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COLLEGE OF FORESTRY-WILDLIFE
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CONE AND SEED PRODUCTION IN CONTROLLED POLLINATION OF PONDEROSA PINE

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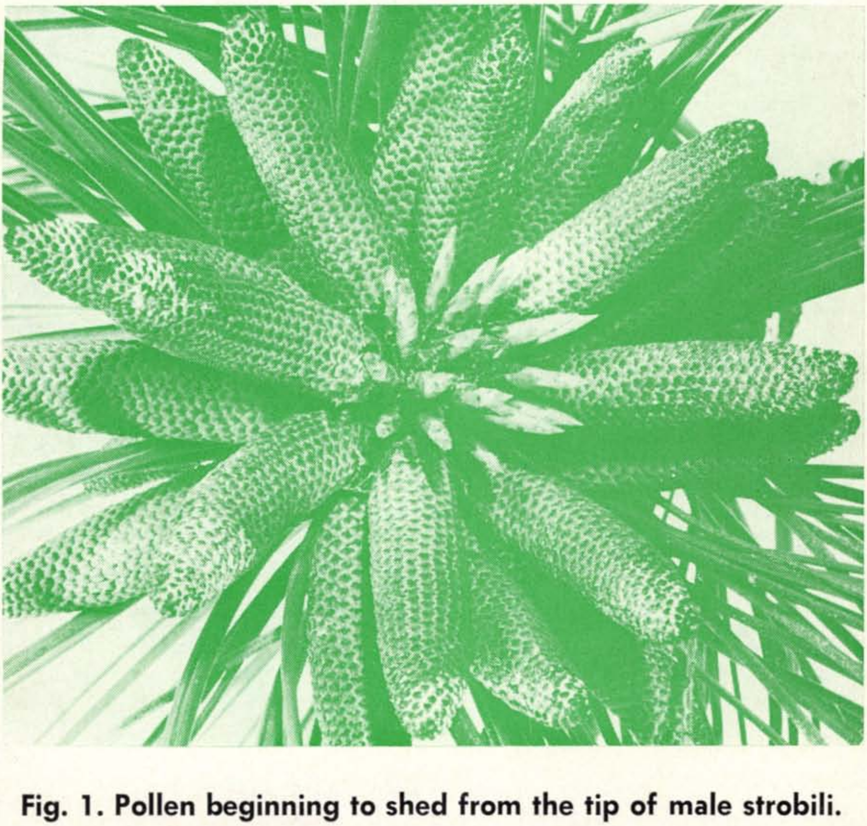

Fig. 1. Pollen beginning to shed from the tip of male strobili.

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CONE AND SEED PRODUCTION IN CONTROLLED POLLINATION OF PONDEROSA PINE[1]

By

Chi-Wu Wang[2]

This report is based on the cone and seed production from controlled pollinations of ponderosa pine during 1964-70. The work included the intraecotypic pollinations of 10-tree diallel crosses; interecotypic pollination between Arizona, Oregon, and the local Idaho ecotypes; and selfing experiments.

POLLINATION PROCEDURE

Fresh pollen was used in controlled pollinations with the exception of a few occasions in interecotypic crosses. The pollen was collected by forcing nearly matured male strobili 5 to 10 days before natural pollen shedding. The pollen was extracted, screened, and stored at about 40° F. in a desiccator until used.

Female flowers were isolated by using transparent sausage casing bags. The reusable, nonwoven plastic pollination bag, with or without windows, also was tried with equal success. The inside temperature of the reusable type is probably lower than the sausage casing but the sausage casing is more visible and considerably cheaper than the former.

The isolated flowers were dusted with pollen using a syringe pollinator. The needle puncture on each isolation bag was sealed with masking tape after pollination. One flower-bearing shoot was included in each bag. The flowers developed into a cluster of cones after fertilization. Each cluster on the average included two cones (Table III) but the number varied from one to nine.

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Fig. 2. Controlled pollination of ponderosa pine. Female strobili were generally found at the upper part of the crown.

