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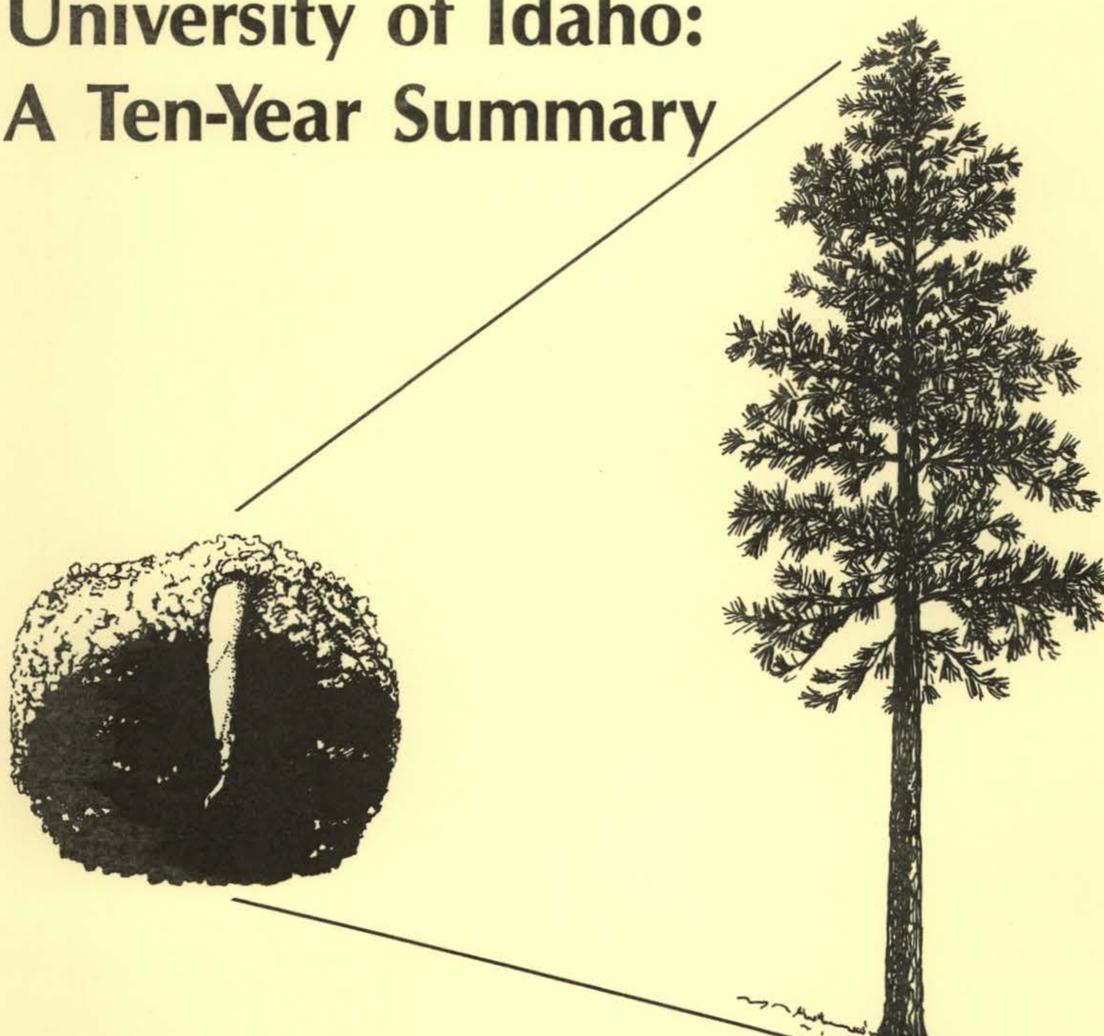
Seed Wafer Research at the University of Idaho: A Ten-Year Summary



by
David L. Adams
Carl E. Dirks
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INTRODUCTION

Coating, pelleting and encapsulating seeds to facilitate sowing and germination have long been pursued as regeneration alternatives in agriculture, range management, and forestry. Although encapsulation and other treatments have several possible benefits, no entirely satisfactory methodology has yet been developed for use in forestry.

Direct seeding as a forest regeneration alternative has the advantage of low relative expense and rapid coverage of large areas. There is also the advantage that seedlings are established in place and are not subject to the root injury and shock associated with transplanting. However, this technique has not been highly successful in the western U.S. due to drought conditions, seeds falling on incompatible microsites, and severe depredation by birds and rodents. As expensive genetically improved seed is more widely used, broadcast seeding will likely become even less acceptable.

Planting of bare-root or containerized seedlings overcomes many of the problems associated with direct seeding. Seedlings are produced in nursery seedbeds or container greenhouses under controlled conditions for outplanting in the field. Although this technique has some definite advantages, it is also much more expensive.

Encapsulation of conifer seed has been investigated at the University of Idaho as an alternate to direct seeding and planting of seedlings. This work began in 1974 at the suggestion of John Dale (then a graduate student). A pilot study was initiated by David L. Adams, professor of silviculture, and Dale, now with the USDA Forest Service. The "seed wafer" idea as developed by Paul E. Johnson (Johnson et al. 1970) at Purdue University in 1969 (DeTar and Johnson 1971) was initially intended for agricultural applications in precision planting of small, irregularly shaped vegetable seeds. The wafer is a round tablet, 1.9 cm in diameter and 0.95 cm thick, composed of a seed (or seeds) embedded in vermiculite and activated carbon bound by methylcellulose. The wafer provides a favorable environment for germination and is easy to plant. Wafers are pressed into the soil by hand or the flat heel of a boot. Various fertilizers, growth regulators, repellents, and fungicides can be added to further enhance germination and early growth. When the encapsulated seed is planted at or just beneath the soil surface, moisture is absorbed from the surrounding soil by the wafer medium and is provided to the seed for starting the germination process (DeTar 1973, Fraser 1973, Powell 1980).

