THE GERMINATION OF THE SEED AND THE VEGETATIVE PROPAGATION OF F1 HYBRID GERANIUMS (*PELARGONIUM* X *HORTORUM* BAILEY)

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ABSTRACT

Cairns, Elizabeth Jean. M. Sc., The University of Manitoba, February 1982. The Germination of the Seed and the Vegetative Propagation of F1 Hybrid Geraniums (Pelargonium x hortorum Bailey). Major Professor; L. M. Lenz.

The germination of F1 hybrid geranium (Pelargonium) seed was studied. Improving the germination was the object of the research. The germination percent and the germination rate as determined by germination resistance value were determined for 74 cultivars. There was a definite difference between cultivars in germination percent and rate. Similar high germination percents occurred in temperatures of 14.5°, 20.0° and 25.5°C and a day/night fluctuating temperature (29.4° to 17.2°C). Temperature for maximum germination rate was 20.0°C. Suitable germination media for both germination percent and rate were vermiculite, perlite, filter paper, sand and Zorb-all (turface). The highest germination rate occurred in a saturated medium, while there was no effect on germination percent. There were no consistent effects found in the germination percent or rate using thiram seed treatment or an increased oxygen concentration. While several cultivars showed occasional separation of the radicle and the cotyledons (hypocotyl fracturing) on imbibition of water, Ringo Scarlet appeared to be highly susceptible. In field trails, using seed produced plants, plants from cuttings of seed produced plants and clonal cultivars, the cuttings were superior to seed produced plants, in floriferousness and

growth parameters, which were superior to the clonal cultivars.

INTRODUCTION

Garden geraniums are members of the genus Pelargonium of the family Geraniaceae. Geraniums are used as bedding plants in the garden and for pot plants in the house (Mastalerz 1971). A potted geranium is an ideal gift on Mother's Day and on other occasions.

The F1 hybrid seed geranium was first introduced in the 1960's. Since that time more than 75 cultivars have been produced and offered for sale. Seed geraniums, according to a 1978 study by Voigt, were one of the top 5 flower bedding plants sold.

When geranium seed was originally introduced, a germination difficulty existed. This was found to be caused by a hard seed coat and the presence of oils (Volz 1951). Manipulation (scarification) of the seed coat, substantially increased the germination percent. However, even with scarified seed, the germination percent could be low.

F1 hybrid geranium seed is expensive even when bought in large numbers. A survey of 1980 seed catalogues showed a range in seed cost from 4.8 to 10.4¢ per seed, when purchased in 1,000 seed lots. Therefore, the germination of as many seed as possible is desirable.

A study of the germination of F1 hybrid geranium seed was undertaken after reports of erratic seed germination had been received. F1 hybrid geranium seed was the main subject material that was examined. Further to the above subject area, a field study was conducted comparing plants of seed grown cultivars, cuttings of seed grown cultivars and clonal cultivars.

LITERATURE REVIEW

In the past, most geraniums, in the bedding plant trade, have been vegetatively propagated. Most of the geraniums were clonal cultivars, as true-to-type seed cultivars were not available.

Geranium seed has been available for many years. The first true-to-type seed cultivar was Nittany Lion Red which was an inbred line (Adams 1977). The seed was released in 1964 by Penn State (Craig 1968). The Joseph Harris Seed Company, in 1966, released 'Moreton Hybrids' (Craig 1968) which were later renamed New Era (Craig 1971). In 1968, the Pan American Seed Company released Carefree F1 hybrid seed (Craig 1968). Since 1968, many new cultivars have been introduced. In 1980, the seed of the first 'double flowered' seed produced cultivar was available.

Seed

The geranium seed consists of an embryo composed of a radicle and usually 2 cotyledons. The radicle is long and lies on the back of the cotyledons next to the raphe. The tips of the cotyledons and radicle point to the base of the fruit (Lubbock 1892).

Germination

Seed germination is "the resumption of active growth by the embryo culminating in the development of a young plant from the seed." (Copeland 1976) In order for the seed to germinate, the seed must be ready to germinate and must be supplied with the appropriate environmental conditions. These conditions ".... are available water, proper temperature,

a supply of oxygen, and sometimes light." (Hartmann and Kester 1975)

Germination occurs in 4 stages:

> (1) hydration or imbibition, during which water penetrates into the embryo and hydrates proteins and other colloids, (2) the formation or activation of enzymes, leading to increased metabolic activity, (3) elongation of radicle cells followed by emergence of radicle (embryonic root) from the seed coat (which is germination proper), and (4) subsequent growth of the seedling. (Salisbury and Ross 1978)

Seed of the inbred line, Nittany Lion Red, is scarified to aid in germination (Anonymous 1965), as is the F1 hybrid seed (Kromer 1979, Barna 1979 and Capp 1979). Scarification is necessary as there is a dormancy due to a hard seed coat (Volz 1951). The embryos are thought to be non-dormant (Horn et al. 1973).

Dormancy

> .... Dormancy is the condition of the seed when it fails to germinate due to internal conditions, even though external conditions (e.g., temperature, moisture, and atmosphere) are suitable. (Salisbury and Ross 1978)

Dormancy can be classified into types, which are as follows:

1) A physical dormancy such as a hard seed coat can be present. A hard seed coat prevents the absorption of water (Salisbury and Ross 1978 and Mayer and Poljakoff-Mayber 1978). Several plants and families have hard seed coats: Myrtus communis L. (Khosh-Khui and Bassiri 1976), Geranium carolinianum L. (Baskin and Baskin 1974), the legume family (Copeland 1976) and the geranium family (Justice and Bass 1978).

A hard seed coat dormancy can be naturally overcome in several ways.

> In nature, the seed coat may be broken down or punctured by mechanical abrasion, microbial attack, passage through the digestive tract of animals or exposure to alternating high

> and low temperatures which, by expanding and contracting the seed coat cause it to crack. (Mayer and Poljakoff-Mayber 1978)

2) In addition to the hard seed coat, there can be waxy materials present in the seed coat preventing the absorption of oxygen or water (Salisbury and Ross 1978). Acid scarification overcomes this type of dormancy.

Chemical dormancies may be present in some seed. Two types of chemical dormancy follow:

1) The fruit surrounding the seed may contain chemical inhibitors to germination, and

2) Chemical inhibitors to germination may be present in the seed coats (Salisbury and Ross 1978).

After-ripening may be required. "After-ripening may be defined as any changes which occur in seeds during storage as a result of which germination is improved." (Mayer and Poljakoff-Mayber 1978) After-ripening can occur in dry storage. The period of time involved in dry after-ripening can vary: For barley (Hordeum L.) 2 weeks are required, for Cyperus L. 7 years are necessary. In some seed, chemical or physical changes must occur in the seed or the seed coat before the seed can germinate (Mayer and Poljakoff-Mayber 1978).

> The composition of the storage materials present in the seed may alter, the permeability of the seed may change, substances promoting germination may appear or inhibitory ones may disappear. In no case has it been possible to ascribe after-ripening to any one definite event. (Mayer and Poljakoff-Mayber 1978)

Scarification

Agriculture and horticulture usually can not wait for the natural

course; seed is scarified. Scarification is "the process of mechanically abrading a seed coat to make it more permeable to water." (Copeland 1976)

Scarification may be accomplished by:

1. shaking with an abrasive,
2. acid scarification,
3. treatment with alcohol (Mayer and Poljakoff-Mayber 1978),
4. treating with boiling water,
5. burning with an electric needle,
6. clipping the apex of the seed,
7. piercing the embryo with a sharp needle, and
8. exposure to fluctuating temperatures (Copeland 1976).

These treatments increase the water permeability as well as increase the gas permeability of the seed coat, can change the sensitivity of the seed to temperature and may even destroy or remove inhibitory substances (Mayer and Poljakoff-Mayber 1978).

It has been shown that the

> removal or damage to parts of the seed coats, or increasing oxygen tension of the surrounding air leads to increases in the rate of embryo respiration in many species of seeds, and frequently results in germination, and the inference often made is that increased oxygen leads to an increase in the availability of energy by oxidation processes. (Villiers 1972)

If Avena fatua L. seed is placed in high oxygen tension, germination is markedly enhanced (Johnson 1935).

The hard seed coat and the presence of oils tend to inhibit the imbibition of water necessary for germination in the geranium seed (Volz 1951). Therefore, for maximum germination the seed must be scarified.

Many scarification methods have been used with geranium seed to

overcome the hard seed coat. Cuocolo and Duranti (1977) found a 3 to 5 minute concentrated sulphuric acid scarification superior to abrasion or puncturing. The latter two produced embryo injuries. Sulphuric acid treatments over 5 minutes resulted in a reduced germination percent and increased the number of abnormal seedlings.

Fries (1977) stated that germination of 95-100% could be obtained by removal of a small portion of the seed coat. Dallon and Durkin (1979) removed the tip of the cotyledonary end of the seed and increased germination to 100% from a low of approximately 20%.

The research staff of Goldsmith Seeds found sulphuric acid, sand paper and mechanical pricking of the seed coat effective in overcoming the hard seed coats. They appear to prefer the use of sulphuric acid (Capp 1979). Ferry-Morse Seed Company used either sulphuric acid or hydrochloric acid for scarification (Kromer 1979), while seed from Harris Seeds may have been mechanically clipped (Barna 1979).

Tests on seed in 1959, although not on F1 hybrid seed, indicated clipping, filing, pinhole and sand paper treatment to increase the germination to 80% or better (Craig and Walker 1959). Heit, in 1971, reported concentrated sulphuric acid treatment of 5 to 8 minutes at room temperature on dehulled seed, not F1 hybrid seed, to be the most effective scarification method.

Scarification increases both the rate and percent of germination. Maximum germination of scarified seed occurs within 14 days (Craig 1968, Heit 1971 and Holden 1976). While, scarification has been used, Heit (1971) found unscarified, non F1 hybrid geranium seed, Geranium, Zonale Mixed, ".... to germinate slowly and fairly consistently over several

weeks, months or years without any special treatment." (Table 1)

There is a continuum from hard to soft seed coats in any lot of geranium seed so acid scarification can damage embryos and thus decrease germination (Horn et al. 1973). Germination of geranium seed is genetically controlled. The pollen parent has little effect on the germination of geranium seed. There is a maternal influence on the germination of the seed and increased germination can be selected (Horn et al. 1973). In 1968, Craig had a large number of inbred lines which gave 90 to 100% germination without scarification.

Environmental Factors

Temperature

Hartmann and Kester, 1975, describe temperature as "perhaps the single most important environmental factor that regulates germination ...." Kotowski (1926) stated temperature affected both the germination percent and the germination rate. According to Koller (1972) the rate of germination usually increases as the temperature rises. As the temperature rises the rate of water imbibition is more rapid and this higher uptake increases the germination rate (Gulliver and Heydecker 1973).

It was indicated by Gulliver and Heydecker (1973) that there is an optimum temperature for germination to occur and that as the temperature increases above this optimum the germination rate declines due to seed injury. The germination percentage could remain relatively constant in the middle part of the temperature range, if sufficient time were allowed for germination to take place (Hartmann and Kester 1975).

Table 1. Percent of seed germinated over time for Geranium, Zonale Mixed, seed (Heit 1971).

	Percent Germinated				
	Time Period				
Lot Number	1 week	1 month	6 months	1 year	2 years
1	6	26	41	45	52
2	8	32	46	54	58
3	12	42	58	65	69

Gulliver and Heydecker (1973) stated ".... that widely fluctuating temperatures are .... less beneficial than an equable regime" with peas. They also indicated "the rate of germination at alternating temperatures has often been found to be higher than at the constant mean temperature." Hartmann and Kester (1975) stated that "fluctuating day-night temperatures sometimes give better results than constant temperatures for .... seed germination ...."

Côme and Tissaoui (1973) stated that there was a relationship between temperature and the amount of oxygen available to the embryo of germinating seed. The higher the temperature used for germinating seed, the lower the quantity of oxygen available. At this time, the requirement for oxygen in the embryo is increasing, therefore, ".... germination is often inhibited through relatively high temperatures (for example 25^{o} and 30^{o}C) ...." (Côme and Tissaoui 1973). Côme and Tissaoui (1973) continued

> from a practical point of view, one should frequently lower the temperature at which the seeds are placed to germinate. Germination may be slower under these cooler conditions but it will take place, and often more uniformly.

After germination, if there is a requirement for a higher temperature, the seedling may be placed in an environment with an increased temperature.

A high constant temperature is most frequently recommended for F1 hybrid geranium seed germination. Some recommended temperatures have been:

20 - 30^{o}C (Heit 1971),

23.9^{o}C constant (Adams 1977),

22 - 24^{o}C (Anonymous 1980a),

21 - 24°C (Anonymous 1975),

21.1°C constant (Carlson 1976),

18.3 - 21.1°C (Capp 1979) and

12.8 - 18.3°C (Craig 1967).

Experiments using constant temperatures of 5, 10, 15, 20, 25 and 30°C have been conducted. The conclusion was: the optimum temperature for geranium seed germination was 20 - 25°C. Temperatures over 25°C tended to depress the germination percent. With increasing temperatures to 25°C, there was an increase in the germination percent (Horn et al. 1973).

Bass (1979) indicated a Dutch seed firm has had some success using an alternating day/night temperature of 33°C during the day and 12°C at night.

Moisture

Seed responds in a similar pattern to increases in moisture content in the medium as to increases in temperature. There is an optimum medium moisture content for maximum germination percent. Germination percents are lower on each side of this optimum. There is also an optimum for germination rate. A water supply, which is over the optimum required, stresses the seed eliminating some of the seed; germination is higher for the survivors. Stress ".... may not only result from too rapid water uptake, but also from reduced oxygen availability ...." (Gulliver and Heydecker 1973).

The amount of water different species require for germination varies. "Celery requires that soil moisture be near field capacity, whereas tomato will germinate with soil moisture just above the permanent wilting

point." (Janick 1972)

Little data exist on geraniun seed germination. Randolph (1971) stated that geranium seed is totally imbibed " .... in as little as eight hours. Once the seed have swollen it is extremely critical that they do not dry out." Reference is made to preventing moisture loss from the seed flats by covering the flats with plastic (Anonymous 1980a). The use of overhead misters has been recommended by Adams (1977) and Randolph (1971).

Moisture and Physical Injury. Rapid uptake of water by localized embryo tissues can lead to fractures in those tissues (Moore 1973). Transverse cracking of the cotyledons in bean cultivars has been demonstrated to occur by planting dry bean seed in wet soils (Dickson et al. 1973). Increased transverse cracking was associated with increased seed coat permeability. There were susceptible cultivars (McCollum 1953).

Media

The medium in which seed germinates can affect the germination of the seed (Currie 1973). Several media have been used for the germination of geranium seed. A fine textured, well drained, pathogen free medium such as Jiffy-Mix was preferred by Randolph (1971) but a 1:1:1 mix of soil, peat moss and perlite could be used. Redi-Earth was found by Dallon and Durkin (1971) to be superior to peat moss or petri dishes and filter paper, which were superior to a sand-peat moss mixture, which was superior to Terralite. A sterilized medium was recommended by Stokes (Anonymous 1980a), Holden (1976) and Adams (1977).

The pH of the media, used to germinate seed on, can be important. Justice and Reece, 1954, stated "germination can proceed over a wide

range of hydrogen-ion concentrations. The germination of almost all species occurs readily between pH values of 4.0 and 7.6." (Copeland 1976)

Seed Treatments - Fungicides

Seed companies are now selling seed which has been pretreated with fungicides to fight pathogens carried on the outside of the seeds (Maude and Keyworth 1967). Thiram and Captan have been used. One method of applying thiram to seed was a thiram soak "combined with a sufficiently high temperature (30^{o}) for a sufficiently long time (24h, or in some instances 12 h)." (Maude 1973) The seed after treatment was dried in a rapid air stream at 25^{o}C.

Longden (1973) stated the ".... pretreatment of seeds by wetting and drying .... uniformly improves the rate of seedling emergence." Using a thiram soak, germination depression should not occur, but some Brassica L. seed lots have shown a decrease in germination as a result of using a thiram soak and this effect was not consistent (Maude 1973).

The application of thiram to geranium seed appeared to enhance the germination of the seed (Capp 1979). Thiram is being applied to geranium seed by several seed companies, two of which are: Sluis & Groot B. V. and Goldsmith Seeds, Inc.

Seed Storage

For man to use a seed produced plant for any purpose, the seed must be stored from one growing season to the next.

In considering the germination of seed, vigor and viability are important. Vigor is "the vitality or strength of germination, especially under

unfavorable conditions." (Copeland 1976) "Seed viability indicates that a seed contains structures and substances including enzyme systems which give it the capacity to germinate under favorable conditions in the absence of dormancy." (Copeland 1976) Seed viability can be simply defined as alive (Copeland 1976).

Vigor will decrease prior to the loss of germination percent (Figure 1). The first signs of loss of vigor in the

> aging of a seed are slower growth, inability to germinate at the extremes of its environmental range, and greater susceptiblity to attacks by microorganisms at its environmental extremes. (Harrington 1972)

Abnormalities are next to appear (Harrington 1972).

During storage seed will deteriorate. This is inevitable. It is possible to slow this process with adequate storage conditions. Harrington (1959) gave 2 guides for the storing of seed in relation ".... to the effects of seed moisture and ambient temperature on the rates of seed aging."

> 1. For each 1% increase in seed moisture the life of the seed is halved. This rule applies when seed moisture content is between 5 and 14% ....
> 2. For each 5^{o}C increase in seed temperature the life of the seed is halved.

Many factors can affect the storage life of seed:

1. moisture content of the seed in storage,
2. temperature of storage,
3. preharvest conditions - weather and nutrition,
4. mechanical injury prior to storage,
5. seed size,
6. seed maturity at harvest,
7. whether seed is stored scarified or unscarified and

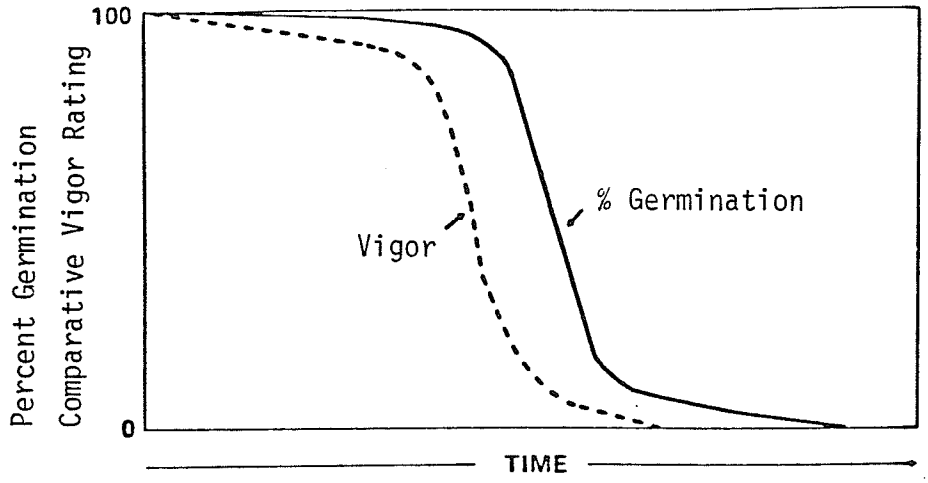


Figure 1. The decline in vigor and germination of a seed lot with time. The absolute value for time is primarily a function of plant species, temperature of storage, and seed moisture. (Harrington 1972)

8. genetic storage potential of the seed (Justice and Bass 1978).

The life-span of seed can vary from species to species. Acer saccharinum L. seed live a few days under natural conditions (Jones 1920), whereas willow, poplar and elm seed lose viability in a few months (Copeland 1976). However, certain weed species have maintained viability for 40 years in trials started by Beal (Darlington 1951).

Little has been written about geranium seed storage. Bass (1979) indicated that germination of scarified geranium seed begins to decline after 6 months. Craig (1967) stated "the seed is ready for germination after the husk is removed and may be planted immediately or stored up to a year without decreasing its germination ability." Clifford (1970) said of unscarified Pelargonium seed: "Seed of most of the genus remain viable for seven years and goes off rapidly after that; most zonal seed lasts no longer than three years."

Germination Rhythms

Rhythms are found in many plant activities. A seed germination rhythm has been observed in many species. Early studies were conducted using weed seed in the hope that a discovery of the germination periods could be used to control those species (Chepil 1946).

Chepil, in 1946, reported a periodic response in germination which was common to the majority of the 58 species used and ".... was about the same on clay, loam, and sandy soil and was not entirely dependent on the variation in moisture content of the soil." For most of the species the periods of peak germination were apparently predetermined at the start, so that weather variation had little if any effect on the behavior of the seed. One conclusion Chepil drew was:

> the emergence data .... indicate that periodicity of germination throughout the year after ripening follows the same general trend as that for seeds that have lain in cultivated soil for one or more years.
>
> Germination of certain seeds appears to be best at certain times during the year, even though the seeds have been stored under conditions of constant temperature, light, and moisture. (Salisbury and Ross 1978)

Vegetative Propagation

Many ornamental plants are vegetatively or asexually propagated by the regeneration of plant tissues or plant parts. With vegetative propagation,

> .... heterozygous material may be perpetuated without alteration. In addition, vegetative propagation may be easier and faster than seed propagation, as seed dormancy problems may be completely eliminated and the juvenile stage reduced. (Janick 1972)

According to Mastalerz (1967) "from a rooted cutting, it should not take more than 6 to 8 weeks to produce a 4-inch geranium" with at least one flower cluster. However, F1 hybrid seed produced plants take 2 or 3 times longer or 16 to 18 weeks to flower (Adams 1977).

MATERIALS AND METHODS

To determine the optimum germination conditions for geranium hybrid seed, several trials were conducted using the following germinators at the temperatures indicated:

A. General Electric, Precision Scientific, Model 805, Incubator (20°C),
B. germination chamber, Controlled Environments Ltd., Model I 24 (14.5°C),
C. growth chamber, Controlled Environments Ltd., Model EF7H (25.5° and 20°C),
D. germination chamber remodelled from a commercial hatchery unit (20°C) and
E. open area under lights to obtain a widely fluctuating temperature (17.2 to 29.4°C).

Germinators A, B, C and D varied by $\pm$ 1°C. Each experiment was carried out in one chamber except where indicated.

Most of the seed in the experiments was received scarified or was hand clipped with toe nail clippers prior to use. In one experiment the seed was used unscarified.

Although the seed upon receipt was handled in a similar manner, stored at 5°C and 50% relative humidity, no indication as to age or previous handling could be ascertained for any of the seed, except that most of the seed had been scarified and some seed had been treated with thiram.

In order to obtain one figure for each sample of seed for as many as

11 days of counting, a germination resistance value, a measurement of the relative rate of germination, was determined. The germination resistance test gives the time in hours to 50% germination, i. e. if 88% of the seed germinate, the germination resistance value indicates the number of hours required for 44% of the seed to germinate (Gordon 1971) (Figure 2).

Cultivar Germination Trials - Spring and Fall

In the spring of 1980, seed of 67 geranium cultivars was received. This seed was used in germination tests to determine cultivar germination resistance values and percents, and to determine if there were any difference between spring and fall germination of the 29 cultivars which were common to both the spring and fall germination trials.

The seed was placed in 10 cm pyrex petri dishes on 4 sheets of No. 1 Whatman filter paper, to which 6 ml of distilled, deionized water were added. The seed was distributed on the filter paper to avoid any possible interference between one seed and another. The number of seed per cultivar sample and the number of samples varied; these data are presented in Table 2. The petri dishes were placed in plastic bags to retain moisture and then wrapped in aluminum foil to exclude light. The seed was germinated at 20^{o}C, in germinator A.

One preliminary study indicated the majority of the seed germinated in 12 days and also that no seed germinated on day 1 or day 2 (Appendix Table 1). However, in other early trials some seed did germinate on day 2 (Appendix Table 2) and therefore the germinated seed was counted daily from day 2 to day 12. Germination was considered to have occurred if the radicle were protruding approximately 5 mm. Furthermore, any

$$GR = \frac{\frac{t_1}{2}(n_1) + \frac{t_2 + t_1}{2}(n_2 - n_1) + \ldots \frac{t_i + t_{i-1}}{2}(n_i - n_{i-1}) \text{ hours}}{n_i}$$

t_1, t_2, t_i, etc. = first, second and ith hours of the test.

n_1, n_2, n_i, etc. = total number of seeds germinating by the above times.

Figure 2. Germination resistance equation (Gordon 1971).

Table 2. Cultivars, sample numbers and seed numbers used in the spring germination trials.

The following cultivars had 4 samples of 20 seed each:

Bright Eyes	Encounter Red	Red Apple - F2
Capri Brick Red	Encounter Salmon	Red Delicious - F2
Capri Deep Red	Fire Flash	Red Express
Capri White	Florence	Red Standard
Carefree Light Salmon	Friendship	Salmon Express
Carefree Scarlet	Geranium Mixed	Salmon Flash
Cherry Glow	Gremlin Coral	Scarlet Flash
Colorama - F2	Innocence	Smash Hit Red
Debutante	Knockout	Sooner Red
Deep Rose Flash	Love Song	Sooner Salmon
Dynamite	Orange Punch	Sprinter White
Empress Red	Paintbox Mixed	Surefire
Empress Salmon		

The following cultivars had 2 samples of 20 seed each:

Cherie	Mustang	Showgirl
Festival Salmon	Ringo Rose	Snow White
Festival Scarlet	Ringo Rouge	Snowdon
Festival White	Ringo Salmon	Sprinter Deep Red
Heidi	Ringo Scarlet	Sprinter Salmon
Ice Queen	Rosita	Tiffany
Jackpot	Rosita '80	Vulcan

Three cultivars had 6 samples of 20 seed each:

Bambi - F2	Sprinter Scarlet	Marathon

One cultivar had 5 samples of 20 seed each:

Fleuriste Mixture - F2

Five cultivars had varying sample and seed numbers:

Cultivar	Number of Samples	Number of Seed
Del Greco Mixed	1	20
Dwarf Sprinter Red	1	29
Firecracker	1	10
Miniskirt Mixed	1	12
Red Champion	2	29

seed with abnormal development was recorded. Abnormal development was considered to be:

1. embryos which expanded but failed to develop any further;
2. embryos showing physical damage such as broken cotyledons, broken radicle and
3. deteriorated seed; seed which did not germinate; etc.