FLOWERING OF PONDEROSA PINE

The time when female strobili became receptive for pollination fluctuated from May 17 to June 6 during 1964-70. Roeser (1941) observed a close synchronization of ponderosa pine flowering and the last spring frost in Colorado. In northern Idaho, the beginning of pollen shedding (Fig. 1) as a rule preceded the blooming of female flowers by about two to five days. The time of flowering (Table I, Fig. 3) as indicated by the number of days from the beginning of the year was found positively correlated with the last spring frost of the year (**$r = 0.868$**).

Table I. Flowering of Ponderosa Pine.

Year	Date Flowering	Last Spring Frost (a)
1964	June 6	May 25 (b)
1965	May 24	May 6
1966	May 18	April 27
1967	June 5	May 12
1968	May 31	May 5
1969	May 17	April 30
1970	June 5	May 14 (c)

(a) Viola Hills (3150 ft.) 4 miles north of Moscow, 32° F., except (b) 33° F. and (c) Moscow (2610 ft.), 33° F. (Day 1964-70).

A good seed crop always was associated with an ample pollen supply, and ponderosa pine was most lavish in pollen production. The last good cone year was 1958 in southern Idaho and at the height of the blooming season, pollen was so abundant that views beyond one to two hundred yards were obscured (Curtis 1962).

The size of male strobili varied considerably between trees, and seemed to be a consistent individual tree character. About four to ten grams of dry pollen could be extracted from one hundred male strobili (Table II).

Phenological observations of six natural stands of ponderosa pine on open slopes and sheltered valleys within a range of 30 miles in Latah County showed that the flowering date among trees within a stand and betwen stands varied less than two days. The female flowers remained susceptive for about a week. The shedding of pollen continued for several days depending on the weather, although the bulk of pollen was depleted in a few hours on a warm and windy day. No evidence of phenological breeding barriers were observed. However, there was greater chance of genetic isolation by flowering time between elevations. The ponderosa pine of Bald Mountain (5,500 ft.) blooms ten days later than Idaho City (4,200 ft.) less than 20 miles apart.

Table II. Pollen Production of Ponderosa Pine.

	Average*	Range
Weight of 10 male strobili with pollen (gram)	1.423	0.913 - 1.860
Weight of pollen of 10 strobili (gram)	0.724	0.392 - 1.000

(*) Average air-dry weight of two 10-strobili samples from seven trees.

INTRAECOTYPIC POLLINATION

In the intraecotypic pollination of ponderosa pine, a total of 22 trees in six natural stands were used as seed trees and pollen sources. They are naturally regenerated trees of Latah County in northern Idaho. In the four cone crops so far obtained, intraecotypic crosses produced 69.05 seeds per cone. This was nearly as many as those produced by wind pollination in the same group of trees (Table III). For comparison, the cumulative average of seeds per cone for controlled pollination in the three pollination years, 1964, 1966 and 1967, was 69.75 and the average seeds per cone produced in wind pollination by the same group of trees during the three-year period was 70.92.

About four to five weeks after artificial pollination, when the isolation bags were removed (Fig. 4), the fertilized strobili had developed into succulent conelets, deep purplish red in color. The average survival of the control pollinated cones at the time of harvest was 52.10 percent. Destruction of matured cones was done mostly by squirrels shortly before cone collection. The damage was especially serious in years of poor cone crop such as in 1967 and 1968.

Table III. Cone and seed production in intraecotypic pollination of ponderosa pine.

Pollination Year	Female Parents	Pollen Parent	Cone Cluster Pollinated	Cone Cluster % Survived	Cones Per Cluster (a) Mean	Cones Per Cluster (a) Range	Seeds Per Cone (b) Mean	Seeds Per Cone (b) Range (c)	Basis of Seed Count (Cones)
Column (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Controlled pollination									
1964	22	8	444	67.34	2.35	1-4.50	78.70	40.80-126.83	701
1966	15	6	544	62.68	1.77	1-3.20	67.32	31.00-101.82	605
1967	11	10	440	38.40	2.05	1-4.00	55.87	14.00- 97.00	346
1968	7	10	213	21.59	1.28	1-1.80	49.50	31.00- 71.33	59
Total and Average	22	10	1641	52.10	2.00		69.05		1711
Wind pollination									
1964	19	Wind					71.24	27.84-105.30	209
1966	1	Wind					65.95		20
1967	10	Wind					71.73	17.00-110.00	38
Total and Average	22						70.92		267

(a) Mature seed bearing cones. (b) Well-formed seed, not germination tested. (c) Tree means.

