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Vacuum Collection of Douglas-Fir Pollen for Supplemental Mass Pollinations

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Abstract

An Aget Cyclone dust collector and peripheral equipment were fieldtested for use in vacuuming large quantities of pollen from 30- to 40-foot trees in a Douglas-fir seed orchard. The Cyclone machine (Model 20SN31P) operated without a vacuum bag or filter device, so no blockage or reduction in vacuum efficiency occurred when large volumes of pollen were collected. Vacuum heads were fabricated out of sheet metal, aluminum or Lexan plastic. The Lexan head was preferred because it was durable and weighed only 12 ounces. Lightweight extension poles and hose permitted workers on the ground to gather pollen from as high as 25 feet. The weight of each collection apparatus (22-foot-long extension pole, 25 feet of 4-inch hose, and Lexan vacuum head) was 9.5 pounds. Approximately one-tenth quart of pollen per minute was gathered by four people working simultaneously with the Cyclone machine. Effect of vacuuming on pollen performance was tested by controlled pollinations. The number of filled seeds per cone and percentage of round seed that were filled were significantly greater ($p<0.05$) from vacuum-collected pollen than from catkin-gathered pollen. In vitro pollen germination tests indicated no significant difference between vacuum- and nonvacuum-collected pollens. Use of the equipment and procedures outlined in this report will allow cost-efficient collection of hundred-liter quantities of pollens and greatly enhance supplemental mass pollination in Douglas-fir orchards.

Keywords: Pollination, pollen, pollen collection, supplemental mass pollination, Douglas-fir, *Pseudotsuga menziesii,* vacuuming.

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Introduction

The genetic efficiency of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seed orchards, like most wind-pollinated orchards, is diminished by pollen contamination, selfing, nonrandom spacing and irregular number of ramets per clone, imprecise floral phenology, and variable male and female strobili production (El-Kassaby and others 1988, Erickson and Adams 1989). Most tree breeders would like to genetically upgrade seed quality by having more control over the effective pollen parents. Attempts have been made to achieve the latter through supplemental mass pollination (SMP); but because highly limited quantities of pollen can be collected with existing equipment, SMP has been limited to pollination of individual flower clusters or small areas of trees with hand-held wands or applicators. Cost-effective SMP requires efficient equipment and techniques for pollen collection and pollinations so that a majority of flowers on large trees can be effectively pollinated in a short time.

This report describes the successful efforts of a team of investigators from the Pacific Northwest Research Station, Siuslaw National Forest, and the Missoula Technology and Development Center to obtain, develop, and fieldtest equipment used in gathering the large quantities of pollen needed for SMP operations in Douglas-fir seed orchards. The equipment (vacuum machine, vacuum heads, extension poles, and duct hoses) and collection techniques were evaluated at the U.S. Department of Agriculture, Forest Service, Beaver Creek Seed Orchard near Corvallis, Oregon, in April 1990.

Equipment

Vacuum Machine

Conventional vacuum machines cannot effectively collect large quantities of pollen because they quickly lose efficiency when air movement becomes restricted by the pollen accumulating in the collector bag. This critical design limitation is not present in the vacuum device tested in this report: the Model 20SN31P Aget Cyclone Dust Collector produced by the Aget Manufacturing Company of Adrian, Michigan.[1] Cyclone machines use negative pressure and centrifugal force rather than bags or physical barriers to separate and collect particles.

For safety reasons, the Cyclone Dust Collector was modified to be powered in the orchard by an 8-horsepower gasoline engine, rather than by electric motor. Pulley size was selected in the power conversion so the Cyclone operated at 3300 rpm rather than the 3600 rpm recommended by the manufacturer. The power source, which weighs approximately 500 pounds and is about 7 feet tall, was temporarily mounted on the bed of a pickup truck during pollen collection (fig. 1A). Four duct hoses, each 4 inches in diameter and 25 feet long, were attached to the four attachment points on the inlet manifold (fig. 1B).[2] Four workers can collect pollen at the same time with one machine.

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[1]The use of company or brand name in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the Department of Agriculture of any product or service to the exclusion of others that may be suitable.

