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The Effect of Pollination Bag Type on Fruit Set and Quality in Pecan Hybridization.

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Abstract

Different pollination bag types were investigated in controlled crosses in pecan to determine their effect on internal bag temperatures, nut set, and nut quality. Bag types examined included white and brown paper bags, cellulose casings, and polyester fruit breeding bags. Brown paper bags and large white paper bags had the least internal heat buildup during the daylight hours. No differences were detected among bag types for the number of nuts produced per cluster. While some bag types produced smaller nuts, all nuts were of suitable quality for breeding purposes. This research indicates that white paper bags may be a useful substitute for the cellulose sausage casings that have traditionally been used in pecan breeding.

Pecan is a native North American tree crop of recent domestication. Identification of superior genotypes has been active since the latter half of the 19th century, and many important cultivars have been selected from native or seedling trees. Modern breeding programs make use of large seedling progenies produced from controlled crosses (4, 5). Systematic pecan breeding has been ongoing since the 1940's and has resulted in the release of cultivars with substantial improvements in key horticultural characteristics. Pecan cultivars are highly heterozygous and progeny from controlled crosses show substantial variation for most characters. Because of this variability, large numbers of progeny must be produced and screened in a breeding program in order to have a good likelihood of producing a favorable genotype.

Pecan flowers are produced at different times (dichogamy) and in different locations in the same tree (monoecy). Pistillate flowers are arranged as a spike at the tip of new shoot growth and can consist of one to several individual flowers depending upon cultivar and shoot vigor. Staminate flowers are arranged as a catkin and are produced from lateral buds near the end of the previous seasons growth. Pecans are normally cross-pollinated in nature as a result of dichogamy. Because most pecan trees are planted in orchards of many trees, and native or escaped trees are often in the surrounding vegetation, pecan pollen is ubiquitous during the flowering season. Therefore, to produce controlled crosses female flowers must be isolated from the surrounding environment to prevent fertilization with stray pollen. The usual method of isolation is to encase the female flowers in a transparent tube of cellulose sausage casing (4). Casings are cut into 15 cm length and one end tied closed with a string. The casing is then slipped down over the female flower spike and tied onto the stem which has been wrapped in cotton to prevent damage to the tender new growth. When the flowers are receptive, pollen is puffed into the bag through the use of a hypodermic needle.

Few empirical studies have been done on the effect of bag materials on nut set in pecan breeding after the initial work with cellophane casings (7). Large brown paper bags produced more nuts per cluster than cellulose casings, but they required wire hoops for support, limiting their usefulness in large-scale applications (8). In wheat crosses, bags made out of cellulose dialysis tubing produced higher internal temperatures than white paper bags, possibly leading to physiological damage of the shoots (1). Recently we have had difficulty in obtaining the cellulose casings

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for use in our hybridization work and undertook this study to determine if any of the commonly available pollination bags would be a suitable replacement.

Materials and methods

Five bag types were employed for this study: 1) 3 cm diameter cellulose sausage casings, cut into 15 cm lengths and sealed at one end by folding and stapling, 2) small white water-proof paper shoot bags 5.1 cm x 2.5 cm x 20.3 cm (Lawson 217L, Lawson, Northfield, IL), 3) large white water-proof paper shoot bags 6.4 cm x 2.5 cm x 20.3 cm (Lawson 218), 4) large brown water-proof paper shoot bags 12.1 cm x 6.4 cm x 39.4 cm (Lawson #500), 5) white polyester fruit breeding bags 16 cm x 16 cm x 30 cm (PBS 3d/60, PBS International, Scarborough, UK).