Cone insect and breakage by wind and climbing were minor causes of mortality. Cone insects inflicted serious damage to two trees in 1968.

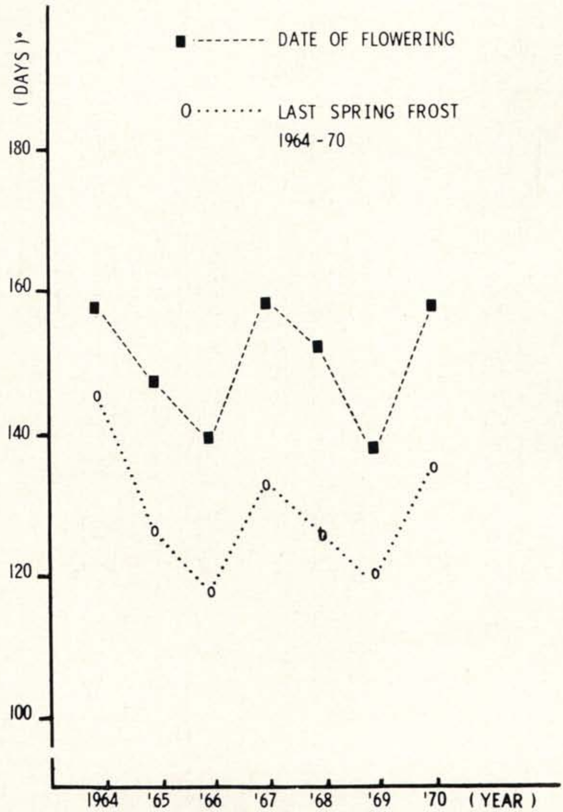

Fig. 3. The flowering of ponderosa pine is found closely synchronized with the last spring frost. (*Number of days from the beginning of the year).

INTERECOTYPIC POLLINATION AND THE EFFECT OF POLLEN STORAGE

In the interectotypic pollinations, pollen from Arizona (Flagstaff), coastal Oregon (Corvallis), and eastern Oregon (Lost Forest) were used in hybridization with ponderosa pine of northern Idaho (Table IV). When fresh pollen was used, interecotypic pollinations produced as many seeds per cone as the intraecotypic crosses by the same seed trees in the same crop year.

Fig. 4. One of the isolation bags was removed showing female strobili 10 days after pollination.

Fig. 5. Female strobili 12 months after pollination. They were full-grown in size but still succulent. After fertilization at about the end of June to early July, over a year after pollination, the cones become hard and woody.

Table IV. Cone and seed production in interecotypic pollination of ponderosa pine.

Pollen Sources	Pollination Year	Female Parents	Cone Cluster Pollinated (a)	Cone Cluster Survived %	Cones Per Cluster (a) Mean	Cones Per Cluster (a) Range	Seeds Per Cone (b) Mean	Seeds Per Cone (b) Range (c)	Basis of Seed Count (Cones)
Column (1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Lost Forest Ore. (1961)*	1964	5	33	27.37	1.33	1.00-2.00	16.9	7.75- 25.33	12
Corvallis, Ore. #1 (1966)**	1966	7	62	54.83	2.18	1.00-2.83	79.8	58.71- 88.62	74
Corvallis, Ore. #2 (1966)**	1966	8	62	54.83	2.06	1.00-3.66	75.1	49.00-116.82	70
Flagstaff, Ariz. (1967)	1968	3	61	26.23	1.19	1.00-1.20	47.1	46.39- 60.00	19
Idaho (1967)	1968	2	47	29.81	1.50	1.00-1.80	41.33	31.00- 50.00	21
Idaho (1968)	1968	2	90	35.55	1.19	1.00-1.31	54.03	50.67- 71.33	38

***Pollen obtained through cooperation of the Bureau of Land Management, Burns, Oregon, and **Dr. Donald Copes, Pacific Northwest Forest and Range Experiment Station, USFS, Corvallis, Oregon. (a) Mature seed bearing cones. (b) Well-formed seed, not germination tested. (c) Tree means.**

One-year-old pollen produced about 20 percent less seed than freshly collected pollen. The stored pollen was kept at about 40° F. in a desiccator. Pollen in storage for more than two years deteriorated considerably under this condition.

