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Pollination Studies with Stone Fruits

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CONTENTS

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INTRODUCTION

IT HAS LONG been recognized that self sterility is common in many species of stone fruits, particularly in plums, sweet cherries, and the cultivated forms of sand cherries. Little was known, however, about the large amount of cross sterility or incompatibility that exists between varieties of these fruits until about 1925 to 1930 when hybrid plums and cherry-plums were planted extensively in Minnesota and nearby states. The problem assumed serious aspects in Minnesota when commercial plantings of the large fruited hybrid plums reached bearing age and failed to set satisfactory crops in spite of profuse bloom.

In 1930, the University of Minnesota Agricultural Experiment Station began a study of cross sterility at the Fruit Breeding Farm, Excelsior, Minnesota. Purpose of the study was to find suitable pollinator varieties and to determine what combinations of varieties would be sufficiently compatible to produce satisfactory crops. This study was continued over a period of 21 years. The fruits involved and the scope of the work are shown in table 1.

It seemed necessary to make the study under normal orchard conditions because the varieties which were obviously incompatible in the orchard had been successfully crossed in the greenhouse where temperature and other environmental factors were maintained at nearly optimum conditions.

In the orchard tests, several methods were tried. At first twenty-pound paper bags were used to enclose flowering branches when the buds were in the

Table 1. Summary of Volume of Work in Pollination Studies

	Number of varieties used as: Male	Female	Number of combinations	Number of tests	Total flowers pollinated
Native and hybrid plum	131	37	814	1,126	210,367
European plum	10	9	32	33	4,077
Cherry-plum	44	29	294	585	75,657
Nanking cherry	18	18	36	85	6,305
Korean cherry	7	7	20	33	2,923
Totals	210	100	1,196	1,862	299,329

Table 2. Germination of Plum Pollen on Artificial Media

Variety	Species	Per cent germination 0-1	1-5	5-15
Elliot	*P. salicina* hybrid	x		
La Crescent	*P. salicina* hybrid x *P. americana*	x		
Monitor	*P. salicina* hybrid	x		
Red Wing	*P. salicina* x *P. americana*	x		
Tom Thumb	*P. Besseyi* hybrid	x		
Underwood	*P. salicina* hybrid x *P. americana*	x		
Fiebing	*P. salicina* hybrid		x	
Radisson	*P. salicina* hybrid		x	
Superior	*P. salicina* x (*P. americana* x *P. Simonii*)		x	
Minn. No. 195	*P. salicina* x (*P. americana* x *P. Simonii*)		x	
Assiniboine	*P. nigra*			x
De Soto	*P. americana*			x
Nicollet	*P. Besseyi* hybrid			x
Rollingstone	*P. americana*			x
Surprise	*P. hortulana Mineri*			x
Tonka	*P. salicina* x *P. americana*			x
Wolf	*P. americana*			x

balloon stage. Similar branches were cut and taken into the greenhouse where they were forced into bloom early and the pollen extracted.

When the flowers under bags in the orchard approached the full-bloom stage, they were pollinated with the previously prepared pollen which was stored in small vials. The flowers under the bags were not emasculated since it had been amply demonstrated that they were self sterile to their own pollen. Camel's hair brushes were used in pollination and were sterilized in 95 per cent alcohol solution before being dipped into the vial. This prevented contamination of the supply of the prepared pollen. The operator used three brushes in rotation so that the alcohol was completely evaporated before a brush was used the second time.

During the first few years of the study all the open blossoms on the enclosed branch were pollinated and counted. Later, this method was modified so that only two or three blossoms per cluster were pollinated. After two years of trial, the paper bag method was abandoned because the bags frequently were torn and because under some conditions the blossoms within the bags appeared to be more subject to frost injury than those in the open.

Another method was the construction of large cheesecloth cages over entire trees. Boquets of the variety to be used in the cross were placed in the tent with a hive of bees. This method was unsatisfactory for a large-scale testing program because of excessive cost and limited number of combinations that could be tested each year.

The method finally adopted was to wrap the flowering branches in cheesecloth or aster cloth. If the cheesecloth was coarse, two thicknesses were used. This method proved to be very satisfactory and was used throughout the experiment beginning in 1932.

In 1930 a light freeze injured most of the bloom in the paper sacks although it did very little damage to flowers in the open. In 1931 the work was confined to cheesecloth cages and bees and was without value. Data for these two years are not included in this report.

A study of pollen germination on artificial media was made by Catharine L. Becker, research assistant in horticulture, in the spring of 1932 to determine whether failure of plum hybrids to set fruit was due to lack of compatibility between the varieties or to lack of viability in pollen grains. Table 2, adapted from Miss Becker's report,[1] indicates very clearly that in general, low pollen viability was characteristic of the hybrid varieties, while varieties of our native species of plums showed relatively high pollen viability. Two exceptions were the hybrids, Nicollet and Tonka, which ranked with the natives in viability. Nicollet proved to be a fairly good pollinizer and Tonka a very poor one. Of the other hybrids mentioned in table 2, only Superior proved to have any value as a pollinizer.