A mature 'Stuart' and a mature 'Farley' tree were used in the experiment. The trees were grown at the Coastal Plain Experiment Station in Tifton, Ga. Tree culture was according to University of Georgia guidelines for commercial pecan production (2). Bag treatments were randomly applied to flowering shoots approximately one week before receptivity. Bags were applied by wrapping the stem with cotton batting, folding the leaves back from the flower cluster, and sliding the bag over the cluster. The bag was then sealed by tying a string around the base of the bag with the cotton serving to seal the bag and protect the tender shoot from damage. Because of their size, the polyester bags covered the entire new shoot and were sealed by tying off on the previous year's growth. The experiment was organized as two completely randomized designs. Treatments consisted of each of the five bag types as well as randomly tagged flower clusters left as unbagged controls. Each treatment was replicated on 40 flowering shoots located on all sides of the tree. Pollen was applied to 25 of the 40 bags in each treatment. The remaining 15 bags were not pollinated in order to serve as unpollinated controls.

Receptivity was assessed by applying a small amount of pollen onto several non-experimental stigmas and gently blowing on them to determine if the pollen would adhere (6). When trees were judged to be receptive, April 24 for 'Stuart' and April 26 for 'Farley', pollen was applied by inserting a hypodermic needle into the bag and puffing a small amount of pollen into the bag in the vicinity of the stigmas. The needle hole was then sealed with a drop of glue. Pollinations were repeated two days later in order to pollinate flowers with delayed receptivity. The 'Stuart' tree was pollinated with 'Desirable' pollen, and the 'Farley' tree was pollinated with 'Oconee' pollen collected during the current season. Unbagged control shoots were pollinated by naturally occurring wind-blown pollen. It was not possible to control the amount of pollen reaching each stigma, but several stigmas were removed from each bag treatment after the first pollination and examined under a microscope for the presence of adhering pollen. All stigmas had from 50 to several hundred pollen grains, so lack of pollen did not appear to be a limiting factor in pollination success. Stems were marked according to bag type used and bags were removed 21 days after the first pollination.

Temperatures within bags were determined over a 5 day period beginning on May 2, 2001. Thermocouples were attached to flowering shoots using masking tape so that the ends were positioned near the middle of the bag. The wires were then loosely covered with cotton batting to shield them from direct heating from solar radiation. The shoot and thermocouples were then bagged with each of the five bag treatments replicated on two separate shoots for a total of ten bagged thermocouples. Thermocouples were positioned on the exterior shoots of the west side of the tree so that all treatments would receive maximum afternoon sunlight. Outside air temperature was determined by attaching a thermocouple to a branch near the bagged shoots and shielding them from direct solar radiation. Thermocouples were connected to a data logger (CR10X, Campbell Scientific, Inc., Utah) and an AM416 Relay Multiplexer (Campbell Scientific). The data logger was programmed to record readings every 10 min and store the hourly averages.

Nuts from tagged terminals were collected in the autumn when the shucks had begun to dehisce. The number of nuts pro-

Table 1. Maximum difference between interior bag air and exterior air temperature.

Bag Type	(Interior Bag - Exterior Air) Temperature (°C)^Z					
	May 2	May 3	May 4	May 5	May 6	5-Day average
Large white paper	5.9^Y	4.1	5.4	4.0	3.5	4.6 b^X
Small white paper	8.8	6.2	8.1	7.6	7.2	7.6 a
Brown paper	2.7	2.4	4.0	3.4	3.5	3.2 b
Polyester	7.6	5.4	8.9	7.0	7.2	7.2 a
Cellulose	6.4	4.7	8.1	8.2	7.6	7.0 a

^{Z}Maximum hourly difference between bag interior temperature and outside air temperature for each 24 hour period.
^{Y}Values represent the average of two replicate bags.
^{X}Mean separation within columns by Duncan's multiple range test at $P \leq 0.05$. Values sharing a common letter are not statistically different.

duced on each shoot was counted. Nuts were allowed to air dry at room temperature for three weeks. Individuals nuts were then weighed and their volume determined by water displacement. Specific gravity was determined for each nut as weight / volume. Data were analyzed using one-way analysis of variance with differences between treatment means determined by Duncan's multiple range test (SigmaStat).