The mention herein of specific products is not to be construed as an endorsement of those products by the authors or by the University of Idaho.

The seed wafer has the following characteristics and potential reforestation advantages.

1. The wafer is hygroscopic and is able to absorb moisture from the surrounding soil, promoting rapid seed germination. The available moisture in the micropores of the vermiculite in the wafers is about 2.5 times that of a silt loam.
2. When wetted, the wafer expands and disintegrates, forming an excellent anti-crustant over the seed (DeTar 1971, 1973). This characteristic helps to overcome problems with soil compaction.
3. The activated carbon in the wafer provides protection against herbicides, improving weed control capabilities (DeTar 1971, 1973).
4. Fertilizers, rodent repellents, and other materials may be added to the wafer mix, enhancing early germination and seedling performance.
5. The wafers are inexpensive to prepare and to plant, reducing regeneration costs.
6. The size and shape of the wafer allow for ease of handling of the seed in the field and for precise spacing of the seed within the area to be regenerated.

The seed wafers used in the projects described in this paper were manufactured in an electrically driven, mechanical piston-cylinder machine built by Paul E. Johnson at Purdue University and borrowed from William DeTar at Western Illinois University. An alternative machine design has been proposed by Walter L. Moden, Jr., professor of agricultural engineering at the University of Idaho. Moden's design features the use of air-operated cylinders and electro-mechanical timers. A machine of this type would greatly reduce manufacturing time, hence, reducing wafer cost. The Johnson-DeTar machine produces an average of 500 wafers per hour. An automated machine could produce an estimated 4000 wafers per hour, reducing the cost from approximately \$12/thousand to less then \$2/thousand (including labor and materials).

The purpose of this paper is to summarize the development of the seed wafer concept at the University of Idaho. Both positive and negative results are reported as an aid to others working with similar projects. Field trials for which follow-up data are not available have not been included. Much of the work reported here is the result of research conducted by graduate students in the Department of Forest Resources. Results from several of the field trials were provided from cooperating companies. Much more detail on most of the reported projects is included in the graduate theses by Dirks (1984), Powell (1980), and Zak (1983).

FIELD STUDIES

Comprehensive replicated, seed wafer field tests involving a wide range of planting sites, dates, species, and planting techniques have not been conducted. However, the field trials which have been established provide case study documentation which indicates conditions where the use of seed wafers may be a viable reforestation alternative. Following are brief descriptions of the field plantings for which results were monitored.

Pilot field study—1974 (John Dale and David Adams)

The study

In a pilot field study, wafers with ponderosa pine and Douglas-fir seed were planted on clearcuts on the Clearwater National Forest in northern Idaho. The seeds were cold-stratified before being enclosed in wafers and spring-planted in May 1974. Planting was done in alternating rows of the two species, with rows two meters apart and wafers at one-meter intervals. The rows were oriented perpendicular to the contour on south- and east-facing slopes on areas that had been site prepared by broadcast burning the previous fall.

Results

Germination and survival rates through the first growing season were 39 percent for ponderosa pine and 9 percent for Douglas-fir. These results, when compared with direct seeding in northern Idaho, were outstanding and stimulated interest in further work.

Fall planting—1974 (David Adams and Don Hanley)

The study

Following the above success with spring planting, a fall trial was conducted. Fall planting would avoid the necessity to stratify the seed, and it was hypothesized that encapsulization in a wafer containing activated carbon would discourage rodent depredation. Wafers containing ponderosa pine and Douglas-fir seed were planted in October 1974 on the same clearcuts as in the previous trial. A one-foot grid was used for planting, with each planting spot marked with a small wood stake.

Results

Rodent depredation was nearly 100 percent within the first week after planting. On some sites, 85 percent of the seeds were extracted from the wafers during the first night. The close planting spacing may have added to the problem, but, regardless, this experience indicated that wafers without some kind of repellent or barrier are vulnerable to rodents.

Field tests of wafer mix and Methocel product—1978 (Luke Powell)

The study

Powell conducted a field test based on growth room results (page 6). Wafers containing ponderosa pine Douglas-fir, and western white pine were planted on three clearcuts located in Latah County, Idaho. Site I was broadcast burned in the fall of 1978 and planted with 2-0 seedlings and seed wafers in the spring of 1979. The seed wafers were planted on northeast and southwest aspects.

Like Site I, Site II was site-prepared by broadcast burning in the fall of 1978. The following spring, Douglas-fir, ponderosa pine, and lodgepole pine seed were aerially seeded by helicopter at the rate of 0.37 kg per hectare. Douglas-fir seed wafers were planted at the same time on a northeast-facing aspect.

Site III was broadcast burned in the fall of 1978 and planted the following spring with western white pine, Douglas-fir, and western redcedar seedlings. White pine seed wafers were planted on a north-facing aspect.

Wafers and control seeds were planted in early May 1979 on each site and evaluated in early fall 1979. The wafers and seeds were planted flush with the soil surface in exposed mineral soil.

