A century of rose germination studies.

Lawrence C. Davis, Spring 2010

This extensive review on rose seed germination includes five parts:

1. Information extracted from the American Rose Annual or American Rose magazine;

2. A summary of Frank Buckley's ARBA review;

3. Information from the scientific literature which deals with some of the more technical aspects;

4. An **annotated bibliography**. This is provided to save you the effort of finding obscure publications only to learn that they contain little or no new, useful information. I have also added a **species index**, immediately following the bibliography, which shows the page number on which germination studies with species are presented. Hybrid classes, such as hybrid musk, are not included, only the presumably "pure species".

5. My personal observations which provide specific examples of parental and seasonal effects;

A few tentative conclusions

After having read a great many papers on techniques for germination of rose seeds, mostly tested in their intact achenes, I can conclude with certainty that there is a great deal of variability that is determined by the parentage of the seed being studied. Thus, there is no one best way to germinate the seeds. There are a few things that might be safe generalizations. The broadest, is that rose species are well adapted through evolution, to survive in the environments in which they grow. So seeds of species that depend on surviving extremely cold winters, or dry conditions, are able to tolerate drying, and freezing, at least while dry. On the other hand, more tropical sorts, which probably include most roses classified as hybrid teas, do not do so well when dried or frozen. For many common species, and the more common garden roses, cool moist stratification or direct planting outdoors in a mild Mediterranean climate may be optimal. Germination may also be better if the seeds mature under somewhat warmer conditions than obtain in the late fall, in the low 70s F, or 20s C until ripening, rather than just above freezing. This poses a problem for hybridizers using hybrid tea types in cool climates. It should be less of a problem with biotypes of species that naturally grow in the location of interest.

For some species, it seems almost obligatory that seeds pass through a warm period before a cool period to maximize germination. So, they may either need to be stored dry for a long period of time, or kept warm and moist before chilling. Even then, they may need rather long times to germinate, often waiting until after a second "winter". There is simply not enough data to say definitely how long those warm and cool periods need to be to maximize germination.

There are probably multiple kinds of dormancy, both the initial inhibition which prevents premature germination within the fruit, and secondary dormancy induced by warm storage or

otherwise unfavorable conditions for sprouting. Crop species grown in temperate climates have been selected to maintain that first kind and minimize the second kind of dormancy. So, that is the sort we are most familiar with. However, there are examples, for instance viviparous seed in maize, where abscisic acid response is defective and so the seed germinates while still on the cob. Similar mutants are found in brassicas, including Arabidopsis. Such seeds often have a very short period of viability. This is a problem in some crops, such as rice where it is difficult to keep seed of some lines viable for more than a year. Tropical trees commonly show that same trait, making it difficult to provide seed banks for security. The other extreme is with weeds that can accumulate a seed bank in the soil, able to survive for decades, only to be released when suitable conditions are provided. If we think of rose species growing everywhere from India to Siberia and at comparable latitudes in North America, it is easy to see how different species might have had different strategies for adaptation to their particular climate.

Part 1. Germination notes in American Rose Annual, a non-exhaustive listing.

American Rose Annual and American Rose magazine articles which reflect in a general way the progress in understanding of factors controlling rose seed germination are not cited in the annotated bibliography, but only in the text that immediately follows this. I've made no systematic search of the magazine, and only cite a few instances of work on germination, noted first by others. Examples from articles in the Annual are more extensive. In fact, I hope I've caught them all. I have not looked at the RNRS Annual (U.K.) myself.

Over two decades ago I copied out some of the articles on hardiness and hybridizing from earlier Rose Annuals and more recently I acquired a full run of Rose Annuals from 1963 onward. My coverage is a bit thin in the 1950s and I may have missed something with a non-obvious title. I went through the listing of titles for hybridization articles in the American Rose Annual that is posted on the RHA website to cross-check my own germ. studies. In earlier years the Annual was indexed in Biological Abstracts, and citations were tabulated by Lela Barton in her **Bibliography of Seeds**, up to the mid 1960s. So we should have decent coverage.

In the beginning

Dr. Walter van Fleet reported (Notes from the Firing Line p 43, 1918) that *R. multiflora* is the best for quick germination, while *R. canina* is the worst. *R. wichurana* is not too bad; likewise offspring of tea roses are satisfactory. He hung on to the planted seeds up to 5 yr, even 7 yr for some. They were almost all grown in the open under lath in beds in the Washington D.C. area (Glenn Dale, MD). That means they had a fairly mild but variable winter experience, with both temperature and day length changing. He said in an interview shortly before he died, that the hybrid wichurana rose later having his name was initially grown in Memphis, TN. It was nearly lost at the point of introduction to the trade too.

In 1920 the Editor of the Rose Annual (McFarland) wrote (p 155) on "Why do rose seeds germinate so slowly?", but just to comment that Dr van Fleet said it was because they need to after-ripen. Important insight at the time, indicating how little was known of physiology.

The next comment appeared in 1924 when the work of William Crocker at the Boyce Thompson Institute (BTI) was mentioned in a footnote (pg 33). He observed the best results with stratification at 41 F (5 C). This footnote was followed up in the 1926 Annual by an interview with the same worker, done by A.C. Fraser, who was in the department of Plant Breeding at Cornell University (p 34). A fundamental conclusion made by Crocker was that dormancy in the roses he was studying did not depend on the seed coat (testa) and achene thickness, but from a requirement for after-ripening of the embryo. He felt that the temperature of after-ripening is critical, with too low or too high a temperature interfering with the process. See the literature summary below for more information on the work of Barton and Crocker. Their observations have been shown to be correct, and several specific regulatory hormones have been identified.

Lela V. Barton had an article in 1937 (p 33) on "Germinating hybrid rose seeds", that provided some useful statistics on rose seeds from both Father G. Schoener in CA and the Brownells in RI. With the seeds from Father Schoener, there were many different crosses involved. Much of his work was introgressing *R gigantea* with HTs, so there may have been more "tropical" genes than in other programs, such as van Fleet or Brownell. Schoener introduced a number of varieties that had success early in the 20th century, the best known perhaps being Arrilaga.

Some seed lots (38-50 % in various years) had below 10 % germ., while 17-27 % of lots gave 11-20 % germ. and only 4-7 % of all gave 41-50 %. That means that another quarter had 21-40 %. A seed lot apparently is all of the seeds from a particular cross, but that is nowhere stated. All lots were initially tested by stratification in moist peat moss, in a refrigerator. All seeds were stratified, although floaters and sinkers were counted and in one season separated for stratification. Of 3,750 floaters in 1931, there was 44 % germ. while for the sinkers (32,037) there was only 30 % germ. Another 168 seed lots from that year were not segregated. In 1929 & 1930 near a quarter of the seeds were floaters.

Crop yr	Seed lots	Total seeds	# germ.	% germ	# discards	% discards
1929	353	68,911	19,161	28	nd	
1930	423	39,344	8,910	17	3,117	35
1931	372	57,719	13,665	24	6,311	46
1932	413	89,101	15,616	18	6,376	41

A test of germ. medium was done in 1932, comparing 7 lots of seed with half of each lot kept in peat and half planted directly into a flat filled with a soil mix, and kept at the same temp. For 5/7 lots the % germ. was better for the seeds in soil. The results shown below are for seed lots in addition to the 413 lots in the above table for 1932, including the 7 split lots, and so can be compared directly. There was better germ. % in the soil and a lower fraction of discards. Placing the flats outside, mulched, in Yonkers, NY (NYC area) to over-winter gave satisfactory results. Average winter temps range from slightly above freezing in Dec (2 C), to just below in Jan (-0.5 C) and a little above in Feb (1 C), with a daily range of 7 C in those months. In Nov the daily av. >8 C, and in Mar ~ 5 C. Seed probably froze a few times, unless very well mulched.

Treatment	Seed lots	Total seeds	# germ.	% germ.	# discard	% discard
soil 41 F, refrigerator	40	11,095	3,735	34	1,241	33
soil mulched outside	35	6,337	1,266	20	352	28
peat, refrigerator	413	89,191	15,616	18	6,376	41

For the seeds from the Brownells, a full decade of results (1926-35) are available. The overall average % germ. was 34 % (10,353 of 30,243). Total seeds varied year by year from 350 to 5300, and % germ. varied from 19-49 %. The Brownells were developing hardy shrub roses mixing HTs and species hybrids, making a wide range of crosses, so the annual germ. % variability may have been due to crosses, or climate, perhaps both.

In the 1937 Annual, M.H. Horvath wrote on "A veteran's experience with rose seeds." Horvath was originator of a number of roses while living in Ohio, including Doubloons, and earlier in RI he produced a series of ramblers. He made no specific quantitative comments, unfortunately.

In 1944 (p 86) Martin Jacobus gave detailed instructions in "Rose germination and growing the young seedlings" based on his experience with three methods of harvest. He gave no actual numbers but said that he preferred letting the hips ripen in moist peat moss in a refrigerator for a while before taking the seeds out and stratifying them at the same temperature until they germ. Roy Shepherd followed up with "Germinating rose seeds" in 1945 (p 121). An article of same title, by Forrest L. Hieatt, appeared in 1947 (p 125). Neither of these adds anything of substance.

Sam Asen's article on "Embryo culture of rose seeds" (p 151) in 1948 gives an example of a technique that may circumvent the dormancy problem at least in some cases. He described how to dissect out the embryos from the hard achenes and grow them on a specific mineral salts medium developed by Tukey. Unfortunately only about 200 embryos per day can be dissected in this way, even by a proficient worker. That makes it a costly process so it is rarely used. Asen's work was later described in detail in an experiment station publication (see below). See also the recent work of Don Holeman, available via the RHA website

An interesting short review of germ. studies, by a college student in South Carolina, was published in 1977. In it the author, Deborah Antley, a student of Charles Jeremias, gave short descriptions of a number of methods previously published in the Annual. The earliest of these that she discussed was the work of Lela Barton in cooperation with William Crocker (1937 Annual). The only other article cited by Antley in which specific germ. percentages are mentioned was by Bernadine Dodek who expected 25 % (1974 Annual). [In fact during 1972 Mrs Dodek got 750 of 1700 seeds to germ. and 400 to survive transplantation.] Antley cited several interesting treatment techniques but none provided quantitative evidence of efficacy. So whether they were better or worse than others is uncertain.

Consensus at mid-century

Roy E. Shepherd's interesting article in the 1954 Annual (p 102) refers to the work of Horvath in the same area of the country (north-eastern Ohio, near Lake Erie) where hips are mature in early fall (at least from once-blooming roses). Horvath recommended harvesting as soon as the hips began to change color and planting directly into flats. Shepherd harvested in mid-Sep., keeping the flats in a cool but not freezing location until first germ. (Nov) and then in a small lean-to greenhouse. Up to 78% emergence was obtained in the first season. He retained flats for two seasons. A controlled experiment was done with *R. multiflora* , tabulated below.

Medium	Germination %	Growth & Transplanting
1.beech sawdust	60	poor, easy
2.peat moss	90	good, fast easy
3.sterile clay loam	55	slow, hard
4.eq. pt. soil, sand, peat	similar to 3	slow, easier
5.eq. pt. sand, peat	75	OK, easy
6.eq. pt. sawdust, peat	50	poor N.C.
7.eq. pt. sand, sawdust	same as 6	poor N.C.
8.eq. pt. soil, sand	70	fair, OK
9.eq. pt. soil, sawdust	95	good, OK
10.eq. pt. soil, sand, sawdust	85	good root, less top, OK
11.eq. pt. soil, sand, peat + commercial fertilizer	60	best color, roots, N.C.
12.eq. pt. sand, peat + fert	>60	" , easy
13.vermiculite	90	poor color, OK
14.eq. pt. sand, vermiculite	85	poor, good
15.milled sphagnum	85	fair, easy
16. #4 below, #15 above achenes	~80	very good, hard
17. leached cinders	N.C.	fast drying, easy
18. eq. pt. sand, cinders		similar to 17

N.C.= no comment by author. [The commercial fertilizer was no doubt nitrate based, rather than urea + ammonium sulfate as used in modern fertilizers which would likely prove toxic to seedlings without a guaranteed source of nitrifying bacteria in the medium.]

The first cotyledons emerged after just 3 wk at 45 F (7 C). Germ. % was very high in some instances, but results are based on only 20 seeds/treatment so reliability cannot be better than +/- 10 %. The experiment was repeated a 2nd year with reportedly comparable results. Ease of transplantation was a big factor favoring some media over others. This work was done before general availability of commercial soil-less mixes.

G.D. Rowley in the 1956 Annual (p 70) discussed his work on "Germination in *R. canina*". See discussion of peer-reviewed articles below. Denison Morey in the same issue (p 64) described "The use of chemicals in breaking seed dormancy in hybrid teas." The Rowley article was reprinted in the RHA Newsletter in Fall 1999. From 600 seeds, 0.7 % germ. the first year, 30.7 % the 2nd year, 1.2 % the 3rd, 0.5 % the 4th and 0.3 % the 5th. In another series, up to 60 % germ. the 2nd year when harvested at the firm red mature stage of the hips, letting them fall from the bush, cleaning and planting directly. Lower percentages were obtained when hips were left until decomposing, with none germ. the 1st year. In another case, hips that stayed on the bush through winter yielded seed that germ. directly (23 %) when planted the next fall.

E.B. Risley had an interesting article in American Rose magazine, p 15 Oct 1958 in which he showed definitely that "Male controls sprouting". With Skinner's Rambler as female parent, different pollen parents showed varied times to germination during stratification at refrigerator temperature in moist sphagnum moss. The quickest were Max Graf 83 d., Persian Yellow 91 d., and O.P. 94 d.. Dream Girl 97 d., Golden Arctic 101 d., and Mandelay 101 d., about 10 d. later. Then came Bonfire 112 d., Lady Penzance 124 d., Prof. Emile Perrot 134 d., Diamond Jubilee and Tawny Gold, both160 d. The slowest was Queen of the Lakes at 173 days. No numbers for quantity of seeds are provided so we only know that "The majority of seeds in each cross germinated soon after the first ones." I have independently observed a similar effect with different parents (see below). Risley was a horticulturalist at the University of New Hampshire, trying to breed hardier ramblers, hence the choice of seed parent.

F.C. Buckley (see below) noted that Shepherd claimed the same as Risley, but had provided no documentation of the effect. Buckley felt that the female parent should be dominant because it provides the carpel and testa of the achene. With a single male, different female parents may well determine different germ. times but it seems that with a single female, different males do indeed influence germ. time, at least in some instances. Probably this is because the male parent does (except in *R. canina*) contribute half the genes of the embryo, which is the responsive tissue. Even in *R canina*, only one set of genes of the maternal parent may be active for most functions (see Werlemark and others in Nyboms' group for evidence).

C.H. Lewis in Salem, VA found a very wide range of germination times for different species and crosses, with a single planting in fall of 1956 showing up to 2 yr delay.(American Rose magazine, Oct.1959 pp 16,17,29)

In the 1960 Rose Annual, Semeniuk and Stewart discussed the "Effect of temperature on germination in four species of roses" (p 104). See also the several articles in the scientific literature from these workers, cited below. The study referred to here is different from any of the scientific peer reviewed journal articles and seems to have been the precursor to several of them.

Unfortunately only summary data are provided for most of the work. Four species were studied, with three dates of harvest and two treatment temperatures of 40 F (4.4 C) and 60 F (15.4 C). In all cases the hips were harvested, then achenes were cleaned, soaked 1 min in 1/10 commercial bleach with a little detergent, selected as "sinkers", then planted in flats in shredded sphagnum moss. Each flat contained 100 seeds of each of the 4 species, with three reps held at each temp. After 30 d, all flats were moved to a greenhouse at 60-65 F for 2 wk, then returned to their previous holding temp. for another 30 d, put in greenhouse 2 wk, returned for 30 d the put in greenhouse 2 wk again. So all seeds were exposed to 3 cycles of constant temp (dark?) and 3 cycles of germ. The first harvest date was Sep 5, 1958, second was Oct 22 after first killing frost, third was Dec 8 after prolonged cold. The av. temp. for Aug is 25 C, Sep is 21.5 C, Oct is 15 C, and Nov is 9 C according to current records, but information for 1958 is hard to retrieve. Data in the table below are for seeds held at 40 F. Only one seed germ. in flats held at 60 F.

Species	Sep 5	Oct 22	Dec 8
blanda	0	2.3	5.0
spaldingii	5.0	11.0	8.0
vienesii	2.3	35.7	15.3
reversa	2.3	65.0	39.0

For the first harvest date there was no germ. after just 30 d, but after 60 d 1.67 % of *vienesii* germ. and 2.3 % of *spaldingii* germ. So in the 3rd cycle there was just 0.6 % germ. for *vienesii* and 2.7 % for *spaldingii*, with 2.3 % for *reversa*. For the 2nd harvest date there was some germ. after 30 d, more after 60 d and for all but *blanda* additional after 90 d. Averaged over all species (dangerous with such discrepancy in total %) relatively more germ. happened after just 2 cool cycles for the later harvest, than for the 2nd harvest. The authors suggest that chilling in the hip may hasten response to cool stratification. But it should be noted that total germ. is consistently poorer for the last than for the 2nd harvest, and the authors suggested that too much cool might induce dormancy. The *R spaldingii* referred to here is presumably a synonym of *R nutkana*, while *R vienesii* is not in any of my books.