Similarly, a germination trial of 36 cultivars was conducted in the fall of 1979. This trial was used as preliminary testing to determine the germination percent and the germination resistance value, and also if there were any difference between the spring and the fall germination of the 29 cultivars which were common to both the spring and fall germination trials.

In the fall trial, 8 ml of distilled, deionized water were added to the petri dishes which were placed in germinator C. There was no significant difference in the germination percents or germination resistance values between 6 and 8 ml of water for the cultivars, Rosita and Ringo Scarlet (Table 3). The other cultivars were not tested. The data on the number of samples per cultivars are presented in Table 4.

Transplanting

To determine the transplantability of cultivars and also to determine if there were any difference between cultivars, the sprouted seed from the spring germination trials was transplanted. The medium used was 2:1:1, soil, sand and peat moss. Transplant survival was recorded for the spring tested cultivars only.

Table 3. Mean germination percent and mean germination resistance value in hours for Rosita and Ringo Scarlet seed, germinated on filter paper, using 6 and 8 ml of water at a temperature of 14.5°C.[z]

Amount of Water	Mean Germination Percent		Mean Germination Resistance Value (hours)	
	Ringo Scarlet[y]	Rosita[y]	Ringo Scarlet	Rosita
6 ml	100.00[x]	98.33[x]	56.11[x]	47.66[x]
8 ml	100.00	98.33	53.28	44.11

[z] trial with Rosita seed and trial with Ringo Scarlet seed were conducted on different dates.

[y] values are a mean of 3 samples of 20 seed.

[x] values within columns do not differ significantly as determined by analyses of variance.

Table 4. Cultivars, sample numbers and seed numbers used in the fall germination trials.

The following cultivars had 4 samples of 21 or more seed:

Carefree Scarlet	Nittany Lion Red
Colorama - F2	Red Champion
Encounter Red	Red Express
Encounter Salmon	Ringo Scarlet
Firecracker	Rose Pink with White Eye
Fleuriste Mixture - F2	Rosita
Friendship	Scarlet Flash
Heidi	Showgirl
Innocence	Sooner Red
Love Song	Sooner Salmon
New Era Bright Red	Sprinter Scarlet
New Era Medium Salmon	Sprinter White
New Era Red	

The following cultivars had varying sample and seed numbers:

Cultivar	Number of Samples	Number of Seed
Cherie Improved	1	12
Cherie - Light Salmon Sprinter	1	21
Ice Queen	1	14
Knockout	1	18
Orange Punch	1	21
Rosita '80	1	9
Snowdon	1	21
Sprinter Mixed	1	4
Mustang	2	32
Ringo Rose	2	33
Ringo Salmon	3	60

Environmental Factors

Temperature

As temperature can affect seed germination, experiments were conducted to determine the optimum germination temperature regime for F1 hybrid geranium seed.

Ten cultivars were tested at 3 constant temperatures, 14.5°, 20° and 25.5°C and a day/night fluctuating (29.4° to 17.2°C) temperature. The 10 cultivars were:

1. Ringo Scarlet - untreated,
2. Rosita - untreated,
3. Snowdon - untreated,
4. Sprinter Scarlet - untreated,
5. Bright Eyes - untreated and treated with thiram,
6. Cherry Glow - untreated and treated with thiram,
7. Geranium Mixed - untreated, an open pollinated line,
8. Sprinter Deep Red - untreated and treated with thiram,
9. Sprinter Salmon - untreated and treated with thiram, and
10. Tiffany - received and stored scarified and unscarified, both clipped just prior to set up.

Three samples of 20 treated seed and 3 samples of 20 untreated seed of the cultivars, Bright Eyes, Cherry Glow, Sprinter Deep Red and Sprinter Salmon were used, except in five instances in 25.5°C where 2 samples of 20 seed each were used of Bright Eyes, treated, Sprinter Deep Red and Sprinter Salmon, both treated and untreated. Three samples of 20 seed stored scarified and 3 samples of 20 seed stored unscarified of the cultivar, Tiffany, were used. Four samples of 20 seed each of the cultivars, Geranium Mixed, Ringo Scarlet, Snowdon and Sprinter Scarlet were used. The total number of seed available was the determining factor in

the number of samples used.

The samples were set up as indicated for the spring cultivar trials, two of which 14.5° and 20°C were conducted simultaneously. The seed in 25.5°C and the day/night fluctuating temperatures were germinated at later dates, with 1 sample of 20 seed of each cultivar in a 20°C temperature, used as controls. The control for the 2 trials, 14.5° and 20°C, was a mean of the total number of samples per cultivar in the 20°C temperature trials. This mean was used for statistical purposes as the control.

Eight ml of water were used to prevent excessive moisture loss that might occur at higher temperatures due to evaporation. It was assumed that a greater moisture loss might occur despite the fact the petri dishes were enclosed; this actually did occur. Germinators A, B, C and E were used.

The germinated seed and the seed with abnormal development were counted daily from day 2 to day 12 inclusive, except for the first 2 temperatures (14.5° and 20°C) which were counted days 2 to 5, 10 and 12, due to illness.

Media

Experiments using filter paper (control), perlite, vermiculite, peat moss, Zorb-all (turface) and sand, all horticultural grades, were conducted to determine if the type of media on which geranium seed was germinated affected the percent and rate of germination.

The sources of the media were:

1. perlite and vermiculite - W. R. Grace & Co., of Canada Ltd.,
2. sphagnum peat moss, Sunshine brand - Western Peat Moss Ltd. and

3. Zorb-all, a product made from montmorillonite clay - IMC Chemical Group, Inc.

The sand was washed torpedo sand which was rewashed using running water until the water ran clear.

The media were mixed with water, allowed to stand overnight in a closed container for the purpose of allowing the water to distribute evenly through the media. The media, which were saturated, were then placed in petri dishes, firmed and made level. The seed was distributed on the media. The dishes were placed in plastic bags, wrapped in aluminum foil and placed at 20°C in germinator A.

Twenty seed per sample were sown. The data on the number of samples are presented in Table 5. The cultivars used in trial I were:

1. Cherie - untreated and treated with thiram,
2. Knockout - untreated and treated with thiram,
3. Paintbox Mixed - untreated,
4. Salmon Express - untreated,
5. Snowdon - untreated and
6. Sprinter Scarlet - untreated.

One control sample on filter paper in a petri dish was used for each cultivar. Counts were made daily from day 2 to day 12.

Trial II was conducted in the same manner using the following cultivars:

1. Knockout - untreated,
2. Ringo Scarlet - untreated,
3. Rosita - untreated,
4. Snowdon - untreated,

Table 5. Cultivars and sample numbers used in media trial I and II.

	Sample Number					
Media	Filter Paper	Vermic-ulite	Peat moss	Zorb-all	Perlite	Sand
Cultivars						
Trial I						
Cherie						
Untreated	1	1	1	1	1	1
Treated	1	1	1	1	1	1
Knockout						
Untreated	1	1	1	1	1	1
Treated	1	1	1	1	1	1
Paintbox Mixed	1	1	1	1	1	1
Salmon Express	1	1	1	1	1	1
Snowdon	1	1	1	1	1	1
Sprinter Scarlet	1	1	1	1	1	1
Trial II						
Knockout	1	1	1	0	1	1
Ringo Scarlet	1	2	2	1	2	1
Rosita	1	2	2	2	2	2
Snowdon	1	2	2	2	2	2
Sprinter Scarlet						
Untreated	1	2	2	2	2	2
Treated	1	2	2	2	2	2
Sprinter White						
Untreated	1	2	2	2	2	2
Treated	1	2	2	2	2	2

5. Sprinter Scarlet - untreated and treated with thiram and
6. Sprinter White - untreated and treated with thiram.

The data on the number of samples are presented in Table 5. The total number of seed available was the determining factor in the cultivars and number of samples used in both of these trials.

Moisture Content of Media

As water is required in order for germination to occur, trials were conducted to determine if differing amounts of water affected the germination of geranium seed.

In trial I, seed of 3 cultivars was tested using sand and 2 water volumes. The cultivars were:

1. Rosita - untreated,
2. Ringo Scarlet - untreated and
3. Sprinter White - untreated and treated with thiram.

A second trial using seed of 2 cultivars, Rosita and Ringo Scarlet, both untreated, and the same water volumes were used to germinate seed.

The sand was sifted through a 1.18 mm screen, washed with running tap water until the water ran clear, and then oven dried overnight at 100°C. Sixty-five g of sand (Table 6) were placed in a petri dish and 13 (saturated medium) or 10 (less than saturation) ml of water were added, mixed, covered, and allowed to stand overnight to allow the water to distribute evenly through the sand. No further water was added during the trials. The dishes were placed in plastic bags, wrapped in aluminum foil and placed in 20°C in germinator A.

A control sample for each cultivar using filter paper in petri dishes was also set at the same time. Each sample contained 20 seed,

Table 6. Percent moisture content of sand.

Weight of Sand	Weight of Water [z]	Percent Moisture in Sand
65 g	13 g	20.00
65 g	10 g	15.38

[z] 1 ml = 1 g

and 2 samples per cultivar for trial I, and 3 samples per cultivar for trial II at each moisture content, were used. Counts were made daily from day 2 to day 12.

Oxygen Concentration

In the storage experiment it was observed after 7 months that the stored scarified seed appeared to be germinating at lower germination resistance values than seed stored unscarified.

Two experiments were conducted to determine whether an increased oxygen concentration would affect the germination percent and rate. Using the cultivar, Tiffany, one sample of 20 scarified clipped seed, another sample of 20 unscarified clipped seed and a third sample of 20 seed unscarified, were placed in separate 125 ml flasks after 5 sheets of No. 1 Whatman filter paper (5.5 cm) and 3 ml of distilled, deionized water had been placed in the flasks. The flasks were then set as in Figure 3.

Flushing with oxygen was carried out for 3 minutes, which was approximately one minute longer than required to exchange the air, which was present, for oxygen. The tubing was clamped, cut and the flasks placed at 20^{o}C in germinator D. Three samples of 20 seed identical to those used with oxygen were placed in petri dishes and used as controls. Counts were made daily on days 2 to day 12.

In the second experiment, Rosita seed, scarified and unscarified, was placed in flasks as indicated. Two samples of each treatment for oxygen treatments were prepared and the 4 flasks were arranged as in Figure 3. Each sample contained 20 seed. Two samples of 20 seed identical to those used with oxygen were placed in petri dishes and used as

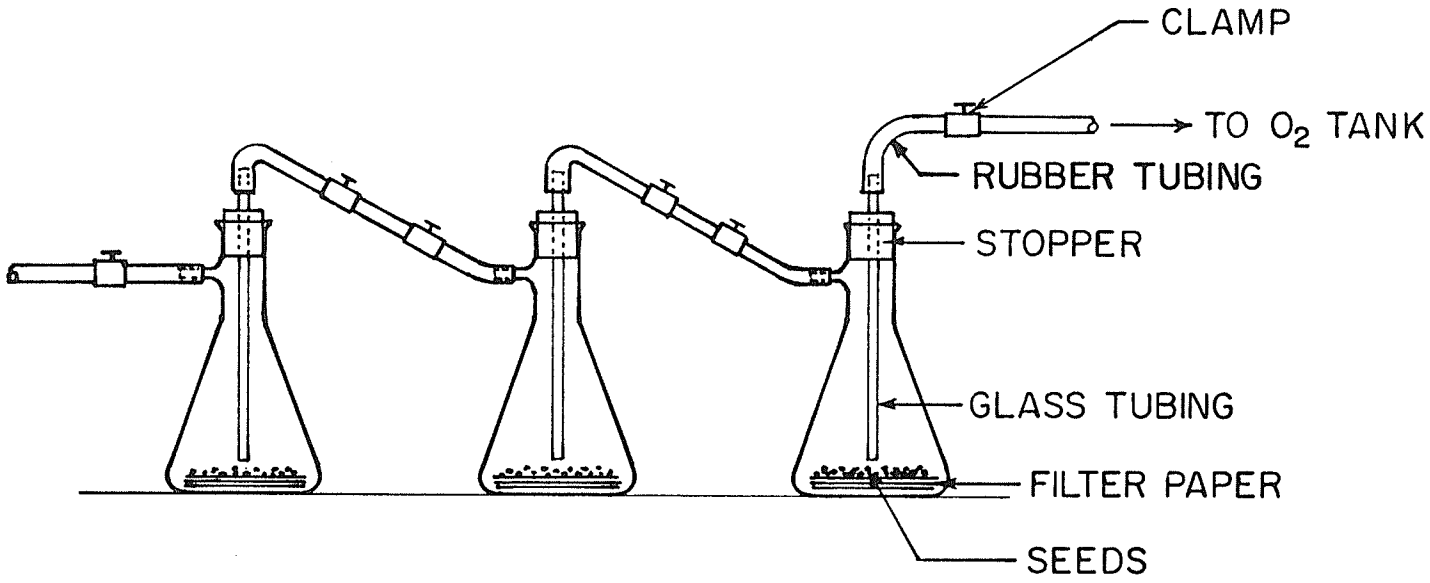


Figure 3. Diagram of apparatus used for oxygen concentration study.

controls.

Scarification Versus Unscarification

One question that required answering was: Does scarification facilitate the germination of F1 hybrid geranium seed?

Seed of 2 cultivars, Ringo Scarlet and Rosita, was placed in petri dishes. Three samples of 20 seed each of clipped, using toe nail clippers, and 3 samples of 20 seed each of unscarified (unclipped) seed were used. The seed was set up, placed in germinator A and counted as in the spring cultivar trials.

Thiram Treated Versus Untreated Seed

A report had been received that treatment with fungicide of geranium seed affected the germination of the seed. Preliminary research indicated there was an enhancement of the germination rate and percent upon treatment of the seed with thiram. Experiments were conducted to confirm these findings as research on effects of thiram treatments on geranium seed had been limited.

The seed of some of the cultivars was received treated and untreated with thiram. Seed of 5 cultivars, treated and untreated, was set and counted as indicated in the spring trials. The cultivars were:

1. Cherie,
2. Knockout,
3. Showgirl,
4. Sprinter Scarlet and
5. Sprinter White.

Three samples of 20 seed each were used for both the treated and un-

treated seed, of each cultivar.

Storage Experiment

As seed is stored from one growing season to the next growing season, a storage experiment was designed to study the effects of storage time on the viability and vigor of F1 hybrid geranium seed.

The 2 cultivars used were Rosita and Ringo Scarlet and these were received and stored both scarified and unscarified. All the seed was placed in bulk storage in brown kraft paper envelopes at a temperature of approximately 5°C and a relative humidity of approximately 50%. Some seed was removed and tested every 2 weeks or more as indicated hereafter. Before the start of storage 6 samples (3 scarified and 3 unscarified, both clipped) of each cultivar were germinated to be used as controls.

Two week storage intervals were used from December to mid-July. The seed was then left in storage, undisturbed until October when 1 trial was conducted. In November, 2 germination trials were conducted at 2 week intervals. Then in January and February, 4 trials were conducted at 2 week intervals.

The unscarified seed was received and stored with husks on. However, just prior to the start of each germination test, one-half of the seed was hand clipped, with toe nail clippers, while the other half was dehusked by hand and clipped (Figure 6).

The seed was then placed in 10 cm petri dishes on 4 sheets of No. 1 Whatman filter paper and 6 ml of distilled, deionized water. The dishes were placed in plastic bags and then wrapped in aluminum foil. The seed was germinated at 20°C in germinators A and D. The number of germinated seed and those with abnormal development were counted daily from day 2 to

day 12.

Three samples of 20 seed each of stored unscarified and clipped and 3 samples of 20 seed each of stored scarified and clipped seed were used for each of the 2 cultivars.

Field Trials

A concern arose during the germination trials; was there a difference between plants grown from seed or plants propagated by cuttings from seed produced plants of the same cultivar and between seed cultivars and commercially available clonal cultivars? An experiment was designed to test whether there was a difference.

Seed Plants

Seed of Rosita and Sprinter Scarlet was set to germinate on March 3, 1980 as in the spring cultivar trials. The germinated seed was transplanted to 48 cell flats (4 x 6 x 6 cm cells) on March 5, 6 and 7. The medium was 2:1:1, soil, sand and peat moss.

Cuttings of Seed Produced Plants

Rosita and Sprinter Scarlet plants were produced from seed in the spring of 1979. These plants were then maintained in the greenhouse for the fall and winter of 1979. As these plants matured, they were allowed to bloom once, to confirm the cultivar. After this, all flower buds were removed as they formed so that the plants could produce vegetative growth.

In the middle of March, 1980, 8 to 10 cm cuttings were taken from these stock plants. These were allowed to dry for an hour so that sealing of the wound might start. The leaves were removed from the bottom

4 to 5 cm of the cutting. The cuttings were then placed in perlite, without the use of hormones, 7 to 10 cuttings to a 6 inch (15.24 cm) pot. The perlite was wetted and kept damp for the rooting period. Flower clusters were removed as they developed. The cuttings were maintained in the greenhouse at an approximate temperature of 21°C. The percent of cuttings that rooted for Rosita and Sprinter Scarlet was recorded.

Since the stock plants that were used for the cuttings were derived from seed produced plants, the cuttings would not be in fact a clone population. Henceforth in this thesis the term cutting will be used to refer to the plants propagated by cuttings, from seed produced plants.

Clonal Cultivars

Rooted cuttings of cultivars Cherry Blossom and Cardinal were purchased from Jack Van Klaveren, Ltd., St. Catharines, Ontario, for mid-April, 1980 planting.

Plants of all 3 propagation methods, seed plants, cuttings and clonal cultivars were planted in 4 inch (10.16 cm) pots in a mixture of 2:1:1, soil, sand and peat moss at the same time. These plants were maintained in the greenhouse at 21°C and then in cold frames until the plants could be planted in the field in early June, all plants being of approximately the same size. A block planting plan was used, using 4 replicates per cultivar and per treatment. Border rows were used (Figure 4).

Each row contained 21 plants, the first and last plant of which in each row were considered to be border plants and were not used to provide any data. The rows were 2.5 feet (76 cm) apart and each plant with-

Border Row - Rosita - cutting			Border Row - Rosita - cutting
1. Rosita - seed			13. Cherry Blossom - clonal
2. Rosita - cutting			14. Rosita - seed
3. Sprinter Scarlet - seed			15. Rosita - cutting
4. Sprinter Scarlet - cutting			16. Cardinal - clonal
5. Cherry Blossom - clonal		P	17. Sprinter Scarlet - seed
6. Cardinal - clonal		A	18. Sprinter Scarlet - cutting
7. Sprinter Scarlet - seed		T	19. Cardinal - clonal
8. Sprinter Scarlet - cutting		H	20. Sprinter Scarlet - seed
9. Cherry Blossom - clonal			21. Sprinter Scarlet - cutting
10. Cardinal - clonal			22. Rosita - seed
11. Rosita - seed			23. Rosita - cutting
12. Rosita - cutting			24. Cherry Blossom - clonal
Border Row - Rosita - cutting			Border Row - Rosita - cutting

Figure 4. Planting-plot-design for field trials.

in a row was 1 foot (30 cm) apart. The spacing between the rows was used to avoid between row competition.

All flower clusters were removed from the plants after being placed in the field, in order that plant energies would be directed to the establishment of the plant in the new environment. The plants were maintained in the field using irrigation, as required, and were maintained weed free by hand weeding.

In order to test the difference between and within cultivars and propagation methods several quantitative observations were made:

1. The number of flower clusters per row was counted on 2 occasions. Each flower cluster having 2 or more open flowers was counted on August 23 and again approximately a month later, September 20.
2. The number of flowers per flower cluster was to be counted on 10 randomly selected flower clusters within each row.
3. The height and diameter of 4 plants, randomly selected within each row, were measured using a meter stick. The diameter used was that across the row, not within the row.
4. The number of leaves, on 3 plants randomly selected within each row, was counted. A leaf was counted if it were unfolded. A number of readings was taken from each of these plants: leaf number (4), branch number (5), the number of branches with flower clusters (6) and dry weight (7).
5. The number of branches on 3 plants - the same plants as in number 4 - was counted. A branch was counted if it were 2.5 cm or longer.
6. The number of branches with flower clusters on them on 3 plants per row - the same plants as in number 4 - was counted. A branch was counted if a flower cluster were present, whether past flowering, currently

flowering or immature.

7. The dry weight of 3 plants per row was to be taken. The leaves and stalks of each plant were washed in water and placed in a preweighed cloth bag, weighed again and hung in a warm unplanted greenhouse to dry until the stalks were dry. The bags were to be reweighed.

A qualitative observation was made on plant habit in reference to the appearance and whether faded flower clusters were retained or hidden by the foliage.

RESULTS AND DISCUSSION

Morphology of the Geranium Seed

The anatomical appearance of the seed was determined by dissection (Figure 5) and the morphological appearance was recorded (Figure 6).

Cultivar Germination Trials - Spring and Fall

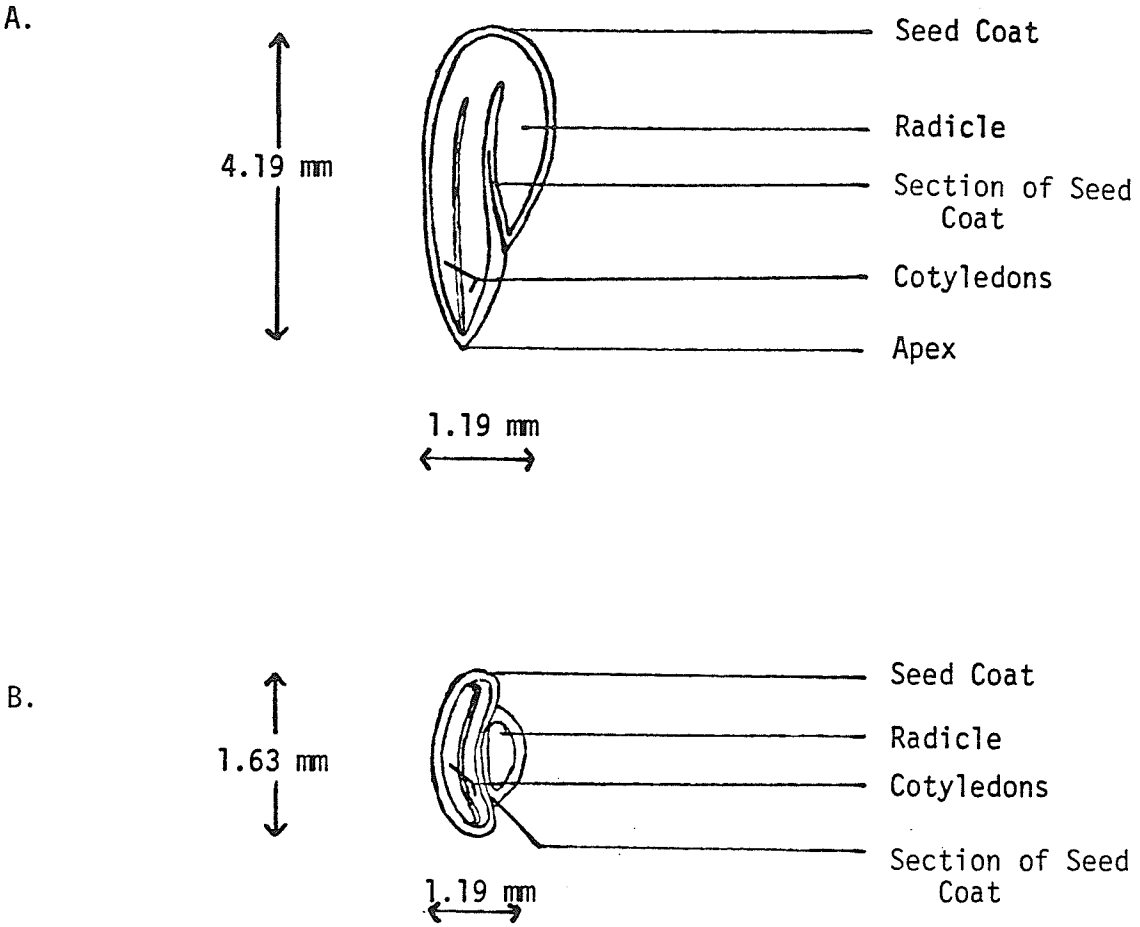
Germination Percent - 29 Cultivars

Twenty-nine cultivars were common to both the spring and the fall germination trials. The fall range for germination percent was 67.30 to 100% (Table 7); the spring range was similar to the fall, 61.25 to 100% (Table 8).

Of the spring germinated cultivars, 20 cultivars (68.97%) germinated at 90% or better (Table 9), 7 cultivars (24.14%) germinated at 80 to 89.9% and 2 cultivars (6.89%) germinated at less than 80%. In the fall, 20 cultivars (68.97%) germinated at 90% or better (Table 9), 6 cultivars (20.69%) germinated at 80 to 89.9% and 3 cultivars (10.34%) germinated at less than 80%.