[2]Specifications and diagrams for the collector drum, vacuum heads, air inlet manifold, and conversion from electric to gasoline power can be obtained from the U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center, Fort Missoula, Montana.

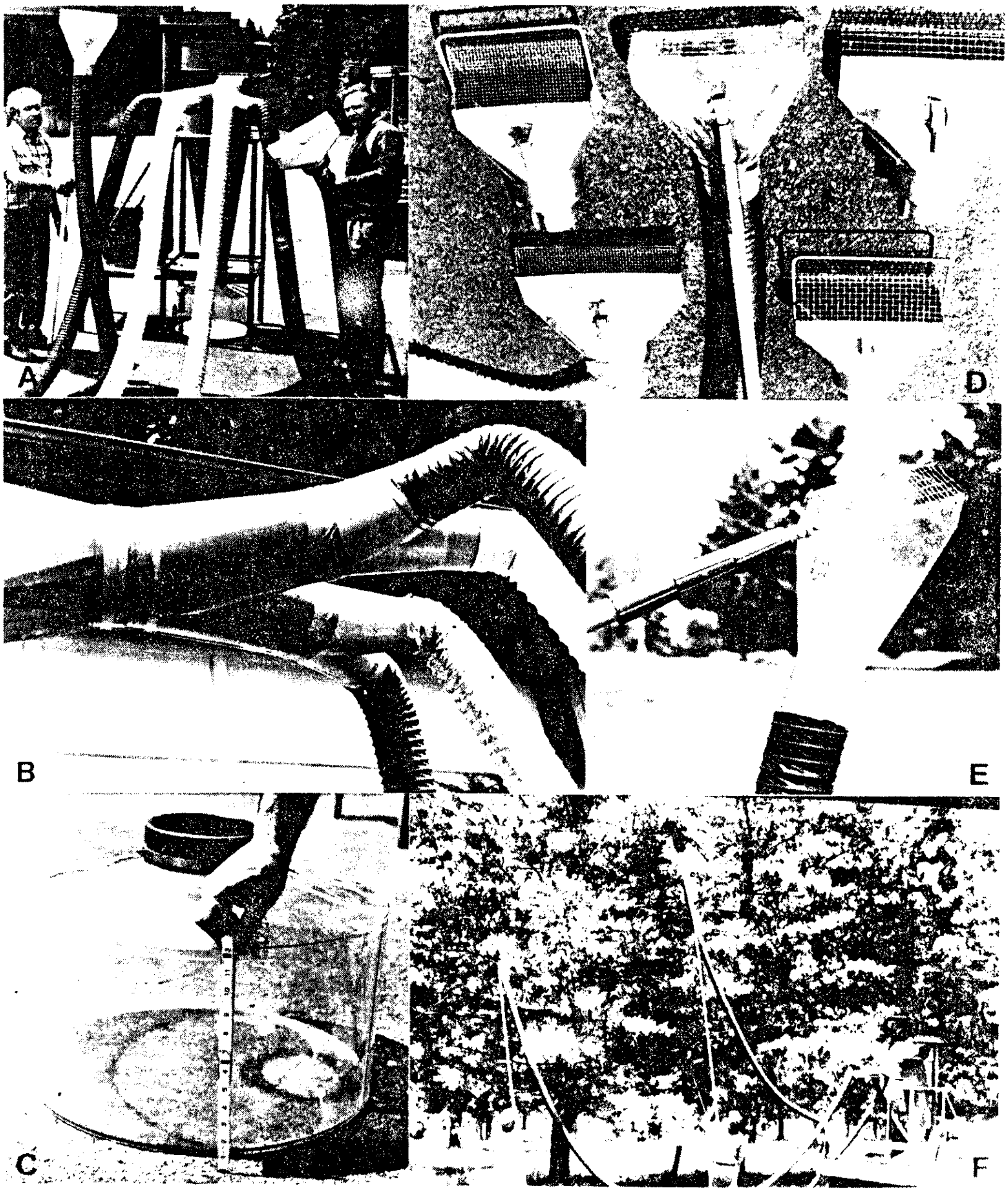

Figure 1–Cyclone dust collector and attachments.
(A) Vacuum with collector and four mounted hoses.
(B) Inlet manifold with 4-inch hoses attached.
(C) Lexan collector drum with rubber connecting gasket.
(D) Vacuum heads showing opening and width dimensions.
(E) Lexan vacuum head attached to extension pole and hose.
(F) Vacuuming pollen from sugar pine trees.