Results

Percent germination on all three study sites was very low. The highest germination was 5.33 percent for Douglas-fir wafers on Site II and 5.33 percent for untreated seed on Site I. It should be noted that moisture was very limited during the 1979 growing season. On Site II the 2-0 bare root seedlings experienced only 4-percent survival, and the helicopter seeding on Site I was considered to be a complete failure.

An interesting observation during the field plantings was that the wafers were noticeably moist the day after planting, even though no precipitation occurred. This points to the wafers' ability to absorb water from the surrounding soil. The wafers also acted as an anti-crustant on the soil surface.

An analysis of mortality was conducted on a subsample of seeds and wafers. There was no trend toward waferized seeds receiving more or less rodent depredation than untreated seeds.

This field trial was largely inconclusive due to the atypically dry spring and summer.

Crowsnest Forest Products, Canada—1980

The study

Foresters from Crowsnest Forest Products, a Canadian firm, expressed interest in seed wafers as a means of regenerating large areas of cutover land. Crowsnest planted 60,000 seed wafers containing single seeds of lodgepole pine, Douglas-fir and white spruce, providing the first "operational" trial. Three areas were planted in subalpine fir-lodgepole pine timber types on two large clearcuts. These areas were harvested over a two-year period (1978-1979) and were site-prepared by slash piling in windrows. Transects were established in the planted areas to obtain a sample of germination results.

Seed wafers manufactured in May 1980 at the University of Idaho were sown on the Canadian sites by a temporary planting crew. The lodgepole pine and Douglas-fir wafers were planted within two weeks of manufacture. The white spruce wafers were exposed to hot sunlight and were not planted for a month after delivery.

Results

Mixed germination rates were observed, ranging from 98 percent for a lodgepole pine plot on a moist slope to almost 0 percent for the spruce. Germination appeared to be dependent on available soil moisture through the summer. Seeds in wafers on moist sites germinated well; those on dry sites fared poorly. The fact that none of the white spruce seeds germinated could have been due to the month-long delay in planting and exposure to hot sun in the rear of a truck.

Weyerhaeuser Corporation—1981

The study

A spot seeding study was established by the Springfield, Oregon, district of Weyerhaeuser Corporation in late February and early March 1981. Two plots were established. One plot was on a steep, south aspect, rocky, low-elevation site. It was logged in 1979 and burned in the winter of 1980 for site preparation. The other plot was on a high elevation, gentle slope, easterly aspect with deep soils. It was logged in 1978 and burned twice within two years.

Treatments, all with Douglas-fir seed, included bare seed and seed wafers with and without two-inch Vexar tube mouse barriers, paper shade blocks, and bare seed coated with Endrin and monastrol green. Each seed spot was scalped to mineral soil.

Results

Mouse barriers were necessary as protection for seed, seed wafers and Endrin-coated seed. The barriers also provided protection from soil ravelling. Even on gentle slopes, spot seeding was not successful without the barriers.

Shade on harsh sites significantly increased survival, but had no effect on the more mesic site.

Ease of planting was the most significant advantage of seed wafers. There were no gains in survival.

Table 1. Results of a 1981 Weyerhaeuser seed wafer, barrier, and seed coating study.

Treatment	Percent Survival		
	Harsh Site	Mesic Site	Combined
Wafers Only	0.2%	0.6%	0.4%
Seed Only	0.0%	0.4%	0.2%
Seed/Endrin	0.5%	0.4%	0.5%
Seed, barriers	33.0%	66.0%	50.0%
Wafers, barriers	31.0%	64.0%	48.0%
Seed, barriers, shade	45.0%	65.0%	56.0%
Wafers, barriers, shade	42.0%	67.0%	54.0%

Boise Cascade Corporation—1982

The study

Boise Cascade established two study plots in central Idaho to test the seed wafer concept, together with plastic sheltercones. Douglas-fir and ponderosa pine seed were sown in four treatments near Cascade and Horseshoe Bend, Idaho.

Results

Germination and first-season survival was higher with seed wafers (with or without sheltercones) than with buried bare seed (with or without sheltercones). Seeds and seed in wafers under sheltercones germinated earlier than those without cones. However, as the summer progressed, some of the seedlings under cones died, apparently from high temperatures.

It was observed in planting that the time to sow wafers was not significantly less than that required to plant 2-0 seedlings with a planting bar. A final observation was that after one year, ponderosa pine seedlings germinated from seed (bare or encapsulated) sown in broadcast-burned soil were noticeably more vigorous than seedlings growing in unburned areas.

Table 2. Results of a 1982 Boise Cascade seed wafer and sheltercone study.

Treatment	Percent 1-year Survival	
	Douglas-fir	Ponderosa pine
Seed Wafer	14%	41%
Bare Seed	11%	27%
Seed Wafer/Sheltercone	15%	39%
Bare Seed/Sheltercone	11%	30%

Boise Cascade/University of Idaho—1983 (Carl Dirks)

The study

Two study plots were established on Boise Cascade land to test the feasibility of using fertilizers in the seed wafer and its effect on seedling growth. Ponderosa pine seed were encapsulated in seed wafers, sown in the field, and covered with 10-inch-long Vexar tubes. Half of the wafers contained 123 mg each of sulfur-coated urea at a 6-percent dissolution rate and containing 39.5-percent nitrogen.