INBREEDING, OUTCROSS, AND WIND-POLLINATION

In the three crop years self-pollination of ten seed trees (Table V) produced on the average 66.40 well formed seeds per cone. This is approximately as many seeds as those produced in outcross (64.68) and wind pollination (67.27) by the same mother trees in the three-year period.

According to the study of ponderosa pine embryogeny by Bucholz and Striemert (1946) the fertilization of embryo takes place nearly 12 months after pollination. The year-old cones and the unfertilized seeds are already fully grown in size but not yet hardened (Fig. 5). A seed in which fertilization fails to take place remains as a full size empty seed in which the stony seed coat may be as fully developed as in a sound seed.

A comparison between the self-pollinated and wind-pollinated seeds of nine mother trees of the same crop year showed that the self-pollinated seeds are considerably lighter in weight and lower in germination capacity. The average 100-seed weight of self-pollinated seeds of the nine mother trees is 4.14 grams and that of the wind-pollinated seed is 5.05 grams. This difference is statistically significant **($P < 0.01$)**. A germination test including four of the above nine pairs of self-and wind-pollinated seed samples are given in Table VI:

Table V. Seed production in inbreeding, outcross, and wind pollination.

Pollination Year	Female Parent (a)	Pollen Parent	Seed Per Cone (b) Mean	Seed Per Cone (b) Range (c)	Basis of Seed Count (Cones)
Inbreeding					
1964	7	7	80.16	48.00-105.00	88
1966	2	2	64.50	64.00- 76.00	24
1967	3	3	54.54	14.25- 93.13	22
Average			66.40		
Outcross					
1964	7	7	76.37	30.00-100.35	198
1966	2	6	78.16	65.95- 87.50	122
1967	3	6	39.51	20.00- 76.75	83
Average			64.68		
Wind pollination					
1964	7	Wind	77.52	53.74-100.50	79
1966	1	Wind	65.95		20
1967	2	Wind	58.33	17.00- 79.00	6
Average			67.27		

(a) The same female parent trees were used in inbreeding, outcross and wind pollinations. (b) Well formed seeds, not germination tested. (c) Tree means.

Table VI. Seed weight and germination percentage of self- and wind-pollinated seeds.

Tree Identity	100-seed Weight (gram) Self	Wind	Germination (%) Self	Wind
2-1	4.03	5.16	22	62
2-2	3.81	5.21	16	64
5-1	4.70	4.44	34	24
5-4	5.86	6.95	12	28

The samples in Table IV were not large enough to show significant differences. The obvious low germination capacity of the wind-pollinated seed in comparison with ordinary commercial sources of ponderosa pine seed essentially was caused by the nature of the test materials. In this study every well-developed seed from the self-pollinated, as well as the wind-pollinated cones, was extracted. This included those in the lower part of the cone which were possibly low in viability and not extractable by ordinary means of tumbling. Seedlings of self-pollination origin were also low in first-year survival.

DISCUSSION AND CONCLUSION

The flowering of ponderosa pine during 1964-70 was found positively correlated with the last spring frost **($r = 0.868$).**

The differences in flowering time of a year in the six natural stands of Latah County were not more than two days. This condition permitted panmictic pollination in the natural population. But between different elevations the differences were found to be great enough to become effective phenological breeding barriers.

On the basis of seed count of well-formed seeds, there were as many seeds per cone produced in controlled pollination as in wind pollination. Self-pollinated seeds were lighter in weight and lower in germination capacity than wind pollinated seeds.

In both the control-pollinated and wind-pollinated seed the well-formed seeds may be full, empty or half-full with embryos and endosperms in various degrees of development. The differences in seed development may be caused by genetic incompatibility. In controlled pollination of local trees the pollen was from a specific male parent, while in wind pollination, the pollen was probably from several adjacent trees. The differences in seed development and germination capacity between the controlled pollination and wind pollination reflect the possible differences in compatibility between the specific parents. In a seed orchard the seed production is from the restricted pollination of a limited number of selected parents. In light of the present study the compatibility between the individual parents should be included as a criterion for selection of the breeding materials.

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