least thought to be adversely correlated, this genetic information and expertise is vital because both the base and ELSTON indices can clearly lead to unacceptable responses from selection. The ability of the SMITH-HAZEL index to take account of phenotypic and genetic correlations, and to be applied with restrictions which limit changes in traits (as a protection against effects of uncertain or non-linear economic weight functions), make it a powerful tool for assuring satisfactory genetic gain when traits are adversely associated.

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Male Sterility in Alnus glutinosa (L.) Gaertn.

By C. LINARES BENSIMON

Department of Forest Genetics and Forest Tree Breeding,
Georg-August-University Göttingen,
Büsgenweg 2, D-3400 Göttingen, Fed. Rep. of Germany

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Summary

The discovery of "non-structural" male sterile plants in *Alnus glutinosa* is reported. Plants bearing mutant male sterile flowers, possessing no apparent morphological differences to normal flowers, produce inviable pollen grains. Pollen viability was determined by germination tests in a medium which permitted 60—80% germination of control pollen if the pollen grains had been previously hydrated.

Key words: Tree, pollen, steritity, method.

Zusammenfassung

Es wird über die Auffindung „nicht-strukturell" männlich-steriler Bäume bei *Alnus glutinosa* berichtet. Männlich-sterile Bäume unterscheiden sich in ihren Blüten morphologisch nicht von normalen Bäumen, erzeugen aber nicht-viablen Pollen. Das in Keimprüfungen zur Untersuchung der Pollenviabilität verwendete Medium erlaubte die Keimung von 60—80% von Kontrollpollen, wenn die Pollenkörner zuvor Wasser aufgenommen hatten.

1. Introduction

The species of the genus Alnus, as well as all *Betulaceae*, are commonly classified as monoecious. In some families there are species which were classified on morphological grounds as monoecious or hermaphrodites, until careful pollination studies revealed that their sexual systems possess other components. Forest trees of great economic importance in the genera *Cedrela, Swietenia, Toona, Entandrophragma* and *Trichilia* of the family *Meliaceae* are illustrative examples (STYLES 1972).

During artificial pollination work carried out with other objectives (LINARES BENSIMON 1984), in March, 1982, the author found three individuals of *Alnus glutinosa* whose male flowers, although normal in appearance, yielded no pollen.

Later observations of anthers of these three trees revealed that even though most anthers dehisced, in all cases the pollen remained adhered to the internal wall of the anthers, forming conglomerates. Apparently these trees were male sterile and in March 1984, experimental tests of pollen viability were carried out. The results are the object of this paper.

2. Material and Methods

The three individuals of *Alnus glutinosa* chosen for this study are located in two plots of the progeny test conducted by the Forest Experimental Station in the state of Hessen (Fed. Rep. of Germany), Compartment Nr 216b of the forest office of Gahrenberg.

These trees were planted in 1969 (WEISGERBER 1974) and, according to the records of this Station, the material originated by crossing the clones R10 and R4 growing in a seed orchard. For this study, the trees are labeled 209-4, 209-7 and 161-4 (plot number-location in the plot). Other trees known to produce abundant pollen were used as controls. A stereomicroscope and a photomicroscope were used to