One plot was on the east slope of Red Ridge, near McCall, Idaho, and the other was on the Clear Creek Tree Farm near Cascade, Idaho. Each plot contained wafers with SCU and wafers not containing SCU, with the two treatments replicated 15 times with ten seeds per replication. Replications were established in a straightforward, complete randomized experimental design.

Germination counts and seedling height data were obtained two, three and five months after sowing.

Results

Sulfur-coated urea in the seed wafer mix had little effect on seedling height after seven months of growth. Germination, likewise, showed little effect from the SCU. Overall germination rates ranged from 38.2 percent to 50.4 percent on one site and 49.8 percent to 63.2 percent on the other.

Improving field germination of ponderosa pine and Douglas-fir seed by using seed wafers and rodent barriers—1984 (Carl Dirks)

The study

Two field studies were conducted on the University of Idaho Experimental Forest, northeast of Moscow, Idaho. These studies were intended to build on the accumulated experience of eight years of study and field trials to improve the conditions for field germination and to test two types of rodent barriers. A secondary objective was to develop an experimental design for seed wafer field plots that would:

a. reduce sources of variation such that significant differences could be detected with a one-acre study plot and 1000 sample seed plots;
b. readily lend itself to statistical analysis using the assumptions of a normal probability distribution and analysis of variance testing procedures; and
c. serve as a standard design for future study plots.

Both field studies were conducted on sites that had been logged and broadcast burned during the previous summer and fall.

Field Study—spring 1981

This study was conducted on two 0.4-hectare plots, one of which was used to test ponderosa pine seed wafers and the other for Douglas-fir. Each plot was set up in a Latin square experimental design with 2 x 3 factorial treatments. Each treatment was replicated six times. The two sets of variables were:

1. seed treatment variables
   a. encapsulated seed (seed wafers)
   b. buried bare seed (control)
2. protection variables
   a. sheltercones
   b. Vexar cones
   c. no protection (control)

The treatments were randomly assigned to the experimental cells within the plot. For each cell, 28 seeds were sown with a uniform spacing. The end result was a 1.3- by 1.3-meter average spacing.

Site preparation on the Douglas-fir plot (fall 1980) resulted in 50-percent duff reduction and many residual logs. The site for this plot was classified as a *Thuja plicata - Pachistima myrsinites* habitat type (Daubenmire and Daubenmire 1968) and was at an elevation of 950 meters. The soils were deep, moderately well-drained silt loam.

Site preparation (fall 1980) on the ponderosa pine plot was much hotter than on the Douglas-fir study site, resulting in almost complete duff removal. The soil was compacted from tractor yarding.

Elevation was 975 meters, and the habitat type was *Abies grandis - Pachistima myrsinites* (Daubenmire and Daubenmire 1968). The soil type was a silt loam, but was more shallow than on the Douglas-fir plot.

Weather conditions were very wet at time of sowing, and soil temperatures averaged four degrees centigrade. Each wafer was sown in the center of a 30-cm by 30-cm scalp exposing mineral soil.

Data on the number of live seedlings as well as seedling height were measured three months and fifteen months after sowing. Cumulative percent germination and survival data were calculated as a measure of the benefit or impact of the seed treatments and protection treatments. Percent mortality of seedlings was calculated in order to discover any adverse effects of the protection treatments on the seedlings after germination.

Results

Ponderosa pine

For ponderosa pine, the treatment combining a seed wafer with a sheltercone resulted in the best three-month germination and survival at 61 percent. The other physical barrier treatments were not significantly poorer. The treatments resulting in lowest germination were seed wafers without protection (2%) and bare seed with no protection (9%) (Fig. 1).

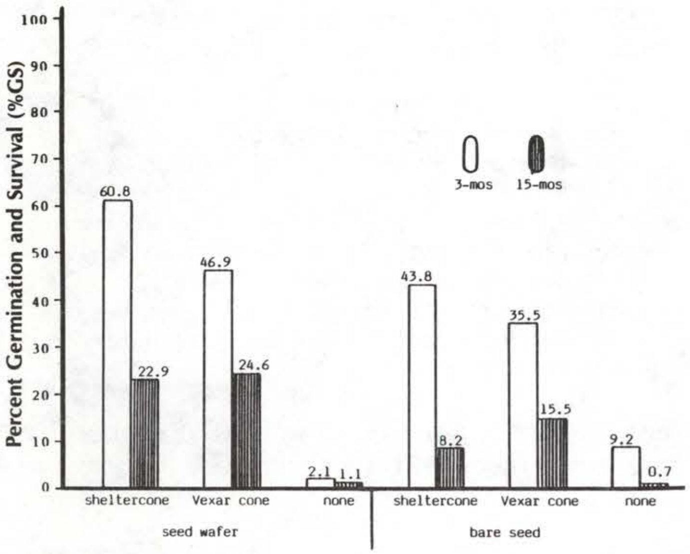

Figure 1. Percent germination and survival for the individual treatments of ponderosa pine in the 1981 field study.

