt the name of the Association should be left as is. Dave McCurdy made the formal motion not to change the name but to leave it as the Northeastern State, Federal and Provincial Nursery Association. On a second by Calvin Gatch and approval from all members present the motion passed. The name is to remain the Northeastern State, Federal, and Provincial Nursery Association.

NEW BUSINESS

Jerry Grebash began a discussion concerning the recognition the Association receives from other organizations and the necessity to invite a representative from the National Association of State Foresters to our future meetings. All present agreed that it would be beneficial to have a liaison with this Association. A suggestion was made that the Executive Committee should pole member Nurserymen and compile a list of current issues affecting them. A member of the Executive Committee should then represent the Association at the next meeting of NASF's Resource Management Committee. This representative could liaison with the Resource Management Committee members on Issues affecting the Northeastern State, Federal and Provincial Nursery Association.

(Note: These minutes have not been approved by the membership.)

Discussion followed on the need for increasing the registration fee for late registrants. Some in attendance felt that the registration fee should remain the same regardless of the date registered by. It was finally concluded to leave this decision up to the host State as the ultimate responsibility for putting the meeting together rests on their shoulders.

The question of who should handle letters of condolence to the families of members who have passed away was addressed. It was agreed that the current Chairman would handle such matters if and when they were brought to his attention by the membership at large.

Up coming meetings were then discussed. The following schedule for meetings was presented:

Connecticut	1996
Minnesota	1997
Maryland	1998
Iowa	1999

Wisconsin offered to fill in one of the years after 1996 if one of the above states were unable to sponsor the meeting.

Length of the Chairman and Vice Chairman terms were then brought into debate. Jim Storandt felt that more continuity could be brought to the Association by extending the terms of these two offices from one year to two years. Because the Association meets only annually, this would allow these officers more time to follow through on projects or plans that resulted from these meetings. As there were no negative comments on this idea, Jim Storandt made a motion to amend the by-laws to make the Chairmanship and Vice-Chairmanship terms two years in length beginning with the 1996 elections. John Solan made a second to this motion and with approval of all members present, the motion was passed.

ELECTIONS

The election committee of Jerry Grebush and John Borkenhagen nominated the following slate of candidates:

Chairman.....Marty Cubanski
Vice-Chairman.....Tom Hill
1 year Nursery Manager....Dan DeHart
2 year Nursery Manager....Don Houseman*
**(2nd year of a 2 year term)*

A motion to close the nominations and cast a unanimous ballot for the above candidates was made by John Solan, seconded by Jim Storandt and approved by all members present. The following is the list of officers for 1995/1996:

Chairman:

Marty Cubanski
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Vice-Chairman:

Tom Hill
Wilson Nursery
Route 4
Boscobel, WI 53805

1 year Nursery Manager:

Dan DeHart
State Forest Nursery
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Concord, NH 03301
603/796-2323

2 year Nursery Manager:

Don Houseman
Union State Nursery
Rt. 1, Box 1331
Jonesboro, Illinois 62952
618/833-6125

Secretary/Treasurer:

David Horvath
Mason State Nursery
17855 N. County Road 2400E.
Topeka, Illinois 61567
309/535-2185

A motion to close the meeting was made by Spencer Stone, seconded by John Solan. With approval of all members present, the meeting was adjourned at 6:50 p.m.

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Indiana Meeting—August 14-17, 1995

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Keywords: Bareroot seedlings, container seedlings, nursery practices, reforestation.

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