The figures for the spring and fall germination trials were similar. Of the 20 cultivars that germinated at 90% or more in the fall, 17 or 85% germinated at 90% or more in the spring germination trials. Six of the 9 cultivars that germinated at 90% or less in the fall did so in the spring.

An analysis of the fall germination indicated there was a highly



Measurement Ranges:

Length 4.01 - 4.39 mm
Cotyledon - radicle
diameter 1.02 - 1.40 mm
Cotyledon width
1.52 - 1.83 mm

Figure 5. Diagram of a geranium seed; A. radicle and cotyledons in longitudinal section, B. radicle and cotyledons in cross section. Physical measurements are of Sprinter Scarlet scarified seed.

Figure 6. Geranium seed.
1. Rosita seed hand clipped and soaked overnight.
2. Geranium seed with husks intact.
3. Rosita seed with husks removed.

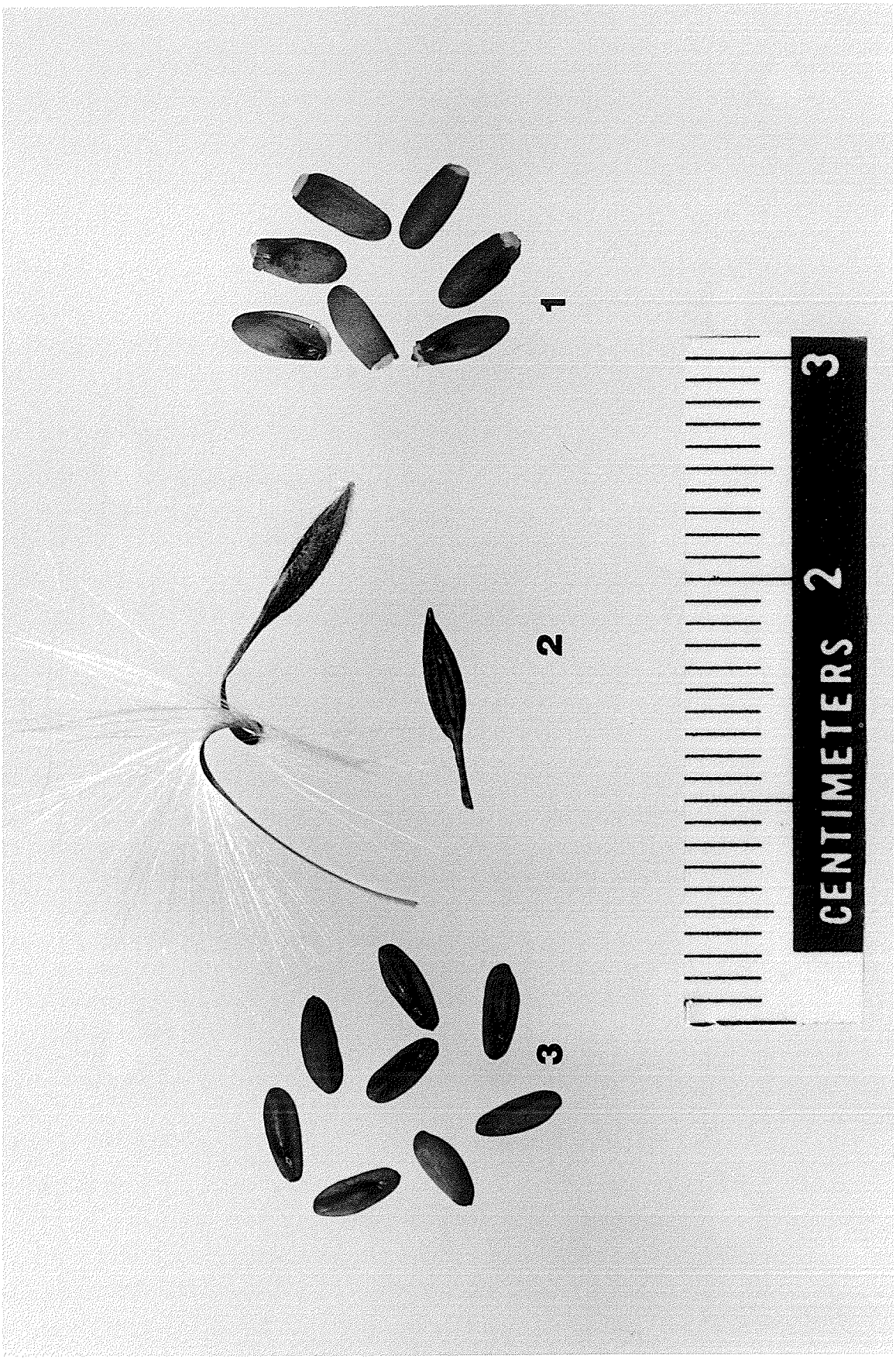

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Table 7. Fall germination of 29 selected cultivars, ranked as to mean germination percent.

Cultivar	Mean Germination Percent	
Ice Queen	100.00	a[z]
Orange Punch	100.00	a
Rosita '80	100.00	a
Snowdon	100.00	a
Ringo Rose	100.00	ab
Innocence	97.85	abc
Ringo Scarlet	97.00	abc
Encounter Red	96.00	abcd
Cherie - Light Salmon Sprinter	95.20	abcde
Sprinter Scarlet	95.00	abcde
Rosita	94.65	abcde
Firecracker	94.00	abcde
Mustang	93.05	abcde
Red Express	93.00	abcde
Red Champion	93.00	abcde
Sooner Red	92.15	bcde
Showgirl	92.00	bcde
Heidi	91.00	cde
Scarlet Flash	90.63	cde
Sooner Salmon	90.48	cde
Ringo Salmon	89.40	cde
Sprinter White	89.00	cde
Knockout	88.90	cdef
Encounter Salmon	84.00	def
Carefree Scarlet	82.55	def
Love Song	80.45	ef
Fleuriste Mixture - F2	71.00	ef
Friendship	68.88	ef
Colorama - F2	67.30	f

[z] mean germination percents followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

Table 8. Spring germination of 29 selected cultivars, ranked as to mean germination percent.

Cultivar	Mean Germination Percent	
Heidi	100.00	a[z]
Ice Queen	100.00	a
Ringo Salmon	100.00	a
Ringo Scarlet	100.00	a
Snowdon	100.00	a
Scarlet Flash	98.75	ab
Cherie	97.50	ab
Ringo Rose	97.50	ab
Sprinter Scarlet	97.50	abc
Innocence	95.00	abcd
Knockout	95.00	abcd
Mustang	95.00	abcd
Rosita '80	95.00	abcd
Red Champion	94.40	abcd
Orange Punch	93.75	abcd
Sprinter White	93.75	abcd
Sooner Red	93.75	abcd
Rosita	92.50	abcde
Encounter Red	91.25	abcde
Firecracker	90.00	abcde
Encounter Salmon	88.75	bcde
Carefree Scarlet	87.50	bcde
Red Express	85.00	cde
Fleuriste Mixture - F2	83.75	def
Friendship	83.75	def
Love Song	80.00	def
Showgirl	80.00	def
Sooner Salmon	73.75	ef
Colorama - F2	61.25	f

[z] mean germination percents followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

Table 9. Comparison of germination percent and numbers of the 29 selected cultivars of the fall versus the spring germination trials.

	Spring		Fall	
Germination Percent	No. of Cultivars	Percent of Cultivars	No. of Cultivars	Percent of Cultivars
90+	20	68.97	20	68.97
80 - 89.9	7	24.14	6	20.69
Less than 80	2	6.89	3	10.34

significant difference between the cultivars (Table 7). Similar results were obtained with the spring germination trials (Table 8).

An analysis of the fall versus the spring germination trials indicated there was a significant difference between the total mean germination percents (93.71% - spring and 88.72% - fall) by using the unpaired t test. It is evident that the seed germinated at a higher percent in the spring. The increased germination percent in the spring may have been due to the fact that the seed was younger in age or to a germination rhythm. In the spring germination trials seed of 6 cultivars,

1. Heidi,
2. Ringo Salmon,
3. Scarlet Flash,
4. Knockout,
5. Fleuriste Mixture - F2, and
6. Friendship,

germinated at 6 or more percent better than did seed of the same cultivars in the fall (10.07% mean increase), whereas in the fall germination trials seed of 5 cultivars,

1. Orange Punch,
2. Red Express,
3. Showgirl,
4. Sooner Salmon, and
5. Colorama - F2,

germinated at 6 or more percent better than did seed of the same cultivars in the spring (9.81% mean increase). The seed of the other 18 cultivars germinated within a 5% range for each cultivar in both the spring and

the fall germination trials.

Germination Rate

The fall range for the germination resistance value was 42.86 to 126.98 hours (Table 10), whereas the spring range for the germination resistance value was 24.90 to 87.72 hours (Table 11). An analysis of the fall (Table 10) and the spring (Table 11) germination resistance values indicated there was a highly significant difference between the cultivars.

An analysis of the fall versus the spring germination trials indicated there was a highly significant difference between the fall and the spring total mean germination resistance values (51.48 hours - spring and 79.09 hours - fall) by using the unpaired t test. The seed used in the fall trials germinated at a slower rate; the germination resistance value was lower in the spring. The decreased germination resistance value in the spring may have been due to the fact that the seed was younger in age and more vigorous or attributable to a germination rhythm. Although seed of 27 cultivars had decreased germination resistance values, it can be stated that for practical purposes that a germination resistance value difference of 24 hours or less is not important. Seed of 17 cultivars took more than 24 hours longer to germinate in the fall, with a mean increase of 49.24 hours in the germination resistance values over the spring values. Seed of 8 cultivars,

1. Firecracker,
2. Scarlet Falsh,
3. Knockout,
4. Ringo Salmon,

Table 10. Fall germination of 29 selected cultivars, ranked as to mean germination resistance value in hours.

Cultivar	Mean Germination Resistance Value (hours)	
Snowdon	42.86	a[z]
Mustang	49.80	ab
Showgirl	49.91	ab
Encounter Salmon	50.02	ab
Ringo Rose	51.15	ab
Encounter Red	60.49	ab
Rosita '80	61.33	ab
Friendship	61.54	ab
Innocence	62.38	ab
Heidi	67.96	abc
Ice Queen	72.00	abcd
Ringo Scarlet	74.30	bcde
Red Express	80.62	cdef
Red Champion	82.25	cdefg
Sooner Red	83.46	cdefg
Knockout	84.75	cdefgh
Ringo Salmon	85.71	cdefghi
Love Song	86.41	defghi
Sprinter Scarlet	91.17	efghi
Scarlet Flash	96.75	fghi
Sooner Salmon	96.90	fghi
Rosita	97.16	fghi
Firecracker	99.04	ghi
Colorama - F2	101.02	hi
Cherie - Light Salmon Sprinter	106.20	hij
Sprinter White	106.84	hij
Carefree Scarlet	108.14	hij
Orange Punch	112.00	ij
Fleuriste Mixture - F2	126.98	j

[z] mean germination resistance values followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

Table 11. Spring germination of 29 selected cultivars, ranked as to mean germination resistance value in hours.

Cultivar	Mean Germination Resistance Value (hours)
Heidi	24.90 a[z]
Ringo Scarlet	25.80 a
Rosita '80	29.37 ab
Mustang	30.00 ab
Snowdon	30.00 ab
Ringo Rose	30.95 ab
Firecracker	32.00 abc
Scarlet Flash	32.98 abc
Red Champion	33.00 abc
Ice Queen	33.90 abc
Knockout	34.58 abc
Ringo Salmon	34.80 abc
Cherie	36.11 abc
Rosita	37.74 abc
Encounter Red	41.73 abc
Sooner Red	43.52 abc
Innocence	43.78 abc
Sprinter Scarlet	44.58 abc
Carefree Scarlet	45.38 abc
Encounter Salmon	47.28 abc
Showgirl	59.98 abcd
Love Song	61.04 bcd
Orange Punch	61.65 bcd
Red Express	64.71 cde
Friendship	68.76 cde
Colorama - F2	78.62 de
Sooner Salmon	85.09 de
Fleuriste Mixture - F2	87.26 e
Sprinter White	87.72 e

[z] mean germination resistance values followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

5. Cherie,
6. Rosita,
7. Carefree Scarlet, and
8. Orange Punch,

germinated in the fall with germination resistance values of 50 hours or greater than did seed of the same cultivars in the spring germination trials.

Germination Percent and Rate Interactions

By day 6, 87.52% and 80.01% germination had occurred for the spring and fall germination trials respectively (Figure 7). In the fall, 88.04% of the seed germinated in 12 days, whereas in the spring 90.38% of the seed germinated in the same period. The germination was faster in the spring with the greatest germination count on day 2 (Figure 8). In the fall the greatest germination occurred on day 3.

Germination Percent - All Cultivars

When the total number of cultivars, fall (36) and spring (67), were compared, the fall range for germination percent (Table 12) was the same as for the 29 cultivars. The spring range for percent was similar (Table 13) except for 2 cultivars, Marathon (56.67%) and Miniskirt Mixed (50.00 5).

Of all the spring germinated cultivars, 38 cultivars (56.72%) germinated at 90% or better (Table 14), 18 cultivars (26.87%) germinated at 80 to 89.9% and 11 cultivars (16.41%) germinated at less than 80%. Thus it may be stated that a greater percent of the cultivars germinated at lower percents than when the 29 cultivars were considered. All the F2

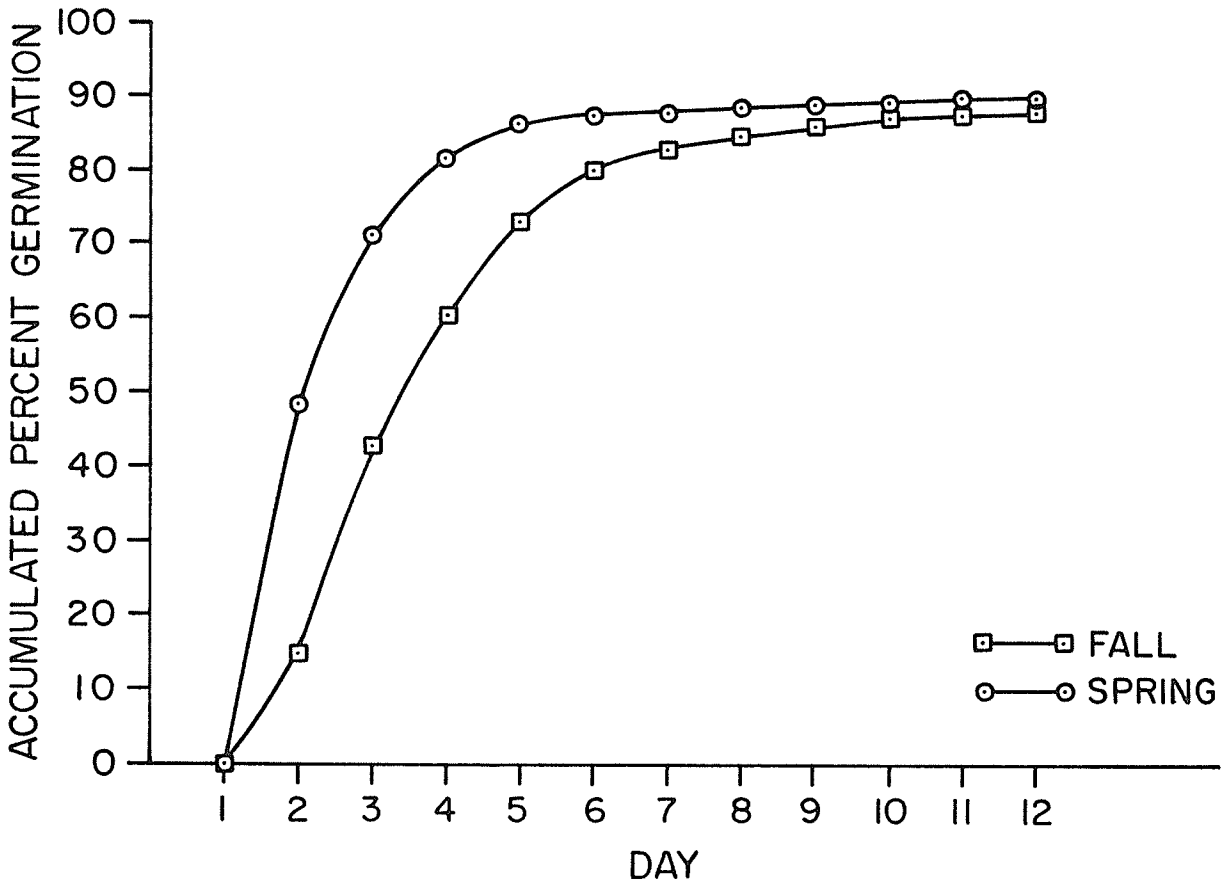

Figure 7. Accumulated germination percent of the total seed by day for spring and fall germination trials for 29 selected cultivars.

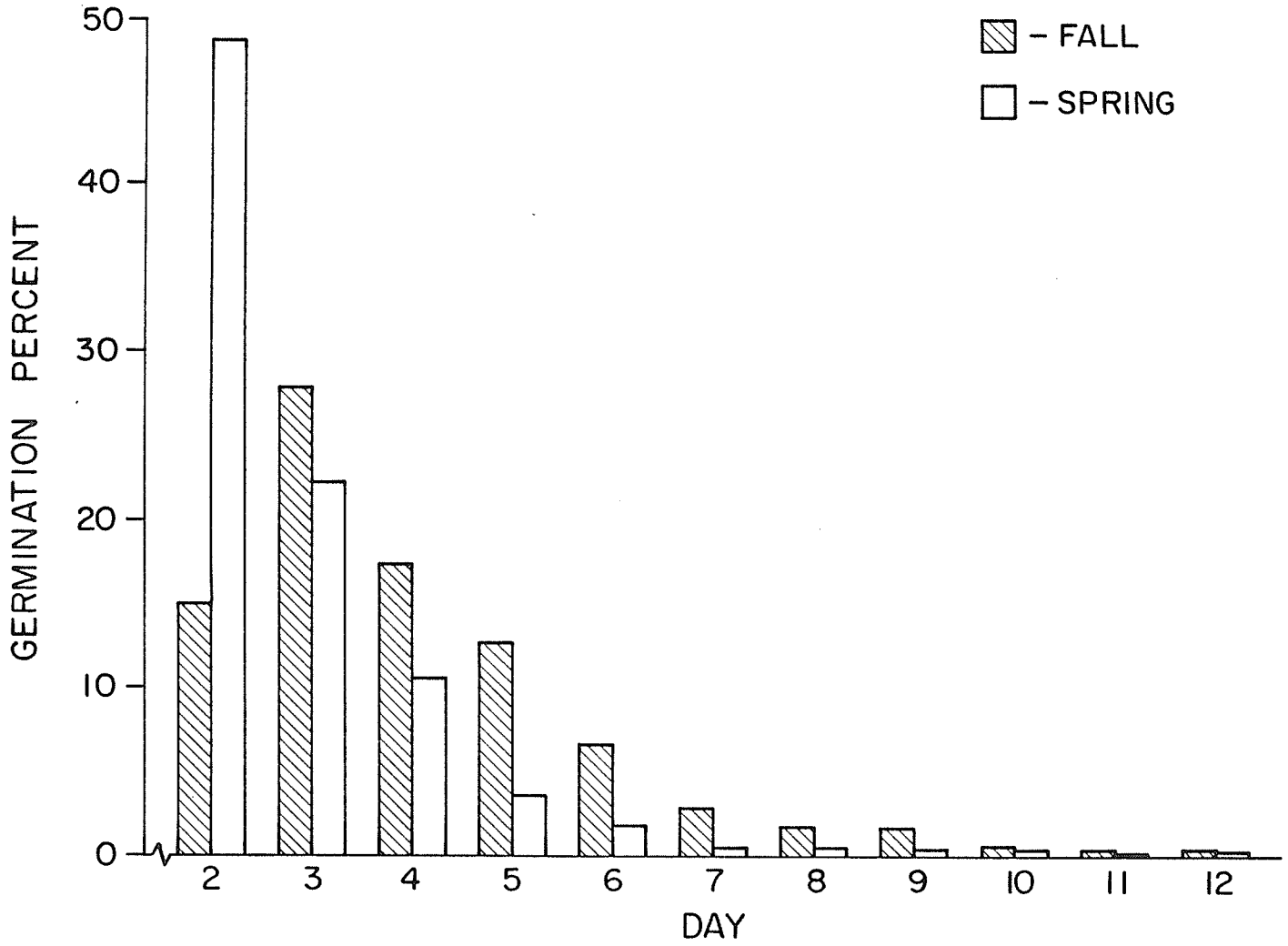

Figure 8. Comparison of fall and spring germination by percent of the total seed per day for 29 selected cultivars.

Table 12. Fall germination, all cultivars, ranked as to mean germination percent.

Cultivar	Mean Germination Percent	
Ringo Rose	100.00	a[z]
Cherie Improved	100.00	ab
Ice Queen	100.00	ab
Orange Punch	100.00	ab
Sprinter Mixed	100.00	ab
Rosita '80	100.00	ab
Snowdon	100.00	ab
Innocence	97.85	ab
Ringo Scarlet	97.00	abc
Encounter Red	97.00	abc
Cherie - Light Salmon Sprinter	95.20	abcd
Sprinter Scarlet	95.00	abcd
Rosita	94.65	abcd
Rose Pink with White Eye	94.08	abcd
Firecracker	94.00	abcd
Mustang	93.05	abcd
Red Champion	93.00	abcd
Red Express	93.00	abcd
Sooner Red	92.15	abcd
Showgirl	92.00	abcd
New Era Red	91.70	abcd
Heidi	91.00	abcd
Scarlet Flash	90.63	abcd
Sooner Salmon	90.48	bcd
Ringo Salmon	89.40	bcde
Sprinter White	89.00	bcde
Knockout	88.90	bcdef
New Era Bright Red	87.00	bcdef
Encounter Salmon	84.00	cdef
Carefree Scarlet	82.55	def
Love Song	80.45	def
New Era Medium Salmon	79.18	def
Nittany Lion Red	75.93	def
Fleuriste Mixture - F2	71.00	def
Friendship	68.88	ef
Colorama - F2	67.30	f

[z] mean germination percents followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

Table 13. Spring germination, all cultivars, ranked as to mean germination percent.

Cultivar	Mean Germination Percent	Cultivar	Mean Germination Percent
Florence	100.00 a[z]	Firecracker	90.00 abcdefgh
Geranium Mixed	100.00 a	Dwarf Sprinter Red	89.70 abcdefgh
Snowdon	100.00 a	Empress Red	88.75 bcdefgh
Ringo Scarlet	100.00 a	Encounter Salmon	88.75 bcdefgh
Ringo Salmon	100.00 a	Fleuriste Mixture - F2	88.00 bcdefgh
Ringo Rouge	100.00 a	Bambi - F2	87.50 cdefgh
Ice Queen	100.00 a	Carefree Scarlet	87.50 cdefgh
Heidi	100.00 a	Capri Deep Red	87.50 cdefgh
Festival Scarlet	100.00 a		
Bright Eyes	98.75 ab	Red Express	85.00 cdefgh
Scarlet Flash	98.75 ab	Salmon Express	85.00 cdefgh
Sprinter Scarlet	97.50 abc	Vulcan	85.00 cdefgh
Capri Brick Red	97.50 abcd	Del Greco Mixed	85.00 cdefgh
Capri White	97.50 abcd	Fire Flash	83.75 defgh
Gremlin Coral	97.50 abcd	Salmon Flash	83.75 defgh
Cherie	97.50 abcde	Friendship	83.75 defgh
Jackpot	97.50 abcde	Dynamite	82.50 efgh
Ringo Rose	97.50 abcde		
Sprinter Deep Red	97.50 abcde	Showgirl	80.00 efgh
Smash Hit Red	96.25 abcde	Red Standard	80.00 efgh
		Love Song	80.00 efgh
Knockout	95.00 abcde		
Innocence	95.00 abcde	Sooner Salmon	73.75 fgh
Rosita '80	95.00 abcdef	Carefree Light Salmon	72.50 fgh
Mustang	95.00 abcdef	Red Delicious - F2	71.25 gh
Sprinter Salmon	95.00 abcdef		
Red Champion	94.40 abcdefg	Paintbox Mixed	70.00 gh
Orange Punch	93.75 abcdefg	Tiffany	70.00 gh
Sooner Red	93.75 abcdefg	Surefire	68.75 gh
Cherry Glow	93.75 abcdefg	Red Apple - F2	68.75 gh
Sprinter White	93.75 abcdefg	Empress Salmon	68.75 gh
Festival Salmon	92.50 abcdefg		
Snow White	92.50 abcdefg	Colorama - F2	61.25 h
Festival White	92.50 abcdefg		
Rosita	92.50 abcdefg	Marathon	56.67 h
Debutante	91.25 abcdefg		
Deep Rose Flash	91.25 abcdefg	Miniskirt Mixed	50.00 h
Encounter Red	91.25 abcdefg		

[z] mean germination percents followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

Table 14. Comparison of germination percent and numbers of cultivars of the fall versus the spring germination trials.

	Spring		Fall	
Germination Percent	No. of Cultivars	Percent of Cultivars	No. of Cultivars	Percent of Cultivars
90+	38	56.72	24	66.67
80 - 89.9	18	26.87	7	19.44
Less than 80	11	16.41	5	13.89

cultivars germinated at 88.00% (Fleuriste Mixture) or less. Red Delicious, Red Apple and Colorama (F2's) were all below 71.50% germination. The spring and fall germination percents for Colorama were similar, 61.25 and 67.30, respectively. Marathon, the first double flowered cultivar, germinated at a mean of 56.67%. On the other hand, all of the F1 and F2 mixed colour cultivars germinated at 88.00% or less.