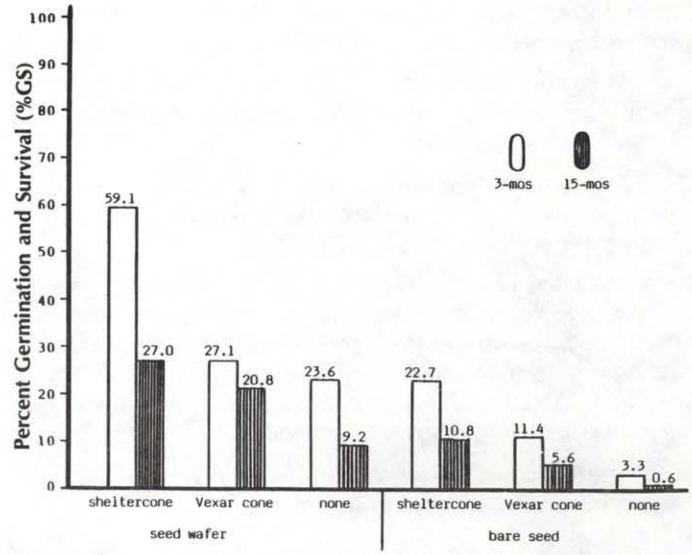

Figure 2. Percent germination and survival for the individual treatments of Douglas-fir in the 1981 field study.

Three-month and fifteen-month measurements indicated that treatments with physical barriers had signifcantly higher percent germination and survival than treatments without. Seed wafers resulted in better germination and survival, but not significantly better.

Seedlings germinated from bare seed experienced a significantly higher death rate (58%) than seedlings from seed wafers (31%). Likewise, seedlings protected by sheltercones had greater mortality (54%) than seedlings protected by Vexar cones (35%). Seedlings not protected had an intermediate mortality rate (47%).

Seedling height differences, although evident early, all but disappeared by 15 months of age.

Douglas-fir

As with ponderosa pine, the highest germination and survival for Douglas-fir occurred with the seed wafer *and* sheltercone treatment (59%). Bare seed with no protection produced the lowest germination and survival (Fig. 2).

Seed wafers produced significantly higher germination and survival than bare seed. Douglas-fir mortality rates were similar to those of ponderosa pine, although differences between treatments were not significant. Seedlings from seed wafers died at a lower rate than from bare seed, and those protected by Vexar cones exhibited lower mortality rates than those with sheltercones or no protection.

Sheltercone-protected seedlings were taller than for other treatments at 3 months, but by age 15 months, Vexar-protected seedlings were taller, although not significantly taller, than sheltercone seedlings.

Field study—spring 1982 (Carl Dirks)

A 1982 study combined trials of ponderosa pine and Douglas-fir on the same plot with treatments as in the 1981 study. A random complete block experimental design, with 2 x 2 x 3 factorial treatments, replaced the 1981 design. The design included 12 blocks or replications of each treatment. Each block contained one experimental cell for each treatment, and like the 1981 trial, a 1.3-meter spacing was used between seed spots.

The 0.4-hectare field plot was located on the University of Idaho Experimental Forest at an elevation of 918 meters and was classified as a *Thuja plicata-Pachistima myrsinites* habitat type. Soils were deep silt loam, and the site was on a southwest-facing slope.

Seed was sown during the first week of May 1982 on saturated soils. Weather conditions were warm and dry at time of sowing, with soil temperature at 7.2 degrees centigrade. Two weeks of warm and dry weather followed seed sowing, causing significant warming and drying of the topsoil. As was done during the 1981 study, a small spot was scalped to mineral soil for each seed spot and seed or wafer pressed into the soil at the center of the spot.

The same data were collected as for the 1981 field study.

Results

The ponderosa pine seed wafer treatments did much better than any other set of treatments. Three-month results for ponderosa pine seed wafers averaged 48 percent, compared to 3 percent for bare seed. Comparable values were 7 percent and 1 percent for Douglas-fir. After

17 months, ponderosa pine seed wafer treatments remained higher in survival (22 %) than bare seed (0.4 %).

The protection treatments for ponderosa pine germination and survival showed no significant differences after either three or fifteen months.

The germination and survival results for Douglas-fir were so low as to make statistical inferences meaningless.

Mortality rates for ponderosa pine seedlings between 3 and 17 months followed a pattern similar to that of the 1981 study. Seedlings from seed wafers had a significantly lower rate than those from bare seed. Seedlings protected by Vexar cones also had a significantly lower rate than those protected by sheltercones.

The few seedlings that germinated from Douglas-fir seed died at a high rate in all treatments.

After 17 months, the ponderosa pine seedlings protected by sheltercones were taller by a significant amount than either Vexar-protected or unprotected seedlings. Seedlings from bare seed were significantly taller than seedlings from seed wafers after 15 months.

There were so few Douglas-fir seedlings that height analysis was difficult.

Physical barrier temperature experiment—1982 (Carl Dirks)

The study

Data collection from the 1981 field study (page 4) indicated a significantly higher level of seedling mortality under sheltercone treatments. In order to determine if high temperatures were a possible cause, an experiment was designed to test the hypothesis that daytime high temperatures inside the plastic sheltercones would be the same as the temperatures outside the cone. A subobjective was to compare the temperatures inside and outside the Vexar cones with those of the sheltercones.

In a field plot located in Moscow, Idaho, five sheltercones and five Vexar cones were installed on mineral soil with no shading. Temperature inside and outside each barrier was measured at soil level, as was that of ambient, shaded air. Measurements were repeated for eight days at mid-afternoon.

Results

Soil-level temperatures inside the sheltercones averaged higher (43.5 degrees centigrade) than outside the cone (41.0 degrees centigrade). Although the differences were not significant, seven of eight replications had higher temperatures inside than outside. Ambient air temperature averaged only 28.1 degrees centigrade.

The reverse was evident for Vexar cones. Temperatures inside the cones were, on the average, two degrees centigrade lower than outside.