All of the native varieties, on the other hand, proved to be good pollinizers for hybrid plums which bloomed at the same time. Many of the hybrids produced large numbers of empty or aborted pollen grains. The first five shown in table 2 produced approximately 50 per cent aborted pollen. It may be assumed that lack of a satisfactory fruit set may be due to defective pollen, low viability of pollen, or incompatibility between varieties. In some cases all three factors may be involved.

NATIVE AND HYBRID PLUMS

Throughout the experiment the primary objective was to discover one or more pollinizers which would insure satisfactory fruit production when used in home or commercial plantings of hybrid plums. In this search 131 standard varieties and selections were tested as pollinizers. These were used on 28 named varieties of plums and nine promising selections under test at the University of Minnesota Fruit Breeding Farm. Most of these 37 varieties were also tested as pollinizers. The pollinizers usually were given a preliminary test on about three commonly grown hybrid plums. The most promising pollinizers in these preliminary tests were screened for their horticultural qualities and the best of them were subjected to more extensive pollination tests. In all, 814 combinations were studied.

On the basis of compatibility alone, the 131 varieties tried as pollinizers were classified into three groups: good, fair, and poor. Thirty-six varieties were rated good, 20 fair, and 75 were poor and worthless as pollinizers.

In tables 3 and 4 respectively are listed all the varieties that were classified as good and fair pollinizers. Information concerning extent of testing, season of bloom, pollen abundance, and species composition is also included in these tables. To conserve space the varieties classified as poor pollinizers are merely enumerated in table 5 (more complete information regarding this group is available in mimeographed form to those who are interested).

From a study of table 3 it becomes apparent that varieties of native American species are good pollinizers almost without exception (note Terry in table 4). Furthermore, it appears that a preponderance of good pollinizers is found in hybrids in which these native species appear as female parents. This becomes more apparent from an inspection of table 6 in which are classified many of the varieties tested on a basis of their component species. Their effectiveness as pollinizers from the standpoint of compatibility is also shown. For instance, it will be observed that of eight varieties of *P. americana*, seven are listed as good pollinizers, one fair, and none poor. Of 15 hybrids in which *P. americana* is a female parent, nine are good pollinizers, one is fair, and five are poor. On the other hand, in 59 varieties in which *P. americana* was used either as a male parent or

[1] Becker, Catharine L. Studies of pollen germination in certain species and interspecific hybrids of Prunus. Am. Soc. Hort. Sci. Proc. 29:122-126. 1932.

Table 3. Hybrid and Native Plums Rated as Good Pollinizers

Variety	Number varieties on which pollinizer was tested	Season of bloom	Species
Assiniboine	7	Early	*P. nigra*
Compass	2	Very late	*P. Besseyi* x *P. hortulana Mineri*
Convoy	3	Late	*P. Besseyi* hybrid
De Soto	15	Late	*P. americana*
Goff	16	Late	*P. americana*
Hazel	14	Medium	*P. americana*
Kaga	26	Early	*P. americana* x *P. Simonii*
New Ulm	12	Late	*P. americana*
Older	18	Medium	*P. salicina* hybrid
Olson	3	Early	*P. nigra*
Rollingstone	12	Late	*P. americana*
South Dakota	27	Medium late	*P. americana* or *P. americana* hybrid
Surprise	31	Late	*P. hortulana Mineri*
Toka	22	Early	*P. americana* x *P. Simonii*
Wolf	13	Late	*P. americana*
Wyant	14	Late	*P. americana*
Minn. No. 55	2	Early	(*P. salicina* x *P. americana*) x *P. sp.*
Minn. No. 84	24	Late	*P. americana* x *P. salicina* hybrid
Minn. No. 89	25	Late	*P. americana* x *P. salicina* hybrid
Minn. No. 107	6	....	*P. americana* x *P. salicina*
Minn. No. 168	4	....	*P. americana* x (*P. Munsoniana* x *P. salicina*)
Minn. No. 182	10	Early	*P. nigra*
Minn. No. 203	9	Medium	*P. salicina* x (*P. americana* x *P. Simonii*)
Minn. No. 206	6	....	(*P. salicina* x *P. americana*) x (*P. salicina* x *P. americana*)
Minn. No. 210	19	Early	*P. salicina* x (*P. americana* x *P. Simonii*)
Minn. No. 211	10	Early	*P. salicina* x (*P. americana* x *P. Simonii*)
Minn. No. 216	3	....	*P. salicina* x *P. nigra*
Minn. No. 228	3	Early	*P. salicina* x (*P. americana* x *P. Simonii*)
Minn. No. 251	3	Late	*P. hortulana Mineri* x *P. americana*
Minn. No. 267	25	Early	(*P. americana* x *P. salicina* hybrid) x *P. salicina* hybrid
Minn. No. 295	3	Medium late	*P. hortulana Mineri* x *P. americana*
Minn. No. 316	3	Medium	(*P. salicinia* x *P. americana*) x (*P. salicina* x *P. americana*)
Minn. No. 319	3	Medium late	*P. salicina* hybrid x *P. nigra*
Minn. No. 333	3	....	(*P. salicinia* x *P. americana*) x (*P. salicinia* hybrid x *P. nigra*)
Minn. No. 351	3	Medium	(*P. salicina* x *P. americana*) x *P. salicina* hybrid
Minn. No. 356	2	Late	(*P. americana* or *P. americana* hybrid) x *P. salicina*

appeared as a component of the male parent, only six are listed as good pollinizers, 11 fair, and 42 are poor.