The Cyclone produced a strong vacuum force by moving 1600 cubic feet of air per minute through the machine. The air, pollen, and debris moved through the interior of an inverted, cone-shaped housing (fig. 1A). The rapid movement of air through the inverted cone caused the air to spiral and created the centrifugal force that held pollen, twigs, and old catkins against the outer walls of the housing. Pollen passed from the small opening at the tip of the inverted cone into a 21- by 13-inch collector drum at the base of the machine. Pollen remained in the drum as a result of the combined actions of negative pressure created by the Venturi tube and the centrifugal force of the spiraling air. The drum was fabricated of clear Lexan plastic so pollen could be observed while the machine was operating. Pollen and other lightweight debris gathered along the outer wall of the drum. Heavy debris escaped the centrifugal force, moved along the bottom of the drum to its center, and was vacuumed from the drum through the middle of the opening while new pollen entered along the side walls. Pollen was poured from the opening in the top of the drum after a rubber gasket that maintained an air-tight seal between the machine and collection drum was detached. The Cyclone machine was turned off before the rubber gasket was removed to prevent pollen in the collector drum from being blown into the surrounding atmosphere.

Peripheral Equipment

Vacuum heads--Collection equipment was fabricated at the Missoula Equipment and Technology Center. The vacuum heads resembled the lower assembly of upright vacuum cleaners (fig. 1D). They were constructed of Lexan plastic, aluminum, or sheet metal and were made in 10-, 12-, or 14- inch widths with 2- or 4-inch-wide vacuum openings. The 12-inch-wide heads of Lexan plastic, aluminum, and sheet metal weighed 0.75, 1.2, and 2.4 pounds, respectively. A simple hinged bracket connected each head to an extension pole, thereby allowing the head to rotate vertically to keep the vacuum opening facing the pendant pollen catkins (fig. 1E).

Extension poles--The extension poles were aluminum Unger window-washer poles (Zimmerman Brush Co, 900-T W. Lake, Chicago, Illinois). The poles could be extended from 6.5 to 22 feet by telescoping the three internal sections into place (fig. 1F). Adjustments in pole length were made quickly and easily by simply loosening the clamp for each section and pulling out or pushing in the desired length of pole. Each extension pole weighed just 3.5 pounds, yet each pole supported the vacuum head and 25 feet of hose without breaking or bending excessively.

Hoses--An air inlet manifold attached to the Cyclone was made with attachment points for four 4-inch-wide hoses (fig. 1B). Suitable hose must be strong but lightweight. Initial fieldtesting was done with heavy-duty, vinyl-coated, fiberglass blowing and exhausting duct weighing about 10 pounds per 25 feet. That hose did not puncture or collapse under vacuum, but heavy hose weight contributed to unnecessary worker fatigue. Additional field tests were made with 25-foot lengths of lightweight (2 pounds per 25 feet) plastic and aluminum clothes dryer ducts and medium-weight, vinyl-coated, fiberglass blowing and exhausting hose that weighed 5 pounds. The lightweight aluminum and plastic hoses were punctured by sharp branch studs and collapsed in accordion fashion under the Cyclone's suction (negative pressure). The medium-weight, vinyl-coated, fiberglass hose was prone to twist at the manifold, but the hose did not collapse. It was sufficiently light to avoid causing undue worker fatigue and, even with the twisting, appeared to function satisfactorily. McMaster-Carr's Supply Co. catalogue indicated the fiberglass hose could withstand a negative pressure equivalent to 7 inches of mercury. Collapse of one or more of the hoses reduces the suction of all hoses attached to the machine.