GREENHOUSE, GROWTH ROOM, AND ENVIRONMENTAL CHAMBER STUDIES

Wafer size, shape, mix, and compaction used in initial studies were all borrowed directly from experience with small vegetable seeds. An early question was whether this configuration is optimal for conifer seeds. Even more basic was the stated assumption that the vermiculite capsule would prove to be a superior environment for conifer seed germination. Although many such questions remain to be answered, information has been accumulated from several studies which should be helpful in guiding future work.

Effects on germination of activated carbon in the wafer mix—1980 (Luke Powell)

The study

As used in agriculture, activated carbon was incorporated in the wafer mix to protect vegetable seeds by absorbing herbicides, thus improving weed-control capabilities (Kratky and Warren 1971, Detar 1973). As a bonus effect, there was a significant trend toward earlier radicle emergence as the carbon content increased from 0 to 7.5 grams per liter of vermiculite mix (Detar 1973). Kratky and Warren (1971) felt that germination was enhanced by the dark color of the carbon, which supposedly increased the temperature of the microenvironment.

Powell (1980) conducted a growth-room experiment to determine whether the inclusion of activated carbon in the wafer mix affects conifer seed germination. Seed of ponderosa pine, Douglas-fir, and western white pine were tested. Wafers with and without carbon, and control seed were sown flush with the surface in soil flats filled with sterilized sand. The flats were watered every other day and percent cumulative germination was recorded. The germination value (Czabator 1962) was calculated for each treatment and used as the criterion for comparison. This value is a composite expression of both speed and completeness.

Results

The inclusion of activated carbon in the mix gave ponderosa pine seed wafers a significant advantage ($P < 0.01$) over seed wafers without activated carbon. The average germination value of ponderosa pine wafers with carbon was 1.58, compared to an average of 0.92 for wafers without carbon. Germination values of Douglas-fir and white pine wafers showed no significant differences between wafers made with and without carbon ($P > 0.05$).

The controlled environment of the growth room provided optimum conditions for seed germination. In this environment, untreated Douglas-fir and ponderosa pine control seeds had significantly greater average germination values than wafers ($P > 0.10$). Results of this study and the next indicate that under laboratory conditions, wafers inhibited germination in two of the three species. Germination under field conditions was greater for wafers than for control seed. The Laboratory Germination Study—1982 (below) was also designed to test the effect of wafers on seed germination.

Effects on germination of the Methocel product and concentration—1980 (Luke Powell)

The study

This experiment tested the Methocel binder and concentration that yielded the strongest bond possible without inhibiting germination. The results of this study were used to guide formulations used in the remainder of the project (Powell 1980).

Products tested were Methocel A15, Methocel A5, and Methocel E50[1]. Each was tested at concentrations of 30 g/1, 20 g/1 and 10 g/1. The experimental design was a 2 x 3 x 3 factorial that included the activated carbon treatments described on page 6.

Results

Significant interactions were found among the different factor level combinations. Of particular interest was the treatment-binder-concentration interaction because it is the interaction that accounts for all factor level combinations. For example, three white pine seed wafer treatments had significantly higher germination values than controls.

As the result of these tests the following wafer treatments were selected for use:

ponderosa pine—wafers composed of vermiculite and carbon bound with Methocel E50 at concentration of 20 g/1;

Douglas-fir—wafers composed of vermiculite and carbon bound with Methocel A5 at concentration of 10 g/1; and

western white pine—wafers composed of vermiculite and carbon bound with Methocel A5 at a concentration of 20 g/1.

It should be noted that Douglas-fir controls had significantly higher ($P<0.01$) germination values than all wafer treatments of that species, and germination values of ponderosa pine revealed no significant differences ($P>0.01$) among untreated control seeds and four wafer treatments.

Effect of wafers on seed water imbibition—1980 (Luke Powell)

The study

The purpose of this experiment was to investigate the physiological effects wafers have on germination, particularly water imbibition (Powell 1980). Western white pine, ponderosa pine, and Douglas-fir were the species tested. A repeated measures design in randomized complete blocks was used with each treatment replicated three times with 150 seeds per replication. Wafers and control seeds were planted flush with the soil surface in flats filled with sterilized sand. The flats, located in a growth room, were watered periodically to keep the sand moist.

Percent moisture content (dry weight basis) of both waferized and untreated seeds was determined through destructive sampling. Each day seeds were removed from each replication of each species. After residual material was washed away, seeds were blotted dry and weighed. Seeds were then baked at 107°C for 16 hours and weighed again.

Results

The rate of water uptake over time for each species is graphically shown in Figures 3, 4 and 5.