Beginnings of the Rose Hybridizers Association

Discussions of germination in the newsletter of the RHA are mentioned only if they contain experimental information not available elsewhere. There is some comment in nearly every issue, but little of it is quantitative or with many details, so it's sometimes hard to convert to useful generalization or to compare with other results. Now of course you can search the whole thing on a CD right back to the beginning. I have taken advantage of that function to find the RHA notes and articles mentioned below.

Early issues of the RHA newsletter provide a number of small but informative experimental treatments for germination, mostly in hybrid teas, floribundas and miniatures. Astor Perry reported (Aug 1970) that during an unseasonably warm autumn in 1968 in Raleigh NC, he did a comparison of three treatments. He put 1/3 of his seed on moist sand at 60 F (15.4 C), 1/3 directly into planting and 1/3 stratified cold for 90 d. In the end, all gave the same % germ. In the same issue Bob Harvey (Muskogee, OK) compared inside and outside planting of seeds treated in Alaska Fish Fertilizer solution. He had over 600 seeds from a cross of Little Darling x Angel Face, harvested Nov 1 and stored in a refrigerator in the hips in moist vermiculate until Feb 21. Whether the hips stayed intact or turned black during storage made no difference for treated seeds planted outside with germ. of 29/171 for regular and 26/149 for blackened hips. Treated seeds inside gave germ. of 32/130 while untreated, inside gave germ. of 37/130. Only untreated seeds outside were noticeably lower in % germ. with 4/157. All were planted in 1:1 peat:vermiculite mix in flats or a prepared bed.

Dale Meinzinger, near Detroit, MI did a very wide range of temperature treatments in winter of 1961 with O.P. seed of Independence (reported in 1970 RHA newsletter). Each of 10 treatments got 300 seeds in one large container of vermiculite. At 40-70 F fluctuating, 30 % germ., at a constant 60-65, 24 % germ., at steady 76 F, 14 % germ. and at a steady 40 F, 25 % germ. Keeping the container by the furnace in the basement was nearly as good with 22 % germ., but when the container was buried outside only 2 % germ. Freezing in saturated vermiculite, or allowing temps to fluctuate from -15 to 40 F gave no germ. Heating to 100 F 3 hr each night, or putting seeds outside each night gave only 4 or 3 % germ. It seems that cool or fluctuating temps were most favorable, as anticipated from the early work of Crocker.

Ralph Moore (coastal CA) made a notable observation on germination of seeds from immature hips which he described in a letter reprinted in the Feb. 1971 RHA Newsletter. Nearly mature but still green hips were harvested, in a greenhouse, then kept in plastic bags, as a single layer, placed under fluorescent lights for 3 weeks about 12 h/d. By that time they had turned color. Seeds were harvested and planted as for the more mature seeds. Overall germ. was about the same though slower and spottier for the less mature seed.

In May 1971 Ernest Williams reported from Dallas a simple comparison of 1000 seeds from O.P. Juliette, kept 13 mo. at 0 F (-20 C) and a like number kept 6 wk at 34 F (1.8 C). In the end both gave similar % germ., in contrast to the findings of Meinzinger with Independence, where the freezing treatment gave no germ. It is not clear which CV named Juliette was used, a mini or a gallica (most likely a mini as that was Williams' specialty).

W.D. Gobbee wrote an article for the Amateur Rose Breeder's Association (ARBA) in the U. K., reprinted in the RHA newsletter in 1976. Half of a range of 1968 crosses were treated with the gibberellic acid (GA_3) at 200 ppm for 24 hr, immediately after harvest. From 17 crosses 77/ 108 treated seeds germ., while only 29/108 from untreated seed did so. In 1969 from 61 crosses, 752/1004 treated seeds germ. while only 398/1004 untreated seeds did so. The 1969 treatment time was 48 hr and the dose was 400 ppm. In both years the seeds were planted directly in soil-less potting medium and maintained in an unheated glasshouse with fluctuating cool temperatures. It appears that GA_3 was effective. Gobbee also treated the newly pollinated hips with GA_3 , referencing an article by E.F. Allen in the RNRS Annual.

In 1978, John Walsh, a student at Simon Fraser University, tested a range of potential germination stimulants, with seeds of O.P. Queen Elizabeth, from George Mander. The seeds, received dry, were soaked 1 d in water, then 1 hr in Chinosol to disinfect them, and then exposed to red light, with additional treatments in various combinations. Each treatment had replicates of 2 x 25 seeds, on moist filter paper in 5 cm petri dishes. Gibberellic acid (GA_3) at 0.5 mM , thiourea at 50 mM or ethylene in a chamber at 5 uL/L (5 ppm) was used in combination with 5 min exposures to the 645 nm red light (50 nm HalfBandWidth) at 4,700 erg/cm^2/sec. In this series, light alone gave 16/50 seeds germ. at 20 C over 80 days, while light + GA_3 gave 28/50 germ. Thiourea had a detrimental effect, as did ethylene, even with GA_3. The untreated control of 8/50. Seeds treated similarly but stored cold for 2 mo. prior to the tests, germ. even less well with only 1-3 seed germ. except for the red light or light + GA_3 treatment with 7 & 6 germ. Nicking the seed coat with a file gave very low germ. except in the unstratified control which managed 10/50 germ. The best were GA with 4 & 2 seeds germ. for stratified and unstratified, or light + GA with 3 & 4 seeds germ. On the other hand George Mander obtained 50/110 germ. seeds when they were kept 2 mo. at 3-6 C and then planted in soil. It is not clear whether he also dried the seed for a time equivalent to the transit time required to get seed to the university.

Colin Horner, also in the U.K., did several studies with GA_3. In 1976 he used crosses of Pink Parfait x Rose Gaujard (PP x RG) giving 162 seeds and Pink Parfait x Arthur Bell (PP x AB) giving 151 seeds. There were 6 treatments so each had 27 or 25 seeds for the two crosses. Results are number of seed germ., not %. The warm treatment was 55-75 F, while cold was a refrigerator. After sowing, flats were in a greenhouse, until June 30. First germ. with GA, Oct 17.

Treatment	PP x RG	PP x AB
Direct sowing Sep 27, 1976	10	11
48 h 250 ppm GA, sow Sep 29	19	17
48 h 250 ppm GA, 2 mo warm, 2 mo cold, sow Jan 27, 1977	8	5
omit GA treatment, “ , “ , “	2	5
Four mo warm, sow Jan 27	4	3
Four mo cold, sow Jan 27	1	1

Evidently for this combination, no advantage was had by cold treatment, and delay in planting after GA treatment seemed to lose its benefits. Two years earlier the same author had tested the benefit of warm/cool stratification. From a cross of Vera Dalton x Elizabeth Harkness, seeds were given 2 mo warm in moist vermiculite, followed by 2 mo cold prior to sowing. In this case 48/84 germ. by July 30 from a planting Jan 27. When seeds of the same cross were held warm for the same time and planted the same day, 91/110 germ. It is surprising that no mention is made of germ. prior to planting, which might be expected.

A simple but informative study was done in 1978 and reported by Tom Johnson in the RHA newsletter in 1978, then reprinted in Winter 1992. There seem to have been 13 x 24 seeds per treatment with 6 treatments. Members of a garden club, near Vancouver B.C., did a collaborative project, so exact growing conditions varied between replicates. There was considerable variation in results between reps, because one person had 100 % germ., while another had 98 % and another 96 %, though the overall average was much lower than that. As in the work of Shepherd, the purpose was to determine the influence of planting medium on germ. Sharp sand served as a control. All media were pasteurized to 180 F (82 C) for 3 hr, but not sterilized. The source of seeds was fresh seed of a single batch from a commercial source, but without species indicated (probably *R. multiflora* given the high germ. %). The best result was with 20 % sand, 80 % black earth giving 84 % germ. Somewhat lower results were found in 4 media of 50:50 or 80:20 sand:earth, coast soil (25 % organic matter) or milled sphagnum (65-71 %) while the pure sand gave 48 %. Some factor in the high humus of soil enhanced germ. %. It could be enzymes from microbes in the soil, or humic substances that bound up abscisic acid and other germination inhibitors.

In the winter of 1981 a member, J. Selby in VA, contributed the following simple statistics for seeds of a cross of Little Darling x assorted miniatures. With 400 seeds planted immediately on separation from the hips, 50 % germ. while for 366 seeds left to dry for 6 wk, only 18 % germ.

During the early 1980s there was discussion of whether the then new fungicide Triforine (Funginex) when used in the garden might reduce germ. of the seeds from hips exposed to it. Mr. J.C. Hooper of Memphis, TN tested this in a large way, by getting seeds from neighbors who did use Funginex, compared to his own seeds where Benlate (benomyl) + Manzate were the fungicides. Half the seeds were germ. under lights, and half in a cold frame. From 2150 seeds under lights with Funginex in the garden of origin, he saw 17 % germ, while with 2450 seeds of the benomyl treated plants he observed 13 %. In the cold frame of 7450 Funginex seed there was 14 % germ., exactly the same as for 2450 of the benomyl series. The plants being grown in the two gardens were not the same but the large numbers involved for each of the two germ. methods indicate no detrimental effect of Funginex, compared Benlate.

From the Spring 1982 RHA newsletter, reprinted 1990, we find a little study done by Paul Jerabek in Ohio. From an assortment of frosted hips, not very ripe, he gathered 1200 seeds. All samples were put in vermiculite. Two pots of 200 each, planted in a coldframe Dec. 7 yielded 39 & 42 seedlings each (about 20 %). Two lots refrigerated 90 days then planted gave just 11 total (<3 %), while two lots dried 4 hr before refrigeration gave 5. Presumably the coldframe provided lower and more variable temperature conditions which may have been beneficial.

In a 1983 RHA newsletter, Bob Harvey reported some tests he did in Oklahoma. From a cross of Lady X x Angel Face he soaked 84 seeds in apple juice for a day and then incubated them in a jar with apple slices for 2 wk. These gave 52/84 germ., while a control not so treated gave 36/84. It was not stated what temperature was used for the treatment or whether there was any stratification done to any of the seeds after the treatment, prior to planting. In another experiment with a cross of Pink Favorite x (Little Darling x Angel Face seedling) 51 seeds sprayed with gibberellin (type or concentration not specified) no seeds germ., whereas 18/60 untreated seeds did germ. For another cross of Little Darling x Angel Face, 80 seeds were soaked in very dilute vinegar (1:33 diln) for a day prior to planting and gave 18 germ while the control showed only 8/78 germ. Finally in a cross of Garden Party x O.P. Paradise seedling a Rootone treatment gave 9/33 germ. vs 5/33 for the untreated control. It seems safe to conclude that the gibberellin used was not beneficial. Apple slices might be. It's not clear if any results are statistically significant. Several other members reported poor results with GA. However, there are important differences between different types of GA and some are not stable for long periods of time, especially in solution. Thus, some kinds of GA might be effective in some cases, while others are not.

In this context the work of Harm Saville is important, for although it is not accompanied by any statistics, it is impressive in working with 40-80,000 seeds per year. It was described in Spring 1989 and of course applies only to miniatures grown continually in greenhouse conditions, in coastal MA. Crosses were pollinated twice and then a drop of 250 mg/L (250 ppm) of GA was applied to the base of the stigmas. Harvested hips (just turning color) were treated to warm stratification 30 d., followed by refrigeration 60 d. Then the paper towel (initially moistened with captan) in which they had been kept through warm and cool phases, was soaked in 250 mg/L GA, squeezed dry and kept for a day before planting. Germ. rates of 30-60 % were obtained in 3 wk.

In the Spring 1994 issue of the RHA Newsletter, Henry Kuska reported on some of his experiments trying to improve rose germination using household enzymes. His work was a follow-up to work reported by Yambe et al (see below). The idea is that some enzymes may specifically attack the "glue" that holds the two parts of the rose achene together and make germination easier, partly by allowing water to pass in to reach the actual seed. He used commercial seed (*R. x rehderiana*) from Park Seed Co. This obviously had been stored dry for some period of time and was specified to need up to two months to germinate. Batches of 25 seeds were soaked in 150 mL of solution (in tap water) for 40 hr, then rinsed several times and placed on coffee filters on wet sand treated with Captan. A dozen treatments were given including just tap water alone, and driselase which was used by Yambe et al. The best germ. was with driselase having 14/25 in 33 days, with 7 emerging in 2 wk. Two other effective treatments were Enforcer Drain Care with 12/25 seeds germ., with 6 in 18 d, and Bromelain with 9/25 by 33 d with 4 in 3 wk. Less effective treatments included Renu contact lens cleaner or Acidophilus (6/25), Drain Solution or Pancreatin (5/25), Papaya or Beno digestive aid (4/25), Drana buildup remover or tap water (3/25) and Natural Brand Enzyme digestive aid (1/25). Driselase contains a pectinase + cellulase while Enforcer contains cellulase among other enzymes. Bromelain is strictly a proteinase, as is Renu with subtilisin. Dose levels and time of treatment were variables that could be changed easily, perhaps with benefit to the germ. rate. The maximum germinability of the seeds is also uncertain, so 14/25 may represent the maximum possible.

The RHA newsletter in Winter 2003 featured several articles on germ., giving details of individual experiences but no numbers. Other discussions of germ. in the RHA newsletter mostly describe people's personal preferences with few hard numbers provided. One instance with specific numbers was provided by David Zlesak, who tried peroxide as a treatment to sterilize and stimulate rose seed. He used "Angel Rose, mixed" from Thompson and Morgan as a seed source. This is a dry seed, polyantha in appearance of the plants, likely diploid. A 24 h soak in water gave 21/35 germ. while either 1 or 3 % peroxide (as purchased) gave 12/35 germ. The conclusion was that peroxide is not beneficial and may be detrimental.

2. Frank Buckley's ARBA Review

Frank Buckley published a 100 page booklet under the imprimatur of the Amateur Rose Breeder's Association (ARBA) in the U.K. It was issued in 1985 and gives an extensive review of many studies and observations on germination. It provides citations to many articles found in the RNRS Rose Annual, and the ARBA News and RHA newsletter prior to 1985.

Buckley provided extensive summaries of the work of Shepherd, mentioned above, and also the 1956 American Rose Annual article by D. Morey on use of chemicals to break dormancy. Morey was a successful breeder for J & P at mid-century and had large amounts of material available to him. In summary, ether, chloroform, thiourea, diastase (a digestive enzyme mix), live yeast, potassium nitrate, sodium thiocyanate, pectinol (a digestive enzyme), alcohol and bleach were all without positive effect at the levels tested. Some of the treatments may have hastened germ. rate but none gave greater total % than for controls.

While Blundell and Jackson working in the U.K. found very positive results with sulfuric acid scarification of hard-seeded species roses, Buckley cites the work of Morey as a warning against its use for typical hybrid tea roses. As he describes it, batches of 200 achenes each, of similar genetic background, were treated with either concentrated or 50 % sulfuric acid for 1, 5 or 20 min. Germination was nil for all treatments, compared to 28 % in an untreated control.. Further tests reported by Morey included 0.2 N hydrochloric acid exposure for 1, 4 or 18 hr. After 6 mo., germ. % was the same, but the 4 & 18 h treatments were delayed compared to control.

From the ARBA newsletter, Buckley cites C. Warner's report of treating 125 achenes of CV Southampton with sulfuric acid for a short time until the coats changed color (~1 min). He obtained 4 % germ. compared to 20 % for a water control. E.F. Allen told Buckley he used 300 achenes of CV Chanelle, exposing them to sulfuric acid for 1 h. The treated achenes showed 1 % germ., compared to 35 % for the control.

Buckley extensively reviewed different germ. media, and treatment conditions, particularly the merits of warm and cold stratification in various combination, direct planting, use of fungicides and merits of scarification. He provides a large amount of practical advice from several sources, but little quantitative comparison of treatments. One example he cites is C. Warner's use of a file to notch achenes of CV Southampton, thereby doubling germ. from 20 % to 44 %.

