stone with very small pit; ripe approximately 115 days from bloom or with 'Flordabelle'. Flowers. Large, self-fertile. Chilling requirement approximately 150 hours.

Fla. 19-37S (Colombina): Sunlite op.; selected 1969. Fruit. Small to medium, round with small tip, about 80g.; skin 50% red over bright yellow ground color, very attractive; flesh yellow, firm and melting, smooth texture; freestone; ripe approximately 90 days from bloom. Flowers: Large, self-fertile. Chilling requirement approximately 400 hours.

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The USDA Pear Breeding Program
I. Emasculation and Pollination

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ABSTRACT

This is the first in a series of reports presenting a detailed account of the different phases of the pear breeding program of the United States Department of Agriculture. It consists of a description of pollen collecting, flower emasculation and pollination, and fruit collecting of numerous pear crosses made at Beltsville during the past 12 years. In 564 crosses between 25 most often used cultivars and selections, the overall seed/pollination ratio was 1:2. The most productive female cultivar 'Kieffer' produced 2 seed for each pollination, whereas 'Dawn' produced only 1 seed in 10 pollinations.

The USDA pear breeding program has spanned a period of years with only some short intervals of little or no activity. The present phase of the program has been continuous since 1960 and is carried on at Beltsville, Maryland and Wooster, Ohio in cooperation with the Ohio Agricultural Research and Development Center. About 31,600 pear seedlings from controlled pollinations are presently growing at these two locations. Some of these have been inoculated in the greenhouse with the fire blight organism *(Erwinia amylovora)* and only the resistant ones planted in the field.

This paper is part one of a series of several reports discussing in more detail the different phases of the breeding program only briefly described in 1967 (1).

Pollen Collection—Pear trees to be used as parents are first selected about mid-February on the basis of existing records, i.e. resistance to fire blight *(Erwinia amylovora)*, leaf spot *(Fabreae maculata)*, or psylla *(Psylla pyricola)*, superior fruit quality or certain components of total quality (grit, texture, size, etc.), and other desirable tree characters.

Pear pollen is collected in late February and early March by cutting dormant branches containing flower buds. Branches are 60-120mm in length with the base cut at a 45° angle to allow

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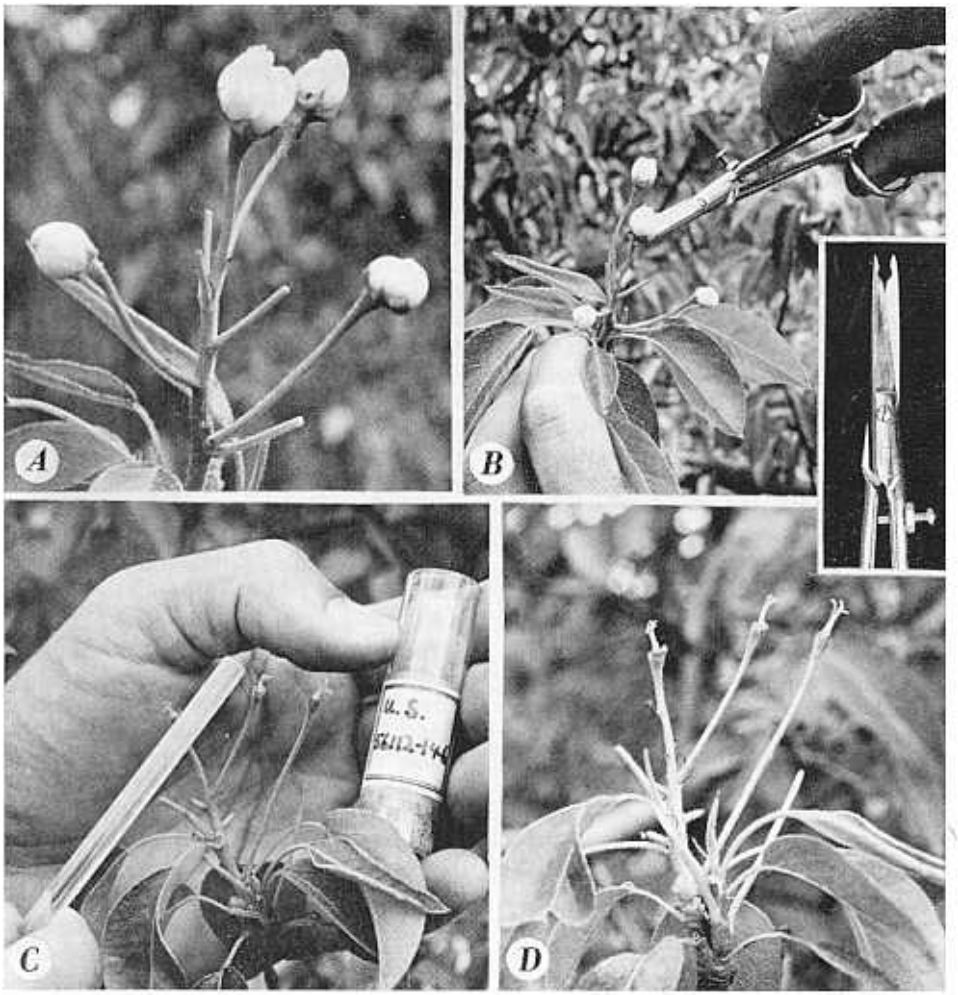

