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Controlled Pollination Techniques for Fraser Fir

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Several methods of pollen forcing and different isolation bags were tested to develop controlled pollination procedures for Fraser fir. Depending on date of pollen shedding, different methods of forcing are recommended. Standard sausage casing was a good, inexpensive isolation bag.

Fraser fir (*Abies fraseri (*Pursh) Poir.) is a small-to-medium-sized tree native to several high-mountain locations in Virginia, North Carolina, and Tennessee (*6*). It is closely related to balsam fir (*A. balsamea* (L.) Mill.), differing mainly in the length of the ovuliferous bracts. In balsam fir, the bracts are completely enclosed within the scales; whereas in Fraser fir, the bracts are longer than the scales and strongly reflexed (*4*).

Natural stands of Fraser fir are most commonly found at elevations of 4,500 feet and higher in climax association with red spruce (*Picea rubens* Sarg.) and yellow birch (*Betula lutea* Michx. f.). As elevation increases, spruce and birch become less frequent; and on the highest peaks, Fraser fir forms pure stands (*1, 5, 12*).

The climate occurring where Fraser fir grows naturally is cool and humid. The mean July temperature is 15.1° C and annual precipitation averages between 200 and 250 centimeters (*1, 2, 8*). The soil is relatively acidic (pH 3.5 to 5.5) with a substantial amount of organic matter (*10*).

Economic Importance

In the southern Appalachian Mountain region, Fraser fir is the most important Christm as tree. It has a natural Christmas tree shape, strong branches to support ornaments, a pleasant aroma, glossy dark-green foliage, and good needle retention (fig. 1). Vigorous 4- to 5-year-old transplants require 7 to 12 years to grow to a market height of 7 to 8 feet (*11*). Fraser fir commands the highest price and is the most preferred commercial Christmas tree in the region. In 1978, the Fraser fir Christmas tree industry in the western counties of North Carolina produced 660,000 cut trees and generated $6,600,000 of gross revenue.[2]

Figure 1.—*An excellent Fraser fir phenotype.*

Purpose of Study

Responding to the needs of a growing commercial Christmas tree industry, the North Carolina Forest Service established a Fraser fir seedling seed orchard at the Linville Nursery in Crossnore, N.C., during the mid-1960's. The trees were selected from cooperating commercial plantations solely on the basis of phenotype. Today, the trees are 12 to 20 feet tall and many are producing cones. The orchard is intensively managed including such practices as mowing, fertilization, subsoiling, and insect control. However, very little is known about pollen collection, pollen handling, and controlled pollination techniques. With these concerns in mind, a study was designed to evaluate and develop methods of controlled pollination in Fraser fir.

Materials and Methods

Fraser fir in natural stands at high elevations normally begins to flower in mid-May and continues

[1]The author was a graduate student at North Carolina State University when the research for this article was conducted.

[2]Huxster, W. Extension Forester, North Carolina State University. Personal communication.

into early June (*7*). However, the seed -orchard at Linville River is located at a much lower elevation, and flowering is somewhat earlier. Two years of observations in the seed orchard indicate that the reproductive buds start to swell in early April and break around the end of the same month.

Studies of controlled pollination in balsam fir and the eastern spruces indicate that the sausage casing isolation bags commonly used in pine pollination may not be satisfactory, mainly because of the heat buildup within the bag[3] (*3*). These investigators recommend either a nonwoven, white fiber bag with a plastic window or a wet-strength Kraft bag. These isolation bags are impervious to pollen; allow the passage of water vapor; are not subject to overheating; and are strong enough to withstand periods of wet, windy weather.

Three isolation bag types were evaluated. The standard sausage casing bag was tested to determine its performance with Fraser fir. A nonwoven, white fiber bag with a plastic window was also used. Third, the Advance 20 "Rain in the Face" 100-percent Kraft bag was tested. In order to follow female flower development, windows were created in the Kraft bags with sausage casing and sealed with duct tape. All seams and corners of the Kraft bags were reinforced with duct tape. The three bags were supported internally with coils of heavy-gage aluminum wire and were placed on branches bearing female cone buds a few days before bud break.

In combination with the three isolation bags, seven methods of pollen collection were devised and tested. The pollen collection methods used were:

1. Sausage casing bags placed on catkin-bearing branches 4 to 5 weeks before expected anthesis.
2. Sausage casing bags with the desiccant Drierite placed on catkin-bearing branches 4 to 5 weeks before anthesis.
3. Polyethylene bags placed on catkin-bearing branches 4 to 5 weeks before anthesis.
4. Polyethylene bags with the desiccant Drierite placed on catkin-bearing branches 4 to 5 weeks before anthesis.
5. Swollen catkins picked off trees, brought indoors, and placed in paper bags with the desiccant Drierite 1 to 2 weeks before anthesis.
6. Catkin-bearing branches cut from trees, brought indoors, and placed in buckets of water under incandescent light, 1 to 1½ weeks before anthesis.
7. Catkins shedding pollen picked and placed in paper bags in a warm, sunny location.