One experiment that Buckley did do, too late to include in the body of the review, was a comparison of scarification methods and gibberellin treatment. Achenes of *R. moyesii* CV Geranium which has high self-fertility, were used with different levels of scarification produced by a blendor (Kenwood brand). Two groups received very high scarification, with one group each of highly, moderately, lightly and unscarified.. All groups were imbibed with moist vermiculite and then the second group of very highly scarified seeds was soaked in 100 ppm of $GA_{4/7}$ (a commercially available mixture sold at that time in the U.K.) Then all groups, consisting of about 50 seeds each, were chilled in a coldframe at ambient winter temperatures. The first seedling emerged in 92 days. After two days the trays were located to 60 F for another 12 days. A count of achenes showing signs of germ. or fully germ. gave levels roughly proportional to the extent of scarification. Unscarified showed 25 % and very highly scarified showed 47 % when untreated and 51 % when $GA_{4/7}$ treated. The others: lightly = 33 %, moderately = 38 %, highly = 44 % are in consistent rank order, but group sizes are too small and there are no replicates so no statistical test is practical here.

Buckley reports on work by Horner who treated unscarified achenes of 3 floribunda (CV unspecified) crosses. Soaking 48 h in 125 ppm GA_3 gave 53 %, $GA_{4/7}$ gave 60 % and water control 27 %. Buckley himself used a batch of achenes of CV Golden Angel which he first scarified and imbibed and then exposed for 48 h to 100 ppm of GA_3, $GA_{4/7}$ or water. The control just began to germ. at day 69 by which time $GA_{4/7}$ was at 57 % and GA_3 at 50 % . By day 76 the GA_3 had reached 60 % and the control 44 %. Final results were not provided; nor were absolute numbers. Both GA treatments may have somewhat hastened germ.

3. Summary of works in the Scientific literature.

This has gradually grown more systematic as I have continued my own work. Recently, Dec 23, 2009, I did a search of the ISI Web of Science covering all databases available at my university, back to about 1969. Papers for which only the abstract has been translated into English were generally omitted from discussion below, or the **Annotated Bibliography** that follows. Most of the more recent literature is published entirely in English, and on reading through the relatively short translated abstracts that were available for older papers from Russia, Croatia etc, I did not see much that wasn't available in more complete form elsewhere. So while priority of observation may not be precisely indicated in the discussion below, I think that most of the important ideas are clearly presented with enough data to support them. I also consulted Lela V. Barton's **Bibliography of Seeds** which contains 18,000 citations. Her compilation extends only until the mid 1960s, but the other available databases are effective for more recent works. She included relatively obscure sources, and also several of the Rose Annual articles mentioned above. I have also checked Biological Abstracts from 1929-1969 by hand, so the coverage of literature available in the U. S. ought to be nearly complete.

Early studies on species

The work of Crocker and Barton at the Boyce Thompson Institute for Plant Research, then in Yonkers, NY, is a classic study of 12 collections of 9 spp of temperate Rosa. Seeds were stratified at 5 C in peat after sterilizing with "uspulum" which is apparently a mixture of mercurous oxide and chlorophenol. Germ. was counted every 2 mo. until 1 yr, then at 18, 24, 27 mo. Unless noted there were 1000 seeds in a sample. An abbreviated table of results is shown.

species	max germ. %	months to 1/2 max germ.	germ. by 1 yr %	additional germ. by 27 mo. %
canina 1	59	>18	20	39
canina 2	6	>18	2	4
carolina 1	57	<4	56	1
carolina 2 (500 seed)	79	<10	47	32
fendleri	21	>24	2	19
helenae (300 seed)	15	<6	15	--
multiflora (200 seed)	72	<4	72	--
rubrifolia	10	<10	9.8	0.2
rugosa (500 seed)	52	<6	50	2
setigera	53	<4	53	--

William Crocker was director of the Boyce Thompson Institute for many years and Lela Barton was a plant physiologist who continued the work even after his death. For their early study, detailed in **Contributions of the BTI** #3, some samples were acquired from seedsmen, specifically sample #2 of *canina*, sample #2 of *carolina* and the 1 *multiflora*, all others from Professor A.C. Frazer. Frazer was a professor of plant breeding (corn) at Cornell University in Ithaca, NY and in the 1920s was working to develop roses with increased hardiness by use of native species. Whether Crocker obtained his seeds fresh in hips, or dried, is unstated. Those from seedsmen, were likely dried before shipping to the BTI.

For species hybrids and HTs (from Father George Schoener in southern California) the average was 37 % germ. for >350 crosses, with > 50,000 seed, using the standard cool stratification, varying from 5 -10 C. The 1st yr saw abt 32 % and the next 6 mo. 5 % germ. but from 41 crosses no seeds had germ. even after that long.

For several spp, 2-4 yr initial dry storage of achenes (temp. not specified) gave reasonable germ. after stratification. Levels reached up to 50 %, even better than with fresh stratified seed. No pre-storage data are available for 4 samples, but results are still worth noting. These are some of the few data available on dry stored seeds, so the table of Crocker and Barton is reproduced below in modified form. The samples below allow comparison to initial results for several spp. The *canina* sample #1 was stored 4 yr, and *setigera* only 2 yr. All others stored 3 yr. Note that *canina* #2 and *multiflora* were from commercial sources; others from Fraser. I've rounded to nearest %. Germ. tests were carried for 27 mo. and the time of last germ. is indicated as Time (mo.)

Species	% germ. fresh	Time (mo.)	% germ. stored	Time (mo.)
blanda	--	--	33	6
canina #1	59	27	37	5
canina #2	6	22	0.2	27
carolina	79	22	7	19
humilis	--	--	7	19
lucida	--	--	33	19
multiflora	72	4	48	5
rubiginosa	--	--	24	19
rugosa (green)	49	10	53	19
rugosa (dried on bush)	27	11	51	15
setigera	53	18	36	15

The next major study of multiple species to turn up was that of Tincker, who worked at the Royal Horticultural Society gardens at Wisley, UK, a little southwest of London. The summers there are much cooler than in the Ithaca, NY area and winters are milder than many parts of the U.S. In the 1920s-1930s the average daily temperatures in summer were in the range of 15 C, with autumn near 10 C and winter about 4 C. (I used historic data to estimate these.) Thus an outside stratification of pots plunged in ashes, as Tincker described it, is much like exposure to the cold chamber used by Crocker and Barton. Also, it may be important that temperatures during ripening of hips were relatively cool, a topic more fully discussed below in relation to the work of Von Abrams and Hand.

Tincker's studies were continued for half a decade (1929-34), testing various factors that might improve germ. of a wide range of species growing at the gardens. Among factors not beneficial to most species when tested in one or more yearly tests were: sulfuric acid scarification, dry storage at either 0 (-2 to 2) C [cold] or 5-9 C [cool] for periods up to 8 mo., exposure to pure oxygen in a sealed container, alternating temperatures (0 to 15 C) for short (hrs) or long (1 wk) periods at the higher temperature, storage at around 0 C in wet moss, soaking seeds after storage before planting, direct autumn planting outside, stratification in moist sand at 0 or 5-9 C, storage in the hips until they decayed, use of older (dried) seed lots. The aim was to obtain prompt germ. at a reasonable %. Some species responded to some treatments to some extent. A diploid *calocarpa* (*rugosa* x *chinensis*) germ. 48 % in 3 mo. after acid scarification, while a control stored cold and dry without scarification gave only 29 %. After 15 mo. the germ. was 58 % and 43 % for the two treatments. This was a rather modest boost.

Stratification in sand with pots plunged outdoors during winter 1929-30 gave av. 14 % germ in 3 mo. for 19 spp. while only *calocarpa*, *rugosa* and *woodsii* germ. appreciably if planted directly after dry storage at 0, 5-9 or 12-18 C. However at 15 mo. av. germ. was 27 % overall, roughly double in 2 yr for those seed lots planted direct. Stratified outdoors, *calocarpa* reached a cumulative 65 %, *rugosa* 63 % and *woodsii* 40 % in the 2nd year. Interestingly, for these 3 spp, the other treatments showed little increased germ. between 3 mo. and 15 mo. following planting. The author concluded that stratification was the best treatment, with the fluctuating outdoors temps beneficial, compared to steady indoor cool or cold, whether wet or dry. The *rugosa* and its hybrid *calocarpa* responded most favorably and *canina* responded least.

The role of maturation temperature

Another early, very important paper that is too little studied now, is that of Von Abrams and Hand. They were working in Scappoose OR, with the Peterson and Dering Co. and had large amounts of HT material available. Only a few of the CVs tested are identified by name and the materials are all from the late 1940s or before, but some near species were involved. Their work was initiated for pragmatic reasons, to maximize germ. during a breeding program, but it also addressed the apparent discrepancy between the work of Crocker and Barton, who were located in Yonkers (NYC suburb) but who used many seeds grown in California and shipped to them, and who found stratification at low temps to be essential, vs Calvino, working in San Remo, Italy who obtained good germ. without it. Crocker and Barton suggest that perhaps winter planting in San Remo was under sufficiently cool conditions (< 10 C Dec.- mid Mar.) to effect after-ripening

for her when planting directly in the soil. Current San Remo climate information (Wikipedia) indicates average temps swing 12 C daily with means of :Dec=7; Jan=6; Feb=6.5; Mar=9. Soil temps at 2 cm track the mean more closely than the daily swing. The average daily low in any month never is <0 C. Alternatively as suggested by Von Abrams and Hand, development of the seed under warmer conditions may reduce the need for after-ripening at low temperature (see their study below).

In the relatively cool climate of Scappoose OR, flowers were pollinated in the last week of June and harvest of mature seeds was done Nov 1, about 120 days later, when days were relatively short and av. temps could be relatively cool, with monthly av. low temp for Oct. as low as 4.3 C and av. hi as low as 14.2 C (in 1949). This varied year to year, reaching 7.6 C for lo (1951) and 22.4 C for hi (1952). The mean 16 h night temp varied from 8.6 C to 18.3 C, more than 2-fold, while the daylight av. temp was 11.7-19.0 C, in different years. For each of 10 crosses in 5 yrs with a test sample of n=900 each, there was a very strong correlation (>0.997) of % germ. to October monthly T_{av} which ranged from 9.2-14.9 C over those years. For the one best cross the % germ. varied from 13-67 % while for the worst it was 1.2-15.9 % for this range of temp. In each instance there was a simple linear relationship over the 5.7 C range of temps available. The 900 seeds in each test case came from at least 15 plants and 100 hips pooled, so the sample should be representative of that set of parents in that location.

The parents included Pinocchio, Else Poulsen, Crimson Glory, Mirandy, three plants which were hybrids of *R. rugosa*, *R. eglanteria* and *R. wichurana*, plus nine other HTs in the total of 10 crosses. Interestingly, the 4 lowest germ. crosses each had one of the species hybrids as a parent. One curious effect was that a cross with the *R wichurana* hybrid as pollen donor had germ. always below 16 % while the reciprocal cross with the *R wichurana* hybrid as seed parent had up to 38 % germ. Two crosses with Crimson Glory as female had up to 36 and 30 % germ. Pinocchio, Else Poulsen and Mirandy were consistently in the top three crosses, all years.

At this distant time we have little idea whether any of these rather extensive efforts resulted in plants actually introduced by P & D. Of Von Abrams roses, Crimson Glory was seed parent to Fidelity, while Else Poulsen was seed parent to Coral Crown and Encore. Pinocchio was pollen parent to Norseman. Nor can we reliably guess which species hybrids might have been used. New Dawn did appear in the pedigree of one Von Abrams rose, Pink Favorite. For many of Von Abrams roses, the parentage was not disclosed prior to patenting and is not given in Modern Roses volumes. Peace was a parent or grandparent of several Von Abrams roses and may well be one of the other HTs in the set of unnamed CVs.

When isolated embryos were tested for viability, four of five crosses in most years exceeded 95 % germ. in 2 wk. The one exception was the poorest performing cross mentioned above (1-16 % germ.) for which results still exceeded 85 % in 4/5 yr. Thus the inhibition of germ. must relate to the testa or pericarp as earlier suggested by Crocker. Von Abrams and Hand were both plant physiologists trained in the best labs of the time at CalTech (Bonner and Galston) and Von Abrams was a faculty member at UC-Davis until at least 1980 after leaving P & D. Their use of embryo culture was only a few years after Lammerts first description of it.

When hips were matured under supplemental lighting and warmth of a greenhouse, dramatic increases of germ. speed and small inc of germ. total were observed for 3 crosses in a middling warm yr. For this instance n=225. No cold stratification was used, yet results were as good as seeds grown outside and then subjected to the standard germ. regimen of 60 d warm, 90 d at 2 C, 60 d warm, 90 d at 2 C and again 60 d warm. Warm in these studies was a min. temp. of 21 C by day and 15 C by night in a greenhouse. In the warmest year of their studies, in fact there was significant germ. in most crosses for seeds planted directly, without any cold stratification.

The authors hinted, with no specific documentation, that longer maturation of the seed might reduce the need for after-ripening through cold-stratification. Nor did they indicate what might have happened if seeds were harvested earlier, prior to the marked cooling of Oct. weather.

One more major study of temp effects, on development and ripening of seeds within hips, is that of de Vries and Dubois. A single cross of HTs Sonia x Hadley was tested by growing at 5 temps of 10, 14, 18, 22 & 26 C from pollination of 40 flowers, to seed harvest in a phytotron (controlled temperature glasshouse). Fruits matured fastest at a continuous 18 C with higher and lower temps showing a marked increase in time to maturity (orange color of hips). Fruit set, fruit wt., & seed #, all increased with temp up to 26 C, while % seed germ. peaked at 22 C, showing over 70 % germ., but with 26 C maturation temp. giving only 63 %, a significant difference. All seeds were stratified in planting flats at 0 C for 4 mo, then germ. at 22 C. There were almost 1500 seeds at 26 C, over 1000 seeds at 22 C, 959 at 18 C, but only 200 at 10 C. None of those latter seeds germ., and from 14 C development, only 17 /310 did. For 18 C just 42 % germ.

These results are consistent with findings of Von Abrams and Hand that low temps during later development deter germ. Those authors depended on natural temp. cycles and av. temp was warmer during July- Sep, than during the final month of maturation. For Portland, OR, July temp. av. 20 C while in Sept is it 17-18 C, and in Oct it is close to 14 C. Von Abrams and Hand noted no correlation of % germ. and daily temps over the final 2 mo. (Sep. + Oct), because there was not much variation in Sep av. temps in the 5 yr of study. The Sonia x Hadley cross may be similar to one of the poorer-responding crosses studied by von Abrams and Hand. Hadley is an old CV, from 1914.

Factors in after-ripening of species seeds

The studies of Semeniuk and Stewart, at the USDA, near Washington DC, lead on from the study of Von Abrams and Hand, to point toward some of the key factors in after-ripening. In one large study with seeds harvested Nov 20, 1959, they examined the difference between continuous cold and interrupted cold for 7 species. There were 18 trays of moist shredded sphagnum, each containing 100 seeds of each of 7 species. Three replicate trays experienced interrupted cold, [6 cycles of 30 d cold (4 C), + 15 d at 60-65 F (15-17 C)], while the other 15 trays were placed in the cold and taken out 3 at a time, at five 30 d intervals (60-180 d) to determine total germination. Trays were checked monthly and any early germ. seeds were scored and removed, but tallied as part of the total for the next indicated cold treatment time.

species**	blanda	bracteata	multiflora	reversa	setigera Beltsville	setigera Serena	wichurana
% germ.	20	14	60	90	90	95	>85
days	>180	180	>180	120	~90	90	60-90
% germ.	10	<10	25	<50	25	>80	>85

**Species and final max germ. % (continuous cold) with days to plateau are shown in the 1st 2 rows of the table. The 3rd row is for the interrupted stratification process.

The time required to reach a plateau was shorter for the interrupted treatments but the max germ. level was dramatically lower for several species, when interrupted. For most species, germ. at constant 4 C eventually equalled that obtained by bringing the trays to 15 C after discrete intervals, with about a 60 d lag for the half-max germ. in continuous cold. This result was derived from the monthly checks of seed germ. in continually cool trays. So continuous storage at low temp with transplantation of the emerging seedlings eventually gives the same overall result as fixed periods of cool treatment. The disadvantage is a chance of damping-off, and the challenge of transplanting. The advantage is that one doesn't lose a large fraction of potential germ., as was observed with the interruption of cold treatment. The implication here is that the Von Abrams and Hand study may have underestimated potential final germ. for the more recalcitrant spp, because they had only two long cold treatments (90 d each), interrupted by an extensive (60 d) warm period.

Semeniuk, Stewart and Uhring extended their studies on dormancy to show a secondary dormancy is induced by warm treatment of seeds even after they are partially after-ripened by cold treatment. For this study just one type was tested, *setigera* CV Serena, a thornless selection of unspecified provenance. Hips were collected after the first killing frost, Dec 7, 1961. They were exposed to a period of low temperatures in the hip on the bush, prior to harvest.