Figure 1. Basic Steps in Pear Pollination

A. Pear flowers in popcorn stage ready for emasculation.

B. Removal of calyx, corolla, and stamens from pear flower with special emasculation scissor (insert).

C. Application of pear pollen to flower stigmas with glass rod, showing the glass vial used for storing pollen.

D. Pollinated pear flowers, showing individual stigmas and slightly swollen receptacles.

for adequate water uptake. The cut ends are placed in small crocks with water in a field laboratory maintained at about 22°C. A fresh cut across the base and a change of water every fourth day allows the buds to open in 10-15 days.

Open blossoms are rubbed across a copper screen sieve with 2mm² openings and the anthers are collected on a clean sheet of paper. Collected anthers are dried by placing them in trays formed by folding single sheets of paper; they are then kept in an enclosed cabinet for 2 days at 22°C to allow the anthers to open and dehisce. When the pollen samples are well dried, they are collected in glass vials (17 x 60mm) with a cork stopper. These vials are a convenient size for use in the field. Vials of pollen are stored in a dessiccator with anhydrous $CaSO_4$ to absorb excess moisture and the dessiccator is kept in a refrigerator maintained at 6°C.

Closer to actual time of bloom (average April 1-10), the selected trees are then checked in the field for flower bud development to determine which trees have adequate blossoms for crossing. About 60-70 trees are selected for crosses and listed on paper in alphabetical (varieties) or numerical (selections) order with about 10 columns to the right of the entry to record changes in the stage of flower bud development. Flower bud stages are recorded every other day using a numerical scoring system as follows: 1) tight, dormant cluster; 2) open cluster with green calyx petals showing; 3) open cluster with reddish buds showing as calyx spreads; 4) open cluster with white petals showing; and 5) balloon or popcorn stage.

Emasculation—Flowers are ready for emasculation when the majority have reached the popcorn stage (Figure 1-A). Blossom petals and anthers are removed with surgical scissors that have a slight curve in the tip of the blades (Figure 1-B). Matching notches are cut in the scissor blades and a set screw is placed in the handle to control closure of the blades.

Some pear varieties require different set screw adjustments to accommodate varying flower sizes and for ease of emasculation. The notched scissor blades are placed below the sepal and above the receptacle and a cut is made with a pull upward, stripping the calyx, corolla, and stamens over the remaining pistil and receptacle (Figure 1-B). Usually three blossoms per cluster are emasculated and the remaining flowers are removed. On a given tree, flowers closest to the tree trunk are emasculated first to avoid inadvertent injury to the pistils as they become exposed. Finally, limbs with emasculated flowers are marked with a color ribbon around the base of the limb.

Pollination—Pollen is preferably applied within 24 hours after emasculation. Emasculated flowers are seldom left unpollinated overnight. Pollen can be applied using the cork stopper on the pollen vial. After shaking the vial, pollen easily adheres to a piece of velvet glued to the bottom of the cork.

In recent years, however, we have used glass rods about 10cm long to apply pollen. After surface sterilization in a small bottle of 70% ethanol, the rod is air dried and then rubbed alongside the nose to collect a slight amount of oil before dipping it into the pollen vial. This results in a uniform adherance of pollen to the glass rod (Figure 1-C). A rod covered with a selected pollen type will cover several stigmas if the rod is methodically twirled and rubbed lightly over the stigmas.

Emasculated flowers are pollinated by starting at the base of the main branch and following each marked side branch from the base to its tip. This prevents skipping over any emas-

culated flowers and possibly damaging them by later touching them with arm or elbow. Because bees seldom visit emasculated flowers, we leave them uncovered following pollination (Figure 1-D). Pollinated flowers are counted during the process of pollination and the final count together with the names of both parents are recorded on a tag placed near the ribbon at the base of the branch. Before another source of pollen is applied, the rod is cleaned by dipping it again in alcohol and letting it air dry.