In the fall, 24 cultivars (66.67%) germinated at 90% or better (Table 14), 7 cultivars (19.44%) germinated at 80 to 89.9% and 5 cultivars (13.89%) germinated at less than 80%.

An analysis of the spring and fall germination indicated that there was a highly significant difference between the cultivar percents for each trial (Tables 13 and 12). An analysis of the fall versus the spring trials indicated that there was no significant difference in the percents (91.18 - spring and 90.72 - fall) as determined by the unpaired t test.

Germination Rate

The fall range for the germination resistance value (Table 15) was the same as for the 29 cultivars and the spring range was essentially the same (Table 16). An analysis of the fall germination indicated that there was a highly significant difference between the cultivars for the germination resistance values (Table 15). A similar result was obtained with the spring cultivar germination trials (Table 16).

Analysis of the fall versus the spring trials indicated there was a highly significant difference between the fall and the spring germination resistance values by using the unpaired t test; the seed in the fall trials germinated at a slower rate.

Table 15. Fall germination, all cultivars, ranked as to mean germination resistance value in hours.

Cultivar	Mean Germination Resistance Value (hours)	
Snowdon	42.86	a[z]
Rose Pink with White Eye	46.59	a
Mustang	49.80	a
Showgirl	49.91	a
Encounter Salmon	50.02	a
Ringo Rose	51.15	a
Encounter Red	60.49	ab
Rosita '80	61.33	abc
Friendship	61.54	abc
New Era Red	65.32	abc
Heidi	67.96	abc
Ice Queen	72.00	abcd
Ringo Scarlet	74.30	bcd
New Era Bright Red	75.45	bcd
Cherie Improved	78.00	bcde
Red Express	80.62	cde
Red Champion	82.25	cde
Sooner Red	83.46	cde
Sprinter Mixed	84.00	cdef
Knockout	84.75	cdef
Ringo Salmon	85.71	cdef
Love Song	86.41	cdef
Sprinter Scarlet	91.17	def
Scarlet Flash	96.75	def
Sooner Salmon	96.90	def
Rosita	97.16	def
Firecracker	99.04	defg
Colorama - F2	101.02	efg
Nittany Lion Red	104.74	efg
Cherie - Light Salmon Sprinter	106.20	efgh
Sprinter White	106.84	fgh
Carefree Scarlet	108.14	fgh
Orange Punch	112.00	fgh
New Era Medium Salmon	115.73	gh
Innocence	124.76	h
Fleuriste Mixture - F2	126.98	h

[z] mean germination resistance values followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

Table 16. Spring germination, all cultivars, ranked as to mean germination resistance value in hours.

Cultivar	Mean Germination Resistance Value (hours)	Cultivar	Mean Germination Resistance Value (hours)
Heidi	24.90 a[z]	Salmon Flash	49.25 abcdefg
Ringo Rouge	25.80 a	Capri Brick Red	49.47 abcdefg
Ringo Scarlet	25.80 a	Fire Flash	49.53 abcdefg
Debutante	27.51 a	Empress Salmon	51.78 abcdefg
Rosita '80	29.37 ab	Festival Scarlet	51.90 abcdefgh
Snowdon	30.00 abc	Deep Rose Flash	55.64 bcdefgh
Mustang	30.00 abc	Snow White	56.65 bcdefghi
Ringo Rose	30.95 abc	Red Delicious - F2	58.10 cdefghi
Dwarf Sprinter Red	31.85 abcd	Showgirl	59.98 cdefghi
Firecracker	32.00 abcd	Love Song	61.04 defghi
Capri White	32.53 abcd	Orange Punch	61.65 defghi
Scarlet Flash	32.98 abcd	Festival White	61.97 defghij
Red Champion	33.00 abcd	Red Standard	62.50 defghij
Ice Queen	33.90 abcd	Red Express	64.71 defghij
Vulcan	34.46 abcd	Geranium Mixed	64.80 defghij
Knockout	34.58 abcd	Smash Hit Red	67.71 defghijk
Ringo Salmon	34.80 abcd	Friendship	68.76 defghijk
Cherie	36.11 abcd	Paintbox Mixed	70.05 efghijk
Florence	37.05 abcd	Salmon Express	71.40 fghijkl
Jackpot	37.10 abcd		
Rosita	37.74 abcd	Surefire	72.18 fghijkl
Bright Eyes	39.14 abcd	Empress Red	72.62 ghijkl
Festival Salmon	41.30 abcd	Gremlin Coral	76.83 hijkl
Encounter Red	41.73 abcd	Colorama - F2	78.62 hijkl
Sprinter Salmon	42.32 abcde	Dynamite	79.13 hijkl
Sooner Red	43.52 abcde	Marathon	79.66 ijkl
Cherry Glow	43.70 abcde	Miniskirt Mixed	82.00 ijkl
Innocence	43.78 abcde	Sooner Salmon	85.09 ijkl
Sprinter Deep Red	43.83 abcdef	Del Greco Mixed	87.26 ijkl
Sprinter Scarlet	44.58 abcdef	Fleuriste Mixture - F2	87.26 jkl
Carefree Scarlet	45.38 abcdef	Sprinter White	87.72 jkl
Capri Deep Red	47.12 abcdef	Bambi - F2	88.13 jkl
Encounter Salmon	47.28 abcdef	Red Apple - F2	90.72 kl
		Carefree Light Salmon	94.69 l
		Tiffany	98.14 l

[z] mean germination resistance values followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

Germination Percent and Rate Interactions

By day 6, 86.63% and 75.91% germination had occurred for the spring and fall germination trials respectively (Figure 9). In the fall, 84.12% of the seed germinated in 12 days; in the spring, 89.58% of the seed germinated in the same time. The germination was faster in the spring with the greatest germination count on day 2 (Figure 10). In the fall, the greatest germination occurred on day 3.

The germination percents and the germination resistance values differed between the fall and the spring germination trials. Several explanations could be advanced to explain these differences:

1. There is a possibility that the seed used in the spring trials was younger in age and thus more vigorous.
2. There may be an annual germination rhythm which peaks in the spring rather than in the fall.
3. As the seeds are different cultivars, they are genetically different. Therefore, differing germination percents and rates may be expected. This is especially evident when the F2's are taken as a group. Low germination percents and higher germination resistance values were consistently found in the F2's.

Many of the cultivars that germinated at high percents in the fall, did so in the spring trials. Seventy-five percent of the cultivars that had low germination percents in the fall were also low in the spring trials. It would appear that this is the genetic germination potential of these seeds. Cultivars differences will be discussed in more detail later.

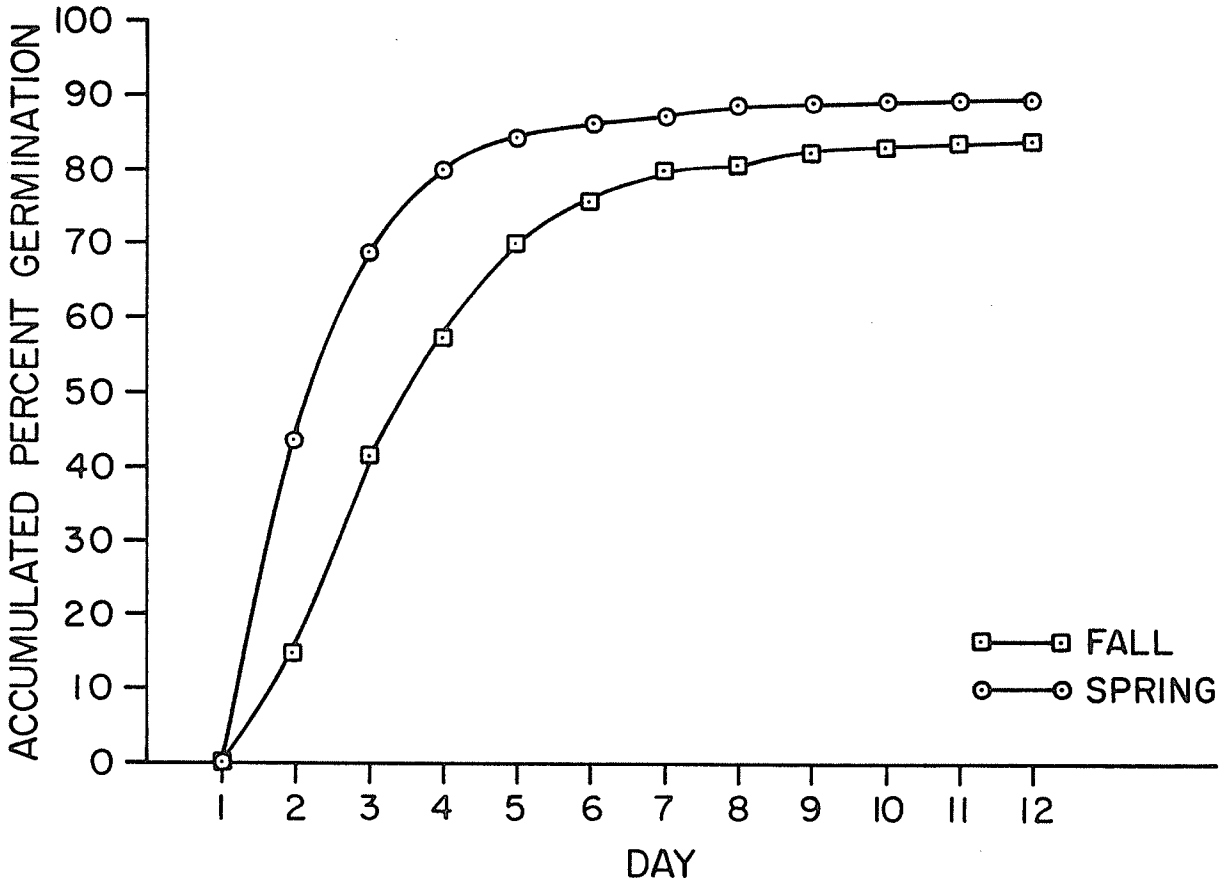

Figure 9. Accumulated germination percent of the total seed by day for spring and fall germination trials, all cultivars.

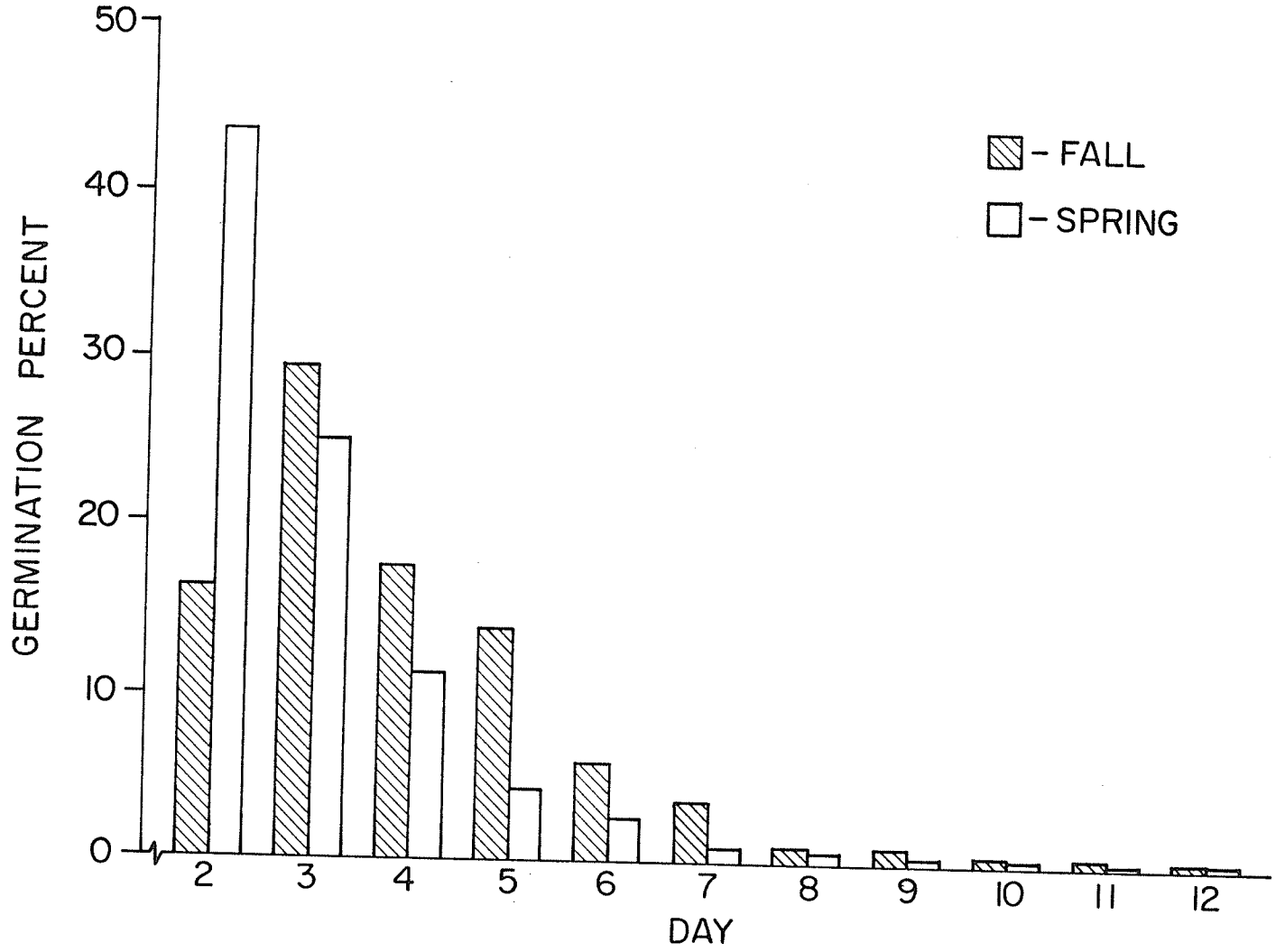

Figure 10. Comparison of fall and spring germination by percent of the total seed per day.

Transplanting

The transplant survival percent varied from 60 to 100% (Table 17). The cultivars are classed as to transplant survival percents in Table 18. More than 57% of the cultivars survived the transplanting at 95% or better, while approximately 76% of the cultivars survived the transplanting at 90% or better.

According to the data in Table 17, there appears to be a relationship between the percent survival on transplanting, germination percents and the germination resistance values, but upon calculation the correlation coefficient r was zero for the germination resistance values versus transplant survival percents, germination resistance values versus germination percents and germination percents versus transplant survival percents. However, 46 cultivars survived transplanting at 91% or better, of these cultivars, 32 (69.52%) cultivars germinated at 85% or better with germination resistance values of 60 hours or less. Therefore, it would appear that if a seed sample germinates rapidly and in the high percentages, the seedlings are more likely to survive transplanting.

Environmental Factors

Temperature

Geranium seed germination trials were conducted to determine the effect of temperature on germination percent and rate.

A separate analysis of variance of the controls indicated there was no significant difference between the dates in either germination percent or germination resistance values.

Table 17. Comparison of transplant survival percent, germination percent and germination resistance value in hours for the spring germinated cultivars.

Cultivar	Percent Survival on Transplanting	Mean Germination Percent	Mean Germination Resistance Value (hours)
Heidi	100.00	100.00[z]	24.90[y]
Ringo Rouge	100.00	100.00	25.80
Ringo Scarlet	100.00	100.00	25.80
Ice Queen	100.00	100.00	33.90
Ringo Salmon	100.00	100.00	34.80
Scarlet Flash	100.00	98.75	32.98
Bright Eyes	100.00	98.75	39.14
Ringo Rose	100.00	97.50	30.95
Cherie	100.00	97.50	36.11
Sprinter Deep Red	100.00	97.50	43.83
Capri Brick Red	100.00	97.50	49.47
Mustang	100.00	95.00	30.00
Innocence	100.00	95.00	43.78
Sooner Red	100.00	93.75	43.52
Cherry Glow	100.00	93.75	43.70
Snow White	100.00	92.50	56.65
Deep Rose Flash	100.00	91.25	55.64
Fire Flash	100.00	83.75	49.53
Carefree Light Salmon	100.00	72.50	94.69
Rosita	97.87	92.50	37.74
Snowdon	96.67	100.00	30.00
Geranium Mixed	96.67	100.00	64.80
Capri White	96.67	97.50	32.53
Jackpot	96.67	97.50	37.10
Smash Hit Red	96.67	96.25	67.71
Rosita '80	96.67	95.00	29.37
Knockout	96.67	95.00	34.58
Sprinter White	96.67	93.75	87.72
Debutante	96.67	91.25	27.51
Encounter Salmon	96.67	88.75	47.28
Salmon Express	96.67	85.00	71.40
Salmon Flash	96.67	83.75	49.25
Sprinter Scarlet	96.55	97.50	44.58
Bambi - F2	96.30	87.50	88.13
Tiffany	96.30	70.00	98.14
Red Delicious - F2	96.00	71.25	58.10
Florence	93.33	100.00	37.05
Gremlin Coral	93.33	97.50	76.83
Sprinter Salmon	93.33	95.00	42.32
Encounter Red	93.33	91.25	41.73
Capri Deep Red	93.33	87.50	47.28
Vulcan	93.33	85.00	34.46
Red Express	93.33	85.00	64.71
Showgirl	93.33	80.00	59.98
Red Champion	92.86	94.40	33.00
Dwarf Sprinter Red	91.67	89.70	31.85
Red Standard	90.00	80.00	62.50
Orange Punch	86.67	93.75	61.65
Del Greco Mixed	86.67	85.00	87.26
Empress Salmon	86.67	68.75	51.78
Fleuriste Mixture - F2	85.00	83.75	87.26
Empress Red	83.33	88.75	72.62
Carefree Scarlet	83.33	87.50	45.38
Friendship	83.33	83.75	68.76
Dynamite	80.00	82.50	79.13
Love Song	80.00	80.00	61.04
Sooner Salmon	80.00	73.75	85.09
Surefire	80.00	68.75	72.18
Marathon	79.82	56.67	79.66
Colorama - F2	78.13	61.25	78.62
Firecracker	77.78	90.00	32.00
Red Apple - F2	73.33	68.75	90.72
Miniskirt Mixed	60.00	50.00	82.00

[z] Comparison using the unpaired t test are presented in Table 13.

[y] Comparison using the unpaired t test are presented in Table 16.

Table 18. Cultivar transplant survival.

Transplant Percent Survival Class	No. of Cultivars	Percent of Cultivars
100	19	29.69
95 - 99.9	17	26.56
90 - 94.9	12	18.75
80 - 89.9	11	17.19
Less than 80	5	7.81

Germination Percent. There were no significant differences in the germination percents for the 4 temperatures used. Snowdon differed from Rosita and this difference was highly significant (Table 19), while the interactions between temperatures and cultivars were significant by analysis of variance. This interaction was attributable to hypocotyl fracturing and there would not have been an interaction if there had been no hypocotyl fracturing.

Germination Rate. The observed germination response to temperature on the basis of germination resistance values, in decreasing order, was:

1. $20^{o}C$,
2. day/night - fluctuating temperatures (17.2^{o} to $29.4^{o}C$) and $25.5^{o}C$, and
3. $14.5^{o}C$ (Table 20).

Temperature has been reported as being very critical in the germination of F1 hybrid geranium seed. A constant high temperature of 20^{o} to $25^{o}C$ has been recommended by several authors and seed companies for the germination of geranium seed (Adams 1977 and Carlson 1976). The geranium seed germination rate increased with an increase in temperature to an optimum temperature of $20^{o}C$. Above $25^{o}C$ the rate decreased. This may have been attributable to an inhibition of germination due to the temperature. Moreover, these observations seem to be in agreement with those of Koller (1972), Gulliver and Heydecker (1973) and Come and Tissaoui (1973), respectively. The seed germinated at a slower rate in $14.5^{o}C$, a lower temperature. Seed in lower temperatures may have had a decreased metabolism and thus a decreased germination rate.

For the germination resistance values, there was a significant dif-

Table 19. Mean germination percent for a 12 day period for 4 temperature regimes.

Cultivar	Mean Germination Percent
Bright Eyes	95.00 ab[zy]
Cherry Glow	96.25 ab
Geranium Mixed	93.44 ab
Ringo Scarlet	87.50 ab
Rosita	96.88 a
Snowdon	85.94 b
Sprinter Scarlet	95.63 ab
Sprinter Deep Red	95.91 ab
Sprinter Salmon	90.00 ab
Tiffany	88.33 ab

[z] mean germination percents for cultivars followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

[y] values are a mean of 3 or 4 samples of 20 seed at each temperature, 14.5°, 20° and 25.5°C and a fluctuating temperature regime (17.2° to 29.4°C).

Table 20. Mean germination resistance value in hours for a 5 day period for 4 temperature regimes.

Cultivar	Mean Germination Resistance Value (hours) Temperature 14.5°C	20°C	25.5°C	Fluctuating day/night	Mean
Bright Eyes	70.12 hijklm[z]	36.29 abcde	50.26 abcdefghijk	51.02 abcdefghijk	51.92 ab[y]
Cherry Glow	67.04 ghijkl	37.50 abcde	38.41 abcdef	33.15 abc	44.03 a
Geranium Mixed	71.73 jklm	58.53 defghijk	59.05 efghijk	65.48 ghijkl	67.30 bc
Ringo Scarlet	63.53 fghijkl	41.62 abcdef	52.90 bcdefghijk	35.30 abcd	48.29 a
Rosita	62.72 fghijkl	34.54 abc	49.42 abcdefghij	44.02 abcdefg	45.17 a
Snowdon	85.02 lm	66.57 ghijkl	67.81 hijkl	70.83 ijklm	72.56 c
Sprinter Scarlet	57.85 cdefghijk	60.90 efghijk	94.24 m	74.82 klm	68.99 c
Sprinter Deep Red	62.54 efghijkl	28.60 ab	61.58 efghijkl	57.30 cdefghijk	51.68 ab
Sprinter Salmon	69.79 hijklm	45.11 abcedfgh	47.49 abcdefghij	46.50 abcdefghi	52.65 ab
Tiffany	63.53 fghijkl	25.16 a	33.04 abc	54.23 bcdefghijk	43.99 a
Mean	67.48 c[x]	44.61 a	56.87 b	53.95 b	

[z] mean germination resistance values followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

[y] mean germination resistance values for cultivars followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

[x] mean germination resistance values for temperatures followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

ference (Table 20) as to which temperature was used, but is this of practical value? The germination resistance value in these experiments varied by less than 24 hours and would not be a major concern.

Germination Percent and Rate Interactions. The maximum germination percent was on day 2 for the day/night fluctuating temperatures and for 20°C. Maximum germination occurred on day 3 for 14.5° and 25.5°C.

Geranium seed germinated over a wide range of temperatures. There were cultivars differences in both the germination percents and the germination resistance values. The effects of thiram treatment and cultivar differences will be discussed later.

Media

Geranium seed germination trials were conducted to determine the effect of media on germination percent and rate.

Germination Percent. The germination percents for the seed used as the controls on filter paper did not differ significantly, at the 5% level of significance, using the unpaired t test for both trials I (May 12, 1980) and II (May 27, 1980).

a. Trial I

According to the data in Table 21, no significant differences were found in the media. However, significant cultivar differences were found (Table 22). Knockout, Sprinter Scarlet, Snowdon and Cherie were similar, with mean germination percents of 88.33% or greater. Salmon Express and Paintbox Mixed differed from the above group, but were similar to each other, with germination percents of 82.50 and 72.50 respectively.

Table 21. Mean germination percent and mean germination resistance value in hours in media trial I, for 6 media.

Media	Mean Germination Percent	Mean Germination Resistance Value (hours)
Filter paper	86.67[z]	72.29[z]
Sand	82.50	72.46
Perlite	93.33	74.60
Zorb-all	90.83	75.30
Vermiculite	90.83	78.24
Peat moss	89.17	80.38

[z] mean germination percents and mean germination resistance values do not differ significantly as determined by analyses of variance.

Table 22. Mean germination percent and mean germination resistance value in hours for media trial I, for 6 cultivars on 6 media.

Cultivar	Mean Germination Percent	Mean Germination Resistance Value (hours)
Knockout	97.50 a[z]	30.50 a[y]
Sprinter Scarlet	97.50 a	30.79 a
Snowdon	88.33 abc	50.14 b
Paintbox Mixed	72.50 c	55.00 b
Cherie	95.00 ab	56.43 b
Salmon Express	82.50 bc	65.38 b

[z] mean germination percents followed by the same letter do not differ significantly as determined by Duncan's New Multiple Range Test (0.01).

[y] mean germination resistance values followed by the same letter do not differ significantly as determined by Duncan's New Multiple Range Test (0.01).

b. Trial II

For trial II, with 3 additional cultivars and 3 of the same cultivars as in trial I, the media did not differ significantly (Table 23), but there were highly significant cultivar differences (Table 24).

Germination Rate. The control germination resistance values for seed germination did not differ significantly at the 5% level of significance, using the unpaired t test, for both trials I and II.

a. Trial I

According to the data in Table 21, there were no significant differences for media in the germination resistance values. However, significant cultivar differences were found (Table 22). Cultivar differences will be discussed later.

b. Trial II

In this trial, there was a highly significant difference between cultivars in the germination resistance values (Table 24). Cultivar differences will be discussed later.

The filter paper, perlite, vermiculite, Zorb-all and sand had similar germination resistance values (Table 23); the range was 45.93 to 51.00 hours. The germination resistance value of peat moss was greater, 66.16 hours, which differed from the other media using the unpaired t test at the 5% level of significance.