Washed seeds were treated with dilute detergent with 0.5 % hypochlorite (1/10 bleach) for 1 min. Six reps. of 10 seeds or embryos were used. Moist perlite was the incubation medium. Cold was 40 F (4.4 C) and warm was 65 F (18.3 C). Germ period was 30 d at 18.3 C in each case. For either seeds or excised embryos there was no germ. after 90 d warm. After 90 d cold there was 56 % germ. for seed and 70 % germ. for embryos, in the following 30 d warm. No embryos germ. from seed held warm 90 d, then dissected and kept warm another 30 d. Seeds chilled for 90 d after 90 d warm gave 48 % germ. in the next 30 d warm. Embryos dissected after 90 d warm, then chilled 90 d and tested warm mostly failed to germ. (just 1.6 %). This suggested to the authors that the seed coat (testa) is important to removing the imposed dormancy.

Stewart and Semeniuk expanded on these observations with a series of complex studies on dormancy breaking and reimposition using several temperatures of treatment. The 5 species CVs were the same as previously, omitting *blanda* and *bracteata*. Hips were harvested in early Dec, cleaned as before, then tested. Generally 3 reps of 25 seeds were used.

In the first expt, *wichurana* and *setigera* CV Serena were compared. Total exposure to cold (4.4 C) was 90 d, with 15 d warm breaks (either 18.3 or 29.4 C) at indicated intervals. The cold exposure was 6 x 15, 3 x 30, 2 x 45 or 1 x 90 periods. Periodic tests (every 15 d) were done on the continuous exposure (last) group to ascertain how the after-ripening was progressing. For *wichurana*, as expected from the earlier work of Semeniuk and Stewart, continuous cold eventually gave nearly as much germ. as having intervals at 18.3 interrupting the 4.4 C treatment. Just 45-60 d was needed for max germ > 70 %. Breaks at 29.4 reduced germ. if imposed after 15 d cold periods. In this instance only 34 % cumulative germ. was seen. Exposure 2 x 30 d cold got 53 % (3rd cycle gained nothing), 2 x 45 d got 76 %, and 60-90 d cold got >60 %. Note though that at 29.4 C the germ. was not as good as at 18.3 C, after continuous cold.

For *setigera* germ. was less, and more delayed. With 18.2 as germ. temp., continuous cold got 36 %, with half the response after the last 15 d. The 2nd 45 d interval gave 47 %. The 2nd & 3rd 30 d intervals gave 48 % (none after the 1st), and 6 x 15 d intervals gave 42 %, when breaks were at 18.3 C (with peak response after 4th & 5th cold exposures). It appears that the warm interval between cool periods was beneficial, or at least not harmful. However, with germ. test at 29.4 C, germ. was poorer; even after continuous cold for 90 d only 8 % germ. So a high temp can reverse the benefits of cold, or germ. at hi temp is unfavorable for this CV, or both.

A 2nd expt used *wichurana*, *reversa* and *setigera* CV Beltsville. With 4 x 30 d periods at 4.4 and alt temp of 4 values [12.8, 18.3, 23.9 & 29.4 C], or 120 d continuous 4.4 C, contrasting effects were seen. Again, higher temps reduced germ. when imposed in breaks. Again for *wichurana* most germ. happened in 1st (& 2nd) 30 d periods. With 29.4 C breaks, germ. was notably less (total 46 %) than with lower temp breaks (69-73 %). However from 120 d continuous cold, best germ. was obtained at 29.3 C (79 %), and at lower temps germ. after continuous cold was a bit lower than when breaks of the same temp as germ. (i.e. 12.8-23.9) were used. For *reversa* most germ. happened after 2nd & 3rd cold periods, and germ. was more sensitive to high temp. Germ. fell from 56 & 58 % at 12.8 & 18.3 C break temps, to 18 % at 23.9 C and only 5 % at 29.4 C. It fell from 53 % at 12.8 or 18.3 C to 33 & 32 % for germ. at 23.9 or 29.4 C after 120 d continuous cold. The *setigera* result was different, with increasingly hi temp breaks decreasing germ. gradually from 39 & 36 % at 12.8 & 18.3 C to 33 & 23 % at 23.9 & 29.4 C. However, high germ. temp after 120 d continuous cold actually increased germ. from 33 & 37 % at 12.8 & 18.3 C germ. to 44 & 43 % at 23.9 & 29.4 C germ. So, some spp do better with warm germ. than others.

A 3rd expt, with seed from a different year presumably, gave somewhat different numbers, but same trends when the warm and cold intervals were 8 x 15 d. In this case, *reversa* was even more sensitive to warm breaks, with no germ. following 23.9 or 29.4 C breaks, and a marked drop in germ. at 23.9 & 29.4 C to 28 & 24 %, vs 48 & 44 % at 12.8 & 18.3 C, after 120 d continuous at 4.4. The *setigera* results were similar to 2nd expt. Most germ. happened after first 2 15 d intervals reaching 52 % at both 12.8 & 18.3 C, 48 % at 23.9 C. However, at 29.4 C there was a little germ. at each 15 d interval, but it eventually reached 48 %. Again, germ. after continuous cold was higher at hi temp, rising from 50 & 56 % at 12.8 & 18.3 C, to 66 & 64 % at 23.9 & 29.4 C. The *multiflora* showed a large drop-off in germ. with hi temp breaks, from 54 % at 12.8 C to 44 & 43 % at 18.3 & 23.9 C and 32 % at 29.4 C, with most germ following 1st 2 cold intervals. Germ. at 4 temps after 120 d cold, decreased from 51 to 47 % with increasing temp.

Expt 4 used varied times and temps of warm stratification, followed by continuous cold until 10 % of seeds germ., then given 15 d at 18.3 C to count total (prompt) germ. Intervals warm were 15, 30, 45, 60 d and temps 18.3, 23.9 and 29.4 C. For *setigera* CV Beltsville, even 15 d at 23.9 or 29.4 significantly lengthened the required time at 4.4 (from ~85 to 120 d), while 18.3 C up to 60 d had no retarding effect. For *multiflora* the impact of warm stratification was less obvious, with 60 d warm increasing needed time at 4.4 C from < 125 d to > 140 d at the two higher temps. For both spp, longer time warm generally decreased total (prompt) germ. There was more variability in this set of 12 treatments and no statistical measures were offered.

The authors propose that there is a compensation temp, above which after-ripening is reversed. Interruptions at lower temps have little effect following a critical time of after-ripening at cold temp. A few things seem clear. The *multiflora* and *setigera* CV Beltsville need only 30 d cold to get max. germ., while *wichurana* needs 45 d and *reversa* and *setigera* CV Serena need 90 d. These last 2 spp were most sensitive to high temps, both as interruptions and for final germ. depression. So the two *setigera* CV are quite different in their behaviors.

The degree-day concept of germination readiness

The previous work of Stewart and Semeniuk had indicated that there is a certain temperature above which rose seed will not germinate, nor will they progress through the necessary after-ripening to allow germination. This may vary for each species, and possibly within species for different climates. For *R nutkana* the compensation temp was deduced to be 15.5 C, and hence the present experiments were undertaken to get more information about the after-ripening needs of this species. The authors looked at degree-days below the critical temperature, trying to determine the minimum chilling requirement. This idea is well established for the flowering of rosaceous fruit trees, where a minimum time below a set temperature determines whether flowers will open in a timely, synchronous fashion.

Three kinds of seeds were used: freshly harvested; 6 month dry-stored at a room temp of 21 C; overwintered in the vicinity of Washington DC. The harvest for batches 1 & 2 was Nov 20, after the 1st killing frost, while over-wintered seeds were collected May 27, six mo. later. All seeds were removed from hips, washed, soaked 1 min in 0.5 % hypochlorite, then stratified, or stored dry at 21 C. Thus the over-wintered and dry-stored were ready for stratification at the same date.

Continuous stratification moist was done for 1 yr, with germ. determined monthly. A range of temps were tested, with those held at 10 C or below moved to 18.5 C after 1 yr for another 15 d to get a final germ. measure (Table 1). Another stratification approach (Table 2) was to hold seed at various temps for 128 d, then move to 4.5 for equal degree-days below 15.5 C, for all those held above 4.5 C during the initial 128 d. So seed held 128 d at 15.5 got an additional 128 d at 4.5, while seed initially at 4.5 was taken directly to germ. at 18.5 C for 15 d, after the first 128 d. At this time (128 d) 10 % of the seeds held at 4.5 C had germ. If the degree-day concept held true, final germ. for all treatments ought to equal that of the 4.5 C seeds.

All samples 3 reps of 25 seed in moist perlite in paper cups covered with thin polyethylene film and maintained near constant for moisture. It appears T optimum is 4.5-7 C for germ. of this

species, independent of prior treatment, and the simple degree-day concept is not supported, if results of the 2nd table are also considered. There, it seems 128 d at 4.5 C after a high temp for 128 d is better than just 128 d at 4.5 C. This is consistent with the notion that warm stratification followed by cool is the best treatment, but not consistent with needing longer at 4.5 C following warm exposure. From the 1st table, dry storage seems beneficial, if the cold after is long enough, but still not as good as warm stratification followed by cold (2nd table). Over-wintering hips for this species in this year gave about half loss of germ. So, the range of cold temperatures found over winter at this latitude for seeds in the hips is not helpful. The authors do not state whether 128 d at 4.5 C gives germ. near equal 1 yr, but comparing tables 1 & 2 it appears not. (Compare 48 to 65 % or 51 to 73 %, for 4.5 C held 128 vs 365 d.)

Moist stratification storage temp.	Deg-days below 15.5 C	fresh % germ.	dry 6 mo % germ.	over-winter % germ.
1.5	5110	61	48	19
4.5	4015	65	73	35
7.0	3102	71	75	25
10.0	2007	55	59	35
13.0	912	3	17	7
15.5	0	4	0	0
18.5	0	0	0	0

T init. (C), first 128 d	d at 4.5 C after 128 d at T init.	deg-days at 4.5 C	fresh % germ.	dry-stored % germ.	over-winter % germ.
1.5	--	1792	49	40	31
4.5	--	1408	48	51	37
7.0	32	"	39	59	29
10.0	64	"	44	64	49
13.0	96	"	63	64	43
15.5	128	"	71	65	32
18.5	128	"	72	63	33

A small study with *R. blanda* was done to follow up on the rather low % germ. reported above that used seeds from 1959. A new crop of seed harvested Dec 7, 1961 was tested for after-ripening up to 300 d at 35 & 40 F (2.2. & 4.4 C). As before there were 3 reps of 25 seeds in moist perlite, kept covered with polyethylene film in 6 oz cups, for each time and germ. temp.

Incubation was in continuous darkness for indicated times, after which cups were moved to 55 or 65 F (12.8 & 18.3 C) for 30 d to estimate germ. (still in darkness). No difference was noted with germ. temp, but there was considerable difference with stratification temp. [I have rounded to nearest % germ. values.] The authors noted that the max. germ. may be limited by presence of European rose-seed chalcid, which was found in a later crop (1963) infesting up to half the achenes.

Days	90	120	150	180	210	240	270	300
2.2 C	0.7	7	9	13	17	21	36	41
4.4 C	7	11	13	22	27	40	53	48
Av.	4	9	11	18	22	31	44	45

Values shown are % from a total of 150 seeds at each time and temperature

While Semeniuk and Stewart were working in the U.S., Jackson and Blundell were examining the inhibitory factors in roses common to Europe, in Wales. For the common *R rugosa*, using embryos excised from achenes that had been stored at 2 C for 3 mo months out of the hip, germ. was complete within 3 d. The embryo + testa yielded 40 % in the same time, with no further increase, while intact achenes showed no germ. in 10 d. With *R arvensis*, water soaking seeds (embryo + testa) extracted from hips after storing 3 mo cold, gave only 10 % germ even though half ruptured the testa within a day. Soaking with GA or benzylamino purine (BAP) gave 60 % germ. within a week. Naked embryos, unsoaked, gave only 40 % germ in the same time. In each case there was some increase during the following 2 mo. When control seeds were re-soaked with water (after 2 wk) there was a second burst of germ. to >50 % within 2 wk. Using BAP in the soak gave near 100 % germ. in the same time. The authors interpreted their results as indicating the presence of inhibitors in testa. Leaching improves germ., and BAP counteracts the inhibitor. Tests of achenes variously nicked and cut indicated that the pericarp was not just a physical barrier to germ.

By paper chromatography an inhibitory fraction was isolated and tested on *R rugosa* embryos. Later work with isolated embryos confirmed that the inhibitor was abscisic acid (ABA). Jackson showed that while 1 ug/mL of ABA could delay germ. for ~ 1 wk, rinsing the naked embryos immediately released inhibition. At 10 ug/mL ABA, there was only 19 % germ. at 17 d, but when GA was added at 150 ug/mL, or BAP was added at 10 ug/mL there was 100 % germ. in the same time.

Biological digestion processes

One of the most interesting and novel studies is that of Cullum et al (1990) reported at the International plant propagators society. They were studying the practical problem of getting high and uniform germination of *R. corymbifera* 'Laxa' which is used in large quantity for rootstock production in England. They found that treatment with a compost activator "Garotta" was very effective in assuring that achenes would germinate when planted in mid-March following

harvest. The formulation of "Garotta" is proprietary but it presumably contains bacteria and/or fungi which are able to soften the outer coat of the achene. Until their work, treatment with concentrated sulfuric acid was the standard procedure for enhancing germination. That was not particularly effective and was difficult to control except in industrial scale work. Natural stratification reportedly gives only 7-15 % germ. with that species.

The activator treatment method was very simple, and tolerant of variations. The basic method consists of mixing 2.5 parts by wt of moist vermiculite (1 part vermiculite + 1.6 parts water) with freshly separated achenes, then adding ~1-2 % by wt of the activator. The mix was stored at a defined temperature, usually 20 C, for 4-12 wk, followed by 12 wk at 4 C. Germinated seeds were counted 2 wk after planting on moist paper in Petri dishes. Resulting germ. was very high, >80 %), though field emergence was lower (~45 %). There was variation in rates for control vs treated year by year (4 yr), with the treated seeds consistently showing 75-90 % but controls varying from <5 to near 50 %.

Cullum et al provide all the data of their 4 replicates for each treatment so it is possible to see the variation inherent in this kind of study. With 25 achenes/rep, a range of +/- 1 or 2, was seen. For 50 achenes/rep it was about +/- 2 or 3 and for 100 achenes/rep about +/- 6. This is reasonable overall, though there were single replicates that varied 1.5 x above or below the mean of their treatment. So unreplicated studies like those of Shepherd reported in the American Rose Annual, discussed above, must be taken cautiously. The reported statistic is exactly what is expected with an average % standard deviation roughly the square root of N.

Another study of treatment effects on a single species (*R. bracteata*) was that done by W.C. McCully. His interest was in the conditions for natural spread of this invasive species, commonly known as MacCartney's rose, in Texas rangelands. On each of 6 feeding dates 6 wk apart, four mature cows were fed hips (25 each) and the recovered achenes were tested for germination. About half the achenes ingested were recovered, mostly within 2-3 days. From 100 total hips, 2500-5500 achenes were recovered.. Best germ. was obtained with hips fed in mid-August when range cattle normally began to browse the roses. A 12 kg portion of the collected material from each animal (1 kg/collection period, 2x /d for 6 d) was processed to isolate the intact achenes, while another 3 kg portion (from all 4 cows) was mixed with sphagnum moss and either stratified at 5 C (41 F), or at room temperature (RT). The washed isolated achenes were germ. tested on moist filter paper in duplicate 100 seeds lots, either at 5 C or at RT.

The germ. test was continued from Aug 1948 until April 4, 1950, so that the total potential time for germ. varied with date of feeding from 20 to ~10 months. This could have affected the results, as could the difference between germ. testing on filter paper and that with cow dung. The best result was for achenes retained in the dung and directly placed at RT in Aug. This mixture ripened well. Here 32/62 (53 %) of seeds germ. in 18 mo. whereas when stratified at 5 C only 9/72 (12 %) seeds germ. At RT, 25 of 32 germ. occurred after 14 mo., while at 5 C, germ. was spread evenly from 6-14 mo. For washed seeds at RT there was no germ. while at 5 C there were 10/200 (5 %) germ. From the Oct. 2 feeding, 8/107 (7.5 %) retained seeds germ. at 5 C, while 20/91 (21 %) did so at RT, all after 12 mo. For washed seeds only 3/200 germ at 5 C and none at RT in 18 mo.

Interestingly, the germ. at RT was concentrated around cooler months of the year, with shorter days. The author did not state whether temp. or daylength was controlled in the RT condition. It is not specified whether the study was done in a laboratory with windows, but presumably it was not in a glasshouse or growth chamber, or that would have been specified. As discussed below in the work of Anderson and Byrne, filter paper seems to be a very ineffective medium for rose achene germ. of *R. bracteata,* so we can only evaluate the difference in hip maturity and temperature for the cow dung.

For Nov., Jan., Feb. Apr. tests, germ. was very small. Seed tested in Aug. without first feeding to cattle gave no germ. in tests on filter paper. The results of Semeniuk et al were better than this (10-14 %), but not so good as for the early season fed hips in this study. McCully showed a photo, but provided no quantitative estimate, of high germ. % in cattle dung on the range. Natually aged cowpats make an effective growth medium for this species.