Fruit Collection—Fruit from emasculated and pollinated flowers are harvested in late August or early September. If possible, only one cross is made on each tree to avoid a mix-up of fruit at harvest time. If a fruit drops on the ground, it can be easily recognized by the lack of a regular calyx. Fruits are stored in individual plastic bags in regular fruit boxes that are placed in a cold storage facility maintained at 0°C. The collection and preparation of seed for germination, growth and care of seedlings in the greenhouse, and subsequent planting in the field will be discussed in Part II.

Results and Discussion

During the past 12 years, many crosses have been made in the pear breeding program. In addition to

Table 1. Pollination Data Records for 9 Pear Cultivars and 16 Selections used in the Breeding Program at Beltsville, Maryland, during the Period 1962-1974.

Seed Parent[1]	Number of crosses	Flowers emasculated	Number of fruit	Number of seed	Seed/ Fruit	Fruit/ Flower	Seed/ Flower
Bartlett	29	6,011	674		3.12		.35
Dawn	14	3,105	197		1.50		.10
Kieffer	19	6,116	1,629		7.42		1.98
*Magness	60	13,724	3,415		3.20		.80
Maxine	9	2,846	251		6.89		.61
Moonglow	70	15,549	2,355		3.86		.58
R.C.W.	7	1,801	207		3.53		.41
Richard Peters	22	2,198	269		4.50		.55
*Waite	5	1,115	126		4.29		.49
US 264	13	1,723	101		3.86		.23
US 301	25	4,100	377		3.85		.35
US 307	8	1,052	72		1.92		.13
US 309	36	8,212	1,634		3.24		.65
US 337	19	2,782	324		4.03		.47
US 342	29	5,233	538		4.44		.46
US 386	30	4,892	767		4.80		.75
US 414	14	2,401	258		3.90		.42
US 446	8	1,475	238		4.50		.73
US 505	28	6,523	292		3.17		.14
*US 643	35	6,581	929		4.42		.62
*US 56109-43	13	4,533	316		4.34		.30
*US 56111-8	9	2,140	206		5.35		.51
*US 56111-20	8	1,739	239		4.83		.66
US 56112-36	29	10,233	757		4.36		.32
US 56112-146	25	6,790	430		4.70		.30
	564	122,874	16,601		4.18		.57

[1]Seed parents marked with an asterisk are male sterile.

several U.S. selections, many cultivars were used as female trees and those most often used are presented in Table 1. In 564 crosses involving 9 cultivars and 16 selections, a total of 122,874 pollinations produced 69,432 seed. This is an overall ratio of 1 seed per 2 pollinations. This ratio ranged from 2 seed for each pollination in 'Kieffer' to only 1 seed per 10 pollinations for 'Dawn'. Between these two extremes, 21 of the 25 seed parents produced from 1 seed/10 flowers to 1 seed/flower (Table 2). The most productive of these were 'Magness', 'Maxine', U.S. 309, U.S. 386, U.S. 446, and U.S. 56111-20.

The 'Magness' pear tree has small, unattractive, male-sterile flowers and comes into bearing very slowly. Artificial pollinations have resulted in 24 percent of the flowers being fertilized in nearly 9000 pollinations (2). The data in Table 1 on other male sterile parents show that there is no apparent correlation between male sterility, fruit set and seed production.

A viable breeding program can best be maintained when 2,000-4,000 seedlings are planted in the field each year. Thus, the production of about 7,000 seeds per year appears quite satisfactory if the seedlings are not inoculated and screened for fire blight resistance. During the past 5 years, most seedling populations in our breeding program have been screened with the mass-inoculation technique (3). When seedlings are screened for one or more diseases or insects, one must expect an 85-90% mortality. Therefore, if the screened seedlings represent about 10% of the seedlings produced, our aim is to make approximately 30,000 pollinations per year.

Table 2. Grouping of 25 Seed Parents into 4 Categories based on Fruit Set and Seed Production.

Number of seed parents	Number of fruit/flower	Number of seed/ fruit	Number of seed/ flower
3	0.04-0.07	1.5-3.1	0.0-0.15
11	0.09-0.12	3.1-4.7	0.15-0.5
10	0.09-0.25	3.2-6.9	0.5-1.0
1	>0.25	>6.9	>1.0

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Fruit Improvement Through Single Cell Culture[1]

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Many fruit cultivars, although widely grown and popular with the public, are found to be deficient for certain characteristics such as disease and insect resistance, pigmentation, time of harvest, fruit set, nutritive value, storage ability, etc. Cultivar improvement for such characters has traditionally been approached from two directions: 1) using the sexual system to produce variable populations from which improved forms of the original cultivar can be selected, and 2) the use of mutagens (both chemical and physical) on clonal plants to produce mutants which will represent an improved form of the parental plant.

[1]This paper is primarily a discussion of the plant breeding ramifications of a review paper by the author covering all areas of variation associated with plant cell culture (8).

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