As pollen was collected by methods 1 through 6, it was dried in the pollen room at the School of Forestry on the North Carolina State University campus at Raleigh. Pollen ready for use was sealed in bottles and refrigerated until needed. Pollen collected by method 7 was used on the same day it was obtained and was applied with a camel's hair brush. Pollen collected by methods 1 through 6 was applied with a bulb syringe developed by Dr. Thomas Perry of North Carolina State University. In all, there were 21 treatment combinations. Because the seed orchard at Crossnore is not clonal, it was impossible to have true replications. Also, there were not enough female cones on any one tree to include all treatment combinations on a single tree. Therefore, all treatment combinations of a single pollination method were placed on the same tree, four trees being used in the study. Each treatment combination was repeated three times.

The female conelets of Fraser fir elongate rapidly, and isolation bags were removed approximately 1 week after pollination to prevent the conelets from pushing up against the bags. Conelet development was checked periodically throughout the summer.

The cones were harvested during the first week of September and

[3]McCormack, M.L., Jr. Extension Forester, University of Maine,. Personal communication.

returned to Raleigh for processing. Paper bags containing cones were placed in a control room under warm, dry conditions. In approximately 2 weeks, the cones had disintegrated and seeds were extracted. A sample of 100 seeds was taken from each seedlot and x-rayed to determine the percentage of viability. The appropriate fixed-effects model is:

$Y_{ijk} = P_i + I_j + (PI)_{ij} + E_{ijk}$

where $_i$ = 1...7; $_j$ = 1...3; $_k$ = *1...3*

P = pollen collection method

I = isolation bag

(PI) = pollen-by-bag interaction

E = error

and the analysis of variance is summarized in table 1.

Results

The mean performance of each treatment combination is summarized in table 2. Analysis of variance reveals that there were no significant differences among 21 treatment combinations. However, the method of pollen collection does show a significant effect (table 3). Discounting sausage casing without desiccant (method 1), the other six methods of pollen collection perform similarly (table 4); and pollen collection effects were not significant. The three isolation bags performed similarly with regard to foreign pollen contamination. But the sausage casing and white fiber bags were able to withstand wet, windy conditions and did not tear at the corners as did some of the Kraft bags.

Table 1.—*Analysis of variance for 21 controlled pollination procedures of Fraser fir*

Source	Degrees of freedom	Error (mean square)
Pollen collection method	*p*-1	$\sigma_e^2 + ki\,\Sigma_i\, p_j^2 \;/\; (p-1)$
Isolation bag	*i*-1	$\sigma_e^2 + kp\,\Sigma_j\, I_j^2 \;/\; (i-1)$
P x 1	(*p*-1) (*i*-1)	$\sigma_e^2 + k\,\Sigma_i\,\Sigma_j\,(PI)\,2_{ij} \;/\; (p-1)\,(i-1)$
Error	*pi*(*k*-1)	σ_e^2
Total	*pik* - 1	

Because flowering is protogynous in Fraser fir, pollen forcing is necessary. The pollen collection method chosen depends on the time of flowering, cost of materials, and ease of method. Bringing cut branches indoors in buckets under incandescent light works well for the trees that shed pollen early. Despite the poor performance of forcing with sausage casing, this collection method will produce pollen if bags are placed only on the north and east sides of late-flowering trees. Pollen is best applied with a bulb syringe after air drying. Isolation bags should be removed as soon as there is danger of the conelets growing against the sides of the bag.

Discussion

Unlike the pines, the true firs produce mature cones in 1 year. Cone initials are laid down in the late summer of the first year, starting to swell in late March to early April of the following spring. Female cones are usually concentrated in the uppermost part of the crown, while males are usually located in the middle one-half. Rarely do males and females occur on the same branch. Female cone buds emerge from the tops of branches of the previous year's growth, while males are clustered on the undersides of branches.

Bisporangiate cones do occur in Fraser fir, although rarely. In these reproductive structures, the male

Table 2.—*Percentage of filled seed per treatment combination in test of controlled pollination methods in seed orchard Fraser fir*

Pollen collection[1] method	Isolation bag			
	Sausage casing	White fiber	Wet-strength Kraft	Mean
1	1.33	2.00	0.00	1.11
2	7.33	15.33	18.00	13.55
3	39.33	13.00	13.00	21.78
4	17.33	7.00	5.00	9.78
5	23.33	17.00	28.33	22.89
6	23.33	6.33	15.00	14.89
7	28.33	17.00	16.33	20.55
Mean	20.04	11.09	13.66	

[1] 1 = forced on tree with sausage casing; 2 = forced on tree with sausage casing plus desiccant; 3 = forced on tree with polyethylene; 4 = forced on tree with polyethylene plus desiccant; 5 = forced indoors in paper bag with desiccant; 6 = forced indoors under incandescent light; and 7 = wet pollen applied with a brush.