Yambe and Takeno tried several commercially available fungal enzyme fractions to hasten digestion of the pericarp of *R. multiflora* rose achenes. The germ. test was done on moist filter paper under continuous light for 20 d at 25 C, following enzyme treatment. A soak up to 36 h with enzyme was done, in triplicate, by placing 10 mL solution with 50 achenes in a test tube and rotating it slowly at 30 C under continuous light, then achenes were washed and germ. tested..

Different levels of Driselase were tested first, each for 36 h. Max germ. was 75 % for the 1 % soln, and its germ. half-time was 4 d. When just 0.5 % was used, germ. rose linearly with time, reaching 40 % in 20 d. With 0.1 % the response was approx linear but reaching only 15 % germ. in 20 d, while the control for this lot showed only about 2 % germ.

For 1 % enzyme, a 12 h incubation gave a half-time of 7 d with a slower approach to the max. of 70 % than when exposure was longer. A 24 h treatment reduced the half-time to 6 d, while for 36 h it was < 4 d and for 48 h exposure the max germ. level was attained in 4 d. Similar results were obtained with 2 % enzyme solution. A 60 h exposure was neither beneficial nor detrimental

When other enzymes were tested, a “pure” cellulase 36 h treatment gave a max germ. of near 50 % at 1 % enzyme, and only 30 % at 2 % enzyme. For a crude cellulase Onozuka there was again inhibition at 2 % enzyme but the max germ. was close to 80 % at 0.5 or 1 % enzyme. A pectinase gave a near linear response over the concentration range 0-0.2 % when treatment was 36 h, reaching over 75 % germ. at 0.2 % enzyme. Higher levels of pectinase or longer times were not tested in these comparisons. Fewer than 10 % of untreated achenes germ. in 20 d.

More recent species tests

Felicitas Svejda, working in Canada looked at a hybrid *R. gallica* "Ekta" and two hybrid *R. rugosa* CVs. Ekta is derived from Alika (bred by Hansen), crossed with American Beauty, an older H.P. Frau Dagmar Hastrup (sometimes Hartopp) is of uncertain pedigree, while Tetonkaha is a cross of *R rugosa* x *R blanda*. There were 150 seeds per replication and three replications in each study, with moist peat used as the stratification medium. The first study was to determine optimum stratification time and temperature, after various pre-treatments of the harvested seed. All seeds were thoroughly cleaned, then washed with 1/10 diluted bleach (hypochlorite) before treatments. A rotary file was used to scarify seeds in one treatment with Ekta.

Treatment of *R. gallica*, CV Ekta	direct planting	150 d 3 C	150 d 20 C, then 150 d 3 C
none	0	17.4	68.0
1 h sulfuric acid	0.5	70.6	75.5
File scarification	1.3	14.6	18.8
1 min 90 C water	4.7	2.3	42.7

All treatments for the hybrid *rugosas* shown below received 90 days at 3 C following the indicated warm stratification. Germ. values are mean % (3 x 150 seeds)

Days warm stratification	0	60	90	120	150
Frau Dagmar Hastrup	32.4	59.8	34.0	18.0	4.9
Tetonkaha	0.2	2.7	3.3	2.2	0.9

Tillberg (1983) focused on *R rugosa* (rubra) mainly to study levels of ABA. She used a commercial source of (presumably dried) seeds that had a reported germ. of 83 %. Most studies were done in Petri dishes with moist filter paper. Triplicates of 50 seeds were used. After about 10 weeks at 4 C, there was a notable increase in germ. when transferred to 20 C for 11 d. After 14 wk, germ. occurred in continuous cold. It reached half max at ~23 wk. Excised embryos germ. in <3 d at 20 C, with 30 % doing so after 3 wk cold, 50 % at 4 wk and 100 % at 5 wk. Seeds kept at 17 C did not germ. in 14 wk, and embryos from these did not germ. Tillberg also tried scarification which did not overcome what she interpreted as the internal dormancy of embryos. She deduced that ABA may be a factor in dormancy but the failure of warm embryos to germ. indicates something else going on.

A paper of particular interest to people trying to work with complex species hybrids was published in 2007 in Acta Horticulturae 751:503-507. Natalie Anderson and David Byrne at Texas A & M, studied *R bracteata*, *R blanda*, Cytology 127- a tetraploid of *R bracteata*, and several complex tetraploids. They used seed of year 2000. They first tested the effect of leaching

on germ. of O.P seeds from a near-species hybrid *R. wichurana* x Old Blush commonly labeled WOB-28 (probably with 1999 seed). Suspension in aerated water for 3-14 days gave no benefit. Unleached seed had the best germ. after 8 wk stratification at 2.8 C (1 part water to 2 parts peat by wt.)in moist milled sphagnum peat. Agar (as a 0.7 % gel) was ineffective, giving about 1/4 the germination of peat. The other seeds were then tested on different stratification media, being kept at the same temp of 2.8 C for 10-12 wk. Again the sphagnum was better, compared to filter paper, perlite, sand or vermiculite.

It may be important that the seeds were not directly in contact with the stratification media in these treatments. Instead, each of the three replicates having 110-4600 seeds depending on the cross, was in a coffee filter which was then covered with the stratification medium with one container serving for the several different seed sources for any one replicate. Thus any microbes or chemicals important to the stratification process would have to migrate from medium to seeds, through a coffee filter. There must be some transferrable materials involved in the overall process, because just keeping the filter paper moist gave almost zero germ., except for *R. blanda* which had about 5 %.

The highest germ rate was for *R bracteata* at 40 % on peat, 37 % on moist perlite, and about 20 % on sand or vermiculite. *R blanda* didn't show such a contrast but didn't reach even 20 % on any medium. Semeniuk and Stewart found that *R blanda* took close to a year to germ. at this temp. Cytology 127 gave only 3-4 %, pretty much the same on all media. Several seedlings descended from Bayse's Blueberry (which has *R virginiana* & *R carolina*) and 86-7 (a cross of *R wichurana* and *R rugosa*) generally did best on the peat and perlite media and usually not so well on the sand and vermiculite. Filter paper alone was poor for all tested seed lots. Strangely, Carefree Beauty gave very low germ. under all treatments (< 3 %). No explanation for that failure is indicated. Perhaps it is a climatic effect. Zlesak, in Minnesota, reported 40-80 %, and I've usually seen 30-60 % in KS.

Another expt tested direct stratification in growth trays vs transplanting from small containers as seedlings emerged. In this study Sunshine Mix #4 gave the best stratification results, and transplanting gave loss due to injury, but no numerical results are shown. The transplanting effect was tested for each medium (sand, perlite, milled sphagnum and S.M. 4) compared in trays vs small containers.

Werlemark et al did one of the most extensive studies of germination for species roses, focusing on the dogroses (Caninae) which are often used as rootstocks. Their particular interest was for use in rosehip plantings where large amounts of material needed to be produced economically. They used about 50,000 seeds, collected from several locations around Sweden. All the hips were gathered in the same autumn of 1987, following a cool wet summer. Hips from multiple plants of four species and one species hybrid were gathered. Seeds were removed from hips with a mechanical juice mixer. At least 400 achenes were sown for each strain with a maximum of 200 per pot. Two treatments were imposed, either moist at 20 C for 12 wk followed by moist cooled to 5 C for 12 wk (treatment 1), or cooled for 24 wk at 5 C (treatment 2). Pots were then placed outside for germination and after a season outside, all pots were returned to 5 C for ~ 6 mo, followed by germination outside again. There were differences between species in their responses

to the treatments and a clear difference between the two treatments of the 1st year. Because of varying numbers of replications in different species it was difficult to draw many statistical conclusions beyond the obvious ones. A simplified table of results is presented here.

Percentage germination of different species of dogrose, following warm and cold treatments

Taxon	treat. 1, yr 1	treat. 2, yr 1	treat. 1, yr 1 + 2	treat. 2, yr 1 + 2
dumalis subsp *coriifolia*	14.7	0.3	42.6	17.3
dumalis subsp *dumalis*	7.1	0.2	28.6	12.0
rubiginosa	18.8	0.2	24.0	6.9
sherardi var venusta	5.0	1.5	8.5	5.3
villosa subsp *mollis*	8.8	1.7	21.7	14.5
canina x *dumalis*	3.3	0	14.3	4.0
Average	9.7	0.8	23.5	11.1

Werlemark et al cite the work of Rowley as in agreement with theirs. Rowley found that 2 mo at 20 C followed by 2 mo at 5 C worked well, giving 60 % germ. Similarly Nyholm found that 5-6 mo at 20 C followed by the same at 5 C gave 50 % germ. for *R. canina*. With *R. rubiginosa* a month less warm and a month longer cold gave 70 % germ. Studies by Suszka and Bujarska-Borkowska found 16 wk at 25 C followed by the same time at 3 C was best, with > 70 % germ.

Benetka studied a rootstock CV commonly used in the Czech Republic, a selection from the CV Pollmeriana which is a *R coriifolia*. That is, it is a Caninae type, used for understock commonly called Laxa. Seeds were obtained from several sources over several years (1983-1987), exposed to 9 wk at 20 C for warm stratification in 1987, following, in 8 of 12 instances, dry storage at 35 C for 2 wk first in the year of harvest (1983, 1986 or 1987). Following the 20 C stratification, seeds were dried and stored at 4 C. Each year some were tested for germ. by cold stratification 13-14 wk at 6 C, beginning in early Jan, followed by germination outside for scoring after 25 & 50 d. Single lots of 72 seeds were tested for each of a dozen samples, some of which were size selected seeds, some the heat treated vs untreated, from 2 different local or 2 commercial sources.

Part of one lot of commercial seed, designated as the control series, received neither the warm dry treatment at 35 C for 2 wk in its year of harvest (1986), nor the warm moist stratification in fall 1987. It showed no germ. in 1988 or 1989, but in 1995 reached 27 %. Seeds from the same lot dried at 35 C and warm stratified, attained 93 % in 1992. Some treatments attained consistent germ. levels over 85 %, while others reached a peak after several years and then declined. Here is a summary averaging together the dozen different treatment conditions and sources of seeds. The 50 d result for the very best lot did not differ greatly from the average of all those receiving the warm stratification. Those not getting 35 C treatment may have germ. slower (lower at 25 d).

Treatment	1988	1989	1990	1991	1992	1993	1995
best, yellow-green hips, 1983	46	87	87	88	85	89	85
average 12 samples	43	74	85	77	80	72	62
control, 1986 commercial	0	0	13	15	18	19	27

Among species of roses, *Rosa persica* is the most distant from others genetically. He et al compared germ. of that species to *R. multiflora* and *R platyacantha*. Numbers of seeds per treatment were small, with final germ. test on 2 reps of 20 seeds each. It is interesting to note that for *R. persica* the fastest germ. was actually with no cold stratification, while multiflora benefitted from a short (1 mo.) cool treatment. The 3rd species *platyacantha,* showed no germ. at all the 1st yr following the indicated stratification times, but did germ. in the 2nd yr (no #s provided.

Effect of stratification time on % germ. & 50 % germ. time	0 mo. %	0 mo. weeks	1 mo. %	1 mo. weeks	2.5 mo. %	2.5 mo. weeks
persica	45	7	57	8	45	11
multiflora	33	10	53	14	5	18

A recent paper authored by a group in Turkey (Alp et al 2009), at Yunzuncu University discusses germination of several species roses of interest. A couple of the roses studied there are the familiar *R. canina* and *R dumalis*, along with *R heckeliana* (a member of the Caninae) and *R pulverelanta* (Syn. *R. glutinosa*, of the Caninae). All four are grown for their fruits in Turkey. Seeds were warm stratified (25 C) for 10-12 weeks and then cold stratified at 5 C, and finally germ. at 22 C. The *R heckeliana* only required 1-3 weeks of cold to germ. after the warm treatment, whereas the other 3 spp were given a total 31 weeks warm + cold, then moved to 22 C. The authors imply that *R heckeliana* actually goes into secondary dormancy if kept warm too long. Thus at 12 wks vs 10 wks warm, the rapid germ. in cold treatment declines from 16 % to < 1 %. For the other species, rates were around 20 % after the specified warm + cold treatment. For an October harvest, that gives a May germ. The authors had five replicates of 100 seeds each in their tests so the germ. % is likely fairly reliable for the specified conditions. Prolonged warm moist stratification was found beneficial earlier by Benetka (1984).

A study on *Rosa multibracteata* Hemsl. & Wilson was recently authored by Z.Q. Zhou et al (2009) from Chengdu, China. The rose is native to western China, where it grown in arid and semi-arid regions. The authors concluded that dry storage for 68 weeks, followed by cold stratification for 16 or 24 weeks gave the best result of around 75 % germ. As reported by others, including Don Holeman, in his recent studies, removing the pericarp does little to improve germination. Removing the testa, the thin layer around the true seed, did have a big effect, but only about half as much as the prolonged stratification treatment, i.e. 38 vs 75 % germ. Scarification of the entire achene with sulfuric acid, or warm stratification, had no effect by itself, but the scarified seed improved its germ. with longer cold storage. GA_3 and smoke water did not

stimulate germ. The authors concluded that there was not simply physical dormancy. Long dry storage, even 2-4 yr, was also reported to work well for some species, in early studies by Crocker and Barton. More recently Benetka reported very long dry storage with high germ.

The work of Zhou et al was a very carefully done study, with three replicates of 50 seeds in each of many treatments. Removal of the testa on freshly harvested seeds was the quickest way to elicit germ., though only 37 % germ. directly this way. Removal of the pericarp on fresh seeds gave only 5 % germ., slightly better than smoke water treatment (4 %) and treatment with GA_3 (0-3 %). Five weeks warm (25 C) followed by a minimum of 8 weeks at 5 C gave an ultimate level of 80 % germ. if the seeds were kept in the 5 C treatment, under 14 h light, but the germ. rate in the cold of course was much slower than if the seeds were moved to a constant 20-30 C after 8 wk. However the final germ. % for these latter warm tests was only around 30 %, compared to the ultimate 80 % at 5 C. Putting the seeds under conditions of 14 h day/10 h night daily temperature cycling again accelerated germ. rate under higher temp., but the ultimate % germ. was decreased at higher cycling temps. Results are summarized in a table.

Temperature	5	10	15	20	25	30	5/15	10/20	15/25	20/30
% germ.	77	65	43	36	23	30	50	51	42	32

The importance of water potential during germ. was also tested. After 4 weeks of warm stratification and 8 weeks cold, seeds were germ. at 20 C under 14 h light and 10 C during 10 h dark. Best germ. was obtained with no water vapor deficit, that is with a wet medium, which in this case was filter paper wetted with a polyethylene glycol polymer at different amounts per petri dish of 50 seeds.

The same group of Zhou et al, from Chengdu, PRC reported recently (2008) in the Belgian Journal of Botany (vol 141, pp 103-111) on some of the requirements for effective germination of seeds of *R soulieana*, one of the species that grows abundantly in dry valleys of southwestern China. Seeds for this study were obtained about 100 km west and 200 km north of Chengdu, near the town of Diexi, in the Minjiang valley, where annual rainfall is about 0.5 m and potential evapotranspiration is 1 m, in a continental climate with almost all rain coming during the summer growing season. Mean annual temperature is 11 C at an altitude above 2,000 m with low soil fertility. Plants range in size from 1-3 m in height and diameter in that setting. Hips were obtained from 20 + plants, achenes extracted, washed and dried 3 d. Prior to stratification achenes were soaked 2 d in water.

The first comparison was for stratification in moist sphagnum (4 vol/vol seed) vs dry storage until a germ. test, which was done at a constant 10 C in a growth chamber with seeds on moist filter paper in petri dishes, with 14 hr light and 10 hr dark. Tests were also done to determine the effect of water stress (polyethylene glycol added to water) and various light intensities and temperatures on germ. rates. Three replicates of 50 seeds were used in each treatment and statistical analysis was done. The first table shows the key results, rounded to nearest % or days to germination.

Treatment condition	germination (%)	time to germ. (d)
1 week dry, ambient 10-25 C	31	81
13 “ ”	41	52
28 “ ”	68	42
12 week light, 5 C stratified	50	15
12 week dark, 5 C stratified	50	14
4 wk light 25 C, 8 week light 5 C stratified	58	8

Based on these results, this species is relatively indifferent to moist vs dry storage with a slight advantage to moist cool vs warm dry over a comparable time period, but better results with prolonged warm dry storage for total germ. However, the key factor in field establishment may be time to germ. which is notably faster in the stratified seeds.

Some water stress was tolerated during germ., but not extreme (water potential more negative than -0.4 mPa). At 25 C, light intensity had no effect on either germ. %, or mean days to germ. This means that depth of seed in soil has little effect on germinability.