The consideration is whether a 20.23 hour in trail II (Table 23) or an 8.09 hour in trial I (Table 21) germination resistance range difference between the media with the greatest and lowest value are large enough to be of a concern to the grower. One day is not a major concern;

Table 23. Mean germination percent and mean germination resistance value in hours in media trial II, for 6 media.

Media	Mean Germination Percent	Mean Germination Resistance Value (hours)
Vermiculite	94.55[z]	51.57 a[y]
Peat moss	91.82	66.16 b
Zorb-all	91.67	51.00 a
Filter paper	90.00	46.74 a
Sand	90.00	45.93 a
Perlite	89.09	49.93 a

z mean germination percents do not differ significantly as determined by analysis of variance.

y mean germination resistance values followed by the same letter do not differ significantly as determined by the unpaired t test (0.05).

Table 24. Mean germination percent and mean germination resistance value in hours for media trial II, for 6 cultivars on 6 media.

Cultivars	Mean Germination Percent	Mean Germination Resistance Value (hours)
Knockout	97.00 ab[z]	45.13 ab[y]
Ringo Scarlet	90.56 abc	39.51 a
Rosita	99.09 a	33.38 a
Snowdon	87.73 bc	64.51 c
Sprinter Scarlet	85.00 c	49.83 b
Sprinter White	91.36 bc	76.25 c

z mean germination percents followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

y mean germination resistance values followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

therefore, the grower's concern would be to maximize his returns using the media with which the grower has the most expertise.

Geranium seed will germinate well on a wide range of media as shown shown by Randolph (1971) and Dallon and Durkin (1971).

Between the 2 media trials which were conducted 15 days apart there was a noticeable difference between the germination resistance values for each medium and between the germination percent of seed of Sprinter Scarlet and Knockout on one occasion. These will be discussed under germination rhythms.

The germination resistance value was significantly different for seed germinated on peat moss in trial II. More trials would need to be conducted in order to determine if this effect held or was specific to this trial only. This difference may have been due to the low pH of peat moss. As the pH of the peat moss in these trials was in the range of 3.6 to 3.8, it is possible that the pH factor may have been responsible for the greater germination resistance values on this medium in the 2 trials.

Moisture Content of Media

As most of the experimentation was conducted using saturated filter papers, trials were conducted using different media moisture contents.

Germination Percent

a. Trial I

The water content of the media and cultivars were not significant when the germination percents were analysed (Tables 25 and 26).

b. Trial II

When the germination percents were considered, there was a highly

Table 25. Effect of media moisture content on mean germination percent and mean germination resistance value, trial I.

Medium and Water Content	Mean Germination Percent	Mean Germination Resistance Value (hours)
Filter paper (6 ml H_2O)	91.67[z]	52.41 a[y]
Sand (13 ml/65 g)	93.33	51.25 a
Sand (10 ml/65 g)	96.67	77.17 b

[z] mean germination percents do not differ significantly as determined by analysis of variance.

[y] mean germination resistance values followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

Table 26. Effect of media moisture content on mean germination percent and mean germination resistance value for 3 cultivars, trial I.

Cultivar and Water Content of Media	Mean Germination Percent	Mean Germination Resistance Value (hours)
Ringo Scarlet		
Filter paper (6 ml H_2O)	80.00[z]	48.00[z]
Sand (13 ml/65 g)	87.50	30.42
Sand (10 ml/65 g)	95.00	71.37
Rosita		
Filter paper (6 ml H_2O)	100.00	36.60
Sand (13 ml/65 g)	97.50	31.12
Sand (10 ml/65 g)	97.50	61.71
Sprinter White		
Filter paper (6 ml H_2O)	95.00	72.63
Sand (13 ml/65 g)	95.00	92.20
Sand (10 ml/65 g)	97.50	98.43
Cultivar Means		
Ringo Scarlet	89.00[z]	50.31 a[y]
Rosita	98.00	44.45 a
Sprinter White	96.00	90.78 b

[z] mean germination percents and mean germination resistance values do not differ significantly as determined by analyses of variance.

[y] mean cultivar germination resistance values followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

significant difference between the 2 cultivars (Table 27). The water content of the media was not significant in effect on the germination percent.

Germination Rate

a. Trial I

In trials with varying water contents of the media, as the water content decreased, the germination resistance value increased (Table 25). These differences were highly significant. In Ringo Scarlet, Sprinter White and Rosita, the germination resistance value increased (Table 26) as the water content of the sand decreased by 3 ml from 13 ml to 10 ml. The germination resistance value was decreased in the presence of a greater water content in the sand. Using the germination resistance value the difference between cultivars was highly significant (Table 27). Cultivar differences will be discussed later.

b. Trial II

Results of trial II, again showed that as the water content of the media decreased the germination resistance value increased (Table 28). These differences between moisture contents were highly significant. The differences between cultivars were nonsignificant (Table 27).

Geranium seed appeared to favour a media moisture above field capacity for germination. Decreasing the moisture content below saturation, increased the time required for germination to occur. Thus, as Gulliver and Heydecker (1973) stated, there appears to be an optimum water supply for an optimum germination rate.

Table 27. Effect of media moisture content on mean germination percent and mean germination resistance value for 2 cultivars, trial II.

Cultivar and Moisture Content of Media	Mean Germination Percent	Mean Germination Resistance Value (hours)
Rosita		
Filter paper (6 ml H_2O)	95.00[z]	54.95[z]
Sand (13 ml/65 g)	98.33	42.66
Sand (10 ml/65 g)	98.33	63.71
Ringo Scarlet		
Filter paper (6 ml H_2O)	80.00	60.75
Sand (13 ml/65 g)	85.00	30.12
Sand (10 ml/65 g)	90.00	85.89
Cultivar Means		
Rosita	97.86[y]	53.44[z]
Ringo Scarlet	86.43	58.40

[z] mean germination percents and mean germination resistance values do not differ significantly as determined by analyses of variance.

[y] mean cultivar germination resistance values differ significantly as determined by analysis of variance.

Table 28. Effect of media moisture content on mean germination percent and mean germination resistance value, trial II.

Medium and Water Content	Mean Germination Percent	Mean Germination Resistance Value (hours)
Filter paper (6 ml H_2O)	87.50[z]	36.39 a[y]
Sand (13 ml/65 g)	91.67	57.85 a
Sand (10 ml/65 g)	94.17	74.80 b

[z] mean germination percents do not differ significantly as determined by analysis of variance.

[y] mean germination resistance values followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

Oxygen Concentration

Oxygen is required for germination to occur.

Germination Percent. With the cultivar, Rosita, the use of an increased oxygen concentration had no significant effect on the germination percent (Table 29). The treatment (scarification) was significant. The seed had been placed to germinate, scarified and unscarified, and it was here that a highly significant difference was found, between scarification and unscarification.

According to the data in Table 30, no significant differences were found in the germination percent for a trial conducted with the cultivar, Tiffany.

Germination Rate. With the cultivar, Rosita, the use of an increased oxygen concentration did not significantly affect the germination resistance values (Table 29); however, scarification produced a highly significant decrease in the germination resistance values.

According to the data in Table 30, no significant differences were found in the germination resistance values for a trial conducted with the cultivar, Tiffany.

As both of the above trials were conducted on a small scale, larger replicated trials will be required to demonstrate the effects of an increased oxygen concentration on the germination of geranium seed.

Scarification Versus Unscarification

Scarification increases the germination of seeds by removing parts of the seed coat so that water or gases may permeate the seed coat more easily. Most of the commercially available F1 hybrid geranium seed is

Table 29. Germination percent and germination resistance value in hours for seed of the cultivar, Rosita, in an increased oxygen concentration.

	Mean Germination Percent			Mean Germination Resistance Value (hours)		
Treatment	Oxygen	Control	Means	Oxygen	Control	Means
Seed Coat Treatment						
Scarified	100.00[z]	100.00[z]	100.00[y]	25.80[z]	60.60[z]	43.20[x]
Unscarified	32.50	20.00	26.25	82.00	102.00	92.00
Means	66.25	60.00		53.90	81.30	

[z] mean germination percents and mean germination resistance values do not differ significantly as determined by analysis of variance.

[y] mean germination percents for seed coat treatment differ significantly as determined by analysis of variance (0.01).

[x] mean germination resistance values for seed coat treatment differ significantly as determined by analysis of variance (0.01).

Table 30. Germination percent and germination resistance value in hours for seed of the cultivar, Tiffany, in an increased oxygen concentration.

	Mean Germination[z] Percent			Mean Germination[z] Resistance Value (hours)		
Treatment	Oxygen	Control	Means	Oxygen	Control	Means
Seed Coat Treatment						
Scarified	95.00	80.00	87.50	27.16	30.75	28.96
Unscarified	50.00	5.00	27.50	60.00	24.00[y]	42.00
Means	72.50	42.50		43.58	56.75	

[z] mean germination percents and mean germination resistance values do not differ significantly as determined by analysis of variance.

[y] 1 seed germinated.

scarified.

Germination Percent. In a scarified versus unscarified seed experiment, Ringo Scarlet germinated at 71.67 and 55.00% for scarified and unscarified seed respectively (Table 31). With the other cultivar, Rosita, the mean germination percent varied widely between the scarified and unscarified seed, 98.33 and 23.33%, respectively.

The differences between the treatments (Table 31) were highly significant for both cultivars. Cultivar x treatment differences were highly significant also by analysis of variance (Appendix Table 10). Scarification increased the germination percents for seed of both of the cultivars, Rosita and Ringo Scarlet.

Germination Rate. The germination resistance values differed by more than 109 hours for Ringo Scarlet (Table 31). In the other cultivar, Rosita, the mean germination resistance values varied widely between the scarified and unscarified seed, 31.39 to 121.20 hours, respectively.

Cultivar differences were significant; but treatment differences were highly significant by analysis of variance (Table 31). In the scarified versus unscarified germination tests, it appeared that scarification is required to increase the germination percent and decrease the germination resistance values of Ringo Scarlet and Rosita seed.

There is a dormancy in F1 hybrid geranium seed that is broken with seed scarification. Hand clipping, mechanical clipping and acid scarification, are all satisfactory methods of increasing the germination percents as reported by Fries (1966), Heit (1971) and Barna (1979).

Table 31. Mean germination percent and mean germination resistance value in hours for seed of 2 cultivars, Rosita and Ringo Scarlet, germinated unscarified and scarified (clipped).

Cultivar	Mean Germination Percent	Mean Germination Resistance Value (hours)
Rosita		
Unscarified	23.33 a[z]	121.20
Scarified	98.33 d	31.39
Ringo Scarlet		
Unscarified	55.00 b	195.62
Scarified	71.67 c	85.79
Treatment Means		
Unscarified	39.17 a[y]	158.41 a[x]
Scarified	85.00 b	58.59 b

[z] mean germination percents differ significantly as determined by Duncan's New Multiple Range Test (0.01).

[y] mean germination percents differ significantly as determined by analysis of variance (0.01).

[x] mean germination resistance values differ significantly as determined by analysis of variance (0.01).

Thiram Treated Versus Untreated Seed

Thiram is a fungicide which is used as a seed protectorant. Commercially treated and untreated seed of individual cultivars was used in many of the experiments - temperature, media and media moisture content. These will be now discussed.

Experiment - Thiram Treated Versus Untreated Seed

Germination Percent. The treatments did not significantly differ between the five cultivars for thiram treated and untreated seed (Table 32). Cherie and Showgirl differed and this cultivar difference was significant. There were highly significant differences between treatments x cultivars (Appendix Table 11) by analysis of variance. Thiram treatment increased the germination percent of seed of Sprinter Scarlet, while thiram treatment decreased the germination percent of seed of Knockout. Similar seed germination percents were found in thiram treated and untreated seed of the other 3 cultivars.

Germination Rate. The germination resistance values for treatments did not significantly differ by analysis of variance (Table 32), while there was a highly significant difference between cultivars (Table 32). Knockout, Showgirl, Sprinter Scarlet and Sprinter White were statistically similar, while Cherie was different.

Thus, there was in this experiment no difference in thiram treated or untreated seed in both the germination percent and the germination resistance value. However, there were differences in the interaction of treatments and cultivars in the germination percents. Cultivar differences will be discussed later.

Table 32. Mean germination percent and mean germination resistance value in hours of thiram treated and untreated seed for 5 cultivars.

Cultivar and Treatment	Mean Germination Percent	Mean Germination Resistance Value (hours)
Cherie		
Untreated	98.33[z]	83.29[z]
Treated	98.33	80.34
Knockout		
Untreated	98.33	53.24
Treated	83.33	55.66
Showgirl		
Untreated	88.33	54.14
Treated	90.00	45.75
Sprinter Scarlet		
Untreated	88.33	47.68
Treated	98.33	49.52
Sprinter White		
Untreated	96.67	68.22
Treated	95.00	55.06
Cultivar Means for Treated and Untreated Seed		
Cherie	98.33 a[y]	81.82 b[x]
Knockout	90.83 ab	54.45 a
Showgirl	89.17 b	49.95 a
Sprinter Scarlet	93.33 ab	48.60 a
Sprinter White	95.83 ab	61.64 a

[z] mean germination percents and mean germination resistance values do not differ significantly as determined by analyses of variance.

[y] cultivar germination percent means, for thiram treated and untreated seed, followed by the same letter do not differ significantly as determined by Duncan's New Multiple Range Test (0.05).

[x] cultivar germination resistance value means, for thiram treated and untreated seed, followed by the same letter do not differ significantly as determined by Duncan's New Multiple Range Test (0.01).

Experiment - Temperature

Germination Percent. Neither temperature differences nor the difference between thiram treated and untreated seed significantly affected the germination percent (Table 33). For the 3 cultivars, Bright Eyes, Cherry Glow and Sprinter Deep Red, the germination percents were statistically similar; but Sprinter Salmon differed significantly (Table 34), using the unpaired t test at the 1% level of significance. The interaction of cultivars x treatments was highly significant by analysis of variance (Appendix Table 12). According to the data in Table 33, there were no statistical differences between thiram treated and untreated seed of each cultivar, but Bright Eyes and Cherry Glow, (both treated and untreated) and Sprinter Deep Red (untreated) were similar, while Bright Eyes (untreated), Cherry Glow (treated), Sprinter Deep Red (treated) and Sprinter Salmon (untreated and treated) were similar.

Germination Rate. With the germination resistance value, the temperatures (Table 33), cultivars (Table 34), treatments (Table 33) and cultivars x treatments (Appendix Table 13) were all highly significant by analysis of variance. Treatment with thiram increased the germination resistance values in the cultivar, Sprinter Salmon, in 25.5^{o}C and day/night fluctuating temperature regimes. Conversely the germination resistance values were decreased for Sprinter Deep Red in the same temperature regimes. The germination resistance values were decreased for thiram treated seed of Bright Eyes in the 4 temperatures regimes, whereas there was no thiram effect on Cherry Glow in any of the 4 temperature regimes. Overall, the germination resistance value was decreased for

Table 33. Comparison of mean germination percent and mean germination resistance value in hours of 4 cultivars with thiram treated and untreated seed.

	Mean Germination Percent					Mean Germination Resistance Value (hours)				
	Temperature (^{o}C)									
Cultivars	14.5	20.0	25.5	Day/night Fluctuating	Mean	14.5	20.0	25.5	Day/night Fluctuating	Mean
Bright Eyes										
Untreated	96.67	95.00	95.00	93.33	95.00 abc[z]	70.12	36.29	50.26	51.02	51.92 bc[z]
Treated	100.00	100.00	90.00	98.33	97.73 a	57.80	27.58	40.34	25.87	37.67 a
Cherry Glow										
Untreated	98.33	93.33	96.67	96.67	96.25 ab	67.04	37.50	38.41	33.15	44.03 ab
Treated	90.00	93.33	96.67	93.33	93.33 abc	71.12	41.64	40.88	36.35	47.50 b
Sprinter Deep Red										
Untreated	95.00	95.00	97.50	96.67	95.91 ab	62.54	28.60	61.58	57.30	51.68 bc
Treated	90.00	93.33	92.50	95.00	92.73 bc	56.08	30.00	32.10	26.16	36.45 a
Sprinter Salmon										
Untreated	93.33	91.67	82.50	90.00	90.00 c	69.79	45.11	47.49	46.50	52.65 b
Treated	95.00	85.00	90.00	86.67	90.00 c	71.23	40.33	58.50	67.22	59.39 c
Mean	94.79[y]	93.33[y]	93.16[y]	93.75[y]		65.92 c[x]	36.91 a[x]	45.72 b[x]	45.95 ab[x]	

[z] values in columns followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

[y] mean germination percents do not differ significantly as determined by analysis of variance.

[x] mean germination resistance values for each temperature followed by the same letter do not differ significantly as determined by the unpaired t test.

Table 34. Mean germination percent and mean germination resistance value in hours for 4 cultivars for 4 temperature regimes[z].

Cultivar	Mean Germination Percent	Mean Germination Resistance Value (hours)
Bright Eyes	96.30 a[y]	45.11 a[x]
Cherry Glow	94.79 a	45.75 a
Sprinter Deep Red	94.32 a	44.06 a
Sprinter Salmon	89.55 b	56.93 b

[z] temperature regimes were: 14.5°, 20.0° and 25.5°C and day/night fluctuating temperature (29.4° to 17.2°C).

[y] mean germination percents followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

[x] mean germination resistance value followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

thiram treated seed of Bright Eyes and Sprinter Deep Red, whereas the germination resistance value was increased for Sprinter Salmon (Table 33). Thus thiram treatment did affect the germination resistance values of the seed. Cultivar differences will be discussed later.

Experiment - Media

In the media trials, a separate analysis of variance of thiram treated versus untreated seed was conducted. The media germination trials were conducted on 2 dates and the differences (Tables 35 and 36) between the 2 trials will be discussed under germination rhythms.

Germination Percent

a. Trial I

The differences between the treatments were highly significant (Table 37). Thiram treatment decreased the germination percent of the cultivar, Knockout, while thiram treatment did not affect seed of the cultivar, Cherie. The differences between media (Table 38) and between cultivars (Table 37) were not significant. The interaction of cultivars x treatments was significant by analysis of variance (Appendix Table 14).

b. Trial II

The differences between the cultivars were not significant (Table 39). Thiram treatment increased the germination percent for the cultivar, Sprinter Scarlet, while thiram treatment did not affect seed of the cultivar, Sprinter White. Media (Table 38), treatments (Table 39), media x treatments, cultivars x treatments and media x cultivars x treatments (Appendix Table 15) were highly significant but media x cultivars was significant by analysis of variance. Media, media x

Table 35. Mean germination percent and mean germination resistance value in hours on 6 media, for cultivars, Cherie and Knockout, thiram treated and untreated seed, media trial I.

	Mean Germination Percent				Mean Germination Resistance Value (hours)			
Cultivar	Cherie		Knockout		Cherie		Knockout	
Media	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
Filter Paper	100	95	100	85	70.80	61.26	42.00	30.35
Perlite	95	95	100	75	52.42	54.32	24.00	58.40
Vermiculite	100	100	95	70	49.80	48.60	24.00	45.43
Peat Moss	85	100	100	100	48.00	54.60	45.00	28.80
Zorb-all	90	95	100	80	53.33	50.53	24.00	33.00
Sand	100	85	90	55	64.20	76.94	24.00	53.45

Table 36. Mean germination percent and mean germination resistance value in hours on 6 media, for cultivars, Sprinter Scarlet and Sprinter White, thiram treated and untreated seed, media trial II.

	Mean Germination Percent						Mean Germination Resistance Value (hours)					
Cultivar	Sprinter Scarlet		Sprinter White		Mean		Sprinter Scarlet		Sprinter White		Mean	
Media	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
Filter paper	80.0	90.0	95.0	95.0	87.50	92.50	38.25	33.33	72.63	56.21	55.44	44.77
Perlite	80.0	97.5	92.5	95.0	86.25	96.25	48.38	33.60	65.53	49.90	56.96	41.75
Vermiculite	92.5	97.5	95.0	92.5	93.75	95.00	52.00	33.60	76.60	61.35	64.30	47.48
Peat moss	85.0	100.0	92.5	100.0	88.75	100.00	78.00	57.43	88.92	55.80	83.46	56.62
Zorb-all	85.0	97.5	87.5	95.0	86.25	96.25	44.25	43.12	80.88	64.03	62.57	53.58
Sand	85.0	95.0	87.5	87.5	86.25	91.25	32.34	34.10	71.13	49.84	51.74	41.97

Table 37. Mean germination percent and mean germination resistance value in hours by cultivar and thiram treatment for 2 cultivars on 6 media, trial I.

Cultivar and Treatment	Mean Germination Percent	Mean Germination Resistance Value (hours)
Cherie		
Untreated	95.00 a[z]	56.43
Treated	95.00 a	57.71
Knockout		
Untreated	97.50 a	30.50
Treated	77.50 b	41.57
Cultivar Means		
Cherie	95.00	57.07 b[y]
Knockout	87.50	36.04 a
Treatment Means		
Untreated	96.25 a[x]	43.46[v]
Treated	86.25 b	49.64

z mean germination percents followed by the same letter do not differ significantly as determined by Duncan's New Multiple Range Test (0.01).

y mean germination resistance values differ significantly as determined by analysis of variance (0.01).

x mean germination percents differ significantly as determined by analysis of variance (0.01).

v mean germination resistance values do not differ significantly as determined by analysis of variance.

Table 38. Mean germination percent and mean germination resistance value in hours for media trial I and II using thiram treated and untreated seed.

	Mean Germination Percent		Mean Germination Resistance Value (hours)	
Media	Trial I	Trial II	Trial I	Trial II
Filter paper	95.00[z]	90.00 ab[y]	51.10[z]	49.79 a[x]
Perlite	91.25	91.25 ab	47.29	49.35 a
Vermiculite	91.25	94.38 a	41.96	55.82 a
Peat moss	96.25	94.38 a	44.10	70.04 b
Zorb-all	91.25	91.25 ab	40.22	58.09 ab
Sand	82.50	88.75 b	43.75	46.85 a

[z] mean germination percents, trial I, and mean germination resistance values, trial I, do not differ significantly as determined by analyses of variance.

[y] mean germination percents followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

[x] mean germination resistance values followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

Table 39. Mean germination percent and mean germination resistance value in hours by cultivars and thiram treatment for 2 cultivars on 6 media, trial II.

Cultivar and Treatment	Mean Germination Percent	Mean Germination Resistance Value (hours)
Sprinter Scarlet		
Untreated	85.00 c[z]	49.83 b[z]
Treated	96.82 a	39.68 a
Sprinter White		
Untreated	91.36 b	76.25 d
Treated	94.09 ab	56.09 c
Cultivar Means		
Sprinter Scarlet	90.91[y]	44.76 a[x]
Sprinter White	92.73	66.17 b
Treatment Means		
Untreated	88.18 a[x]	63.04[y]
Treated	95.45 b	47.88

[z] values in columns followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

[y] do not differ significantly as determined by analysis of variance.

[x] values in columns followed by the same letter do not differ significantly as determined by analysis of variance (0.01).

cultivars, media x treatments and cultivars x treatment differences were due to hypocotyl fractures.

Hypocotyl Fracturing. Of Sprinter Scarlet, untreated seed, 8.64% had separated radicles and cotyledons (hypocotyl fractures) upon germination, while 1.82% hypocotyl fracturing occurred in Sprinter Scarlet, thiram treated seed. Hypocotyl fracturing will be discussed later.

Germination Rate

a. Trial I

Media and treatment were not significant in trial I (Table 38 and 37) for the germination resistance values; however, there was a highly significant difference between cultivars (Table 37), which will be discussed later.

b. Trial II

There were differences in the germination resistance values in trial II. The germination resistance value was increased in peat moss for thiram treated and untreated seed of Sprinter Scarlet. Sprinter White seed, both treated and untreated, germinated with higher germination resistance values on all the media than did Sprinter Scarlet seed, both treated and untreated. These values were: 56.09, 76.25, 29.68 and 49.83 hours, respectively (Table 39). Thiram decreased the germination resistance values, except for Sprinter Scarlet seed on sand and on Zorb-all where thiram treatment had no effect. The difference in the germination resistance values between the 2 cultivars was highly significant. By analysis of variance, differences between treatments and between media were highly significant.

Thus, in media trial I, thiram treatment significantly affected the germination percents, but not the germination resistance values. In trial II, thiram treatment significantly affected the germination resistance values and percents.

Experiment - Moisture Content of Media

Germination Percent. The differences between the moisture content of the media and between treatments did not differ significantly by analysis of variance of the germination percents (Table 40).

Germination Rate. Thiram treatment in this trial had no significant effect (Table 40); but the differences between the moisture contents of the media were significant.

Thus, in this trial, thiram treatment of the seed had no effect on the germination resistance values or the germination percents.

Treatment Summary

Germination Percent. According to the data in Table 41, this is what can be observed. Thiram treatment was highly significant in media trial I and II and not significant in the other 3 trials. In media trial I, the germination percents were decreased with thiram, for the seed of 1 cultivar, whereas in media trial II, the germination percents were increased with thiram treatment, for the seed of 1 cultivar.

Germination Rate. According to the data in Table 42, this is what can be observed. Thiram treatment was highly significant in the temperature trials and in media trial II, and not signficant in the other 3 trials.

Table 40. Mean germination percent and mean germination resistance value in hours for Sprinter White, thiram treated and untreated seed.