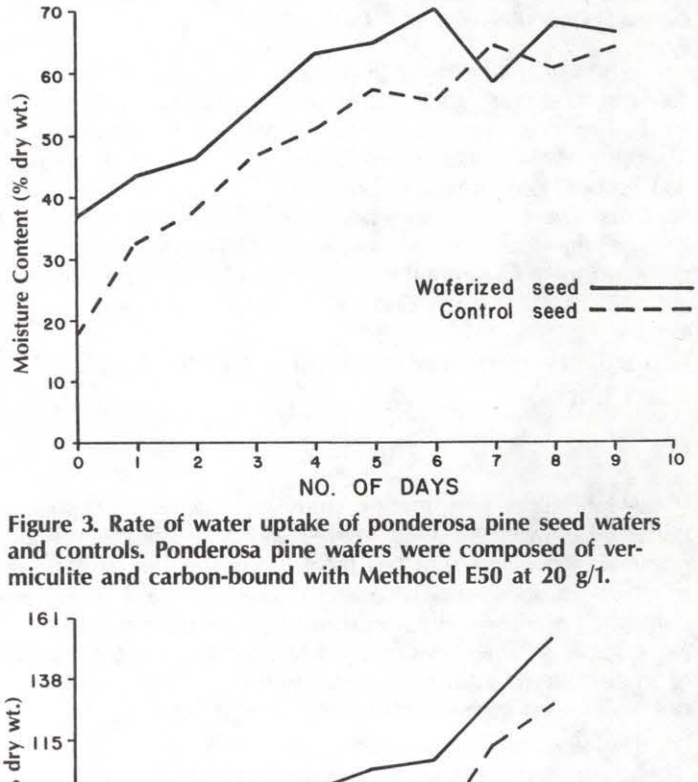

Figure 3. Rate of water uptake of ponderosa pine seed wafers and controls. Ponderosa pine wafers were composed of vermiculite and carbon-bound with Methocel E50 at 20 g/1.

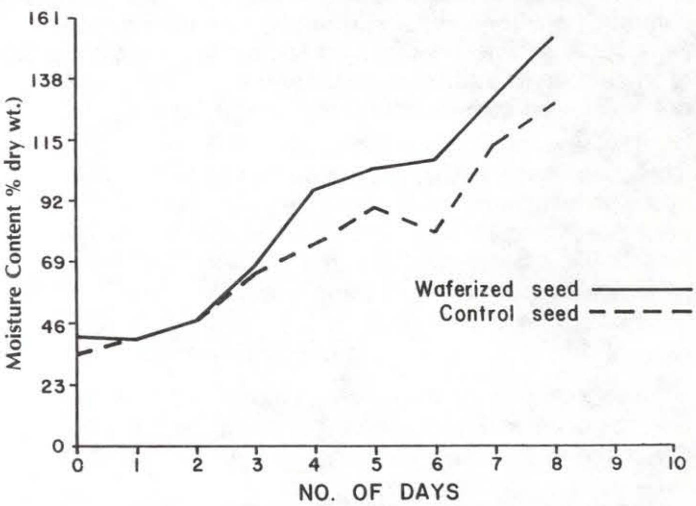

Figure 4. Rate of water uptake of Douglas-fir seed wafers and controls. Douglas-fir seed wafers were composed of vermiculite and carbon-bound by Methocel A5 at 10 g/1.

[1]Trademark of Dow Chemical.

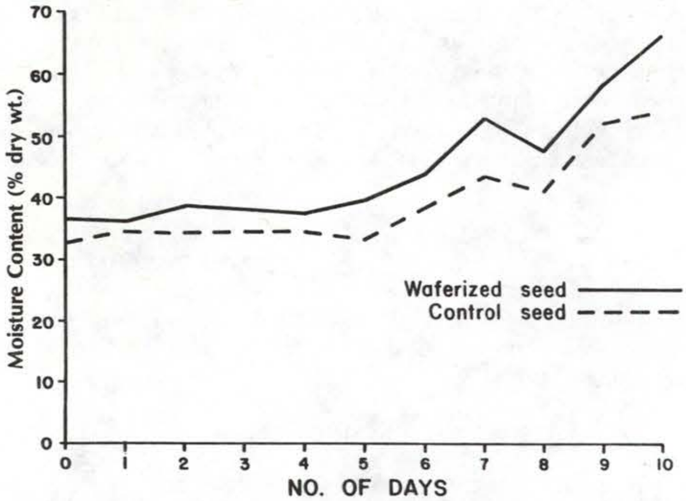

Figure 5. Rate of water uptake of white pine seed wafers and controls. White pine wafers were composed of vermiculite and carbon-bound with Methocel A5 at g/1.

White pine in seed wafers consistently had higher moisture contents (percent dry weight) than did control seeds. However, these differences were not significant ($P > 0.10$). Wafers of ponderosa pine and Douglas-fir also had higher rates of water uptake than their respective controls. These differences became significant for Douglas-fir 4 days into the experiment. The dip in the percent moisture content curve for ponderosa pine wafers at 7 days is most likely due to sampling variation.

Laboratory germination study—1982 (Carl Dirks)

The study

A laboratory germination study was conducted concurrently with Dirks' 1982 field study (page 5). The primary objectives were to test the hypotheses that (1) germination of ponderosa pine and Douglas-fir seed in a controlled environment would not be improved by encapsulation in a seed wafer, and (2) that in the absence of small rodents and birds, protection treatments would not affect seed germination of the two species.

The study was conducted in an indoor growth room with controlled lighting. A random complete block design with treatments identical to the 1982 field study was used. Seeds and seeds in wafers were sown in shallow pans holding sterile sand. Sheltercone and Vexar cone barriers were placed over appropriate bare seed or wafers. Pans were watered whenever the sand showed signs of drying below a depth of one centimeter.

The total cumulative number of germinated seed per cell was counted and recorded beginning with the ninth day of the experiment. Counting continued for 30 days.

Results

For ponderosa pine, the encapsulated seed germinated significantly better than dried bare seed. Unprotected seed also germinated better than either of the two protected treatments.

For Douglas-fir, there were not any significant differences in seed treatments. Seed under sheltercones germinated at a significantly lower percentage than seed with Vexar or no-protection treatments.