Only a few hybrids derived from *P. nigra* or *P. hortulana Mineri* were included in the study. It is believed that the small number of varieties in which *P. nigra* was the female parent may account for the fact that all three are classed as poor, with none in the good or fair classes. This is the only group which does not follow the pattern in the group *P. americana* and its hybrids.

No varieties of pure *P. salicina* or *P. Simonii* were tested as pollinizers because they lack winter hardiness. These species are represented, however, as components of hybrids in two fairly large and representative groups. Varieties of *P. salicina* are, in general, regarded as poor pollinizers. The rela-

Table 4. Hybrid and Native Plums Rated as Fair Pollinizers

Variety	Number varieties on which pollinizer was tested	Season of bloom	Species
Ember	24	Medium	*P. salicina* hybrid x *P. americana*
Golden Rod	3	Medium	*P. salicina* hybrid x *P. americana*
Hanska	17	Early	*P. americana* x *P. Simonii*
Loring	3	Early	*P. salicina* hybrid
Redglow	10	Medium	*P. salicina* x *P. Munsoniana*
Superior	18	Medium early	*P. salicina* x (*P. americana* x *P. Simonii*)
Shiro	1	....	*P. salicina* hybrid
Terry	9	Very late	*P. americana*
A x W No. 5	4	....	*P. salicina* x *P. americana*
Minn. No. 121	2	....	*P. salicina* hybrid x *P. americana*
Minn. No. 128	5	....	(*P. salicina* x *P. americana*) x *P. salicina*
Minn. No. 200	5	....	*P. salicina* x (*P. americana* x *P. Simonii*)
Minn. No. 201	5	Early	*P. salicina* x (*P. americana* x *P. Simonii*)
Minn. No. 231	3	Medium	*P. Besseyi* x (*P. Munsoniana* x *P. salicina*) x *P. salicina*
Minn. No. 244	3	Early	*P. salicina* x (*P. americana* x *P. Simonii*)
Minn. No. 262	3	Medium	*P. salicina* x *P. americana*
Minn. No. 277	3	Medium	*P. salicina* x *P. americana*
Minn. No. 301	3	Very early	(*P. salicina* x *P. americana*) x *P. persica* (apomictic)
Minn. No. 320	3	Medium early	*P. salicina* hybrid x *P. nigra*
Minn. No. 325	3	Late	(*P. americana* x *P. salicina* hybrid) x *P. americana* or *P. americana* hybrid

Table 5. Pollinizers Tested and Rated as Poor

Named varieties	Minnesota selections		
Anoka	B x W No. 1	Minn. No. 135	Minn. No. 284
Elliot	B x W No. 2	Minn. No. 196	Minn. No. 285
Fiebing	Minn. No. 53	Minn. No. 197	Minn. No. 286
Hennepin	Minn. No. 56	Minn. No. 199	Minn. No. 290
La Crescent	Minn. No. 60	Minn. No. 204	Minn. No. 293
Monitor	Minn. No. 61	Minn. No. 205	Minn. No. 294
Mendota	Minn. No. 75	Minn. No. 207	Minn. No. 297
Opata	Minn. No. 87	Minn. No. 209	Minn. No. 322
Pembina	Minn. No. 102	Minn. No. 215	Minn. No. 324
Pipestone	Minn. No. 105	Minn. No. 217	Minn. No. 326
Radisson	Minn. No. 111	Minn. No. 225	Minn. No. 339
Redcoat	Minn. No. 124	Minn. No. 229	Minn. No. 372
Redwing	Minn. No. 126	Minn. No. 230	
Sapa	Minn. No. 133	Minn. No. 232	
St. Anthony	Minn. No. 155	Minn. No. 237	
Tecumseh	Minn. No. 158	Minn. No. 263	
Tonka	Minn. No. 177	Minn. No. 265	
Tokata	Minn. No. 178	Minn. No. 266	
Underwood	Minn. No. 186	Minn. No. 274	
Wachampa	Minn. No. 188	Minn. No. 278	
Waneta	Minn. No. 191	Minn. No. 279	

Table 6. Effectiveness of Plum Varieties as Pollinizers in Relation to Their Component Species

Component species	Number varieties tested	Effectiveness as pollinizers: Good	Fair	Poor
P. americana	8	7	1	0
P. americana of uncertain purity	1	1	0	0
Hybrids with *P. americana* as female parent	15	9	1	5
Other hybrids containing *P. americana*	59	6	11	42
P. americana x *P. Simonii*	3	3	0	0
P. Simonii x *P. americana*	1	0	0	1
Other hybrids containing *P. Simonii*	19	4	4	11
P. nigra	3	3	0	0
Hybrids with *P. nigra* as female parent	3	0	0	3
Other hybrids containing *P. nigra*	7	3	1	3
P. hortulana Mineri	1	1	0	0
Hybrids with *P. hortulana Mineri* as female parent	2	2	0	0
Other hybrids containing *P. hortulana Mineri*	4	1	0	3
Hybrids with *P. salicina* as female parent	45	5	8	32
Hybrids with *P. salicina* hybrids as female parent	39	7	8	24
Other hybrids containing *P. salicina*	23	6	2	15

tively small number of good pollinizing varieties found in the large group of *P. salicina* hybrids indicates that the dubious reputation of that species is well founded. The evidence regarding *P. Simonii* hybrids is not as clear. Further data presented in table 7, however, indicate that this species may contribute something to its hybrids to improve their value as pollinizers.