The effect of either constant temp or cycling day/night temp was compared under low light conditions with previously stratified seed, as shown in the next table. Warmer incubation hastens germ. and increases rate slightly, up to 20 C, above which % germ. declines. If there is day/night temp. cycling, overall cooler av. temps are favored slightly. This pattern of response is clearly of ecological advantage to this species where it normally grows. Again results are rounded av.

Temperature	5	10	15	20	25	30	5/15	10/20	15/25	20/30
% germ.	45	50	51	60	44	24	63	50	45	41
germ. time (d)	16	10	6	5	6	4	6	8	7	4

For those particularly concerned with HT roses, the work of Bo et al is important. They used Crimson Glory as the source of seed and compared scarification with hydrochloric, sulfuric and nitric acid and sodium hydroxide. Treatment with concentrated hydrochloric acid for 2 hr was sufficient to soften the pericarp without injuring the embryo. Comparison of germination of naked embryos, embryos with testa, and intact achenes, showed that the naked embryos all germinated in 8 d but the other treatments did not in 22 d. Seed germ. inhibitor was extractable from the testa and pericarp, as measured with tests using Chinese cabbage seeds growth inhibition. ABA was shown to be present at several times higher concentrations in pericarp and testa than in embryos. Bo et al did not directly prove that it was ABA that inhibited seed germination, however. The pericarp may contain many other germ. inhibitors too.

Younis et al in 2007 reported studies on the rose Gruss an Teplitz (a tetraploid China hybrid),

comparing hot water, sulfuric and nitric acid treatments to break dormancy immediately after harvest. Ripe hips were soaked in water to soften them for a couple days, then pressed through a screen or put in a blender to loosen the pulp, which was then washed off. Following a couple days drying on filter paper, seeds were either plunged in boiling water and held for two days, and an unspecified temp., wetted in distilled water, or exposed to 50 % sulfuric acid for 30-90 sec or 65 % nitric acid for 30-90 sec. The germ. was recorded at days 2, 4, 6, & 8 after washing and putting on moist filter papers. The distilled water treatment gave no germ. in that time while the hot water showed about 3 % in 3 replicates of 50 seeds. The sulfuric acid treatment for 30 or 60 sec gave over 40 % germ., while nitric scarcely exceeded 10 %.

Grossi and Jay, in Lyon France, sought to answer an obvious question:"How does each parent contribute to seed germination?" Risley had suggested decades ago that the male determined germ. time, based on study of one seed parent with many pollen donors. Their approach was to make a number of crosses using "7 moschata and HP roses" as female parents and 4 species + 7 modern roses as pollen donors. Using helpmefind for names, the current classification does not agree very well with their statement regarding female parents. Best guesses have been added into the table below, but there are sometimes two roses of different classes with the same name. Their plant material was obtained from J-P Guillot, a rose breeder. All the pollen had been stored frozen from the previous season and was tested for viability.

All seeds were harvested after 4 mo., held warm 1 mo., then at 4 C for 2 mo. prior to sowing into peat (5 cm) on vermiculite (10 cm) then covered with sand 1 cm. After 2 mo at -2 C, they were placed in a warm greenhouse for 6 wk. It is not stated whether the seed were moist or dry during the first two treatments.

Based on the results shown below, I would say that the authors had not found a suitable stratification regimen for the species hybrids. Their germ. was lower (6/7 cases) than for the modern pollen donor on the same female parent. Total seed # was unspecified but at least 10 hips were obtained for each cross. So total seed numbers per cross may have ranged upward from 50 to over 200. No formal statistical analysis is possible, but germ. % is probably a fairly close estimate for the specific conditions used.

The authors also examined the dimensions (length, width and weight) and numbers of achenes/hip, finding a dominant influence of the female parent on seed size. Generally (6/7 cases) there were more seeds per hip when a species was use as pollen donor, than when a modern rose was used.

I find it interesting that Ballerina is an effective pollen parent but unresponsive as a seed parent, if in fact it is the same CV in both instances. It also appears that *R albertii* is a recalcitrant male influence. There is a surprisingly wide difference in the two crosses with *R setigera*, indicating a strong maternal effect or a difference of combining ability. From the information provided there was no way to know if the pollen donor Cornelia is a musk or HT. It had even better germ than a cross of Ballerina (musk) onto a polyantha.

Female parent	Pollen parent	seed #/hip	% germ.
Ballerina, HM	*R. albertii*	14	0
Ballerina, HM	Louis de Funes, HT (1987)	5	0
Baron Girod de l'Ain, HP	*R. albertii*	15	1
Baron Girod de l'Ain, HP	Ena Harkness, HT (1948)	10	26
Fritz Nobis, H. rubiginosa	*R. setigera*	13	1
Fritz Nobis, H. rubiginosa	Mme.R.C. Appert, HT (1917)	11	11
Old Blush, Tea? or Noisette	*R. setigera*	8	21
Old Blush, Tea, or Noisette?	M. Hilling, H moysii (1959)	10	13
Raymond Privat, polyantha	*R spinossissima*	23	26
Raymond Privat, polyantha	Ballerina, HM? or Fl	15	46
Triomphe de Guillot fils, Tea	*R. foetida*	18	0
Triomphe de Guillot fils, Tea	Chacok, HT, Fl (1983)	6	25
Vielchenblau, polyantha	*R albertii*	13	0
Vielchenblau, polyantha	Cornelia, HM? or HT	9	59

Voyiatzi et al studied three tea, or HT, climbers in Greece. The winter temperature regime is very similar to that in San Remo, Italy, where Eva Calvino had worked some 60 years previously, and had reported on treatments to enhance rose seed germination. She found that the climate favored direct stratification in the ground, rather than in a controlled temperature chamber. Voyiatzi et al were located at Thessaloniki, and thanks to the marvels of Wikipedia, I was able to learn something about their climate. The monthly T(av) is: Nov, 10.5 C; Dec, 7 C; Jan, 5 C; Feb, 6.5 C; Mar, 9.5 C. The av. lo in Nov is 7 C and in Dec 3 C. The daily swing is less than at San Remo, only 7-9 C between monthly av. hi and lo, all winter.

The first experiment was done with Cl Westerland in 1992 as shown below. There were 3 reps of 15-20 seeds in each treatment, harvested Oct 20, 17-18 wk post-pollination when hips were turning orange. The LSD (least significant difference) in the results shown below was < 2 % for germ. and < 3 d for time to 50 % max. germ. at p= 0.025 by a standard analysis of variance. In their paper the treatments were numbered for convenience of discussion. The scarification technique of rubbing with coarse sand is not described in any detail

#	germ. %	time (d)	Treatment method
Cont.	10.7	59.8	direct 5 C moist stratification 110 d, germ. in glasshouse
1	22.7	49.5	30 min 30% peroxide first, stratify and germ. as above
2	31.6	51.2	2 d water, sand rub 10 min, 30 min 30 % peroxide, then stratify
3	56.7	34.7	20 min comm. hypochlorite bleach between sand and peroxide
4	58.9	27.4	water, sand, bleach, omit peroxide
5	59.3	22.9	water, sand, bleach, winter outdoors
6	39.3	36.5	soak conc sulfuric 10 min, then stratify
7	31.6	35.9	20 min sulfuric
8	69.2	33.1	30 min sulfuric
9	59.9	34.0	60 min sulfuric

It is apparent that scarification, and use of bleach were beneficial for both time and % germ. Acid scarification was similar to sand in % germ., but not such quick germ. Outdoor stratification might not exceed acid scarification for % germ. but gave faster germ.

Another experiment tested the best of the above treatments on Cl Queen Elizabeth with 5 reps of 20 seeds each. The LSD for % germ. was ~ 6 and for days < 9. For this year (1993), pollination and harvest (early? Nov.) were later but maturity was 17-18 wk post-pollination.

#	% germ.	time (d)	treatment steps
C	10.7	54.8	direct stratification 5 C 45 d, germ. glasshouse
1	67.7	18.6	water 48 hr, sand rub 10 min, bleach 20 min, stratify outside
2	62.5	45.8	30 min sulfuric acid, stratify 5 C 45 d
3	39.8	45.3	water 48 hr, sand rub 10 min, bleach 20 min, stratify 5 C, 45 d

In this second year, outside stratification was clearly superior to constant cold for both % germ. and time to germ., while better than acid scarification only in time to germ. Note that the stratification time was shortened to just 45 d in this year, from 110 d in 1st year study.

A third experiment using 3 CVs and 3 treatments was done the next year with harvest in Nov. 17-18 wk after pollination. There were 3 reps of 20 seeds for each treatment, giving LSD (p= 0.05) germ % > 7 and days ~ 14. No untreated control was tested. Stratification time was presumably 45 d but not specified. The CVs were Cl Queen Elizabeth, Cl Independence Day and

Cl Soraya. There were significant diffs in % germ. and germ. time depending on CV and treatment. The germ. time for the CV Q.E. was much longer than in the previous year. Maybe the glasshouse temp. and lighting or daylength is a factor. Outdoor stratification was optimum, in % germ., and time except for Soraya which had fast but poor germ. after 5 C stratification. Estimates transcribed from a graph are shown below. Some measures on seedlings from the 3rd experiment below are omitted from discussion because they don't really say much beyond the observation that direct planting tends to give more leafy plants in the same length of time. That is presumably because the time to germ. is shorter

Treatment	Queen E. % germ.	Queen E. time (days)	Ind. Day % germ.	Ind. Day time (days)	Soraya % germ.	Soraya time (days)
1 outside	65	65	51	68	50	80
2 acid, 5 C	61	96	41	103	22	80
3 water, sand, bleach, 5 C	46	103	32	100	8	40

These studies confirm Calvino's studies in showing that for a mild Mediterranean climate, outdoor stratification is highly effective for HT and Pernetiana type roses. All 3 of these CVs carry some genes from Pernet-Ducher's yellows, and of course some teas. Independence Day is a rather old CV (1919) while the other two are from the mid-1950s.

5. Annotated bibliography

Alp, S., Celik, F., Turkoglu, N., Karagoz, S. (2009) **African Journal of Biotechnology** 8:5838-5841 The effects of different warm stratification periods on the seed germination of some *Rosa* taxa. See text.

Anderson, N., Byrne, D.H. (2007) **Acta Horticulturae** 751:503-506 Methods for Rosa germination. See text.

Barton, Lela V. (1939) **Scientific Hort.** 7:186-193 Experiments at the Boyce Thompson Institute on germination and dormancy in seeds. In Table 11 of Chapter 3 of Crockers' book, (below), she shows that for *R. multiflora*, the best temperature is 5 C with an optimal range of 5-8 C over a time of 50 days.

Bekendam, J. (1973) **Bedrijfsontwikkeling** 4:1143-51. Germination capacity of *R canina* and *R inermis*. Pretreatment moist with 10-20 C, then 5 C for germ. best. Drying freshly harvested seed at least 2 wk at 35 C, and leaching with water both help. Up to 70-80 % germ. gotten. (in Dutch)

Benetka, V. (1984) **Hort. Abstracts** # 4733 Shortening the dormant period in seeds of the rose rootstock Powuv Cerveny by sowing in autumn of the harvest year. Apparently dealing with a very difficult cultivar the treatment was to dry hips 2 weeks at 35 C, then stratify in perlite at 20 C for 20 months, followed by 3 mo. at 6 C. This gave 60-90% germination. Removing pulp was not important, repeated temperature cycles not useful.

Benetka, V. (1998) **Acta Pruhoniciana** 66:37-41 Effect of warm stratification on seed viability of the rootstock rose Pavuv cerveny (Pollmeriana). See text.

Blundell, J.B. (1973) **Gardener's Chronicle** 174:16-19 Rootstock seed growth improved. Sulfuric acid treatment was used to hasten the germ. response in a massive scale work.

Blundell, J.B., and Jackson, G.A.D. (1970) Rose Annual pp 129-135 Rose seed germination in relation to stock production. Concluded that acid treatment, stratification and spring sowing gave best results for CVs Inermis, Laxa, Pfander and *R rugosa*. A warm stratification (26 C) followed by 2 C, with acid pre-treatment was optimum for *R canina*, getting >90 % germ. within 10 mo at 2 C after 3 mo at 26 C, and acid. Continuous warm gave only 17 % in same time. Omitting the warm stratification gave 62 % germ.

Bo, J., Huiru, D., and Xiahon, Y. (1993) (International Symposium on Cultivar Improvement of Horticultural Crops Part 3: Flowers) **Acta Horticulturae** 104:40-47) Shortening the hybridization breeding cycle of a rose- a study on mechanisms controlling achene dormancy. See text.

Buckley, F.C. (1985) **Amateur Rose Breeder's Association**, England. Germination of rose achenes: a review and analysis of practices and some suggestions for future investigations. See text.

Calvino, E.M. (1930) **Report and Proceedings of the 9th International Horticultural Congress, London** 9:150-153 (As quoted by Crocker in Biol Abs 7:#1522) Germ. incr. with hip maturity from 1/4 in green, to 27 % in yel., 30 % in or., 42 % red. Direct planting, no prior stratification with emergence 7 wk to peak by 4-5 mo. Seed treat with 1/1000 Mgcresol 1h incr % by 1/3. Chilling 16 d at 0 C hastens germ. 1 mo.

Crocker, William (1948) **Growth of Plants. 20 years of research at the Boyce Thompson Institute**, Reinhold Publ Co. Chapter 3 Dormancy in seed. Figure 29 pg 89 shows that 5 C in moist sand for 6 mo is best for *R. rubiginosa* compared to dry, or 0, 5, 10, 15, 20. The effect of temperature difference was quite marked.

Crocker, W. (1927) **Boyce Thompson Institute Professional Papers** 1:36-41 Dormancy in hybrid seeds. Data the same as in the 1948 book.

Crocker, W. and Barton, L.V. (1931) **Contributions of the Boyce Thompson Institute** 3:385-404 After-ripening, germination and storage of certain rosaceous seeds. See text.

Cullum, F.J., Bradley, S.J., and Williams, M.E. (1990) **Proc. Intl. Plant Prop. Soc**. 40: 244-250 Improved germination of *R. corymbifera* L. seed using a compost activator. See text.

Dadlani, N.K., Venkataramana, K.T., Mathews, R.R. and Singh, B. (1989) **Seed Research** (India) 17:193-196 Seed germination in roses. Open pollinated seeds of 6 CVs compared stratified or scarified with sulfuric acid for 1 hr. In another series, hips were harvested at various times after pollination then stratified for 1 mo. and germinated at 20 C. No treatment gave >20 % germ.

Densmore, R., and Zasada, J.C. (1977) **Canadian Field Naturalist** 9:58-63 Germination requirements of the Alaskan *Rosa acicularis*. 2 mo warm, 3 mo. cold, then germ. 5-20 C OK. Sulfuric acid no sub for warm stratification. In field. 2 winters needed to germ.

De Vries, D.P. and Dubois, L.A.M. (1987) **Euphytica** 36:117-120 The effect of temperature on fruit set, seed set and germination in “Sonia” x “Hadley” hybrid tea rose crosses. See text.

Feuerhahn, B. and Spethmann, W. (1995) **Gartenbaumagazin** 4:26-6 Compost activator improves the germination of rose seeds. Confirms the work of Cullum with 11 species. A 12 wk at 20-25 C in sand bentonite in trays followed by cold treatment at 4.5 C in peat:sand mix. Sowing in greenhouse at 10-15 C gave up to 90 % germ. and the sample with activator did better. (From Abstract)

Foster, T.C., and Wright, C.J. (1983) **Scientific Hort**. 34:116-125 The germination of *R. dumetorum* Laxa.

Grossi, C, and Jay, M. (2000) **Plant Varieties and Seeds** 13:11-15 Lineage and inheritance in roses in relation to seed morphology and physiology. See text.

Gudin, S., Arene, L., Chavagnat, A. and Bulard, C. (1990) **HortSci** 25:786-788 Influence of endocarp thickness on rose achene germination: genetic and environmental factors. Two crosses with different male parent on same female showed thinker endocarp correlates to lower germ. while pericarp thickness is unchanged. Two crosses (different parental pairs) on two dates of pollination (Mar. vs May) show different % germ. with endocarp thickness as a main factor. Measured faster growth of embryo at higher temp of development in May, vs Mar yielded better % germ., presumably because of measured thinner endocarp under these conditions.

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Haenchen, E. (1969) **Hort. Abstracts** 39: 3300 Problems of stratification of rose rootstock seeds. The author claims that the hip retards germ. and that removing or crushing the flesh helps.

He, H., Ueda, Y., Kurosawa, T., Ogawa, S., Nishino, E., Wang, B., and Liao, K. (2001) **Acta Horticulturae** 547: 129-140 Morphological character and germination in achenes of *Rosa persica* Michx. This is one of the most distant members of the rose family, also known as *Hulthemia.* Compared to *R. multiflora* the outer pericarp is thicker. ABA level is low, imbibition is faster than in R. multiflora and germ. is rapid. (See text)

Holloway, P.S. (1996) **Georgeson Botanical Notes** #25 Feb. www.alaskarosesociety.org/documents/seed_germ1.htm Seed germination in wild and cultivated roses. Author claims that 2 mo warm, 2 mo cold, then germ. warm with if necessary cycles of 1 mo cold and warm again.