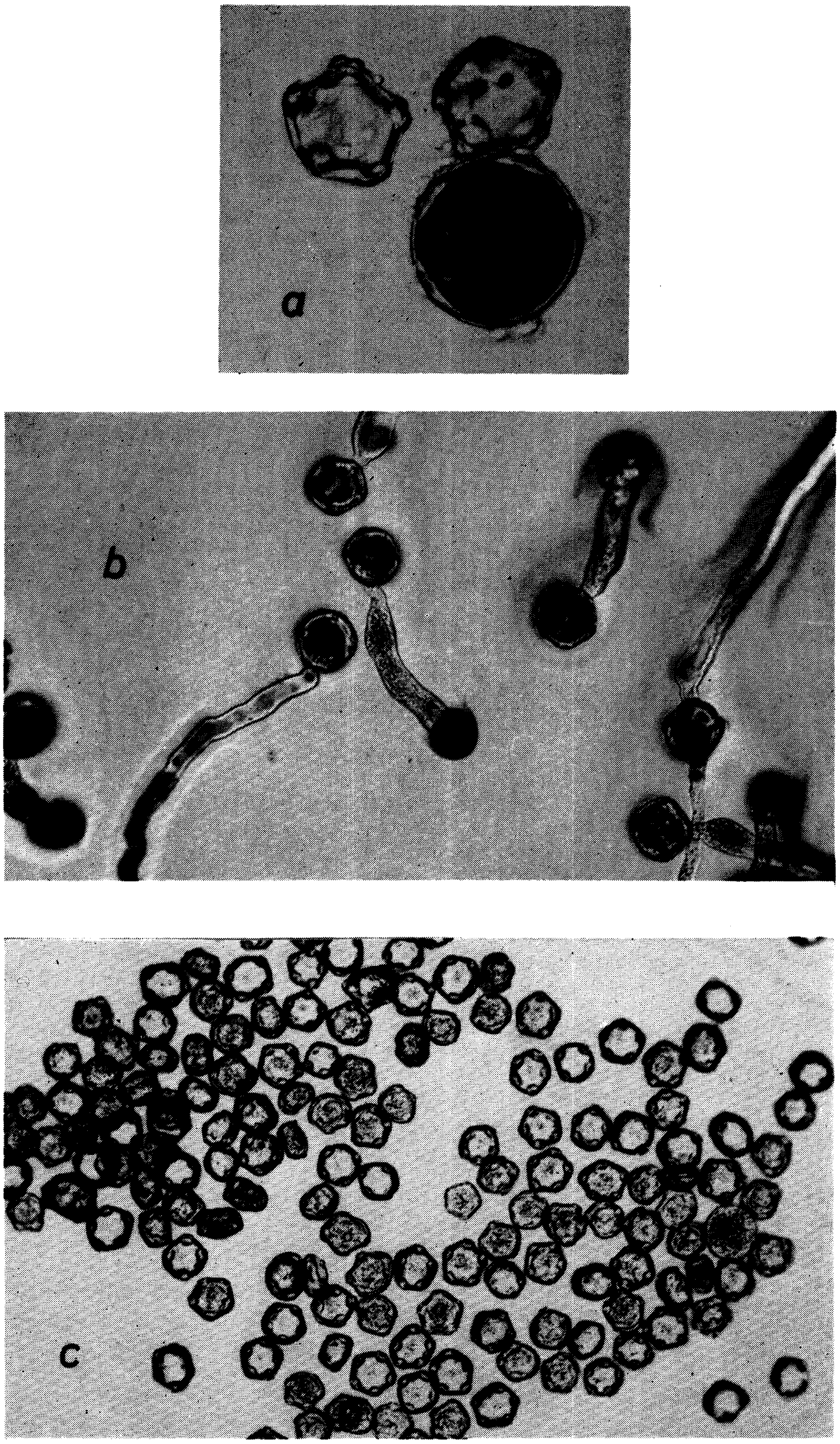

Figure 1. — a) Hydrated and non-hydrated pollen grains, (approx. 640 ×) b) Germinated pollen grains of male fertile individuals. (approx. 384 ×) c) Ungerminated pollen grains of male sterile individuals. (approx. 384 ×)

observe anthers and pollen grains respectively. Pollen viability was determined by germination tests in an artificial medium containing: 10 mg H_3BO_3, 10 mg $CaCl_2$, 20 g sucrose and 1 g agar in 100 cc of twice distilled water. The mixture was boiled in a hot water bath for 20 minutes, then cooled and poured into petri dishes.

After hydration for 1 to 2 hours in a moist chamber with approximately 100% relative humidity at 26° C, the pollen grains were dispersed in the germination medium contained in the petri dishes, which were then placed in the same moist chamber for 24 hours. Stain tests with acetocarmine were also carried out.

3. Results

3.1 Anthesis, dehiscence and pollen production

The male flowers of the investigated trees showed normal anthesis and thus did not differ in this character from the other trees. Although 100% of the anthers produced pollen, only 80% dehisced. In all cases, there is an abundant pollen production, but the pollen grains adher to the internal walls of the anthers, building sticky conglomerates, and hence giving the impression that no pollen is produced. These conglomerates are occasionally able to issue from the anthers, but because of their weight they are unlikely to be widely dispersed.