The unbalanced distribution of good and poor pollinizers among the hybrid plum pollinizers shown in table 4 leads to speculation as to the cause of such distribution. For more than 40 years the University of Minnesota Fruit Breeding Farm has conducted an extensive breeding program with stone fruits. Many thousands of seedlings have been produced from crosses between many species of Prunus. Somewhat casual studies of these interspecific hybrids have uncovered the interesting fact that often an abnormally high percentage of seedlings in such hybrid progenies closely resemble the maternal parent. Angelo and Alderman[2] report that in reciprocal crosses between *P. salicina* and *P. americana* and between *P. nigra* and *P. salicina*, leaf

Table 7. Effectiveness of Plum Varieties as Pollinizers in Relation to Parental Varieties from Which They Were Derived

Number varieties tested	Parents: Female		Male	Effectiveness as pollinizers: Good	Fair	Poor
15	Burbank	x	Kaga	4	4	7
24	Burbank	x	Nine varieties	1	4	19
1	De Soto	x	Burbank	1	....	....
1	Burbank	x	De Soto	....	....	1
16	Shiro	x	Eight varieties	2	2	12
4	Three varieties	x	Shiro	2	0	2
2	South Dakota	x	Two varieties	1	0	1
2	Minn. No. 89	x	South Dakota	1	0	1

[2] Angelo, Ernest, and Alderman, W. H. Fruit and leaf characters in interspecific hybrids of Prunus. Amer. Soc. Hort. Sci. Proc. 29:115-117. 1932.

types of both parental species and intermediate leaf types appear in the progenies. The leaf types of the maternal species, however, are always found in greater numbers than those of the paternal species. In F_2 populations derived by sib mating hybrids of *P. salicina* x *P. americana*, these authors report 66.9 per cent of the progeny of salicina leaf type and 7.5 per cent of americana leaf type. *P. salicina*, in this case, was the maternal parent of the sibs.

A still more startling situation is reported by Wilcox[3] involving crosses between peaches and plums. When the peach was used as a maternal parent, all of the offspring were apparently normal peaches. In the reciprocal cross, the offspring contained a few sterile hybrids and considerable numbers of normal plums.

Similar conditions have arisen between crosses of *P. tomentosa* x *P. Besseyi* or *P. Besseyi* hybrids. True hybrids were seldom produced but large numbers of *P. tomentosa* seedlings were common. In some progenies the individuals were all *P. tomentosa*. Similarly in a cross of *P. japonica* x Kaga *(P. americana* x *P. Simonii)* plum the progeny consisted of several hundred *P. japonica* and three questionable hybrids.

In view of these and many other cases which might be cited, it seems clear that the phenomenon of apomixis (reproduction without sexual fertilization) is a common occurrence in interspecific crosses of Prunus. With this in mind it is suggested that an unsuspected mixture of apomictically derived varieties may account for the unbalanced numbers of good and poor pollinizers among hybrid plum varieties.

It may be possible that the genetic composition of an individual hybrid variety may be more important than its component species. Table 7 presents a summary in which pollinizers are classified in relation to the parental varieties from which they were derived. In one group 39 varieties have Burbank as a common maternal parent. In 15 of these the male parent is Kaga. Eight of the 15 are rated as good or fair pollinizers and seven as poor. The other 24 varieties were derived from various male parents other than Kaga. This group contains only one good pollinizer, four fair, and 19 poor. It seems likely that Kaga with its heritage from *P. Simonii* may be largely responsible for the high percentage of good pollinizers in this group. This appears all the more likely in view of the fact that none of the male parents of the group of 24 Burbank seedlings contained any admixture of *P. Simonii* and that 16 of the 24 had *P. americana* as a male parent. This quite obviously is a case of gene influence rather than apomixis.

The other groups in table 7 represent reciprocal crosses in which the same variety appears as male and female parent in contrasting groups. Because small numbers are involved, no conclusions can be justified. It might be suggested, however, that in the 16 varieties having Shiro as a maternal parent some form of apomixis may be involved to account for the large number of poor pollinizers. Shiro itself is of complex origin and is rated as a fair pollinizer on the basis of a single test.

We now come to a more practical consideration of plum pollinizers. In table 8 the compatibility of 18 of the most important pollinizer varieties is shown when these pollinizers are used on 22 varieties of plums and three Minnesota selections. It may be noted that two cherry-plums, Convoy and Sapa, are included among the pollinizers. As a general rule cherry-plums would be of little value as plum pollinizers be-

[3] Wilcox, A. N. The importance of the parental genotype in the breeding of fruit. Sixth Internat. Cong. Genetics. Proc. 2:212-213. 1932.