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Jackson, G.A.D., and Blundell, J.B. (1963) **J. Hort. Sci**. 38:310-320 Germination in *Rosa.* A detailed article on various treatments that improve germination. See text.

Jackson, G.A.D., and Blundell, J.B. (1965) **Nature** 205:518-519 Germination of *Rosa arvensis*. The testa contains an inhibitor of germination.

Jackson, G.A.D. (1968) **Soc Chem Ind Monograph** 31:127-156 Hormonal control of fruit development, seed dormancy and germination with particular reference to Rosa. Auxin can induce parthenocarpy (unpollinated seed formation). Removal of ABA induces rapid germination of embryo. Gibberellic acid, benzyl-amino-purine (kinetin) and indole-acetic acid (auxin) all stimulate germination.

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germination. Scarification was of no benefit, but leaching gave a 2x increase in germination. After 14 weeks at 4 C, there was a transient rise of a zeatin or ribosyl-zeatin-like material which may relate to the release from dormancy.

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McCully, W.G. (1951) **J Range Mgt** 4:101-106 Recovery and viability of MacCartney rose seeds fed to cattle. See text.

McKelvie, A.D., and Walker, K.C. (1975) **J. Hort Sci**. 50:179-181 Germination of hybrid tea rose seed. Extracted embryos would germinate after 7 d at 20 C, but from hips of 15-20 weeks maturity achenes took 10 wk moist storage at 4 C to overcome the cold requirement. Treatment with Zn.HCl (Cross and Bevan reagent) helped soften the pericarp in older achenes.

McKelvie, A.D. and Walker, K.C. **Gardener's Chronicle** 178 (1): 39 Hybrid Teas from seed under trial. A fairly elaborate treatment regimen of 2 wk at 20 C, 2 wk cold, 10 d at 4 C followed by treatment with ZnHCl (Cross and Bevan's reagent) to soften the pericarp cellulose, then 15 wk at 4 C. Starting with 20 wk hips, this gave 20-27 % germ.

Maharana, T, Singh, S.P., Singh, D.N., Nandi, A., and Tripathy, P. (1994) **J. Ornament. Hort**. 2:32-36 Effect of different treatments on germination and post germination aspects of rose achenes. Eleven CV tested in 1986-87. 20 min sulfuric acid treatment followed by washing and refrigeration in sphagnum gave 41 % germ, 87 % of these healthy.

Marchant, R., Power, J.B., Davey, M.R. and Chartier-Hollis, J. (1993) **Euphytica** 74:187-193 Embryo rescue, for the production of F1 hybrids in English Rose. Seeds of two proprietary crosses of David Austin were stratified 8 wk at 0 C to give 27/50 and 10/30 germ. while embryo rescue gave 100 % when testa was removed.

Meyer, S. E. (N.D.) http://www.ntsl.fs.fed.us/wpsm/Rosa.pdf on the Rosaceae. Excellent review with 4 of 6 pp text focused on germination. With ~40 refs. + table of typical achene wt., stratification requirements for 12 spp collected from earlier sources. All of the cited refs. on germ. are found in the present list.

Mirov, N.T. and Kraebel, C.J. (1937) **Forest Research Notes**. California Forest and Range Experiment Station, Forest Service, USDA, Berkeley, CA #18, 27 pp Collecting and propagating the seeds of California wild plants. For three species growing wild in California, 3 mo. cold stratification was effective. *Rosa californica* took about 104 d to germ. at rates up to 62 %, while *R. gymnocarpa* took 80 d with 43 % germ. and *R. nutkana* took 100 d with 50 % germ. These were best values, not multi-year averages, on tests of 100 seeds.

Morey, D. (1960) **Proceedings of the 10th Annual Meeting of the Plant Propagators Society**. pp 267-273 Seed stratification techniques with emphasis on roses. Notes that *R. canina* needs a warm pretreatment of 2 mo. before cold stratification; *R. laevigata* takes up to 3 yr. The HTs will germ. in cold if a few hr/d above O C.

Morpeth, D.R. and Hall, A.M. (2000) **Seed Sci. Res**. 10:489-494 Microbial enhancement of seed germination in *Rosa corymbifera* "Laxa" Adding a compost activator "Garotta" increased germ. to 95%, consistently over 5 yr. See text.

Morpeth, D.R., Hall, A.M. and Cullum, F.J. (1997) In **Basic and Applied Aspects of Seed Biology** (Proc 5th Int Workshop on Seeds) Involvement of microbes and enzymes in the pretreatment of woody seeds to overcome dormancy. The warm stratification phase can be cut from 12 to 6 wk by adding Garotta, then 12 wk cold gives >80 % germ in field or lab for Laxa rootstock.

Roberts, L. R. (1979) **Plant propagator** 25:13-14 Practical aspects of the acid treatment of rose seed *Rosa dumetorium* Laxa dormancy breaking by acid treatment, storage temperature and sowing (Shardlow, ADAS is not a co-author as shown by Meyer, but an address)

Rowley, G.D. (1953) **Annual Reports of the John Innes Institute**. Germination in *Rosa*. Same comments as Morey (above) on *R. canina*.

Semeniuk, P. and Stewart, R.N. (1962) **Proc Amer. Soc. Hort. Sci.** 80: 615-621 Temperature reversal of after-ripening of rose seeds. Simple storage at 40 F, gives as good germination as more elaborate treatments. See text.

Semeniuk, P.,Stewart, R.N., and Uhring, J. (1963) **Proc Amer. Soc. Hort. Sci.** 83:825-828 Induced secondary dormancy of rose embryos. Warm temps after harvest make seeds harder to germ. See text.

Semeniuk, P. and Stewart, R.N. (1964) **Proc Amer. Soc. Hort. Sci.** 85:639-641 Low temperature requirements for after-ripening of seed of *R. blanda*. At 40 F germ. takes 300 d., and at 35 F it is even slower. See text.

Semeniuk, P. and Stewart, R.N. (1966) **Proc. Amer. Soc. Hort. Sci.** 89:689-693 Effect of temperature and duration of the after-ripening period on germination of *R. nutkana* seeds. A warm after-ripening followed by 4 mo. cold is beneficial while drying or over-wintering on the plant is not helpful. See text.

Stewart, R.N. and Semeniuk, P. (1965) **Amer. J. Bot.** 52:755-760 The effect of the interaction of temperature with after-ripening requirement and compensating temperature on germination in five species of Rosa. There is a critical temperature at or above which no germination, after-ripening or dormancy occurs. This varies widely with species. See text.

Suszka, B., and Bujarska-Borkowska, B. (1987) **Arboretum Kornicke Rocznik** 32:231-296

Seed after-ripening, germination and seedling emergence of *Rosa canina* L and some of its rootstock selections.

Svejda, F. (1968) **HortSci** 3:184-185 Effect of temperature and seed coat treatment on the germination of rose seeds. See text.

Svejda, F.J. and Poapst, P.A. (1972) **Can. J. Pl. Sci** 52:1049-1058 Effects of different after-ripening treatments on germination and endogenous growth inhibitors in *R. rugosa*. A 24 hr leaching before stratification improved germ. in *R. rugosa*, but leaching cannot sub for after-ripening. A bioassay of inhibitors showed two were present, one is presumed to be abscisic acid (ABA). A 4 wk moist treatment at 20 C followed by 8 wk at 4 C gave best % germ. for 1 yr stored seed.

Tillberg, E. (1983) **Physiol. Plantarum** 58:243-248 Levels of endogenous ABA in achenes of *R. rugosa* during dormancy release and germination. See text.

Tillberg, E. (1984) **Pl. Physiol**. 76:84-87 Levels of endogenous indole acetic acid in achenes of *R. rugosa* during dormancy release and germination. Concludes that IAA is not involved in dormancy because at 14 wk stratification at 4 C levels of IAA are similar to 2 wk at 17 C. At 17 C the IAA levels decline even further but germ. does not increase. There is a pulse increase of IAA at germ. time.

Tincker, M.A.H. (1935) **J. Royal Hort. Soc**. 60:399-417 Rose seeds: their after-ripening and germination. Detailed studies on more than a dozen species showing effects of many combinations of treatments See text. Note that this is the correct authorship citation. Meyer and other authors misread the heading, attributing 2nd authorship to Wisley, a location.

Van Hulle, J. (1965) **Meded. BedrVoorlicht**. **Oost-Vlaanderen** 33: 6 pp Sowing rose rootstocks. (Paraphrasing the abstract) Five media: peat, sand, perlite, 1:1 sand/peat and 3:1 peat/perlite for *R canina* and sand only for *R rubiginosa* compared with seeds kept up to 3 mo. Peat was best, sand poorest, 3 mo better than shorter times.

Von Abrams, G.J. and Hand, M.E. (1956) **Amer. J. Bot**. 43:7-12 Seed dormancy in *Rosa* as a function of climate. The average daily temp. in Oct. correlates with germ. Higher temp gives higher rate. With high light and temp. very little dormancy was seen. Excised embryos germ. even when achene is dormant. A very important paper. See text.

Voyiatzi, C.I., Koutsika, M.S., and Vavdinoudi, E. (1999) **Plant Var. and Seeds** 12:65-72 Presowing treatments affect seed germination and plantlet vigour of some climbing rose varieties. See text.

Werlemark, G., Carlson-Nilsson, B.U., Uggla, M. And Nybom, H. (1995) **Acta Agric. Scand. B** 45:278-282 Effects of temperature treatments on seedling emergence in dogroses. See text.

Yambe, Y. and Takeno, K. (1992) **HortSci** 27:1018-1020 Improvement of rose achene

germination by treatment with macerating enzymes. For *R. multiflora*, treatment with Driselase, cellulase and pectinase tested. The last of these loosens the suture, increasing germ. most while Driselase is less effective and cellulase has least effect. Activated charcoal to remove ABA is of some help.

Yambe, Y. , Hori, Y. and Takeno, K. (1992) **J. Japanese Soc. for Hort. Sci.** 61: 383-387 Levels of endogenous abscisic acid in rose achenes and leaching with activated charcoal to improve germination. Achenes of *R. multiflora* floated in tray of water with activated charcoal to remove ABA. Results better at 5 C than 25 C.

Yambe, Y. (1995) **J. Amer. Soc. Hort. Sci**. 120: 953-955 Light and phytochrome involvement in *R. multiflora* seed germination. Interesting but complex results See text.

Younis, A., Riaz, A., Ahmed, R., Raza, A. (2007) **Acta Horticulturae** 755:105-108 Effect of hot water, sulfuric acid and nitric acid on the germination of rose seeds. See text.

Zhou, Z-Q., Bao, W-K., Wu, N (2009) **Scientia horticulturae** 110:434-441 Dormancy and germination in *Rosa multibracteata* Hemsl. & E.H. Wilson. See text.

Zhou, Z-Q., Wu, N., Bao, W-K. and Qui, P-F. (2008) **Belgian J. Bot.** 141:103-111. Post-dispersal factors regulating dormancy and germination of *Rosa soulieana* seeds. See text.

Zlesak, D.C. (2005) **HortSci** 40:1931-1932 The effects of short-term drying on rose seed germination. Variable tolerance to 4 d drying followed by stratification of 12 wk at 4 C, with germ. at 14 C. *R. rubiginosa* lost about1/3 to half their germ. on drying (2 yr tested) while *R. rugosa* showed similar effect in 1 yr, and *R setigera* had over 90 % germ. dried or not. For CV "Carefree Beauty" there was no effect of short-term drying, but year to year variation was considerable 64 vs ~35 % germ. The CV "George Vancouver"was insensitive to 4 d dry.

Index to Species

Descriptive terms cited are those of the original authors and not necessarily those of modern taxonomy. The only exception is for *R. wichurana*, where the spelling has been modified for consistency. Some subspecies or varieties may well have one or more synonyms, as found, for instance in Modern Roses 11. *R.persica* is often denoted as *Hulthemia persica*, but the author's usage has been retained. Please note that page numbers include the annotated bibliography (pp 36-42). If there is no other page indicated, there may be a short description of germination conditions provided there.

5. My personal experience

Over the years since the early 1980s I have kept track of seed germination more and less precisely for a fairly wide range of crosses involving mostly; Carefree Beauty; a hardy seedling of Carefree Beauty x Rise 'N Shine which I call PS; product of a cross of CB x Golden Arctic [Brownell's American Pillar # 84] which I call Arctic Sunrise (AS); New Dawn; and Silver Moon (an old van Fleet rose) as seed parents. Thus, most of my experience is restricted to the moderately hardy kinds of complex hybrids. For information on species roses we need to depend on the careful observations provided by a few early workers, cited above from the Rose Annual, and recent studies in more detail in the scientific literature (see below). For the more tender hybrid teas, information in the Rose Annual and the RHA newsletter can be referred to. On the RHA site there is a list of articles in the Rose Annual having to do with hybridization. That list includes germ. studies, many of which were discussed above.

I settled on a fairly simple system early on, being willing to accept 25-30 % as the likely germ. rate that I could expect. Most years I harvest the hips in mid-September to mid-October, depending on my available time and the approach of frost. Pollination is generally done from about May 25 until July 1, basically with the first grand flush of blossoms. I have used the second round on Carefree Beauty which will produce new flowers quickly if the first flowers are removed, or fail to pollinate. I've paid no attention to temperature effects on pollination efficiency or seed maturation and it may well be a contributing factor in my overall results, but averaged over two decades it should even out, more or less. Analysis of the weather over the past 25 years provides the following range of values. At least one day exceeded 100 F (years out of 25): 6 in Jn, 17 in Jl, 17 in Au & 4 in Sp. The average daily maximum exceeded (degrees F, in years out of 25): 85 in 14 Jn; 90 in 14 Jl; 85 in 20 Au; and 80 in 15 Sp. The daily average in Sep ranged from 61-76 F over those years, while average low ranged from 47-65 F. Converting this to degrees C, and comparing to the work of von Abrams and Hand (see below), it is clear that our lowest daily average in Sep is higher than their highest daily average in Scappoose, OR.

Here the hips are usually opened soon after picking. After harvest until opening they are stored in a refrigerator. Our first hard frost comes after mid-October but we typically have 10 or more very cool nights in the preceding month. Harvested seeds are counted and then placed in small plastic bags with some wetted peat moss which has been squeezed until it stops dripping. The seeds are mixed with the peat, usually one cross per bag. Batches of over 200 or so seeds are typically split into two bags. All the bags are placed together in another larger bag and kept in a coldroom or refrigerator at a nominal 4 C. About February 1st, I begin to check for sprouted seeds and pick out the germ. ones to plant. Usually I return the seeds to the coldroom for a month or so and plant another batch. I generally don't bother with later recalcitrant seeds, though sometimes I put them into the garden where they have another chance to emerge. Very few ever do.

I never bother to do float tests or plant the seed directly in growing trays. I have limited space in a basement under fluorescent lights to grow the seedlings and I want to maximize use of the light. I used to plant one seed per cell of the 12 sixpaks in a seedling flat, giving 72 per tray. In more recent years I have doubled that density without loss of flowering. I now plant 144 germ. seeds (at any stage beyond opening of the achene) in a tray of 12 sixpak seedling flats. Roughly

half of the planted, germ. seeds actually grow to the stage of transplanting outside, as noted by Mrs Dodek. This is a common experience of agronomists who actually distinguish germ. from emergence in crop plants. Many weak seeds don't have the strength to produce a proper plant. So my "germination" numbers may be higher than those of folks who count only emerging seedlings. They do correspond to the work of Crocker and Barton who followed a strategy similar to the one I have adopted. There is a slight bias toward multiples of six because sometimes I plant seeds with the achene open, without an emerged root, just to fill out a sixpak. I did not record all details every year. If it is not given here, it is not recorded anywhere.

Below are some tables detailing the variation in germ. as a function of the maternal or paternal parent. Also noted are some open-pollinated instances. One really should not talk of percentage germ. for numbers less than 100. So in many instances I have put % in ( ) or just shown the fraction of germ./seeds stratified. Numbers might be slightly lower if only those seeds with a root of 2 mm or more were counted as germ., as some were counted if the achene was open, even though no root elongation showed. In large batches, that is a trivial difference but for some small groups with low germ. it could affect calculated percentages significantly. Usually for small total seed numbers, there were few hips from a single plant, so a wide range of specific physiological effects could be influencing the results. I rarely have two or more parental plants of one CV to work with. Because of the observations of von Abrams and Hand discussed below, I have examined the monthly temperature averages for each year, as related to % germ. I can see no trend to it, perhaps because I have such a heterogenous lot of crosses, and a warmer climate, unlike their studies, repeating the same crosses over and over in large quantity, year after year.