Treatment and Water Content	Mean Germination Percent	Mean Germination Resistance Value (hours)
Untreated		
Filter paper (6 ml H_2O)	95.00	72.63
Sand (13 ml/65 g)	95.00	92.20
Sand (10 ml/65 g)	97.50	98.43
Treated		
Filter paper (6 ml H_2O)	95.00	54.95
Sand (13 ml/65 g)	87.50	70.10
Sand (10 ml/65 g)	85.00	129.47
Treatment Means		
Untreated	96.00[z]	90.78[z]
Treated	88.00	90.82
Moisture Content of Media Means		
Filter paper (6 ml H_2O)	95.00[z]	63.79 a[y]
Sand (13 ml/65 g)	91.25	81.15 a
Sand (10 ml/65 g)	91.25	113.95 b

[z] do not differ significantly as determined by analysis of variance.

[y] mean germination resistance values followed by the same letter do not differ significantly as determined by the unpaired t test (0.05).

Table 41. Summary of the thiram treated versus untreated seed trials for germination percent.

Trial	Temperature	Cultivar	Thiram Treatment	Media	Water Content
Thiram Treatment	n/a	*	ns	n/a	n/a
Temperature	ns	**	ns	n/a	n/a
Media					
Trial I	n/a	ns	**	ns	n/a
Trial II	n/a	ns	**	**	n/a
Water Content of Medium	n/a	n/a	ns	n/a	ns

** - highly significant by analysis of variance.

* - significant by analysis of variance.

ns - nonsignificant by analysis of variance.

n/a - not applicable.

Table 42. Summary of the thiram treated versus untreated seed trials for germination resistance value in hours.

Trial	Temperature	Cultivar	Thiram Treatment	Media	Water Content
Thiram Treatment	n/a	**	ns	n/a	n/a
Temperature	**	**	**	n/a	n/a
Media					
Trial I	n/a	**	ns	ns	n/a
Trial II	n/a	**	**	**	n/a
Water Content of Medium	n/a	n/a	ns	n/a	*

** - highly significant by analysis of variance.

* - significant by analysis of variance.

ns - nonsignificant by analysis of variance.

n/a - not applicable.

In both trials, the germination resistance values were decreased with thiram treatment. In 3 of 4 cultivars in the media trials, the germination resistance values for seed treated with thiram were decreased on peat moss. This represented a reversal in the trend that occurred with untreated seeds and peat moss.

If thiram is applied to geranium seed, as previously discussed, then the improvement of the germination resistance values may have been due to the method of application (a soak) rather than due to any effect of thiram. Geranium seed is totally imbibed in as short a time period as 8 hours, according to Randolph (1971); therefore, if the thiram were applied in a soak this may have initiated some of the germination processes and, in some cases, the treated seed could have had a 'head start' over untreated seed. Thus, treatment of the seed with thiram can have a varied effect on the germination percent and the germination resistance value.

Longdon, 1973, stated that treatment of seeds improved the rate of seedling emergence and this did occur. Maude, 1973, indicated that in Brassica seed lots, a decrease in germination could occur. This effect was not consistent and this was shown in media trial I to be the case. In these trials thiram had no effect in more than one half of the trials and thus any thiram effect on geranium seeds would appear not to be consistent.

Cultivar Summary

According to the data in Tables 41 and 42, there were cultivar differences in the germination percents in 2 trials and in the germination resistance values in 2 trials and these differences will be discussed later.

Storage Experiment

Commercially scarified and unscarified seed of 2 cultivars, Rosita and Ringo Scarlet, was received from the same source on November 22, 1979. This seed was in transit at least a month and was supposed to be of the 1979 crop year. The seed would have had to have been scarified in October, 1979 or earlier.

Germination Percent

No pattern was established in the germination percents of Rosita or Ringo Scarlet seed, stored scarified or unscarified. An analysis of variance indicated there were no significant differences between dates and treatments. However, cultivar differences were significant.

Hypocotyl Fracturing

During the storage trials, up to 12 months from the original scarification, large numbers of Ringo Scarlet seed had hypocotyl fracturing. After a storage period of one year, germination trials of Ringo Scarlet and Rosita produced no hypocotyl fractures. It appeared that the number of hypocotyl fractures decreased with age and thus the actual germination percent remained consistently high for Rosita and Ringo Scarlet. Hypocotyl fractures will be discussed in more detail later.

Deteriorated Seed

The numbers of deteriorated seed varied from 0 to 5 seed (0 to 2.08%) per trial. The maximum number for the 3 samples (60 seeds) of one cultivar and treatment was 2 or 3.33%. According to the data in Table 43, similar numbers were found in stored scarified and unscarified seed with the greatest number found in Rosita stored unscarified seed.

Table 43. Number and percent of deteriorated seed found in the storage trials by cultivar and by treatment.

Cultivar and Treatment	Number of Deteriorated Seed	Percent of Total Seed All Trials
Rosita		
Stored Unscarified	11	0.80
Stored Scarified	8	0.58
Ringo Scarlet		
Stored Unscarified	2	0.14
Stored Scarified	6	0.43
Total	27	0.49

Less than 1% deteriorated seed was found in the total number of samples.

Germination Rate

For Rosita and Ringo Scarlet seed, stored scarified and unscarified, the germination resistance values appeared to increase with time (Table 44), although no pattern was established between individual dates. Initially, the scarified and unscarified seed germinated with similar germination resistance values for Rosita, but within a month the germination resistance values for stored unscarified seed increased and remained higher throughout the trials. Initially, Ringo Scarlet seed showed a difference and the germination resistance values remained higher for the stored unscarified seed throughout the trials.

An analysis of variance of the germination resistance values with time (Table 44), cultivars, treatments and all 2 way interactions indicated all were highly significant (Appendix Table 16). With 16 months storage, the germination resistance value increased; these increases were significant. The range in mean germination resistance values was 24.20, 21.40, 41.00 and 19.20 hours for Rosita seed stored unscarified and scarified and Ringo Scarlet seed stored unscarified and scarified, respectively.

In these trials the germination resistance value was less for stored scarified seed than for stored unscarified seed in most trials, for both cultivars. Seed is scarified to remove part of the seed coat so that gases and moisture may permeate the seed coat more easily. It may have been that oxygen and moisture penetrated the seed coats of the scarified seed, thus 'advancing' some of the germination processes over those of unscarified seed, as respiration in a scarified seed should be

Table 44. Effect of storage time on germination resistance values of Rosita and Ringo Scarlet seed.[z]

Mean Germination Resistance Value (hours)						
Cultivar		Rosita		Ringo Scarlet		
Starting Date	Trial Number	Stored Unscarified	Stored Scarified	Stored Unscarified	Stored Scarified	Mean
Nov. 26/79	Prestorage	42.17	38.00	50.80	36.40	41.84 efg[y]
Dec. 10	1	26.60	25.26	36.40	29.40	29.42 a
Dec. 24	2	38.20	28.12	57.80	28.03	38.04 cdef
Jan. 7/80	3	45.60	25.20	41.40	31.60	35.95 bcde
Jan. 21	4	31.22	24.60	36.15	27.00	29.74 a
Feb. 4	5	32.40	24.00	49.07	26.60	33.02 abc
Feb. 18	6	35.40	24.63	42.20	24.60	31.71 ab
Mar. 3	7	30.76	24.00	46.60	27.20	32.11 abc
Mar. 17	8	30.00	26.47	57.20	29.24	35.75 bcde
Mar. 31	9	38.60	30.00	48.00	32.69	37.32 bcde
Apr. 14	10	50.02	43.02	55.74	43.20	47.93 h
Apr. 28	11	35.74	25.20	53.31	34.79	37.26 bcde
May 12	12	29.73	25.80	56.80	24.00	34.08 abcd
May 26	13	46.52	26.40	50.80	28.80	38.13 cdef
June 9	14	46.80	30.32	74.40	41.57	48.27 h
June 23	15	30.28	28.00	49.00	28.48	39.94 def
Oct. 16	16	37.42	24.00	29.00	25.60	29.01 a
Nov. 5	17	47.27	35.26	48.33	31.60	40.62 efg
Nov. 19	18	45.80	38.60	44.23	32.40	40.26 def
Jan. 5/81	19	39.48	37.30	34.40	32.20	35.85 bcde
Jan. 19	20	52.48	39.06	33.40	38.60	40.89 efg
Feb. 2	21	49.44	44.40	45.00	37.60	44.11 efgh
Feb. 16	22	50.80	45.40	49.80	39.60	46.40 gh

[z] mean germination resistance values are derived from 3 samples of 20 seed each. One half of the samples were scarified before storage.

[y] mean germination resistance values followed by the same letter do not differ significantly as determined by Duncan's New Multiple Range Test (0.01).

faster than in an unscarified seed due to an increased oxygen supply. However, the unscarified seed was under a reduced supply situation until clipping (scarification) at which time oxygen then had to be distributed to all the surfaces of the seed. Thus, the previously scarified seed may have been given a 'head start'.

The germination resistance values were higher with time and this would help to account for some of the differences between time x cultivars and time x treatments but cultivars and treatments did react with the storage periods to produce different results from germination trial to germination trial.

Although the germination resistance value increased with time and this increase was significant, the grower would still obtain high germination percentages. The grower could use the seed. A loss in vigor had occurred, but as yet this loss did not affect the use of the seed for most growers.

Storage of Other Geranium Seed

The seed of 12 of the cultivars (Table 45) used in the fall germination experiment had been acquired in February and March of 1979. This seed would have been scarified prior to those dates. The germination percents were more than 88% for 11 (91.67%) of the cultivars. Thus, the germination percent appeared to remain fairly high for seed that had been scarified 7 months earlier.

Colorama, a F2, was low in the fall (Table 7) and again low in the spring (Table 8) germination trials for germination percents using seed which had been on hand and recently acquired seed respectively.

Cultivar differences between germination percents (Tables 7 and 8)

Table 45. Mean germination percent and mean germination resistance value in hours of scarified seed stored for at least 7 months.

Cultivar	Mean Germination Percent	Mean Germination Resistance Value (hours)
Cherie Improved	100.00 a[z]	98.00 c[z]
Colorama - F2	67.30 b	101.02 c
Ice Queen	100.00 a	72.00 abc
Knockout	88.90 ab	84.75 abc
Mustang	93.05 ab	49.80 a
Ringo Rose	100.00 a	51.15 a
Ringo Salmon	89.40 ab	85.71 bc
Ringo Scarlet	97.00 a	74.30 abc
Sprinter Mixed	100.00 a	84.00 abc
Rosita '80	100.00 a	61.33 ab
Rosita	94.65 a	97.16 c
Sprinter Scarlet	95.00 a	91.17 bc

[z] mean germination percents followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

[y] mean germination resistance values followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

and germination resistance values (Tables 10 and 11) for both the spring and fall germination trials were highly significant by analyses of variance. Thus it would appear that germination percents are a cultivar and seed lot characteristic and not a characteristic of geranium seed in particular.

The findings of the storage experiment with Rosita and Ringo Scarlet seed and with the above cultivars indicated that scarified geranium seed had a longer life span than that indicated by Bass (1979) for geranium seed stored under unknown conditions. The seed may be scarified and held safely for more than 1 year at approximately 5^{o}C and a 50% relative humidity.

Hypocotyl Fracturing and Emergence

In most of the experiments, some seed would germinate and upon examination the radicle and cotyledons would be separated (hypocotyl fractured), actually as the radicle emerged from the seed coat (germination) the hypocotyl would fracture. The break usually occurred at the base of the seed where the radicle folded over to lie on the cotyledons (Figure 11). The effect was found in the spring and fall cultivar trials, temperature, media, moisture content of the media, thiram treated versus untreated seed and storage experiments. Although hypocotyl fracturing occurred in many cultivars, there were several cultivars in which this appeared to occur in greater numbers.

Experiment - Cultivar Germination Trials - Spring and Fall

According to the data in Table 46, 34 of 67 (50.75%) cultivars showed hypocotyl fracturing in the spring germination trials. Twenty of 36 (55.56%) cultivars showed hypocotyl fracturing in the fall germi-

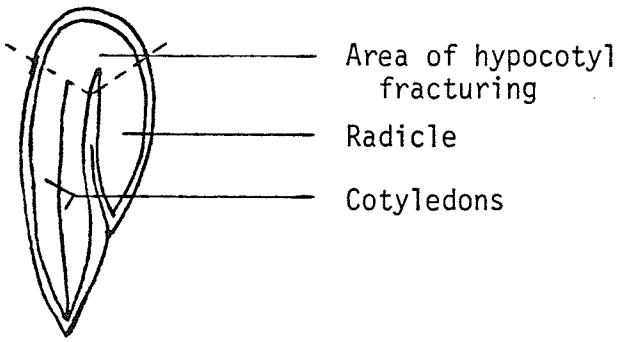

Figure 11. Hypocotyl fracturing of the geranium seed.

Table 46. Number and percent of hypocotyl fractures for the cultivars in the spring and fall germination trials.

Cultivar	Spring[z]		Fall[y]	
	Number of Hypocotyl Fractures	Percent of Total Seed Used	Number of Hypocotyl Fractures	Percent of Total Seed Used
Fire Flash	9	11.25	n/u	--
Red Express	9	11.25	1	1.00
Capri Deep Red	9	11.25	n/u	--
Carefree Scarlet	7	8.75	10	9.71
Empress Red	7	8.75	n/u	--
Salmon Flash	6	7.50	n/u	--
Empress Salmon	5	6.25	n/u	--
Encounter Red	5	6.25	2	2.00
Marathon	4	3.33	n/u	--
Paintbox Mixed	4	5.00	n/u	--
Red Delicious - F2	4	5.00	n/u	--
Deep Rose Flash	4	5.00	n/u	--
Surefire	4	5.00	n/u	--
Red Apple - F2	4	5.00	n/u	--
Carefree Light Salmon	4	5.00	n/u	--
Orange Punch	3	3.75	0	0
Dynamite	3	3.75	n/u	--
Salmon Express	3	3.75	n/u	--
Colorama - F2	3	3.75	9	8.41
Capri White	2	2.50	n/u	--
Love Song	2	2.50	3	2.94
Miniskirt Mixed	2	16.67	n/u	--
Vulcan	2	5.00	n/u	--
Encounter Salmon	1	1.25	2	2.00
Capri Brick Red	1	1.25	n/u	--
Red Champion	1	3.45	6	6.00
Scarlet Flash	1	1.25	6	6.25
Sprinter Deep Red	1	2.50	n/u	--
Sprinter Scarlet	1	0.83	2	2.00
Friendship	1	1.25	2	2.30
Gremlin Coral	1	1.25	n/u	--
Del Greco Mixed	1	5.00	n/u	--
Firecracker	1	10.00	2	1.98
Snow White	1	2.50	n/u	--
New Era Medium Salmon	n/u	--	3	3.13
Nittany Lion Red	n/u	--	2	1.85
Ringo Scarlet	0	0	2	2.00
Sooner Salmon	0	0	2	1.87
New Era Bright Red	n/u	--	2	2.00
Mustang	0	0	1	3.13
Rose Pink with White Eye	n/u	--	1	0.98
Rosita	0	0	1	0.89
Sprinter White	0	0	1	1.00

[z] No hypocotyl fracturing occurred in the other 28 cultivars used in the spring germination trials.

[y] No hypocotyl fracturing occurred in the other 15 cultivars used in the fall germination trials.

n/u - not used.

nation trials. Eleven cultivars with hypocotyl fractures were common to both the spring and fall germination trials.

Experiment - Temperature

The amount of hypocotyl fracturing varied with the temperature (Table 47). The greatest damage occurred at 20°C (2.50%) and the least at 25.5°C (0.67%). In those cultivars that showed a high level of hypocotyl fracturing there may be an effect of temperature. Hypocotyl fracturing appeared to affect greatly Ringo Scarlet seed (Table 48), accounting for 58.06% of the total hypocotyl fractures that occurred in the temperature trials. In 14.5° and 20.0°C temperature trials, it would appear that effect of temperature on hypocotyl fracturing would be of an economic importance. No fractures occurred in 25.5°C trials for Ringo Scarlet and perhaps with the tendency for hypocotyl fracturing that Ringo Scarlet had, it might be best to germinate the seed at 25.5°C.

Experiment - Media

a. Trial I. In media trial I, only Paintbox Mixed seed was greatly affected by hypocotyl fracturing. There was 6.67% (Table 49) fracturing, with a mean germination percent of 72.50. The number of hypocotyl fractures in the other cultivars was low, averaging 0 to 2.50%. In the media, the highest number of hypocotyl fractures was found on filter paper and sand (3.33%) and the lowest on perlite and peat moss (0.83%). Of the total seed used, there was 2.22% hypocotyl fracturing.

b. Trial II. In media trial II, seed of 2 cultivars was greatly affected by hypocotyl fracturing. These were Ringo Scarlet with 9.44%

Table 47. Number and percent of hypocotyl fractures by temperature regime for 10 cultivars.

Temperature (°C)	Number of Hypocotyl Fractures	Percent of Total Seed
14.5	20	2.00
20.0	25	2.50
25.5	6	0.67
Fluctuating day/night	11	1.10
Total	62	2.28

Table 48. Number and percent of hypocotyl fractures and percent germination by temperature regime for Ringo Scarlet.

Temperature (°C)	Number of Hypocotyl Fractures	Percent[z] of Total Fractures	Percent of Seed with Fractures	Germination Percent without Fractures
14.5	15	75.00	18.75	81.25
20.0	18	72.00	22.50	75.00
25.5	0	0	0	98.75
Fluctuating day/night	3	27.27	3.75	95.00
Total	36	58.06	11.25	87.50

[z] percent of total number of hypocotyl fractures that occurred in each temperature.

Table 49. Number and percent of hypocotyl fractures for 6 cultivars on 6 media, trial I.

	Hypocotyl Fractures							
Cultivar	Paintbox Mixed	Salmon Express	Snowdon	Knockout	Cherie	Sprinter Scarlet	Number per Medium	Percent per Medium
Media								
Filter Paper								
Number	2	1	1	0	0	0	4	--
Percent	10.00	5.00	5.00	0	0	0	--	3.33
Perlite								
Number	1	0	0	0	0	0	1	--
Percent	5.00	0	0	0	0	0	--	0.83
Vermiculite								
Number	1	0	1	1	0	0	3	--
Percent	5.00	0	5.00	5.00	0	0	--	2.50
Peat Moss								
Number	0	1	0	0	0	0	1	--
Percent	0	5.00	0	0	0	0	--	0.83
Zorb-all								
Number	2	1	0	0	0	0	3	--
Percent	10.00	5.00	0	0	0	0	--	2.50
Sand								
Number	2	0	1	1	0	0	4	--
Percent	10.00	0	5.00	5.00	0	0	--	3.33
Totals								
Number	8	3	3	2	0	0	16	
Percent	6.67	2.50	2.50	1.67	0	0	2.22	

(Table 50) of the seed with hypocotyl fractures and Sprinter Scarlet untreated seed with 8.64% hypocotyl fractures. The germination percent for Ringo Scarlet was 90.56, while there was an 85.00% germination for Sprinter Scarlet. The number of hypocotyl fractures in the other cultivars was low. In the media, the highest number of hypocotyl fractures was found on filter paper (5.00%) and the lowest on Zorb-all (1.43%). Of the total seed used, there was 2.73% hypocotyl fracturing.

Experiment - Moisture Content of Media

The amount of hypocotyl fracturing varied with the water contents of the media.

a. Trial I. In the water content of the media trial I, 4 (5.00%) hypocotyl fractures (Table 51) were found in the controls, on filter paper. At 13 ml of water in the sand, there were 7 (4.38%) hypocotyl fractures, while at 10 ml of water, there was 1 (0.63%) hypocotyl fracture. There were 6 (6.00%) fractures in seed of Ringo Scarlet.

b. Trial II. Similar results were found in trial II (Table 52). Of 120 seed in 13 ml of water, there were 9 (7.50%) hypocotyl fractures. In 10 ml of water, there was 1 (0.83%) hypocotyl fracture. All fracturing occurred in the cultivar, Ringo Scarlet.

The amount of hypocotyl fracturing decreased with decreasing moisture content of the media.

Experiment - Thiram Treated Versus Untreated Seed

Hypocotyl fracturing occurred in the thiram treated versus untreated seed experiment. Hypocotyl fracturing was found in Showgirl - treated seed (5.00%) and in Sprinter Scarlet - untreated (6.67%) and treated

Table 50. Number and percent of hypocotyl fractures for 6 cultivars on 6 media, trial II.

	Hypocotyl Fractures							
Cultivar[z]	Ringo Scarlet	Snowdon	Sprinter Scarlet Untreated	Sprinter Scarlet Treated	Sprinter White Untreated	Sprinter White Treated	Number per Medium	Percent per Medium
Media								
Filter Paper								
Number	3	1	3	2	0	0	9	--
Percent	15.00	5.00	15.00	10.00	0	0	--	5.00
Perlite								
Number	5	0	5	0	0	1	11	--
Percent	12.50	0	12.50	0	0	2.50	--	3.44
Vermiculite								
Number	2	2	2	0	0	0	6	--
Percent	5.00	5.00	5.00	0	0	0	--	1.88
Peat Moss								
Number	5	0	2	0	0	0	7	--
Percent	12.50	0	5.00	0	0	0	--	2.19
Zorb-all								
Number	1	0	3	0	0	0	4	--
Percent	5.00	0	7.50	0	0	0	--	1.43
Sand								
Number	1	2	4	2	1	0	10	--
Percent	5.00	5.00	10.00	5.00	5.00	0	--	3.33
Totals								
Number	17	5	19	4	1	1	47	
Percent	9.44	2.27	8.64	1.82	0.45	0.45	2.73	

[z] no hypocotyl fractures were found in Knockout or Rosita.

Table 51. Number and percent of hypocotyl fractures for 3 cultivars and 3 moisture regimes, trial I.

	Number of Hypocotyl Fractures		
Moisture Regimes	Filter paper (6 ml H_2O)	Sand (13 ml/65 g)	Sand (10 ml/65 g)
Cultivar			
Ringo Scarlet	4	5	1
Rosita	0	0	0
Sprinter White			
Untreated	0	0	0
Treated (thiram)	0	2	0
Total Number of Seed	80	160	160
Percent of Seed with Hypocotyl Fractures	5.00	4.38	0.63

Table 52. Number and percent of hypocotyl fractures for 2 cultivars and 3 moisture regimes, trial II.

	Number of Hypocotyl Fractures		
Moisture Regimes	Filter paper (6 ml H_2O)	Sand (13 ml/65 g)	Sand (10 ml/65 g)
Cultivar			
Rosita	0	0	0
Ringo Scarlet	2	9	1
Total Number of Seed	40	120	120
Percent of Seed with Hypocotyl Fractures	5.00	7.50	0.83

91.67%) seed. A total of 4 hypocotyl fractures was found in each of the treatments. Of the total seed used in the experiment, there was 1.33% hypocotyl fracturing.

Experiment - Storage Experiment

Hypocotyl fracturing was also found in the storage experiment in both of the cultivars, Rosita and Ringo Scarlet. It was not found in seed of Rosita which had been stored unscarified and clipped just prior to sowing. In Rosita seed, stored scarified, 0.58% of the total seed used had hypocotyl fractures (Table 53). In Ringo Scarlet seed, stored scarified, 3.99% of the total seed upon germination was fractured. Ringo Scarlet seed, stored unscarified, showed 6.45% hypocotyl fracturing. The percent of hypocotyl fracturing varied from 0 to 16.67% of 60 seed on individual sowing dates for Ringo Scarlet. The hypocotyl fracturing varied from 0 to 5.83%, on individual dates for the total of 240 seed (both cultivars) used on that date. An analysis of variance of the hypocotyl fractures indicated that only differences between cultivars were significant.

Although the numbers of hypocotyl fractures varied from sowing date to sowing date, the number of hypocotyl fractures did not increase with time. In fact, there was a dramatic decrease to nonoccurrence with storage of 1 year. It would appear that as the seed ages, susceptibility to damage occurring on rapid uptake of water decreased due to internal changes in the seed or that the seed moisture content increased in storage due to high relative humidity, so that the expansion of the seed was not quite so drastic as in younger seed.

Seed of the cultivar, Ringo Scarlet, was highly susceptible to

Table 53. Number of, percent of and percent range of hypocotyl fractures by cultivar and treatment in the storage experiment.

Cultivar and Treatment	Total of Number Hypocotyl Fractures	Percent of Total Seed Used	Percent Range		
Rosita					
Unscarified	0/1380	0	0	-	0
Scarified	8/1380	0.58	0	-	3.33
Ringo Scarlet					
Unscarified	89/1380	6.45	0	-	16.67
Scarified	55/1380	3.99	0	-	11.67

hypocotyl fracturing, whereas seed of several other cultivars, Paintbox Mixed, Sprinter Scarlet and Carefree Scarlet, was moderately susceptible to hypocotyl fracturing upon uptake of water. Moore (1973) stated that rapid uptake of water by localized embryo tissues could lead to fracture of tissues. The susceptibility to hypocotyl fracturing may have been enhanced as most of the germination experiments were conducted using saturated media. This factor might have helped to increase hypocotyl fracturing as water would be more available to the seed.

Ringo Scarlet seed in most of the experiments was hand clipped as was Rosita seed but in the latter case little or no hypocotyl fracturing occurred. Seed of several cultivars was received mechanically clipped and seed of some cultivars was overscarified. Overscarification was the description used for seed in which the cotyledons and/or radicle were visible; parts of the seed coat had been completely removed.

Of the cultivars tested, 11 (Table 54) were clipped and 13 overscarified; most showed hypocotyl fracturing. Forty-three cultivars were scarified and hypocotyl fractures occurred in 12. Increased availability of water due to modification of the seed coat appeared to lead to increased damage.