Table 8. Compatibility between 25 Plum Varieties and 18 Varieties Used as Pollinizers

Varieties receiving pollinizers	Varieties used as pollinizers																	
	Assiniboine	De Soto	Ember	Goff	Hanska	Hazel	Kaga	Redglow	Superior	South Dakota	Surprise	Toka	Convoy	Sapa	Wolf	Wyant	Minn. No. 89	Minn. No. 267
Ember	—	F*	—	G	G	G	F	G	G	G	G	G	G	P	F	G	G	G
Elliot	G	G	G	—	P	G	G	G	F	G	G	G	—	P	G	G	G	G
Hanska	—	—	G	G	—	—	—	—	—	G	G	—	—	—	—	—	G	—
Hazel	—	—	G	—	—	—	P	—	P	G	G	P	—	—	—	—	—	—
Hennepin	—	G	F	F	P	G	G	F	—	G	G	G	—	P	G	G	G	G
Kaga	—	—	G	—	—	G	—	—	G	G	G	G	—	—	—	—	G	G
La Crescent	G	G	P	—	P	G	G	F	P	G	G	G	—	P	G	G	G	G
Mendota	G	G	F	—	—	—	G	—	F	G	G	P	—	P	F	G	—	F
Monitor	—	G	F	G	P	—	F	—	G	G	G	F	—	P	G	G	G	F
Pipestone	—	F	—	F	—	F	F	F	F	G	P	G	—	—	—	—	G	G
Radisson	G	—	—	—	G	—	G	—	—	—	—	G	—	—	—	—	—	F
Redglow	—	F	P	F	—	G	G	—	—	G	G	G	—	—	—	—	G	G
Redcoat	—	G	—	—	F	G	G	P	P	G	G	G	—	—	G	G	G	G
Redwing	—	G	F	—	F	—	G	—	F	G	G	G	—	P	G	G	—	G
South Dakota	—	—	F	G	G	G	G	F	F	—	G	G	G	G	—	—	G	G
Superior	G	—	P	G	G	G	G	F	—	G	G	G	—	—	—	—	G	G
Surprise	—	—	G	G	G	G	G	—	—	G	—	G	—	—	—	G	G	F
Toka	—	—	G	—	—	G	G	F	G	G	G	—	—	—	—	—	—	G
Tecumseh	—	—	—	G	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tonka	—	G	P	—	F	—	P	P	P	G	G	G	—	—	G	—	F	G
Underwood	G	G	P	G	F	G	G	P	F	G	G	G	—	P	G	F	G	G
Waneta	—	G	G	—	G	—	G	—	F	G	G	G	—	G	G	G	—	G
Minn. No. 89	—	—	F	—	—	—	F	—	—	G	P	—	G	G	—	—	—	P
Minn. No. 225	—	—	F	—	—	—	P	P	—	G	G	G	—	—	—	—	G	F
Minn. No. 267	—	—	F	—	—	F	F	—	F	G	F	G	—	P	P	—	G	—

* Compatibility ratings: G = good; F = fair; P = poor.

cause they bloom much later than plums. The two varieties included in table 8 bloom early enough, however, to overlap the blooming period of some varieties of later blooming plums, and hence, they may be of some interest.

South Dakota is rated good on all varieties on which it was used and nearly all other pollinizers are good on South Dakota. Ember, Redglow, and Superior are included among the pollinizers even though they rate only fair from the standpoint of compatibility. They are varieties that are likely to be grown in home and commercial plantings and will have some value as pollinizers in certain combinations. These three varieties would not be sufficient for all pollinizing requirements in the average orchard but they would supplement the activity of other pollinizers. South Dakota and Toka are probably the best general pollinizers in the group and are worth growing for their horticultural value in any plum planting.

The large number of possible satisfactory combinations which might be selected from table 8 may be confusing to the grower who would like to produce a succession of plums from a few good varieties throughout the ripening season. Such a planting is suggested in table 9 with six excellent varieties and the two recommended pollinizers, Toka and South Dakota. These two show good compatability with all varieties except themselves. Superior, Redglow, and Ember also will supplement the action of South Dakota and Toka and

Table 9. Varieties of Plums Suggested for Home or Commercial Planting Showing Interaction of Pollinizers

Varieties in order of ripening	Season of bloom	Varieties which will act as pollinizers, and degree of compatibility				
		Toka	South Dakota	Superior	Redglow	Ember
Underwood	Mid-season	G*	G	F	P	P
Hennepin	Late	G	G	—	F	F
Redcoat	Early to mid-season	G	G	P	P	P
Superior	Early	G	G	—	F	P
Redglow	Mid-season	G	G	—	—	P
Toka	Early	—	G	G	F	F
South Dakota	Mid-season to late	G	—	F	F	F
Ember	Mid-season	G	G	G	G	—

* Compatibility ratings: G = good; F = fair; P = poor.

help to insure satisfactory fruit production in the orchard. It will be noted that every variety in the orchard will be provided with a good pollinizer regardless of the blooming season. Such an orchard if given reasonably good culture should prove to be reliably productive. If the planting is to be in northern Minnesota it might be wise to omit Superior and possibly Ember because they may not be fully winter hardy.