Pollinations in 1982

Carefree Beauty was the mother, giving 3-4 seeds per hip that set. For most crosses about half the pollinations failed. Open-pollinated hips contained an average of 7 seeds.

Pollen parent	Germinated fraction	Percentage
Rise 'N Shine	30/67	(45)
Doubloons	54/108	50
Orange Ruffels	30/47	(64)
Sunbright	30/45	(67)
Good News	18/26	(69)
Golden Arctic	134/200	67
Gold Masterpiece	72/126	57
Peace	3/5	
Goldrush	3/4	

In the same season 43 O-P seeds of General Jaqueminot gave no germ. while O-P Rise 'N Shine gave 36/85 (42 %). It is worth noting that Doubloons is never repeat-blooming in my climate but a goodly fraction of its offspring are.

1983

A similar set of crosses was done as in 1982. In this case only the fraction surviving to be recorded on a label after emergence is recorded. So % germ. may be a bit lower than if all achenes with a root tip showing were recorded. The property of flowering in the 1st season is given. The flowering fraction gives some indication of remontancy, though some plants were simply too weak to produce a bloom, so might or might not be remontant if studied longer. Others may have produced only one bloom early on, and then become strictly vegetative.

Pollen parent	Surviving fraction & (%)	Flowering fraction (% of total starting seeds)
Doubloons	33/54 (61)	19/33 (35)
Golden Arctic	79/134 (59)	54/79 (40)
Rise 'N Shine	20/30 (66)	16/20 (53)
Good News	9/18 (50)	9/9 (50)
Gold Masterpiece	29/72 (40)	22/29 (30)

1986

Pollen parent	Fraction germinated	Percentage
Golden Showers	54/420	13
Golden Arctic	186/650	29
High Noon	108/366	29
Sunny June	72/210	34
Sunbright	30/161	19
Golden Sun	18/71	(25)
Lowell Thomas	6/38	(16)
Captain Thomas	36/158	23
Gold Masterpiece	72/211	34
Golden Girl	0/17	(0)
self (O-P)	30/105	29

The very large 1986 crop was harvested in two stages, Sep 14 & 20. Again, Carefree Beauty is the female parent. Planting was in later January. There is no obvious explanation for the lower percentage germination in this year. Some of the crosses are the same as previous years.

In a limited number of crosses with New Dawn as female parent, with the following named CV as pollen parent, the fraction germinated was: 10/17 for Golden Showers (>1/2); 24/73 (~1/3) for Rainbow's End; 36/120 (<1/3) for Rise 'N Shine.

1987

Pollen parent	Fraction germinated & %	Fraction after Jan 22
Austrian Copper	24/35 (69)	2/24
High Noon	255/700 36	45/255
Rise 'N Shine	15/24 (62)	3/15
Gold Showers	15/32 (47)	0
Gold Medal	42/58 (72)	0
Sunbright	18/38 (47)	0
Goldene Sonne	32/128 25	1/32
Maigold	6/20	0
Gold Masterpiece	83/207 40	0
Sunny June	36/56 (64)	8/36
Golden Girl	9/17	0
Crimson Glory	128/269 48	54/128
Eclipse	34/47 (72)	3/34
Dr. Huey	24/35 (69)	6/24
Peace	164/294 56	100/164
Mirandy	21/45 (47)	0
General Jacqueminot	96/208 (46)	0
Black Jade	39/77 (51)	21/39
self (O-P)	no count	5/44

Crosses onto Carefree Beauty, began May 10.. Harvest began Sep 5 with those hips showing orange color, and continued til early Oct, most by Sep 25. I could see no significant difference in number of seeds/hip on different harvest dates. Pollination results for most pollen parents were better this year, up to 7 seeds/hip for many CVs. Germination was significant by Jan 8. For 2/3 of the CVs most seeds emerged by Jan 22. Crimson Glory, Black Jade and Peace were noteworthy in having a significant fraction of seeds emerging later, through Feb 19.

The above results are consistent with the work of Risley who showed that the pollen parent may determine germination speed for a single female, by controlling the embryo after-ripening requirement. There could be some effect of pollination date which was not recorded, but most of the roses bloomed at about the same time.

Crosses onto New Dawn were successful with pollen from Sunny Day, Rainbow's End, Rosie, Golden Arctic, Captain Thomas, High Noon, Rise 'N Shine, Baby Eclipse, Sequoia Gold, September Days. However, there were usually 1- 2 seeds/hip.

1988

I did an experiment to examine the effect of some different treatments on germination of O-P seeds of Doubloons. This was initially an unplanned process; I put away the hips in a plastic bag in the refrigerator (early Oct) and didn't find them until April 10, 1989. The seeds were then separated from the hips in the usual fashion and divided into five groups. A control group of 60 seeds was planted directly along with my usual flats of germinations which were growing well by that time. Four other groups of 100 seeds each received treatments as follows. The first lot were mixed with moist peatmoss and returned to the refrigerator. By mid-August only a few showed signs of germination. By Sep 26, 39 seeds had germinated (39 %). Another 100 seeds received 10 min in sulfuric acid, followed by water washing and then storage in peat. Two seeds germinated by Sep 26. Another lot received 30 min in Chlorox bleach, followed by washing and peat stratification. From this lot 47 seeds came up (47 %). Finally, for another lot, 1 mg gibberellic acid in 30 mL water (33 ppm) was used for 30 min. This lot was not washed but just drained, added to peat and stratified. Emergence was 36 %. From the results it appears that storage in the hip does little for the after-ripening requirements of this CV. Sulfuric acid is detrimental, while bleach might be beneficial and GA_3 has little effect. See below for examples of crosses onto Doubloons or with it as a pollen parent where germ. after just a few months stratification beginning in autumn equals that observed in this test. Above, in 1982 and 1983, it gave better than 50 % germ. as pollen parent to Carefree Beauty in the same time as other parents (4-5 mo.).

1990 & **1992**

A wide range of female parents, seedlings from Carefree Beauty, was used with mainly yellow pollen parents. Numbers of hips and seeds produced for each different pollen parent on a single seed parent varied, but aggregate data may be of some value, because the same container of pollen was used to make as many crosses as there were female parents available on any given day, or until the pollen was depleted. In the first table, results using offspring from crosses of CB as female parent are shown, while in the second table, specific crosses onto Carefree Beauty (CB)

are shown. All those entries with numbers below15 are from crosses of CB x Golden Arctic made in 1983. Numbers in 20s & 30s are CB x High Noon (most), Gold Showers or Captain Thomas (two offspring and one parent). The numbered offspring had been selected to show some indication of yellow color, vigor, doubleness and disease resistance. The names PS and MD stand for my personal names of specific seedlings. PS is a Pink Single (10 petals) with good substance, hardiness and disease resistance. Morning Dew is a pale yellow reasonably hardy floribunda-sized flower, with classic HT form.

Female parent	Fraction germ. 1990 & (%)		Fraction germ. 1992 & (%)	
CB X Rise'N Shine (PS)	100/235	(43)	91/130	70
CB x Sunbright (MD)	11/24	(32)		
#1	19/28	(67)		
#2	105/170	62	50/72	(69)
#3	44/82	(54)		
#4	8/13	(61)		
#5			10/16	(62)
#6	8/17	(47)		
#7			9/35	(26)
#8	176/280	63	45/94	48
#9	166/298	56	15/59	(25)
#10			25/41	(61)
#10A			8/11	(73)
#12	17/29	(59)		
#13			6/31	(19)
A	13/22	(59)	217/513	42
1A	27/42	(64)		
#21	96/121	79	36/60	(60)
#23 + 24	17/24	(71)	8/26	(31)
#25	18/25	(72)		
#31 + 32	8/11	(72)	6/8	

Pollination in 1990 continued later than previous years because the female parents were observed to mature hips relatively quickly in previous years. Pollination went on through mid-July. Harvest was late Sep, with seeds placed in the cold by Oct 1, with germination measured Jan 20, Feb 8 and Mar 9. For most CVs the large majority of germinations occurred by Jan 20. Pollination in 1992 began June 4 after a bad Spring freeze. Harvest was Sep 13, hips were promptly opened, and main planting Feb 9 (about 2/3 of all germ. had occurred by that date).

1990 Crosses onto Carefree Beauty

Pollen parent	Fraction germinated	Percentage
Circus	396/545	73
Rise 'N Shine	85/155	55
Golden Arctic	165/234	71
Captain Thomas	5/6	
Joseph's Coat	76/108	70
Sunsprite	39/90	43

1993

Crossing was done using a range of female parents and a limited selection of pollen parents. Roses began bloom about May 20, but were done by June 20. Harvest was Sep 25. Planting was Jan 28 & Feb 25. Effects of pollen and female parentage are observable in germ. rates. The name CC (Carefree Copper) designates a once-blooming, semi-double very hardy but somewhat disease-susceptible offspring of CB x Austrian Copper. AS is short for Arctic Sunrise, a pink/yellow blend moderately double, totally disease-resistant very hardy rose from CB x Golden Arctic. PS is a cross of CB x Rise 'N Shine, a pink single miniflora

Seed parent	Pollen parent	Fraction germ. & %
Carefree Beauty	General Jacqueminot	137/208 62
"	Yellow minis	154/312 49
"	Sunsprite	119/310 38
"	Orange Everglow	56/150 37
"	Yellow HTs	38/96 39
"	OP	28/66 (42)
"	CC	279/798 35

Seed parent	Pollen parent	Fraction germ. & %
Golden Arctic	CC	18/160 11
CB x Golden Arctic (=AS)	CC	2/15
AS	Sunsprite	36/138 26
AS	Yellow HTs	15/55 (27)
PS	(New Dawn x Rise N Shine)	36/200 18
PS	Sunsprite	22/58 (38)
PS	CC	177/426 42
PS	Orange Everglow	12/25 (48)
Captain Thomas	CC	0/21

1997
Pollinations done late May through June. Germination by Feb 10 . A cross of Silver Moon as female parent with Sunsprite as pollen parent gave 28/36 germination (78 %), while New Dawn as female with Sunsprite for pollen gave 50/96 (50 %).

2000
Most pollinations were done May 15-June 5, with only New Dawn continuing until June 15. Harvest late Sep, germ. mainly by Feb 20. For a few crosses 1/3 or more germ. only after that, by Apr 1, noted in the table as (late). Other crosses not shown, with smaller numbers and on parents less well known, did not show much, if any, of the late germ. Pinky is a hardy, disease-resistant floribunda-sized offspring of CB x (probably) Sunbright, with slow-opening flowers of good substance that retain their petals for several days.

Female parent	Pollen parent	Fraction germ.	Germ %	Fraction late	% late
Carefree Beauty	Sunsprite	12/31	(39)	--	
"	Eclipse	155/308	50	53/155	34
PS	Doubloons	262/600	43	72/262	27
Silver Moon	Goldmoss	17/20	(85)	5/17	
Arctic Sunrise	Goldmoss	63/150	42	27/63	(43)
New Dawn	Sunsprite	48/127	38	--	
Captain Thomas	OP	11/59	(19)	11/11	
Pinky	Doubloons	528/850	62	144/528	27

2002

Most pollinations were done during the narrow window of May 29-June 10, harvest Oct 15. Planted Mar 20 with earliest flower Apr 21 and many by May 10. Note for this and two following years, a factor in the slow and late germ. may be that the storage was close to 2 C which may be below optimal (the coldroom was repaired and set lower). Not noticed until 2005 that planting time was significantly delayed.

Female parent	Pollen parent	Fraction germ. & %
Doubloons	yellow minis	24/46 (60)
"	Goldy (CB x Sunsprite?)	9/56 (17)
Goldy	Doubloons	52/118 44
Goldy	Evergold (Orange Everglow OP), constant blooming	14/35 (40)
New Dawn	Goldy	14/30 (43)
"	Evergold	48/123 39
"	Goldmoss	22/49 (44)
"	Sunsprite	54/101 54
"	yellow minis	51/109 47
Evergold	Doubloons	2/25
"	Sunsprite	2/11
Carefree Beauty	Doubloons/Goldmoss	54/84 (64)
"	Eclipse	39/76 (51)

2003

Pollination late May through most of June. Harvest Oct 12. Planted Apr 11.

Female parent	Pollen parent	Fraction germ. & %
New Dawn	yellow minis	178/371 48
"	Evergold	36/120 30
PS	Sunsprite	24/68 (36)
"	Goldy	60/165 36
Arctic Sunrise	Sunsprite	23/140 16
Silver Moon	Evergold	44/64 (69)
"	Sunsprite	7/8

2004

Pollination May 18 to early June on Silver Moon; May 25 to June 17 on New Dawn. Harvested Silver Moon hips late Aug, stored in refrigerator until Nov. Harvested New Dawn Oct 15. Silver Moon and New Dawn average < 3 seeds/hip. PS has >10; Doubloons 6. Planting was done Mar 23 and May 5. A large fraction was late germinating (after Mar 23) as indicated. The low germination in Silver Moon stored cold prior to stratification suggests maybe it ought not to be stored in the hips. Compare to previous years results.

Female parent	Pollen parent	Fraction germ. & %	Late fraction & %
New Dawn	Goldmoss	30/89 (34)	16/30 (53)
"	Eclipse	4/12 (2 late)	2/4
"	Sunsprite	34/159 22	14/34 (42)
"	Evergold	97/477 20	44/97 44
Doubloons	Sunsprite	51/187 27	28/51 (55)
PS	Doubloons	98/410 24	14/98 14
Silver Moon	Evergold	30/154 19	--
"	Goldmoss	29/59 (49)	4/29
"	Eclipse	4/12	--
"	Sunsprite	17/141 (12)	--

2008

Hips were harvested as they came ripe (Sep 1 onward) and stored in a refrigerator until Nov 1. The achenes then were removed, counted, and transferred to plastic bags with moist peat moss, during the first two weeks of November. Stratification was continuous dark at ~40 F (4 C) until germination, checked at intervals for a year. Below is a summary of results for the dozen crosses that each produced over 40 germinations. For the 20 largest crosses there were over 4100 seeds, and almost 2000 of these germinated, 6/7 in the first six months. For each planting date the % total germ. in the interval to that date is indicated, thus Fb 7 may be inflated some by early germ.

Cross	Fb 7	Mr 8	Ap 1	My 1	My 23	Jn 26	Ag 13	Sp 19	Oc 18	Nv 21	Tot	Germ	%
C.B. x Gen Jaq #1 OP	6	29	11	11	16	14	-	-	7	-	383	145	38
C.B. x Gen Jaq # 3 OP	59	39	-	2	-	-	-	-	-	-	148	51	34
C.B. x Gen Jaq # 4 OP	49	26	10	-	-	4	-	-	-	-	70	47	67
C.B. x Gen Jaq # 5 OP	4	48	11	16	7	10	2	2	-	<1	500	259	54
C.B. x Jos Coat OP	33	67	-	-	-	-	-	-	-	-	129	49	38
Country Dancer OP	20	16	13	22	19	5	4	-	-	-	500	304	60
Sunsprite x C. S.	16	44	16	10	10	-	4	-	-	-	127	50	39
C.B. x Carefree Cu	26	27	-	14	14	17	3	-	-	<1	443	176	40
Winter Sunset OP	16	50	-	24	-	-	10	-	-	-	124	42	34
Silver Moon x C.S.	60	26	6	8	-	-	-	-	-	-	127	53	41
C.B. x Carefree Sun	65	35	-	-	-	-	<1	-	-	-	194	76	39
P.S. x Carefree Cu	14	17	6	17	15	17	10	1	1	<1	659	409	62

In the table C.B = Carefree Beauty, C.S. is Carefree Sunshine, Carefree Cu is (C.B. x Austrian Cu), P.S. is (C.B. x Rise N Shine). The four (C.B. x Gen Jaq) are selected hardy, disease-resistant, reddish, double non-remontant siblings.

Eight more CV, each with >40 seeds harvested, but only 16-38 germ., showed similar timing profiles. Most additional crosses, all with <40 seeds, had a large majority of germ. within the time from Feb.- May. For Knock Out (OP), only two seeds of 25 germ., both in July/August.

Two of four siblings of (C.B. x Gen Jaq OP) showed rapid germ. while the other two had a much more extended season. Two crosses with Carefree Cu, a half species non-remontant parent, gave a very extended germ. period. Three crosses with Carefree Sunshine had reasonably prompt germ. Other crosses (not shown here) with C.S. or C.B. as one parent also had prompt germ., almost done by May 1.

It is clear that germ. varies with the parent combination used, and that the male parent affects germ. time as noted many years ago by E.B. Risley (Am Rose Ann 1958) . For many crosses there would be little lost by only growing out seeds that germ. within six months. For a few though, more than a third of potential seedlings would be discarded. A paper recently discovered in the scientific literature (Grossi and Jay) further supports the impact of both parents in germ. properties. The work of von Abrams and Hand also supports this.