Nitrogen fertilization and ectomycorrhizal inoculation of seedlings through use of seed wafers—1983 (Donald Zak)

The study

Nitrogen deficiencies are common throughout Inland Northwest coniferous ecosystems, and silvicultural practices in this region do not promote the maintenance of viable residual populations of ectomycorrhizal fungi. The seed wafer was evaluated as a potential practical method of in-field N fertilization and ectomycorrhizal inoculation of seedlings (Zak 1983). Western white pine seedlings were grown in a controlled environment chamber to determine the effect of *Pisolithus tinctorius* and sulfur-coated urea (SCU) on growth and nutrition. SCU with dissolution rates of 6 percent, 18 percent and 25.7 percent N released in one week were incorporated in seed wafers. Basidiospores of *P. tinctorius* were used to provide inoculation.

Results

Nitrogen fertilization elicited the greatest response in the growth and nutritional parameters under study. Treatments containing 6 percent SCU produced the greatest total biomass, below ground biomass, and foliar N levels. These responses suggest that the 6 percent SCU treatment closely meets the physiological needs of the seedlings under the experimental conditions used.

Ectomycorrhizal root tip development was not affected by inoculation and N fertilization treatments. Therefore, it appears that residual ectomycorrhizal fungi and *P. tinctorius* were equally efficient in the establishment of a symbiotic root-fungus association. Foliar N levels were significantly higher in seedlings inoculated with *P. tinctorius.* Similar but nonsignificant trends were also exhibited in total biomass, below-ground biomass, and foliar phosphorous. These findings support the hypothesis that *P. tinctorum did* produce infection in inoculated treatments.

Significant treatment effects were not apparent throughout the four-month data, but significant differences developed by seven months.

This study established that superior seedlings can be produced from N-fertilized and -inoculated seed wafers in the controlled environment.

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

The various informal field trials and more formally designed experiments with seed wafers lead to the following conclusions and impressions.

1. The concept of a conifer regeneration system through the use of seed wafers has potential and merits further study and development.
2. Application of the methodology with ponderosa pine, a large-seeded species, has been shown to yield germination and survival rates of approximately 50 percent when applied on mesic sites.
3. Satisfactory germination and survival rates with ponderosa pine are highly dependent upon protection from birds and rodents.
4. In the Inland Empire, seed wafers should be sown as early in the spring as possible for best results.
5. Trials with Douglas-fir have been variable and have yielded mostly unsatisfactory results.
6. The one Canadian operational application with lodgepole pine was successful, adding to the evidence that the method is currently most applicable with larger-seeded species.
7. There has been insufficient experience with species other than ponderosa pine and Douglas-fir to provide a basis for recommendation.
8. Seed wafers facilitate handling and planting small seeds.

Additional study recommendations include:

1. Research and development dealing with other species,
2. The study of rodent repellents applied in the mix as an alternative to physical barriers for protection,
3. A systematic set of studies to determine appropriate application in terms of planting site, weather conditions, and planting date,
4. Investigation of additional wafer sizes, shapes, and compaction rates as related to species and planting requirements,
5. The use of multiple seeds per wafer for small, low viability seeds,
6. The development of a high-speed automated wafer machine,
7. The development of a rapid planting system, and
8. An economic study to determine the cost effectiveness of the use of seed wafers as compared with other artificial regeneration alternatives.

LITERATURE CITED

Czabator, F.J. 1962. Germination value: An index combining speed and completeness of pine seed germination. Forest Science 8(4):386-396.

Daubenmire, R., and J.B. Daubenmire. 1968. Forest vegetation of eastern Washington and northern Idaho. Washington Agricultural Experiment Station, College of Agriculture, Washington State University Technical Bulletin 60. 104 pp.

DeTar, W.R. 1973. Seed wafer research, 1971 to 1973. ASDE Paper No. 73-101, presented to Annual Meeting of American Society of Agricultural Engineers in Lexington, Kentucky, June 18-21, 1973. 33 pp.

DeTar, W.R., and P.E. Johnson. 1971. Tomato seed wafers, a progress report. ASAE Paper No. 71-102, presented to Annual Meeting of American Society of Agricultural Engineers in Pullman, Washington, June 27-30, 1971.

Dirks, C.E. 1984. Improving field germination of artificially sown ponderosa pine and Douglas-fir seed by using seed wafers and rodent barriers. Master's Thesis, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow. 100 pp.

Fraser, J.W. 1973. Seed treatments (including repellents). Pages 77-90 *in* Proceedings: Direct Seeding Symposium. Timmins, Ontario, Sept. 11-13, 1973. Department of Environment Canadian Forest Service Publication No. 1339.

Johnson, P.E., C.G. Haugh, G.F. Warren, G.E. Wilcox, and B.A. Kratky. 1970. To plant vegetables with seed wafers. Paper No. J-667, American Society Agricultural Engineers, St. Joseph, Michigan, 30 pp.

Kratky, B.A., and G.F. Warren. 1971. Activated carbon-vermiculite mixture for increasing herbicide selectivity. Weed Science 19:79.

Powell, L.P. 1980. The use of seed wafers on reforestation. Master's Thesis, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow. 88 pp.

Zak, D.R. 1983. The effect of *Disolithus tinctorius* and sulfur-coated urea on the growth and nutritional status of western white pine raised from seed wafers. Master's Thesis, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow. 100 pp.