Although the degree of seed coat remaining could not be ascertained, the hypocotyl fractures found in those cultivars which were classified as scarified could have been due to the degree of scarification or to cultivar susceptibility. This injury was similar to that discussed by Moore (1973) and Dickson et al. (1973). Dickson et al. described transverse cracking of cotyledons in bean cultivars. McCollum (1953) indicated that transverse cotyledon cracking increased with increased seed

Table 54. Number and percent of cultivars with hypocotyl fractures by type and degree of seed scarification.

Scarification Classification	No. of Cultivars in Trials	No. of Cultivars with Hypocotyl Fractures	Percent of Cultivars with Hypocotyl Fractures
Clipped	11	10	90.91
Overscarified	13	12	92.31
Scarified	43	12	27.91

coat permeability and that there were susceptible cultivars. This appeared to be so with seed of the various cultivars of geraniums. There were susceptible cultivars, and increased seed coat permeability due to scarification seemed to lead to increased damage.

Although in bean cultivars the cotyledons were susceptible, in the geranium the point of juncture between the radicle and the cotyledons was the susceptible area. Upon dissection of the seed, it was noticed that a section of the seed coat which was connected to the outer seed coat encased the radicle (Figure 5), approximately one half the length of the radicle. It was difficult to remove this covering without causing hypocotyl fractures. This encasement may have added to or caused an increased number of hypocotyl fractures.

Cultivar Differences

In many of the germination trials there were cultivar differences in either the germination percents or the germination resistance values, several explanations could be advanced to explain those differences:

1. preharvest conditions such as weather and nutrition can affect the ability of seed to germinate,
2. harvesting, post harvest handling and storage conditions would affect the ability of seed to germinate.

The above 2 conditions could cause differences between seed lots and within a given lot of seed of the same cultivar, therefore, trials conducted with seed of the same cultivar may differ.

3. As cultivars are different, the ultimate potential of the seed of individual cultivars for germination percent and germination resistance value will vary due to differences in the genetic makeup of the seed.

Germination Rhythm

Seed of several species have been demonstrated to show germination peak period(s) throughout the year (Chepil 1946).

Experiment - Cultivar Germination Trails - Spring and Fall

This effect appeared to be found between the fall (Tables 7 and 10) and spring (Tables 8 and 11) germination trials, as there was a difference in the germination percent of the 29 cultivars. The difference was 4.99%, a significant difference. Twenty-five (86.21%) cultivars germinated at similar percents, while 4 differed. Only 1 cultivar was of the same seed lot in both trials - Red Champion. In the fall, the germination percent was 93.00; in the spring, the germination percent was 94.40.

The differences in germination percents between the fall and the spring germination trials could be due to seed lot difference as 13.79% of the cultivars varied.

There was a difference in the germination resistance values of the 29 cultivars in the spring and fall germination trials (Tables 11 and 10). Explanations can be advanced to explain the differences:

1. For each cultivar 2 seed lots were used except for Red Champion where one seed lot was used for both the spring and fall germination trial samples. Although different seed lots may differ, in this case 92.86% of the cultivars having 2 seed lots reacted in the same way.
2. For Red Champion, the fall germination resistance value was 82.25 hours; while the spring value was 33.00 hours, when the seed was 7 months older. The seed germinated at an increased rate in the spring. Therefore it would seem that some factor other than seed lot differences affected the germination resistance values. It would appear that spring

is the better time to germinate F1 hybrid geranium seed as in the spring there is a decreased germination resistance value. Seed germinates faster. This difference could be due to a seasonal peak in the germination rate - rhythm.

Experiment - Media

The media trials were started on May 12 and May 27, 1980. The germination percents (Table 55) for the 3 cultivars varied from date to date. Cultivar differences were highly significant. There was no significant difference between media by analysis of variance. The difference between the 2 dates was significant by analysis of variance. A higher percent of the seed germinated in the trial starting May 12, 1980. A greater percent of the seed of Sprinter Scarlet germinated in trial I, while the germination percents were similar for the other 2 cultivars in both trials.

The difference in the germination resistance values was highly significant for the dates (Table 55), media (Appendix Table 20) and cultivars by analysis of variance. With all the factors between the 2 trials constant except for the dates, no conclusion can be drawn except that the seed took longer to germinate during trial II, 14.23 to 19.04 hours longer per cultivar. Larger replicated trials with several cultivars would need to be conducted before a conclusion could be drawn as to whether this was a function of a germination rhythm or variability within seed lots. Cultivar and media differences have been previously discussed.

Table 55. Mean germination percent and mean germination resistance value for 3 cultivars in media trial I and II.

	Mean Germination Percent			Mean Germination Resistance Value (hours)		
Cultivar	Trial I	Trial II	Means	Trial I	Trial II	Means
Knockout	97.50	97.00	97.25 a[z]	30.50	44.73	37.62 a[y]
Sprinter Scarlet	97.50	85.00	91.25 ab	30.79	49.83	40.31 a
Snowdon	88.33	87.73	88.03 b	50.14	64.51	57.33 b
Means	94.44[x]	89.07[x]		37.15[v]	53.74[v]	

[z] mean germination percents followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

[y] mean germination resistance values followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

[x] mean germination percents differ significantly as determined by analysis of variance (0.05).

[v] mean germination resistance values differ significantly as determined by analysis of variance (0.01).

Experiment - Storage Experiment

At certain times of the year the time for germination to occur in the storage trials was longer. In the storage experiments there were several increases in the germination resistance values (Table 44) but no time pattern was established either for germination resistance values or germination percents. There was also no pattern in hypocotyl fracturing.

The experiments were not planned to determine periodicity. More trials would have to be conducted over a longer time period in order to determine if a seasonal periodicity in the germination percent and germination resistance value of geranium seed exist.

Field Trials

Cuttings were taken from seed produced stock plants of Rosita and Sprinter Scarlet and maintained in the greenhouse. According to the data in Table 56, 75.14% of the Sprinter Scarlet cuttings and 85.16% of the Rosita cuttings rooted.

Number of Flower Clusters per Row

Seed Plants Versus Cuttings. The number of flower clusters per row increased on the 2 dates for the 2 treatments of Rosita and Sprinter Scarlet (Table 57). According to the data in Table 58, the difference in the flower cluster number was similar within the 2 cultivars, Rosita and Sprinter Scarlet. The mean number of flower clusters per row for Rosita and Sprinter Scarlet was 104.65 and 122.38 (Table 59), respectively. Here, the difference was highly significant.

The seed plants produced fewer flower clusters, 85.25 per row (Table 59), while the greatest number were on the cuttings, 141.69, and

Table 56. Number and percent of rooted cuttings of Rosita and Sprinter Scarlet.

Cultivar	Number of Cuttings	Number Rooted	Percent Rooted
Rosita	256	218	85.16
Sprinter Scarlet	173	130	75.14

Table 57. Mean number of flower clusters per row and cultivar, comparison for 2 dates.

Cultivar	Flower Clusters per Row Date 1	Flower Clusters per Row Date 2	Mean Number of Flower Clusters per Row
Rosita - seed	58.50	95.50	77.00
Sprinter Scarlet - seed	78.00	109.00	93.50
Cardinal - clonal	102.25	108.75	105.50
Cherry Blossom - clonal	118.25	120.00	119.13
Rosita - cutting	113.75	150.50	132.13
Sprinter Scarlet - cutting	136.00	166.50	151.25

Table 58. Difference in the number of flower clusters between seed produced and cutting produced plants of Rosita and Sprinter Scarlet on 2 dates.

Cultivar	Mean Number of Flower Clusters per Row Date 1	Date 2
Rosita	55.25	55.00
Sprinter Scarlet	58.00	57.50

Table 59. Mean number of flower clusters by cultivar per row and by propagation method.

Cultivar	Number of Flower Clusters	Comparison of 4 Cultivars	Comparison of 2 Cultivars
Rosita	104.65	a[z]	a[y]
Sprinter Scarlet	122.38	b	b
Cherry Blossom	119.50	ab	
Cardinal	105.50	ab	
Propagation Method Means			
Seed	85.25	c[x]	b[y]
Cuttings	141.69	a	a
Clonal	112.31	b	

[z] mean number of flower clusters followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

[y] mean number of flower clusters differ significantly as determined by analysis of variance (0.01).

[x] mean number of flower clusters followed by the same letter do not differ significantly as determined by Duncan's New Multiple Range Test (0.01).

therefore showed the greatest colour in the field. The difference between the seed plants and the cuttings was highly significant. The plants continued to produced flowers, and the difference between the 2 dates, August 23 and September 20, was significant (Table 60).

The cuttings came from mature plants; the seed plants were produced from seed and thus went through a juvenile stage. Both the seed plants and the cuttings have an ultimate flower cluster potential and it appears that both grow to that potential at the same rate. It may have been that the potential had not been reached by either the seed produced plants or the cuttings. The difference between the plants might have been lessened if the growing season were longer.

Seed Plants Versus Cuttings Versus Clonal Cultivars. Similar numbers of flower clusters for both dates were found on the clonal cultivars. Cherry Blossom counts were 118.25 and 120, whereas the counts for Cardinal were 102.25 and 108.75 flower clusters per row of plants (Table 59). As the flower cluster counts were similar on both dates for the for the clonal cultivars, it would appear that the flower cluster potential had been reached by the clonal cultivars. The number of flower clusters increased from the first to the second date, for the seed produced plants and for the plants produced from cuttings.

There were highly significant differences between the cultivars (Table 59). Significantly fewer flower clusters were produced by Rosita than were produced by Sprinter Scarlet. Cultivar differences will be discussed later. Differences between propagation methods were highly significant. Cuttings (Figure 12) produced the most flowers (Table 59), followed by the clonal cultivars, followed by the seed plants. The

Table 60. Total number of flower clusters for two dates.

Date	Number of Flower Clusters for 4 Cultivars	Number of Flower Clusters for 2 Cultivars[y]
1	2,432[z]	1,550[z]
2	3,001	2,086

[z] number of flower clusters differ significantly as determined by analysis of variance (0.01).

[y] The cultivars were Rosita and Sprinter Scarlet.

Cardinal - clonal | Sprinter Scarlet - cutting | Sprinter Scarlet - seed

Figure 12. Floriferousness of Cardinal, clonal cultivar, and Sprinter Scarlet, seed plants and cuttings of seed plants, in the field trials.

difference between the 2 dates (Table 60) was highly significant by analysis of variance.

No attempt was made to compare flowering dates as the cuttings continued to produce flower clusters from the day they were taken as cuttings.

Number of Flowers per Flower Cluster

An attempt was made to count the number of flowers per flower cluster. All flower clusters on 2 Rosita cutting produced plants were counted; and it was found that the number of flowers per cluster varied from 22 to 78. This method of comparison was discontinued due to extreme variability.

Height x Diameter

Seed Plants Versus Cuttings. The height x diameter between Rosita and Sprinter Scarlet, seed plants and cuttings, varied; 2,007.09, 1,993.98, 2,035.81 and 1,380.73 cm^2 (Table 61), respectively. The differences between the cultivars and between propagation methods were highly significant by analysis of variance.

Seed Plants Versus Cuttings Versus Clonal Cultivars. The height and diameter of the seed produced plants, cuttings and clonal cultivars varied (Table 62). By visual observation the clonal cultivars were shortest; the cuttings appeared to be of medium height, the seed produced plants being tallest. This effect was very pronounced in the middle of August. By late September, the cuttings approached the height of the seed produced plants.

By actual measurement in late September, the heights averaged:

Table 61. Comparison of mean height x diameter of 4 cultivars and 3 propagation methods.

Cultivar	Mean Height x Diameter (cm^2)
Cherry Blossom - clonal	936.35
Cardinal - clonal	1,338.08
Sprinter Scarlet - cutting	1,380.73
Rosita - cutting	1,993.98
Rosita - seed	2,007.09
Sprinter Scarlet - seed	2,035.81

Cultivar Means	Mean Height x diameter (cm^2)	Comparison of 4 Cultivars	Comparison of 2 Cultivars
Rosita	2,000.54	a^z	a^y
Sprinter Scarlet	1,708.27	b	b
Cardinal	1,338.08	c	
Cherry Blossom	936.35	d	
Treatment Means			
Seed	2,021.45	a^x	a^y
Cutting	1,687.36	b	b
Clonal	1,137.22	c	

^{z} mean height x diameter differ significantly as determined by the un- unpaired t test (0.01).

^{y} mean height x diameter differ significantly as determined by the un- of variance (0.01).

^{x} mean height x diameter differ significantly as determined by the un- New Multiple Range Test (0.01).

Table 62. Mean height and mean diameter for 4 cultivars and 3 propagation methods.

	Measurements	
Cultivar	Mean Height (cm)	Mean Diameter (cm)
Cherry Blossom - clonal	27.06	46.00
Cardinal - clonal	32.06	53.81
Sprinter Scarlet - seed	40.25	60.56
Sprinter Scarlet - cutting	31.81	55.00
Rosita - seed	43.75	42.19
Rosita - cutting	43.75	54.06

Cherry Blossom 27.06 cm (Table 62), Cardinal 32.06 cm, Sprinter Scarlet - cutting 31.81 cm, Sprinter Scarlet - seed 40.25, Rosita - seed and cutting 43.75 cm. By measurement, the diameters averaged: Rosita - seed 42.19 cm, Cherry Blossom 46.00 cm, Cardinal 53.81 cm, Rosita - cutting 54.06 cm, Sprinter Scarlet - cutting 55.00 cm and Sprinter Scarlet - seed 60.56 cm. The Sprinter Scarlet - seed plants on average were largest, and were followed in decreasing order of size by: Rosita - seed, Rosita - cutting, Sprinter Scarlet - cutting, Cardinal - clonal cultivar and Cherry Blossom - clonal cultivar. The differences between the cultivars were highly significant (Table 61); and each cultivar varied from the next. The propagation methods were significantly different as determined by Duncan's New Multiple Range Test (0.01). Thus, there was a difference between the cultivars and between the propagation methods in the field. Cultivar differences will be discussed later.

It would appear that the seed produced plants put more energies into producing vegetative tissue, while the cuttings of mature seed plants were initiated into flowering and thus expended energy in both vegetative and reproductive tissues. The clonal cultivars appeared to have a smaller vegetative potential than seed produced plants.

Number of Leaves

Seed Plants Versus Cuttings. The number of leaves on the seed produced plants and plants produced from cuttings (Table 63) varied. The most leaves were found on Sprinter Scarlet seed and cutting produced plants, 190.42 and 143.33, respectively. One hundred thirty-nine and 117.42 leaves were found on seed and cutting produced plants of Rosita, respec-

Table 63. Mean number of leaves by cultivar and by propagation method.

Cultivar	Mean Number of Leaves
Sprinter Scarlet - seed	190.42
Sprinter Scarlet - cutting	143.33
Rosita - seed	139.42
Rosita - cutting	117.42
Cardinal - Clonal	79.33
Cherry Blossom - Clonal	71.34

Cultivar Means	Number of Leaves	Comparison of 4 Cultivars	Comparison of 2 Cultivars
Sprinter Scarlet	166.71	a[z]	a[y]
Rosita	132.58	b	b
Cardinal	79.33	c	
Cherry Blossom	71.33	c	
Propagation Method Means			
Seed	164.92	a[x]	a[v]
Cuttings	130.38	b	b
Clonal	75.33	c	

[z] mean number of leaves followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

[y] mean number of leaves differ significantly as determined by analysis of variance (0.01).

[x] mean number of leaves differ significantly as determined by Duncan's New Multiple Range Test (0.01).

[v] mean number of leaves differ significantly as determined by analysis of variance (0.05).

tively.

The differences between the cultivars (Table 63) were highly significant by analysis of variance, whereas differences between propagation methods were significant.

Seed Plants Versus Cuttings Versus Clonal Cultivars. The fewest leaves were found on the clonal cultivars, Cardinal and Cherry Blossom, at 79.33 and 71.34 leaves, respectively. Thus, the order of leaf number was:

1. Sprinter Scarlet (Table 63),
2. Rosita, and
3. Cardinal and Cherry Blossom.

The differences between cultivars were highly significant by analysis of variance. The differences between propagation methods were highly significant. Cultivar differences will be discussed later.

The differences between the seed produced plants, cuttings and clonal cultivars may be explained as follows: the seed plants had to pass through the juvenile stage, initially putting energies into producing vegetative tissue, while the cuttings started to bloom immediately from the taking of the cuttings. Therefore, some of the energies of the cutting produced plants were redistributed and not available for vegetative growth. The clonal cultivars appear to have a smaller growth potential than do plants from cuttings.

Number of Branches

Seed Plants Versus Cuttings. The mean number of branches varied (Table 64) from 13.83 for Rosita - cutting to 18.08 for Sprinter Scarlet - seed.

Table 64. Mean number of branches by cultivar and by propagation method.

Cultivar	Mean Number of Branches
Cherry Blossom - clonal	7.67
Cardinal - clonal	9.33
Rosita - cutting	13.83
Rosita - seed	15.33
Sprinter Scarlet - cutting	15.42
Sprinter Scarlet - seed	18.08

Cultivar Means	Mean Number of Branches	Comparison of 4 Cultivars	Comparison of 2 Cultivars
Rosita	14.58	b[z]	a[y]
Sprinter Scarlet	16.75	b	b
Cherry Blossom	7.67	a	
Cardinal	9.33	a	
Propagation Method Means			
Seed	16.71	a[x]	a[y]
Cuttings	14.63	a	b
Clonal	8.50	b	

[z] mean number of branches followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

[y] mean number of branches differ significantly as determined by analysis of variance (0.01).

[x] mean number of branches followed by the same letter do not differ significantly as determined by Duncan's New Multiple Range Test (0.01).

The difference between cultivars was significant by analysis of variance, as was the difference between propagation methods.

Seed Plants Versus Cuttings Versus Clonal Cultivars. The mean number of branches per plant varied from 7.67 for Cherry Blossom to 18.08 for Sprinter Scarlet - seed produced plants (Table 64). The difference between cultivars was highly significant, with the cuttings and seed produced plants being significantly different from the clonal cultivars. The difference was also highly significant between the methods of propagation. Cultivar differences will be discussed later. It would appear that the potential for the total number of branches of the seed plants and cuttings was greater than that of the clonal cultivars. In this trial, seed plants were similar to cuttings of the same cultivar.

Number of Branches with Flower Clusters

Seed Plants Versus Cuttings. The mean number of branches with flower clusters per plant (Table 65) varied. There was a significant difference by analysis of variance. Differences between the propagation methods were not significant.

Seed Plants Versus Cuttings Versus Clonal Cultivars. The mean number of branches with flower clusters per plant varied from 6.08 for Cherry Blossom (Table 65) to 11.75 for Sprinter Scarlet - cutting. The differences between cultivars were highly significant as were those between propagation methods. Cultivar differences will be discussed later.

The seed plants and cuttings of the same cultivar appear to have the same potential for the number of branches and this might be expected as both are of the same genetic materials.

Table 65. Mean number of branches with flower clusters by cultivar and propagation method.

Cultivar	Mean Number of Branches with Flower Clusters
Cherry Blossom - clonal	6.08
Rosita - cutting	6.83
Cardinal - clonal	7.42
Rosita - seed	8.67
Sprinter Scarlet - seed	11.33
Sprinter Scarlet - cutting	11.75

Cultivar	Number of Branches	Comparison of 4 Cultivars	Comparison of 2 Cultivars
Cherry Blossom	6.08	a[z]	
Cardinal	7.42	a	
Rosita	7.75	b	a[y]
Sprinter Scarlet	11.54	c	b
Propagation Method Means			
Seed	10.00	a[x]	v
Cuttings	9.29	a	
Clonal	6.75	b	

[z] mean number of branches with flower clusters followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

[y] mean number of branches with flower clusters differ significantly as dtermined by analysis of variance (0.05)

[x] mean number of branches with flower clusters followed by the same letter do not differ significantly as determined by Duncan's New Multiple Range Test (0.01).

[v] mean number of branches with flower clusters do not differ significantly as determined by analysis of variance.

Dry Weights

Before dry weights could be taken the plants had deteriorated to the point that dry weights could not be taken with accuracy. Therefore, this observation could not be used.

Plant Appearance

The seed produced plants had no faded flower clusters showing, i. e. were self-cleaning. The plants produced from cuttings had a few clusters showing. Many faded flower clusters with the flowers retaining senesced petals were found on the clonal cultivars. The clonal cultivars were quite untidy (Figure 13).

Cultivar Differences

The genotypes of cultivars differ; the degree of the difference in the cultivars used in the field trials was unknown. As the hereditary makeup of a plant determines the ultimate potential of a plant it is possible that the potential of each of the 4 cultivars was different, thus the significant cultivar differences which occurred in the field trials may have been due to the genetic material of each cultivar.

Overall the pattern that was established between and within the cultivars was: the clonal cultivars varied from the seed plants and cuttings (Table 66). It can be said that cuttings of the same cultivar produced more flowers on smaller plants. The seed produced plants were taller and had a better appearance. On the other hand, the clonal cultivars had less foliage, were smallest and produced an intermediate number of flowers.

Figure 13. Appearance of Cardinal, clonal cultivar, in the field trials.

Table 66. Summary of field trials by propagation method.

Propagation Method	Number of Flower Clusters	Height x Diameter	Number of Leaves	Number of Branches	Number of Branches with Flower Clusters	Appearance
Seed	L[z]	H	H	H	H	E[y]
Cuttings	H	M	M	H	H	G - E
Clones	M	L	L	L	L	U

[z] L - low
H - high
M - medium
E - excellent
G - good
U - untidy

[y] qualitative measurement.

SUMMARY AND CONCLUSION

A study of the germination and the vegetative propagation of F1 hybrid seed geraniums was undertaken. The parameters of the experimentation included cultivars trials, variables of temperature, media, water content of the medium, oxygen concentration, scarification versus unscarification, fungicide versus nonfungicide seed treatment, storage and field trials.

Under the conditions of the experiments it may be concluded that:

1. There were differences between F1 and F2 hybrid geranium seed, both in germination percent and the germination resistance value.
2. There may have been a seasonal rhythm in the germination of geranium seed.
3. Satisfactory temperatures for the best germination percent varied from 14.5° to 25.5°C and fluctuating temperatures. The seed germinated at high percents between 14.5° and 25.5°C and a fluctuating day/night (29.4° to 17.2°C) temperature.
4. Satisfactory temperature for the best germination resistance value was 20.0°C. Most of the hybrid geranium seed germinated in the first 6 days. Germination resistance value was of no major concern in these trials relative to germination per sé but may relate to the success and vigor of transplanting.
5. Satisfactory germination media for geranium seed were: sand, filter paper, Zorb-all, perlite and vermiculite. Germination resistance value was increased on peat moss. Media had no effect on the germination per-

cent.

6. Germination resistance value for geranium seed was lowest when the moisture content of sand was above field capacity; while the moisture content of the sand had no effect on the germination percent. Decreasing the medium moisture content below saturation increased the time required for germination to occur.

7. An increased oxygen concentration appeared to have no consistent effect on the germination resistance values or on the germination percents.

8. Scarification was required for germination of Rosita, Tiffany and Ringo Scarlet seed and was probably required for seed of other cultivars.

9. Thiram treatment may decrease the germination resistance value. Thiram effect on the germination percent was not consistent.

10. Storage of scarified and unscarified seed up to 16 months did not have a significant effect on the germination percent. The germination resistance value increased in both with time.

11. The number of hypocotyl fractures was related to cultivar susceptibility, type or degree of scarification, temperature and moisture content of the medium.

12. There was a difference in the height and diameter, number of leaves, number of branches, plant appearance and the number of flower clusters per row between seed produced plants and cuttings of the same cultivar.

13. First generation cuttings produced more flower clusters than seed produced plants of the same cultivar.

14. Cuttings were superior to seed produced plants, which were superior to clonal cultivars.

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LIST OF APPENDICES

TABLE PAGE

APPENDIX Table 1. Preliminary Germination Studies. Accumulated germination counts, accumulated germination totals, accumulated percents, number of seed per day, percent per day for 4 cultivars, 1 sample of 20 seed per cultivar.
Light: 14 hours per day
Medium: 2:1:1, soil:sand:peat moss
Temperature: 15.5 to 17.7°C

	Accumulated Germination Count																			
	Day														Week					
Cultivar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	3	4	5	6	7	8[z]
Ringo Scarlet	0	0	1	1	3	4	5	7	12	15	15	17	17	17	18	18	18	18	18	18
Rosita	0	0	3	4	6	9	11	13	14	15	15	15	15	15	15	15	15	15	16	16
Sprinter Scarlet	0	0	2	2	8	10	12	13	13	15	16	16	16	16	19	19	19	19	19	19
Sprinter Mixed	0	0	1	1	5	6	7	9	11	14	15	15	15	15	15	15	15	15	15	15
Accumulated Totals per Day	0	0	7	8	22	29	35	42	50	59	61	63	63	63	67	67	67	67	68	68
Accumulated Percents per Day	0	0	8.75	10.00	27.50	36.25	43.75	52.50	62.50	73.75	76.25	78.75	n/c	n/c	83.75	n/c	n/c	n/c	85.00	n/c
Number of Seed per Day	0	0	7	1	14	7	6	7	8	9	2	2	0	0	4	0	0	0	1	0
Percent per Day	0	0	8.75	1.25	17.50	8.75	7.50	8.75	10.00	11.25	2.50	2.50	0	0	5.00	0	0	0	1.25	0

[z] no germination occurred in weeks 9 and 10.

n/c - no change.