EUROPEAN PLUMS OF THE DAMSON AND PRUNE TYPES

The studies of self and cross fertility in the European plum have been very limited. It may be observed in table 10 that three varieties of the prune type (*P. domestica*) and one Damson (*P. insititia*) are all self and cross fertile. The evidence on cross fertility is not entirely convincing because the flowers were not emasculated before crossing and all were selfed as well as crossed.

The advent of winter-hardy varieties of European plums into Minnesota plum culture requires a more extensive study of their cross and self fertility. Limited studies indicate that these will not present serious pollination difficulties since many will be self fertile and it may be assumed that most of them will be cross fertile.

CHERRY-PLUMS (SAND CHERRIES AND SAND CHERRY HYBRIDS)

The group of fruits classified as cherry-plums has been derived from the native sand cherry (*P. Besseyi*) hybridized with various species of Prunus. As might be expected, this group is extremely variable in tree and fruit characteristics. This variability also applies to the season of bloom although in general this is late compared with the blooming season of plums. Time of flowering of this hybrid group follows more nearly the season of the late blooming sand cherry parent than of the plum.

Table 10. Self and Cross Fertility in European Plums

Varieties	Species	Dietz	Krikon	Mount Royal	Bonne Ste. Anne
Dietz	*P. domestica*	G*	G	G	—
Krikon	*P. insititia*	F	G	F	—
Mount Royal	*P. domestica*	G	G	G	—
Bonne Ste. Anne	*P. domestica*	—	—	—	G

* Set of fruit ratings: G = good; F = fair.

Table 11. Cherry-Plum and Plum Varieties Tested as Pollinizers for Cherry-Plums

Pollinizer varieties	Number varieties on which pollinizer was tested	Compatability rating	Season of bloom	Pollen abundance	Parentage
Brooks	8	F*	Very late	Medium	*P. Besseyi*
Compass	22	G	Late	Good	*P. Besseyi* x Miner plum
Convoy	8	G	Medium	Good	Sand cherry hybrid
Dura	6	G	Medium	Medium	Sapa seedling
Manor	12	F	Early	Good	Sapa seedling
Nicollet	14	G	Medium	Good	Sand cherry hybrid
Oka	16	F	Early	Medium	Sand cherry hybrid
Opata	18	F	Early	Good	*P. Besseyi* x Gold plum
Sapa	21	G	Early-medium	Medium	*P. Besseyi* x Sultan plum
Sapalta	7	G	Medium	Good	Sapa seedling
Wachampa	5	F	Medium	Medium	*P. Besseyi* x Sultan plum
Zumbra	14	F	Late	Good	Sand cherry hybrid
Minn. No. 155	7	G	Medium	Medium	Compass x Formosa plum
Minn. No. 220	5	F	Medium	Medium	(Sand cherry x Climax) x (Sand cherry x Formosa)
Minn. No. 376	5	F	Medium	Medium	Zumbra open
Morden No. 117	2	F	Medium	Medium	Sapa seedling
Morden No. 118	17	F	Early-medium	Medium	Sapa seedling
N3782	8	F	Medium	Medium	Sand cherry hybrid
N3794	7	F	Early	Medium	Oka seedling
Q-8A-55 Morden	4	F	Early	Poor	Sapa seedling
De Soto plum	4	F	Early	Good	*P. americana*
Older plum	3	F	Too early	Good	Hybrid plum
South Dakota plum	7	G	Early	Good	*P. americana*
Surprise plum	2	G	Early	Good	*P. hortulana Mineri*
Toka plum	4	G	Very early	Good	*P. americana* x *P. Simonii*
Minn. No. 84 plum	1	F	Early	Good	*P. americana* x Shiro
Minn. No. 89 plum	5	G	Early	Good	Wastesa x First
Minn. No. 107 plum	1	F	Early	Good	De Soto x Burbank

* Compatability ratings: G = good; F = fair.

Tables 11 and 12 contain summaries of compatibility ratings of 44 varieties of sand cherry, cherry-plums, and plums tested as pollinizers in 294 combinations with 29 varieties of cherry-plums. The limited tests involving 13 varieties of plums used as pollinizers are of little interest from a practical standpoint since most of the plums bloom too early to be effective pollinizers for cherry-plums. In some seasons varieties like South Dakota or Surprise would bloom late enough to overlap the flowering of early blooming cherry-plums such as Oka, Manor, and Sapa. It seems clear that many of the plums are quite compatible with the cherry-plums and may be useful as pollinizers in northern latitudes where the blooming seasons more nearly overlap.

Table 12. Varieties Rated as Poor Pollinizers for Cherry-Plums

Ember plum
Goff plum
Hanska plum
Superior plum
Tokato plum
Minn. No. 202 cherry-plum
Minn. No. 340 cherry-plum
Minn. No. 66 Nanking cherry hybrid
Minn. No. 120 cherry-plum
Minn. No. 123 cherry-plum
Q-55-14 (Morden) cherry-plum
Mordena cherry-plum
Red Cortland cherry-plum
St. Anthony cherry-plum
Tom Thumb cherry-plum