Table 3.—*Analysis of variance for controlled pollination study in seed orchard Fraser fir*

Source	Degrees of freedom	Mean square	F-value [1]
Replication	2	0.0069516	0.26n.s.
Pollen collection method	6	.1624108	6.19**
Isolation bag	2	.0805635	3.07n.s.
Pollen x bag	12	.0262013	1.00n.s.
Error	40	.0262391	

[1] ** = significant at 0.01 level; n.s. = not significant.

cone is located on top of the female cone. A cone of this type is capable of producing sound seeds.

Based on 2 years of observation in the Linville River Fraser fir seed orchard, female flowers break bud between mid- and late April.

Reproductive bud break appears to be dependent on temperature. Warm, sunny days at this time seem to speed the onset of bud break. Following bud break, maximum receptivity is reached within 1 week. The sequence of reproductive structure development in this orchard is protogynous, with the period of maximum pollen flight occurring after the period of maximum receptivity.

After pollination, conelet growth is rapid with cones reaching full size by mid-summer. As maturation proceeds, the scales harden and become woody. Seed dispersal occurs in early September as the cones disintegrate, leaving the central axes on the trees.

Using this background information on the reproductive cycle of Fraser fir, methods of controlled pollination were tested. Analysis of variance revealed that, while there were no significant treatment combination effects, the effect of the pollen collection method was significant (table 3). Discounting the use of sausage casing without a dessicant from the analysis, the other six methods were about equal in producing viable pollen. In this particular crossing study, all bags of a given pollination treatment were placed on a single tree. It is possible that the tree used to test forcing with sausage casing does not produce a high percentage of filled seeds. It is also possible that placement of sausage casing on the south and west sides of trees caused the death of pollen. Forcing with sausage casing plus desiccant did result in successful pollinations.

Recommendations

Based on the reproductive cycle, time of flowering, cost of materials, and ease of methods, the following guidelines are offered for the controlled pollination of Fraser fir.

1. Because flowering is protogynous, pollen forcing is absolutely necessary. It appears that all of the forcing methods tested will deliver viable pollen. However, depending on the time of flowering, different methods should be used.
2. If a proposed pollen parent has a history of early or average pollen anthesis relative to the orchard, cut branches bearing swollen, but still-moist, catkins and place them in buckets of water under incandescent light. This method will start producing pollen in a few days.
3. If a proposed pollen parent has a history of late pollen anthesis relative to the orchard, forcing in place with sausage casing is recommended. Bags should be placed on catkin-bearing branches, preferably on the north and east sides of the tree, to prevent sun scorching. These bags should be in place at least 4 weeks before anthesis.

Table 4.—*Analysis of variance for controlled pollination study, discounting forcing with sausage casing*

Source	Degrees of freedom	Mean square	F-value[1]
Replication	2	0.013561	0.46n.s.
Pollen collection method	5	.061736	2.09n.s.
Bag	2	.094133	3.18n.s.
Pollen x bag	10	.028335	.96n.s.
Error	34	.029599	

[1] n.s. = not significant.

4. Once catkins start to open and pollen is visible, the pollen should be extracted by a forced-air system similar to the one used by the North Carolina State University-Tree Improvement Cooperative (9). This is a critical step in the process. Fraser fir pollen is highly susceptible to molding. If the moisture content is not reduced rapidly, mold starts to form and the pollen is useless.
5. Once pollen is extracted and dried to the 8- to 10-percent moisture content, it should be stored in a cool place until needed. The sooner pollen is used after extraction the better. In the field, pollen lots should be kept in an ice chest until needed.
6. Application of pollen to the female flowers is best accomplished with some type of bulb syringe system. A bulb syringe pollinator developed by Dr. Thomas Perry performed well in this study. Pollen should not be applied with a brush because the method is too time consuming and allows ample opportunity for foreign pollen contamination.
7. The sausage casing bag is suitable for use as an isolation bag. This bag is inexpensive, durable, and easy to make. The largest size available should be used because the flowers of Fraser fir elongate rapidly following pollination. For this same reason, bags should be removed as soon as there is danger of flowers pushing against the bag.

8. A durable tag bearing the identity of the particular cross should be placed loosely around the branch bearing the pollinated flowers. Any other flowers in the vicinity that might cause confusion at harvest should be removed.
9. Cones should be picked when they are woody but still firm. In the Linville River orchard, this occurs during the first week of September. Unnecessary delay may result in a loss of the seeds.

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