APPENDIX Table 2. Preliminary Germination Studies. Accumulated germination counts, accumulated germination totals, accumulated percents, number of seed per day, percent per day for 3 cultivars, 1 sample of 25 seed per cultivar.
Light: none
Medium: Filter paper and petri dishes
Temperature: 14.5°C

	Accumulated Germination Count												
Cultivar	Day 1	2	3	4	5	6	7	8	9	10	11	12	13[z]
Rosita	0	10	23	23	24	24	25	25	25	25	25	25	25
Ringo Scarlet	0	9	18	22	23	24	24	24	24	24	24	24	24
Nittany Lion Red	0	2	6	7	14	15	15	16	16	18	18	18	19
Accumulated Totals per Day	0	21	47	52	61	63	64	65	65	67	67	67	68
Accumulated Percents per Day	0	28.00	62.67	69.33	81.33	84.00	85.33	86.67	n/c	89.33	n/c	n/c	90.67
Number of Seed per Day	0	21	26	5	9	2	1	1	n/c	2	n/c	n/c	1
Percent per Day	0	28.00	34.67	6.67	12.00	2.67	1.33	1.33	n/c	2.67	n/c	n/c	1.33

[z] germination trial terminated.

n/c - no change.

APPENDIX Table 3. Physical measurements for 20 seed of Sprinter Scarlet, scarified.

Length		Diameter			
		Through Radicle and Cotyledons		Cotyledon Width	
Inches	mm	Inches	mm	Inches	mm
0.161	4.089	0.051	1.295	0.065	1.651
0.159	4.038	0.050	1.270	0.067	1.702
0.170	4.318	0.052	1.321	0.063	1.600
0.165	4.191	0.051	1.295	0.067	1.702
0.172	4.369	0.047	1.194	0.063	1.600
0.172	4.369	0.049	1.245	0.061	1.549
0.167	4.242	0.053	1.346	0.067	1.702
0.162	4.115	0.048	1.219	0.062	1.575
0.163	4.140	0.042	1.067	0.066	1.676
0.158	4.013	0.055	1.397	0.061	1.549
0.161	4.089	0.040	1.016	0.060	1.524
0.173	4.394	0.052	1.321	0.064	1.626
0.167	4.242	0.055	1.397	0.061	1.549
0.160	4.064	0.049	1.245	0.066	1.676
0.172	4.369	0.050	1.270	0.065	1.651
0.170	4.318	0.049	1.245	0.065	1.651
0.162	4.115	0.048	1.219	0.072	1.829
0.162	4.115	0.053	1.346	0.065	1.651
0.165	4.191	0.040	1.016	0.060	1.524
0.163	4.140	0.051	1.295	0.060	1.524
Means					
.165	4.191	0.0467	1.186	0.064	1.626

APPENDIX Table 4. Germination percent for spring germination trials - 67 cultivars.

Cultivar	Sample Number 1	2	3	4
4 Samples				
Bright Eyes	100.0	100.0	100.0	95.0
Capri Brick Red	100.0	100.0	90.0	100.0
Capri Deep Red	85.0	90.0	90.0	85.0
Capri White	95.0	95.0	100.0	100.0
Carefree Light Salmon	60.0	85.0	80.0	65.0
Carefree Scarlet	90.0	90.0	90.0	80.0
Cherry Glow	100.0	90.0	95.0	90.0
Colorama - F2	55.0	45.0	80.0	65.0
Debutante	85.0	100.0	85.0	95.0
Deep Rose Flash	95.0	95.0	90.0	85.0
Dynamite	80.0	80.0	80.0	90.0
Empress Red	90.0	95.0	80.0	90.0
Empress Salmon	70.0	70.0	75.0	60.0
Encounter Red	95.0	95.0	90.0	85.0
Encounter Salmon	95.0	85.0	80.0	100.0
Fire Flash	90.0	75.0	75.0	95.0
Florence	100.0	100.0	100.0	100.0
Friendship	85.0	85.0	90.0	90.0
Geranium Mixed	100.0	100.0	100.0	100.0
Gremlin Coral	90.0	90.0	100.0	90.0
Innocence	95.0	95.0	90.0	100.0
Knockout	100.0	95.0	90.0	95.0
Love Song	85.0	80.0	85.0	70.0
Orange Punch	95.0	100.0	90.0	90.0
Paintbox Mixed	80.0	60.0	65.0	75.0
Red Apple - F2	85.0	60.0	70.0	60.0
Red Delicious - F2	55.0	85.0	75.0	70.0
Red Express	90.0	80.0	95.0	75.0
Red Standard	65.0	50.0	75.0	60.0
Salmon Express	90.0	85.0	80.0	85.0
Salmon Flash	75.0	85.0	75.0	100.0
Scarlet Flash	100.0	100.0	95.0	100.0
Smash Hit Red	90.0	95.0	100.0	100.0
Sooner Red	90.0	95.0	90.0	100.0
Sooner Salmon	90.0	65.0	85.0	55.0
Sprinter White	95.0	95.0	90.0	95.0
Surefire	70.0	85.0	55.0	65.0
2 Samples				
Cherie	95.0	100.0		
Festival Salmon	100.0	85.0		
Festival Scarlet	100.0	100.0		

APPENDIX Table 4. (Continued)

Festival White	90.0	95.0		
Heidi	100.0	100.0		
Ice Queen	100.0	100.0		
Jackpot	100.0	95.0		
Mustang	95.0	95.0		
Red Champion	100.0	88.8		
Ringo Rose	100.0	95.0		
Ringo Rouge	100.0	100.0		
Ringo Salmon	100.0	100.0		
Ringo Scarlet	100.0	100.0		
Rosita	90.0	95.0		
Rosita '80	95.0	95.0		
Showgirl	65.0	95.0		
Snow White	85.0	100.0		
Snowdon	100.0	100.0		
Sprinter Deep Red	95.0	100.0		
Sprinter Salmon	95.0	95.0		
Tiffany	70.0	70.0		
Vulcan	90.0	80.0		
6 Samples				
Bambi - F2	95.0	95.0	90.0	75.0
	85.0	85.0		
Marathon	70.0	65.0	65.0	35.0
	45.0	60.0		
Sprinter Scarlet	100.0	100.0	100.0	100.0
	100.0	85.0		
5 Samples				
Fleuriste Mixture - F2	90.0	90.0	100.0	90.0
	70.0			
1 Sample				
Del Greco Mixed	85.0			
Dwarf Sprinter Red	89.7			
Firecracker	90.0			
Miniskirt Mixed	50.0			

APPENDIX Table 5. Germination resistance value in hours for spring germination trials - 67 cultivars.

Cultivar	Sample Number 1	2	3	4
4 Samples				
Bright Eyes	34.20	40.80	34.80	46.74
Capri Brick Red	27.60	48.60	70.67	51.00
Capri Deep Red	58.59	52.00	32.00	45.88
Capri White	31.59	38.53	24.00	36.00
Carefree Light Salmon	100.00	98.12	89.25	91.38
Carefree Scarlet	32.67	26.67	66.67	55.50
Cherry Glow	46.20	42.67	37.26	48.67
Colorama - F2	81.82	89.33	111.00	32.31
Debutante	26.12	30.00	26.12	27.79
Deep Rose Flash	55.58	46.74	56.00	64.24
Dynamite	69.75	59.25	67.50	120.00
Empress Red	68.67	60.00	60.75	101.05
Empress Salmon	54.86	54.86	54.40	43.00
Encounter Red	45.47	36.63	46.00	38.82
Encounter Salmon	49.26	47.29	42.75	49.80
Fire Flash	43.33	55.47	48.80	50.53
Florence	33.00	34.20	41.40	39.60
Friendship	59.29	74.82	43.33	97.60
Geranium Mixed	63.00	75.00	66.60	54.60
Gremlin Coral	81.33	76.00	90.00	60.00
Innocence	41.05	42.95	47.33	43.80
Knockout	25.80	50.53	34.00	28.00
Love Song	68.47	51.75	41.65	82.29
Orange Punch	54.79	73.80	106.20	91.33
Paintbox Mixed	66.75	82.00	61.85	69.60
Red Apple - F2	69.18	87.00	109.71	97.00
Red Delicious - F2	39.27	77.65	61.60	54.86
Red Express	80.00	61.50	54.95	62.40
Red Standard	65.00	50.00	75.00	60.00
Salmon Express	58.67	72.00	72.75	81.18
Salmon Flash	56.00	45.88	46.40	48.70
Scarlet Flash	32.40	34.80	34.11	30.60
Smash Hit Red	70.67	66.95	69.00	64.20
Sooner Red	30.00	40.42	58.67	45.00
Sooner Salmon	86.00	75.69	92.47	86.18
Sprinter White	80.84	100.42	79.33	90.32
Surefire	70.29	75.53	70.91	72.00
2 Samples				
Cherie	40.42	31.80		
Festival Salmon	48.00	34.59		
Festival Scarlet	44.40	59.40		

APPENDIX Table 5. (Continued)

Festival White	50.67	73.67		
Heidi	24.00	25.80		
Ice Queen	40.80	27.00		
Jackpot	41.40	32.80		
Mustang	30.32	29.68		
Red Champion	33.00	33.00		
Ringo Rose	24.00	37.89		
Ringo Rouge	25.80	25.80		
Ringo Salmon	38.40	31.20		
Ringo Scarlet	24.00	27.60		
Rosita	42.00	33.47		
Rosita'80	27.79	30.95		
Showgirl	73.85	46.11		
Snow White	47.29	66.00		
Snowdon	27.60	32.40		
Sprinter Deep Red	49.26	38.40		
Sprinter Salmon	39.16	45.47		
Tiffany	86.57	109.71		
Vulcan	42.67	26.25		
6 Samples				
Bambi - F2	88.42	84.63	121.33	102.40
	76.94	55.06		
Marathon	80.31	101.14	82.67	88.00
	55.71	70.15		
Sprinter Scarlet	25.80	33.00	54.00	43.80
	51.60	59.29		
5 Samples				
Fleuriste Mixture - F2	104.67	46.67	106.20	91.33
	87.43			
1 Sample				
Del Greco Mixed	87.26			
Dwarf Sprinter Red	31.85			
Firecracker	32.00			
Miniskirt Mixed	82.00			

APPENDIX Table 6. Germination percent for fall germination trials - 36 cultivars.

Cultivar	Sample Number 1	2	3	4
4 Samples				
Carefree Scarlet	76.9	80.8	88.5	84.0
Colorama - F2	48.1	66.7	85.2	69.2
Encounter Red	92.0	96.0	96.0	100.0
Encounter Salmon	84.0	84.0	96.0	72.0
Firecracker	96.0	88.0	92.0	100.0
Fleuriste Mixture - F2	64.0	76.0	84.0	60.0
Friendship	81.8	72.7	59.1	61.9
Heidi	96.0	84.0	88.0	96.0
Innocence	95.7	95.7	100.0	100.0
Love Song	88.0	80.0	69.2	84.6
New Era Bright Red	80.0	84.0	92.0	92.0
New Era Medium Salmon	75.0	75.0	66.7	100.0
New Era Red	91.7	83.3	95.8	96.0
Nittany Lion Red	81.5	85.2	66.7	70.3
Red Champion	96.0	88.0	96.0	92.0
Red Express	96.0	88.0	92.0	96.0
Ringo Scarlet	100.0	100.0	92.0	96.0
Rose Pink with White Eye	100.0	92.3	92.0	92.0
Rosita	89.3	92.9	100.0	96.4
Scarlet Flash	87.5	79.2	95.8	100.0
Showgirl	96.0	92.0	92.0	88.0
Sooner Red	88.5	96.1	96.0	88.0
Sooner Salmon	88.5	92.3	88.5	92.6
Sprinter Scarlet	92.0	88.0	100.0	100.0
Sprinter White	92.0	92.0	92.0	80.0
2 Samples				
Mustang	90.9	95.2		
Ringo Rose	100.0	100.0		
3 Samples				
Ringo Salmon	87.5	96.1	84.6	
1 Sample				
Cherie Improved	100.0			
Cherie - Light Sprinter Salmon	95.2			
Ice Queen	100.0			
Knockout	88.9			
Orange Punch	100.0			
Rosita '80	100.0			
Snowdon	100.0			
Sprinter Mixed	100.0			

APPENDIX Table 7. Germination resistance value in hours for fall germination trials - 36 cultivars.

Cultivar	Sample Number 1	2	3	4
4 Samples				
Carefree Scarlet	102.00	111.43	111.13	108.00
Colorama - F2	102.00	101.33	95.40	105.33
Encounter Red	59.48	58.96	63.50	60.00
Encounter Salmon	65.14	43.43	47.50	44.00
Firecracker	103.85	100.36	95.48	96.48
Fleuriste Mixture - F2	144.75	106.00	126.86	130.29
Friendship	56.00	60.00	66.46	63.89
Heidi	71.25	74.86	65.71	60.00
Innocence	57.91	68.00	62.61	61.00
Love Song	99.82	79.80	86.00	80.00
New Era Bright Red	75.60	83.43	75.13	67.64
New Era Medium Salmon	118.67	126.75	106.50	111.00
New Era Red	58.36	81.60	55.83	65.50
Nittany Lion Red	118.36	91.83	114.67	94.11
Red Champion	84.00	72.00	89.00	84.00
Red Express	92.00	82.36	75.13	73.00
Ringo Scarlet	81.00	75.84	84.52	55.83
Rose Pink with White Eye	37.38	41.50	41.22	66.26
Rosita	106.08	88.62	103.71	90.22
Scarlet Flash	94.29	104.40	91.30	97.00
Showgirl	64.00	33.91	54.26	47.45
Sooner Red	99.13	83.52	83.00	68.18
Sooner Salmon	99.65	101.00	87.13	99.82
Sprinter Scarlet	93.50	87.82	94.08	89.28
Sprinter White	103.30	103.64	94.43	126.00
2 Samples				
Mustang	63.60	36.00		
Ringo Rose	63.89	38.40		
3 Samples				
Ringo Salmon	77.14	96.00	84.00	
1 Sample				
Cherie Improved	78.00			
Cherie - Light Sprinter Salmon	106.20			
Ice Queen	72.00			
Knockout	84.75			
Orange Punch	112.00			
Rosita '80	61.33			
Snowdon	42.86			
Sprinter Mixed	84.00			

APPENDIX Table 8. Mean germination percent and mean germination resistance value in hours for 6 cultivars on 6 media, trial II.

	Mean Germination Percent						Mean Germination Resistance Value (hours)					
Medium	Filter Paper	Peat Moss	Zorb-all	Vermic-ulite	Sand	Perlite	Filter Paper	Peat Moss	Zorb-all	Vermic-ulite	Sand	Perlite
Cultivar												
Knockout	100.0	100.0	--[z]	95.0	100.0	90.0	31.20	60.00	--[z]	30.32	27.00	44.67
Ringo Scarlet	85.0	87.5	95.0	95.0	95.0	87.5	32.47	53.90	29.68	42.90	24.00	37.80
Rosita	95.0	100.0	100.0	100.0	100.0	97.5	36.00	43.80	26.70	36.90	25.80	32.39
Snowdon	85.0	87.5	92.5	87.5	80.0	87.5	69.88	69.18	62.84	60.06	59.63	68.19
Sprinter Scarlet	80.0	85.0	85.0	92.5	85.0	80.0	38.25	78.00	44.25	52.00	32.34	48.38
Sprinter White	95.0	92.5	87.5	95.0	87.5	92.5	72.63	88.92	80.88	76.60	71.13	65.53

[z] not included in trials.

APPENDIX Table 9. Media trials - pH of media used.

Media	pH
Filter paper	7.1
Peat moss	3.6 - 3.8
Perlite	7.0 - 7.5
Sand	8.3
Vermiculite	7.0 - 7.5
Zorb-all	4.6
Water, distilled and deionized	6.2

APPENDIX Table 10. Analysis of variance of germination percents for scarified versus unscarified seed.

Analysis of Variance						
Source of Variation	DF	SS	MS	F	5%	1%
Cultivar	1	55.296	55.2960	1.5297ns	5.32	11.26
Treatment	1	3,352.026	3,352.0260	92.7309**	5.32	11.26
Cultivar x treatment	1	1,644.552	1,644.5520	45.4951**	5.32	11.26
Error	8	289.183	36.1479			
Total	11	5,341.057				

APPENDIX Table 11. Analysis of variance of germination percents of thiram treated versus untreated seed.

Analysis of Variance						
Source of Variation	DF	SS	MS	F	5%	1%
Treatments	1	15.57	15.5700	0.3064ns	4.35	8.10
Cultivars	4	750.25	187.5625	3.6916*	2.87	4.43
Treatments x cultivars	4	939.32	234.8300	4.6219**	2.87	4.43
Error	20	1,016.16	50.8080			
Total	29	2,721.30				

APPENDIX Table 12. Analysis of variance of the germination percents of 4 cultivars with thiram treated and untreated seed, in 4 temperature regimes.

Analysis of Variance						
Source of Variation	DF	SS	MS	F	5%	1%
Temperatures	3	93.610	31.2033	0.9292ns	2.749	4.106
Cultivars	3	1,192.470	397.4900	11.8371**	2.749	4.106
Treatments	1	13.680	13.6800	0.4074ns	3.989	7.049
Temperatures x cultivars	9	545.110	60.5678	1.8037ns	2.029	2.699
Temperatures x treatment	3	62.470	20.8233	0.6201ns	2.749	4.106
Cultivars x treatment	3	464.310	154.7770	4.6092**	2.749	4.106
Error	68	2,283.440	33.5800			
Total	90	4,655.090				

APPENDIX Table 13. Analysis of variance of the germination resistance values of 4 cultivars with thiram treated and untreated seed, in 4 temperature regimes.

Analysis of Variance						
Source of Variation	DF	SS	MS	F	5%	1%
Temperatures	3	11,305.62	3,768.5400	51.6747**	2.749	4.106
Cultivars	3	2,407.84	802.6133	11.0055**	2.749	4.106
Treatment	1	592.58	592.5800	8.1255**	3.989	7.049
Temperatures x cultivars	9	1,234.45	137.1611	1.8808ns	2.029	2.699
Temperatures x treatment	3	98.58	32.8600	0.4506ns	2.749	4.106
Cultivars x treatment	3	2,053.92	684.6400	9.3879**	2.749	4.106
Error	68	4,959.11	72.9281			
Total	90	22,652.10				

APPENDIX Table 14. Analysis of variance of the germination percents in media trial I of 2 cultivars with thiram treated and untreated seed.

Analysis of Variance						
Source of Variation	DF	SS	MS	F	5%	1%
Media	5	542.19	108.438	3.0189ns	5.05	10.97
Cultivar	1	206.21	206.210	5.7408ns	6.61	16.26
Treatment	1	712.09	712.090	19.8243**	6.61	16.26
Media x cultivar	5	846.91	169.382	4.1755ns	5.05	10.97
Media x treatment	5	715.25	143.050	3.9825ns	5.05	10.97
Cultivar x treatment	1	560.00	560.000	15.5902*	6.61	16.26
Error	5	179.60	35.920			
Total	23	3,762.25				

APPENDIX Table 15. Analysis of variance of the germination percents in media trial II of 2 cultivars with thiram treated and untreated seed.

Analysis of Variance						
Source of Variation	DF	SS	MS	F	5%	1%
Media	5	367.68	73.536	6.7347**	2.71	4.10
Cultivar	1	6.84	6.840	0.6264ns	4.35	8.10
Treatment	1	1,056.92	1,056.920	96.7964**	4.35	8.10
Media x cultivar	5	162.89	32.578	2.9836*	2.71	4.10
Media x treatment	5	415.88	83.176	7.6175**	2.71	4.10
Cultivar x treatment	1	339.11	339.110	31.0569**	4.35	8.10
Media x cultivar x treatment	5	1,038.96	207.792	19.0303**	2.71	4.10
Error	20	218.38	10.919			
Total	43	3,606.66				

APPENDIX Table 16. Analysis of variance of the germination resistance values in the storage experiment.

Analysis of Variance						
Source of Variation	DF	SS	MS	F	5%	1%
Dates	22	8,509.54	386.8000	14.7847**	1.545	1.835
Cultivar	1	1,248.27	1,248.2700	47.7127**	3.840	6.630
Treatment	1	10,150.02	10,150.0200	387.9651**	3.840	6.630
Dates x cultivar	22	3,717.73	168.9877	6.4592**	1.545	1.835
Dates x treatment	22	2,143.40	97.4273	3.7240**	1.545	1.835
Cultivar x treatment	1	827.89	827.8900	31.6445**	3.840	6.630
Error	206	5,389.41	26.1622			
Total	275	31,986.26				

APPENDIX Table 17. Number of hypocotyl fractures in storage experiment by cultivar treatment.

		Number of Hypocotyl Fractures				
Cultivar		Rosita		Ringo Scarlet		
Starting Date	Trial Number Stored:	Unscar-ified	Scar-ified	Unscar-ified	Scar-ified	Total Numbers
Nov. 26/79	Prestorage	0	1	7	2	10
Dec. 10	1	0	0	5	4	9
Dec. 24	2	0	1	6	0	7
Jan. 7/80	3	0	0	4	4	8
Jan. 21	4	0	1	3	6	10
Feb. 4	5	0	2	7	4	13
Feb. 18	6	0	0	5	2	7
Mar. 3	7	0	0	3	4	7
Mar. 17	8	0	0	6	4	10
Mar. 31	9	0	1	8	3	12
Apr. 14	10	0	0	10	4	14
Apr. 28	11	0	0	5	2	7
May 12	12	0	0	5	1	6
May 26	13	0	0	5	4	9
June 9	14	0	1	6	7	14
June 23	15	0	1	2	4	7
Oct. 16	16	0	0	2	0	2
Nov. 5	17	0	0	0	0	0
Nov. 19	18	0	0	0	0	0
Jan. 5/81	19	0	0	0	0	0
Jan. 19	20	0	0	0	0	0
Feb. 2	21	0	0	0	0	0
Feb. 16	22	0	0	0	0	0
Totals		0	8	89	55	152
Percent of Total Seed Used		0	0.58	6.45	3.99	2.75

APPENDIX Table 18. Number of deteriorated seed in storage experiment by cultivar and by treatment.

		Number of Deteriorated Seed				
Cultivar		Rosita		Ringo Scarlet		
Starting Date	Trial Number Stored:	Unscar-ified	Scar-ified	Unscar-ified	Scar-ified	Total Numbers
Nov. 26/79	Prestorage	1	0	0	0	1
Dec. 10	1	0	1	0	0	1
Dec. 24	2	0	2	0	1	3
Jan. 7/80	3	0	0	0	0	0
Jan. 21	4	1	0	1	0	2
Feb. 4	5	0	1	0	0	1
Feb. 18	6	0	1	0	0	1
Mar. 3	7	2	0	0	0	2
Mar. 17	8	0	0	0	1	1
Mar. 31	9	0	0	0	1	1
Apr. 14	10	2	2	1	0	5
Apr. 28	11	1	0	0	1	2
May 12	12	1	0	0	0	1
May 26	13	0	0	0	0	0
June 9	14	0	0	0	1	1
June 23	15	2	1	0	1	4
Oct. 16	16	1	0	0	0	1
Nov. 5	17	0	0	0	0	0
Nov. 19	18	0	0	0	0	0
Jan. 5/81	19	0	0	0	0	0
Jan. 19	20	0	0	0	0	0
Feb. 2	21	0	0	0	0	0
Feb. 16	22	0	0	0	0	0
Totals		11	8	2	6	27
Percent of Total Seed Used		0.80	0.58	0.14	0.43	0.49

APPENDIX Table 19. Cultivar and type and/or degree of seed scarification in the spring germination trials.

Clipped

Deep Rose Flash
Encounter Red
Fire Flash
Gremlin Coral
Marathon
Red Champion
Red Express
Salmon Express
Salmon Flash
Scarlet Flash

Overscarified

Capri Brick Red
Capri Deep Red
Capri White
Carefree Light Salmon
Carefree Scarlet
Del Greco Mixed
Dynamite
Firecracker
Empress Red
Empress Salmon
Encounter Salmon
Orange Punch

Scarified

Colorama - F2
Friendship
Love Song
Miniskirt Mixed
Paintbox Mixed
Red Apple - F2
Red Delicious - F2
Snow White
Sprinter Deep Red
Sprinter Scarlet
Surefire
Vulcan

Scarified with No Hypocotyl Fracturing

Bambi - F2
Bright Eyes
Cherie
Cherry Glow
Debutante
Dwarf Sprinter Red
Festival Salmon
Festival Scarlet
Festival White
Fleuriste Mixture - F2
Florence
Geranium Mixed
Heidi
Ice Queen
Innocence
Jackpot
Knockout
Mustang
Red Standard
Ringo Rose
Ringo Rouge
Ringo Salmon
Ringo Scarlet
Rosita
Rosita '80
Showgirl
Smash Hit Red
Snowdon
Sooner Red
Sooner Salmon
Sprinter Salmon
Sprinter White
Tiffany

APPENDIX Table 20. Comparison of media mean germination resistance values in media trials I and II for 3 cultivars.

Media	Mean Germination Resistance Value (hours)
Sand	40.09 a[z]
Filter paper	42.90 a
Zorb-all	43.63 a
Vermiculite	46.05 a
Perlite	47.80 ab
Peat moss	60.04 ab

[z] mean germination resistance values followed by the same letter do not differ significantly as determined by the unpaired t test (0.01).

APPENDIX Table 21. Cultivar names. It appears that more than one name is being used for some cultivars. The cultivar names that have been discovered are below.

Synonyms		
Sprinter White	=	Snow White
Sprinter Deep Red	=	Vulcan
Sprinter Salmon	=	Debutante
Marathon	=	Marathon Red
ZL 186 Rose	=	Rosita '80