Table 13. Compatibility Interaction Between 11 Cherry-Plum Varieties

Varieties receiving pollinizers	Varieties used as pollinizers										
	Compass	Convoy	Dura	Manor	Nicollet	Oka	Opata	Sapa	Sapalta	Wachampa	Zumbra
Compass	—	G*	—	F	F	P	F	F	G	—	G
Convoy	G	—	—	F	—	F	P	G	G	—	—
Dura	—	—	—	P	—	—	—	G	—	P	—
Manor	G	G	G	—	—	G	F	G	G	G	—
Nicollet	F	G	—	F	—	P	P	P	G	—	P
Oka	G	—	—	—	G	—	G	G	—	—	G
Opata	G	G	—	G	G	G	—	G	G	—	G
Sapa	G	G	G	G	G	F	G	—	P	G	G
Sapalta	G	G	—	P	—	G	G	P	—	—	—
Wachampa	—	—	P	P	—	—	—	F	—	—	—
Zumbra	G	—	—	—	G	G	G	G	—	—	—

* Compatibility ratings: G = good; F = fair; P = poor.

Within the cherry-plum group the matter of intercompatibility is even more variable than in the plum group. The cherry-plum varieties appear to be quite specific from the standpoint of compatibility requirements. The fact that a pollinizer may work very well with one variety is no indication that it will succeed with any other given variety. The records show that Compass shows good compatibility with 13 out of 22 varieties, fair with two, and poor compatibility with seven. Similarly, Sapa is good with eight varieties, fair with three, and poor with ten. Convoy is the only pollinizer which rates good on all varieties on which it has been tested, but the tests have been limited to only eight combinations.

A selected group of 11 of the most commonly grown varieties of cherry-plums has been arranged in table 13 to show the intercompatibility of these varieties. There are many gaps in this table due to lack of time and opportunity to test all combinations. Sapa is the

Table 14. Varieties of Cherry-plums (Arranged in Order of Ripening) Suggested for Home or Commercial Planting Showing Interaction of Pollinizers

Varieties	Flesh color	Season of bloom	Pollinizers						
			Manor	Oka	Opata	Sapa	Sapalta	Convoy	Compass
Manor	Purple	Early	—	G*	F	G	G	G†	G†
Oka	Purple	Early	—	—	G	G	—	—	G†
Opata	Green	Early	G	G	—	G	G	G	G†
Sapa	Purple	Early-medium	G	F	G	—	P	G	G
Sapalta	Purple	Medium	P	G	G	P	—	G	G
Convoy	Green	Medium	F	F	P	G	G	—	G
Compass	Green	Late	F	P‡	F‡	F	G	G	—

* Compatibility ratings: G = good; F = fair; P = poor.
† Blooms too late.
‡ Blooms too early.

most important and widely grown variety in the group, and it is the only one which has been used in all combinations. It is probable that if these 11 varieties were planted together the pollination requirements for all would be satisfactorily taken care of although the tests completed to date do not show good pollinizers for Wachampa. When the selected varieties are reduced to seven as in table 14 the situation becomes clearer, and it would be safe to assume that all varieties in such a planting would be successfully pollinized regardless of their blooming season. In areas where Dura does well, it might be substituted for Oka or Opata.

NANKING CHERRY *(PRUNUS TOMENTOSA)*

Nanking cherries are grown not only for their fruit but for their decorative value in landscape plantings. Two named varieties and a few numbered selections are sometimes available from nurseries. Plants are also grown from seed and sold as seedlings.

It has been commonly recommended that two or more varieties or seedlings be planted together to provide cross pollination in this species, which was presumed to be largely self sterile. For four years, tests were made on 18 varieties at the Minnesota Fruit Breeding Farm to explore the possibility of finding self-fertile varieties within this collection. The outcome of these tests is summarized in table 15 which shows five varieties to be self fertile, one variety partially self fertile, and 12 entirely self sterile. In addition to the selfing tests, crosses were made between 17 pairs of varieties. All of these combinations proved to be satisfactorily fruitful. On the basis of these tests it seems safe to assume that there is no lack of compatibility between varieties of Nanking cherries.

Table 15. Fertility Conditions in Nanking Cherry, *P. tomentosa*

Self-fertile varieties	**Self-sterile varieties—continued**
Drilea	Minn. No. 20
Orient (Minn. No. 63)	Minn. No. 21
Minn. No. 64	Minn. No. 22
Minn. No. 65	Minn. No. 42
N251	Minn. No. 59
Partially self-fertile varieties	Minn. No. 60
Minn. No. 41	Minn. No. 61
Self-sterile varieties	Minn. No. 62
Minn. No. 5	N4081
Minn. No. 17	N4082

It may be of interest to note the origin of the five self-fertile varieties. Drilea is an introduction from the Dominion Experimental Farm, Morden, Manitoba, Canada, and came from seed of a white-fruited variety grown at the USDA Field Station at Mandan, North Dakota. The other four varieties are from a single line of breeding at the University of Minnesota Fruit Breeding Farm. N251 is a variety which was found growing at the home of O. N. Jensen, Albert Lea, Minnesota, and brought to the Fruit Breeding Farm in 1925. Orient and Minnesota Nos. 64 and 65 grew from selfed seed of N251. It seems clear that there will be no future difficulty in developing self-fertile varieties of the Nanking cherry.