Collection Techniques

The equipment was sufficiently field tested to develop and evaluate techniques that would allow cost-effective collection of large volumes of Douglas-fir pollen. An obvious lesson learned was that four people working from a single machine had to be organized. There was a real potential for confusion and inefficiency when four workers, each with a 22-foot pole and a 25-foot hose, maneuvered around the same tree. When two or more workers simultaneously vacuumed the same tree, the best procedure was for each worker to assume responsibility for vacuuming different quadrants of the crown (fig. 1F). This division of labor helped avoid revacuuming areas that others had already vacuumed. Proper positioning of the vacuum machine in relation to the location of the trees to be vacuumed was critical to productivity. Increasing hose length beyond 25 feet resulted in a reduction in suction. Unused hose connections on the inlet manifold must be kept fully open during vacuuming to ensure maximum air flow through the Venturi device.

Pollen vacuuming was most effective on dry days when peak pollen release occurred. Vacuuming began on the lowest pollen-bearing branches and work progressed systematically towards the top of each tree. The bottom-to-top procedure avoided dislodging pollen from branch areas not yet vacuumed. Two consecutive passes of the collector head along the lower surface of each major branch removed most available pollen. The second pass included bumping the branch with the top edge of the collector head to dislodge additional pollen. Indiscriminately hitting branches followed by attempts to vacuum the pollen from the air was not an effective collection technique because of the large volume of air surrounding the collector heads. Correctly positioned collector heads were no further than 6 to 12 inches from the shedding pollen catkins.

It was difficult to determine when the point of diminished returns was reached. Our observation was that the time to stop vacuuming could best be determined by observing the amount of pollen entering the transparent collector drum during vacuuming. A dense cloud of pollen was visible in the drum during the first two passes of the collector head beneath actively shedding catkins and much less after each additional vacuuming.

The maximum amount of clean pollen collected from a single vacuuming of one tree was 2 quarts. The tree was about 40 feet tall. An average of about 0.1 quart per minute of clean pollen was gathered when the machine and peripheral equipment all functioned properly, the trees had abundant pollen, and the trees were at or near the period of maximum pollen shed. A collection rate of 6.3 quarts per hour should enable four workers using one Cyclone machine to gather several hundred quarts of pollen during peak pollen shed to support a functional SMP program.

Pollen

Handling, Testing, and Storage

Pollen was easily cleaned in the field by passing it through a 50-mesh screen attached to the bottom of a 12- by 12- by 6-inch wood frame. The pollen collected from each tree was cleaned in less than a minute. The cleaned pollen was divided into about 1-quart quantities and temporarily stored in paper pollination bags. At the end of each day, the pollen from each paper pollination bag was spread for drying on a 36- by 36-inch paper located in a 75 °F room at 25-30 percent relative humidity. Pollen should be air dried to 4- to 7-percent moisture content (dry weight basis) before freezer storage or decreased viability occurs (Copes 1985, Webber 1987). Pollen was put in 1-quart polyethylene bags after it dried and was stored without prefreezing in an ultracold freezer at 211 °F. Douglas-fir pollen retains high viability even after 5 years of storage at such moisture and temperatures (unreported data by Copes). Webber (1987) reported successful storage of pollen for several years when the pollen was kept at -14.8 °F and in an atmosphere with little oxygen.

In vitro germination tests (Brewbaker and Kwack 1963), as modified by J.E. Webber[3] were performed on the collected pollen before freezer storage. Nonvacuumed pollen was extracted from collections of catkin-bearing twigs that were actively shedding pollen when the twigs were collected. Both vacuum- and nonvacuum-collected pollen from the same five trees (clones) were evaluated. Pollen collected by vacuuming averaged 92 percent germination (SE = ±1.67) and nonvacuumed pollen 93 percent (SE = ±1.21). Analysis by T-test detected no significant difference in germination percent ($p<0.05$). Vacuumed and nonvacuumed pollen sampled from five clones were used in replicated, controlled pollinations with three other trees. Cones were collected from 89 pollination bags. Seed from two or three cones in each bag was extracted by hand, and each round seed was cut to determine if it was filled or empty. Vacuumed pollen was slightly more effective than nonvacuum-collected pollen in fertilizing and promoting development of filled seeds. The average number of filled seeds per cone from cones pollinated with vacuum-collected pollen was 10.7, nonvacuum-collected pollen 8.2, and wind-pollinated cones just 1.4 (table 1). Data on percentages were transformed to arc sine values and cone and seed data tested by ANOVA (SAS Institute 1985). Differences between vacuumed- and nonvacuumed-pollen treatments in number of filled seeds per cone and percentage of round seeds that were filled were significant ($p<0.05$). No significant differences between vacuum and nonvacuum pollens were detected ($p<0.05$) for number of round seeds per cone or for percentage of pollinated strobili that developed to maturity.