Results and discussion

Pecan pollination in southern Georgia takes place in the late April and early May when the weather is typically very sunny and often quite warm, especially late in the pollination season. Under these conditions temperatures inside of pollination bags can increase to damaging levels (1). Thermocouples were used to monitor temperatures inside of the different bag types. Temperatures were elevated above outside temperatures within all bag types during the daylight hours. It appears that all the white bags, while not transparent, allowed enough solar radiation to pass through the bag to allow greenhouse heating. The polyester bags, which are quite large and built out of a breathable fabric were no better than the paper bags at reducing heat

Table 2. Effect of pollination bag type on nuts per cluster and nut quality produced from artificial hybridization in a 'Stuart' and 'Farley' tree.

Treatment	Nuts per cluster	Nut weight (g)	Nut volume (cc)	Nut specific gravity
'Stuart'				
Unbagged control	1.5 a^Z	9.6 a	12.6 a	0.76 a
Large white paper	1.1 ab	9.3 ab	12.8 a	0.73 ab
Small white paper	0.7 b	8.9 bc	12.3 ab	0.72 b
Brown paper	0.8 b	8.6 c	11.4 c	0.75 ab
Cellulose	0.8 b	9.2 abc	12.3 ab	0.75 ab
Polyester	0.8 b	8.6 c	11.9 bc	0.72 b
'Farley'				
Unbagged Control	1.7	6.6 a^Z	10.2 a	0.65
Large white paper	1.6	5.9 b	9.3 b	0.63
Small white paper	1.3	6.1 ab	9.6 b	0.64
Brown paper	1.9	6.5 ab	9.8 ab	0.66
Cellulose	1.0	5.8 b	9.2 b	0.63
Polyester	1.3	6.2 ab	9.8 ab	0.63

^{Z}Mean separation within columns by Duncan's multiple range test at $P \leq 0.05$. Values sharing a common letter are not statistically different.

buildup (Table 1). The large white and brown paper bags produced less heat buildup than the other bag types (Table 1). The large white paper bags reached a maximum of approximately 6°C above the outside temperature, and the brown paper bags reached a maximum of 4°C above outside temperature. The cellulose, polyester, and small white bags had temperatures more than 8°C above outside temperatures, resulting in inside temperatures as high as 42°C during this period.

The primary function of the pollination bag is to isolate the flower cluster from stray pollen. Since all bag types were equally successful in isolating unpollinated shoots from stray pollen, as judged by the lack of nut set in the unpollinated control shoots, the number of nuts per cluster produced becomes the most important determinant of pollination bag efficiency. All bag types except the large white paper bags produced fewer nuts per cluster than the unbagged control shoots on the 'Stuart' tree (Table 2). No difference in the number of nuts produced per cluster were found among the treatments in the 'Farley' tree.

The quality of nuts produced from each treatment was evaluated by measuring nut weight, volume, and specific gravity. In the 'Stuart' treatments, the brown paper and polyester bags produced lighter nuts than the unbagged control or large white paper bags. In the 'Farley' tree no differences were found among the bag types although the large white paper bags and polyester bags produced lighter nuts than the unbagged control (Table 2). Brown paper bags produced smaller nuts than all other treatments except polyester bags in the 'Stuart' tree, while no significant differences were detected among bag types for nut volume in the 'Farley' tree (Table 2). Specific gravity is a measure of kernel development, with a higher specific gravity indicating a greater degree of kernel development (3). No differences were detected among the bag types for specific gravity, although the small white paper bags and polyester bags had lower specific gravity than the control shoots in the 'Stuart' tree. This indicates that while some bag treatments produced smaller nuts, the kernels were well developed in all the bag treatments. Since nut size is not strongly associated with germination or seedling growth (5), all treatments appear to produce nuts of sufficient quality for breeding purposes.

Overall we found the large white paper bags to be the most useful type employed in this experiment. Internal bag temperatures were lower in this bag type than they were in the cellulose casings, polyester bags, and small white paper bags. They were easy to apply and produced good seed set with adequate quality. In addition, their color makes them easy to see in the tree canopy during pollination, increasing the speed of this process. The cellulose casings that have traditionally been used produced high internal temperatures and required more labor to produce, since individual bags must be cut to length and sealed on one end.

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