KOREAN CHERRY *(PRUNUS JAPONICA)*

Although there are as yet no named varieties of this fruit there is considerable interest in its development. A large number of seedlings have been grown at the University of Minnesota Fruit Breeding Farm and numerous selections of improved types have been made. Seven of the most promising selections were tested in a limited way for self and cross fertility. These tests are summarized in table 16. One of the seven, Minnesota No. 20, proved to be self sterile and another, Minnesota No. 46, proved to be only partially self fertile. The other five are completely self fertile. Crosses were made in 13 pairs of varieties and in all cases these proved to be entirely compatible and fruitful. It would seem in this species, self fertility is the general rule and that there is no lack of compatibility between varieties.

Table 16. Self and Cross Fertility in Korean Cherry, *P. japonica*

Varieties receiving pollinizers	Varieties used as pollinizers						
	Minn. No. 20	Minn. No. 23	Minn. No. 46	Minn. No. 57	Minn. No. 60	Minn. No. 88	Minn. No. 99
Minn. No. 20	P*	G	—	G	—	—	—
Minn. No. 23	G	G	—	G	—	G	—
Minn. No. 46	—	—	F	—	—	—	—
Minn. No. 57	G	G	—	G	—	G	—
Minn. No. 60	G	—	—	G	G	—	—
Minn. No. 88	—	G	—	G	—	G	G
Minn. No. 99	—	—	—	—	—	—	G

* Compatibility ratings: G = good; F = fair; P = poor.

NUMBER AND ARRANGEMENT OF POLLINIZERS

In small home orchards the arrangement of pollinizers is not a problem since the number of trees would seldom exceed six to ten of either plums or cherry-plums. The important matter is to make sure that two or more good pollinizing varieties are included and are planted near the middle of the orchard.

In larger orchards for commercial production the number and arrangement of the pollinizing varieties is highly important. In some cases the fruit of pollinizers may be less desirable than the other varieties and the orchardist will wish to plant a minimum number. Attempts have been made to reduce the ratio to as much as 1 to 8, with the pollinizer placed in the center of a unit of nine trees as shown in the accompanying plan.

X	X	X	X	X	X
X	P	X	X	P	X
X	X	X	X	X	X
X	X	X	X	X	X
X	P	X	X	P	X
X	X	X	X	X	X

This plan has not resulted in satisfactory yields even though each tree is adjacent to a pollinizer. The pollen must be transferred between trees by bees or other insects, and in this case there is too much opportunity for insects to visit the orchard without moving from a pollinizer to trees of other varieties.

To be reasonably certain of adequate pollination, from one-third to one-fourth of the orchard should be planted to pollinizer varieties. A good arrangement is to plant pollinizers in every third row beginning with the second row (see accompanying plan).

X	X	X	X	X	X	X	X	X
P	P	P	P	P	P	P	P	P
X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X
P	P	P	P	P	P	P	P	P
X	X	X	X	X	X	X	X	X

Two or more pollinizer varieties should be used and for most efficient action these should be alternated in the row. For the varieties of plums and cherry-plums mentioned in tables 9 and 14 the following arrangements are suggested.

Row	Plum
1	Redcoat
2	Toka and South Dakota
3	Underwood
4	Superior
5	Toka and South Dakota
6	Redglow
7	Ember
8	Toka and South Dakota
9	Hennepin

Row	Cherry-plum
1	Sapalta
2	Oka
3	Manor
4	Sapa
5	Opata
6	Sapa
7	Sapa
8	Convoy and Compass
9	Sapalta

In this arrangement of the plum orchard two high-quality but sometimes shy-bearing varieties, Underwood and Ember, are placed between the pollinizer rows and varieties that will provide some supplementary pollination. The cherry-plum planting plan provides for a maximum use of purple flesh varieties with the principal emphasis upon the commonly grown variety, Sapa. Unfortunately, Convoy and Manor are two new varieties of Canadian origin which are not as yet widely available in the United States. Many other satisfactory arrangements with these and other varieties may be planned by a careful study of tables 13 and 14.

The necessity for planting a large proportion of the orchard to pollinizers is a consequence of the very short blooming season characteristic of northern regions. Wind, rain, or other unfavorable weather conditions often occur at this time with the result that bees may be able to work only a few hours during the entire flowering period. Under these conditions the set of fruit will be very light unless a bountiful supply of pollinizing varieties is available.

USE OF BOUQUETS AND TOPGRAFTING

In orchards which have been planted without adequate provision for pollination the situation may be helped by introducing large bouquets of good pollinizers in pails of water. These should be placed in the trees or on stands that will provide an elevation of three feet or more above the ground.

A more permanent solution of the problem will follow the grafting of pollinizer varieties into the tops of every third tree or every third row. These grafts should produce some flowers the second year and by the third year become fully effective pollinizers. It is important that the grafts be placed high in the tree rather than in the lower branches to insure vigorous growth and a favorable position to attract bees.

New varieties of plums and cherry-plums are being developed in large numbers by plant breeders in the northern prairie states and in Canada. Before these varieties can be utilized effectively by the fruit grower he must know what pollinizers they will need and whether or not they will successfully pollinate other varieties. Since it is improbable that self-fertile varieties of these fruits will be discovered, it will be desirable if not necessary to continue compatibility studies of this nature indefinitely.