Vacuum-collected pollen may prove superior to hand-gathered pollen because vacuuming collects only fully mature pollen, whereas bags of hand-picked catkins may collect both mature and immature pollen. Vacuuming also shortens the time pollen is processed and handled before it is stored. Viable seed production on study trees was less than normal in both control- and wind-pollinated cones. Damage to female strobili from low temperatures during the breeding season is the suspected cause of a lower number of round seeds and filled, round seeds per cone than is normal in coastal Douglas-fir. In addition, the cones from clone 409 were heavily infected with aphids.

Future Application

The full potential of the Cyclone machine and peripheral equipment for Douglas-fir pollen collection can only be approximated at this time. In 1990, we had a short period in the field to evaluate collector heads of different sizes and materials. Overcoming vacuum hose problems and several other minor technical problems combined to reduce actual time of collection. Results, nevertheless, were so positive that we believe the

[3]Unpublished data. 1988. On file with: British Columbia Ministry of Forests Research Laboratory, Victoria, British Columbia.

Table 1--Cone and seed data for three clones used as females in controlled and wind pollinations[a]

Pollination method and female clone	Cones sampled	Round seeds/cone	Filled seeds/cone	Filled seed efficiency[b]
	- - - - - - - - - - -	Number.new	- - - - - - - - - - -	Percent
Vacuum-collected:				
2	44	40	14	34
17	45	49	12	23
409	29	30	4	12
Mean	38	40	11	23
Nonvacuum-collected:				
2	49	39	13	33
17	42	49	6	13
409	25	30	2	8
Mean	39	39	8	18
Wind pollinated:				
2	9	26	1	3
17	9	34	3	9
409	4	9	1	6
Mean	7	23	2	6

[a]Vacuum- and nonvacuum-collected pollens were used in the controlled pollinations.

[b]Filled seed efficiency = (number of filled seeds divided by the number of round seeds) multiplied by 100.

vacuum equipment and collection procedures described will be useful in Douglas-fir seed orchards.

Employees of the U.S. Department of Agriculture, Forest Service, Dorena Tree Improvement Center near Cottage Grove, Oregon, attempted unsuccessfully to use the same Cyclone Dust Collector for vacuuming pollen of lodgepole pine (*Pinus contorta* Dougl. ex Loud.), white pine (*P. monticola* Dougl. ex D. Don), and sugar pine (*P. lambertiana* Dougl). Pine pollen apparently had different aerodynamics than Douglas-fir pollen. Each pine pollen grain has two air bladders and is generally smaller and lighter in weight than Douglas-fir pollen grains. The vacuum removed the pollen from the pines, but it was blown from the drum along with the debris. Vacuum tests by the Aget Manufacturing Company with sugar pine pollen indicated the Cyclone Dust Collector would retain over 95 percent of entering pollen if a taller collection drum was used. Users who desire to vacuum-collect pollen of species other than Douglas-fir may have to modify the collector drum to accommodate pollen with different characteristics.

Equipment that allows four workers to collect 6.3 quarts of Douglas-fir pollen per hour will drastically change present-day pollen management practices. Rapid collection of large volumes of pollen from select trees will make sufficient pollen readily available. Supplemental mass pollination may become a common procedure in intensively managed orchards and allow orchard managers to exercise greater control over genetic quality and seed recovery. Proper mixing of pollens of desired clones and application of adequate quantity of pollen when a majority of female flowers on each tree first open will help reduce the level of pollen contamination and increase the genetic quality of the resulting seeds. Seed production in young orchards may increase if SMP is performed with stored pollen during years of insufficient orchard pollen production and when used on early or late clones that are drastically out of phase with other clones in flower opening or pollen shed. A reduction in cone collection and seed cleaning costs might occur if fewer bushels of cones are needed to meet seed requirements.

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