3.2 Germination of pollen grains

It was first necessary to find an adequate germination medium which permits a high germination rate of normal pollen in order to compare such pollen with that of the three trees which were supposed to be male sterile.

Several formulae collected from the literature on testing pollen germination of species other than *Alnus glutinosa* were first assayed without success. These formulae included the use of water alone or water with the addition of one or more elements which are known to exert an influence on the pollen tube growth, principally sucrose, H_3BO_3, Ca, Mg, KNO_3 (Stanley and Linskens 1974).

It could be shown that the most critical factor affecting the germination of normal pollen grains of *Alnus glutinosa* was previous hydration, in similar form to that indicated by Ferrari and Wallace (1975) for *Brassica.*

The hydration took place in a moist chamber maintained at about 100% relative humidity by using moistened paper at the bottom of a plastic box. Hydration occurs more uniformly and quickly in this form than in a liquid medium, in which the pollen grains sink.

Under the microscope, hydrated pollen grains are very easy to differentiate from non-hydrated grains. They appear to be larger than non-hydrated and present a manifestly circular form, as opposed to non-hydrated grains, which are more or less pentagonal with the vertex in the pore *(Figure 1 a).* The pollen grains hydrated in this manner begin to germinate approximately three to four hours after being placed in the medium.

With this method, it was possible to obtain 60—80% germination of control pollen, depending on the individual genotypes *(Figure 1 b).*

Addition of permanent artificial light at 26° C accelerates the germination process as compared to room light and temperature conditions.

As expected, pollen grains of the trees 209-4, 209-7 and 161-4 were not able to be hydrated; even if they remained longer (up to 24 hours) in the moist chamber, their shape and size remained unchanged and no tube growth could be observed in the germination medium *(Figure 1 c).* However, by staining test with acetocarmine about 10% of this pollen stained pink.

3.3 Male sterility

Since the selected trees produce pollen grains which are unable to germinate under the investigated conditions, these individuals were taken to be sexually male sterile. Although they are capable to build male flowers, their pollen grains are inviable.

4. Discussion

Germination of pollen grains of *A. glutinosa* takes place successfully after hydration in a moist chamber maintained near to 100% relative humidity. White (1981) reports failure in pollen germination assay using Pfundt's (1910) method who used an agar medium with sucrose concentrations of 10—20%. This lack of germination could be assumed to be partially due to a lack of hydration.

In nature, this finding could explain the great significance of the occurrence of days with high relative humidity following pollination to promote the fertilization. On the other hand, rainy days have a negative effect.

The existence of male sterility in *Alnus glutinosa* was previously unknown. In annual plants of great economic importance, there is a voluminous literature concerning this, but little is known about forest trees.

Male sterility was also observed in other members of the family *Betulaceae* such as *Betula verrucosa* and *B. pubescens* (Dellingshausen and Stern 1958). This discovery suggests the hypothesis that the existence of male sterility could perhaps be a widespread phenomenon in this family.

Johns *et al.* (1981) classified male sterility in angiosperms as "structural" and "non-structural", depending on the existence or lack of "structural abnormalities in the flowers or in the reproductive organs". Although the origin of these phenomena must be considered to be a consequence of structural changes in the genome (mutations), for simplicity, the male sterility observed here in *A. glutinosa* is considered as "non-structural", which means that no morphological differences between normal male flowers and mutant sterile flowers were recorded. A similar form of male sterility has been reported to exist in *Hevea brasiliensis* (Majumdar 1967). In this form of male sterility it is assumed that the gene effect produces a breakdown of the microsporogenesis or microgametogenesis, giving rise to an abnormal pollen grain formation; the resulting pollen grains become sterile or abort. Some of them might contain an irregular number of chromosomes which stain for acetocarmine, but are unable to further development. The genes controlling this character could be located in the nucleus or in the cytoplasm or in both, in which case the two factors may interact jointly to cause male sterility. Further studies are necessary to explain this phenomenon in *A. glutinosa.* The mode of inheritance and the effects on the genetic system of this tree could not be determined on the basis of this study.

For practical purposes, the discovery of male sterile individuals in this species could be of great importance in tree breeding in cases where undesirable pollen must be excluded in the production of hybrid seeds.

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The Efficiency of Early and Indirect Selection In Three Sycamore Genetic Tests[1])

By R. J. NEBGEN and W. J. LOWE[2])

Texas A & M University,
College Station, Texas 77843, USA

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Abstract

The efficiency of early and indirect selection was examined for 21 open pollinated sycamore families in Texas, Louisiana, and Arkansas from plantings at two locations in Texas and one location in Louisiana. Direct selection (best families + best individual within a family) for seven-year height, DBH, and volume resulted in predicted gains of 20, 27, and 77 percent over their plantation means. Expected gains from direct selection for wood specific gravity and branch angle were 7.4 percent and 6.3 percent.

Indirect selection for seven-year height or DBH would be highly efficient in improving 7-year volume (89 and 91 percent). Selecting for seven-year growth traits would result in slight positive gains in wood specific gravity (0.1 to 0.6 percent gain over the plantation mean) and slight losses in branch angle (0.7 to 3.3 percent under the plantation mean).

Height at three years and height, DBH, and volume at five years all appear to be good predictors of seven-year volume. Early selection for any of these traits would result in 88 to 105 percent as much gain as would direct selection for 7-year volume. Selection for one-year height was 67 percent as effective as direct selection for seven-year volume. Selection based on any of the early growth traits resulted in slight gains in specific gravity and slight losses in branch angle.

Summary

The efficiency of early and indirect selection was examined for 21 seven-year-old open-pollinated families of sycamore from Texas, Louisiana, and Arkansas planted at three locations. Traits measured were: total height, DBH, volume, branch angle, and wood specific gravity.

Results were:

(1) Gains in seven-year height, DBH, or volume from direct selection of the best tree in each of the best 10 families represented a 20, 27, and 77 percent increase over the plantation means, respectively (1.5 m, 2.0 cm, and 14.34 dm^3 increases). Direct selection for wood specific gravity resulted in a 7.4 percent increase over the plantation mean and branch angle could be increased 3.4^0 towards horizontal.

(2) Combined selection for seven-year height or DBH would be highly efficient in improving volume growth (89 and 91 percent). Selection for seven-year growth traits would result in slight positive gains in wood specific gravity (5 to 10 percent as much gain as direct selection) and a slight or negligible loss in branch angle (0.5^0 to 1.8^0).

Key words: *Platanus occidentails* L., genetic gain, direct selection, breeding cycle.

Zusammenfassung

Bei 21 sieben Jahre alten Familien von *Platanus occidentalis* L. (frei abgeblüht), aus Texas, Louisiana und Arkansas, die in drei Versuchsflächen, zwei in Texas und eine in Louisiana, ausgepflanzt worden waren, wurde der Nutzeffekt frühzeitiger und indirekter Selektion geprüft. Es wurden die Merkmale Gesamthöhe, Durchmesser in Brusthöhe, Volumen, Astwinkel und spezifisches Gewicht des Holzes gemessen bzw. festgestellt.

Ergebnisse:

1.) Bei direkter Selektion des besten Baumes in jeder der besten 10 Familien lagen die Gesamthöhe im Alter 7, der Brusthöhendurchmesser und das Volumen 20,27 and 77% bzw. 1,5 m, 2,0 cm und 14,34 m^3 über den Versuchsflächen-Mittelwerten. Bei direkter Selektion ergaben sich für das spezifische Gewicht des Holzes 7,4% mehr und der Astwinkel konnte $3{,}4^0$ mehr zur Horizontalen hin zunehmen.

2.) Bei der kombinierten Selektion würde bei der Gesamthöhe im Alter 7 oder beim Brusthöhendurchmesser das Volumenwachstum in höchstem Maße verbessert werden (89 und 91%). Aus einer Selektion auf Wachstumsmerkmale im Alter 7 würden nur geringe positive Gewinne resultieren, was das spezifische Gewicht des Holzes betrifft (5—10% der bei der direkten Selektion erzielten Gewinne) und leichte oder unbedeutende Verluste beim Astwinkel ($0{,}5$—$1{,}8^0$).

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[2]) Research Forester, Champion International, Huntsville, Texas, USA; Associate Geneticist, Texas Forest Service and Assistant Professor, Texas Agricultural Experiment Station, College Station, Texas, USA.