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EXPERIMENTAL CONTROL OF STORAGE
DISEASES OF CUT PEONY FLOWERS

Thesis for the Degree of M. S.
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Margaret C. Ohlander
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This is to certify that the

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Experimental Control of Storage Diseases of Peonies

presented by

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Major professor

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EXPERIMENTAL CONTROL OF STORAGE DISEASES
OF
CUT PEONY FLOWERS

by
margaret C. Chlander

A THESIS

Submitted to the School of Graduate Studies of Michigan State College
of Agriculture and Applied Science in partial fulfillment
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INTRODUCTION

The present experiments were undertaken in an attempt to prolong the storage life of peonies by using improved packaging techniques in conjunction with methods of disease control.

Prolonged storage of many kinds of cut flowers would benefit growers, wholesalers, retailers, and consumers. A successful storage program would relieve the peak demands at holidays, provide a greater variety of flowers at all seasons, stabilize flower prices, and eliminate the dumping of surplus flowers by spreading a naturally short crop-season over a longer period.

In comparison to the extensive research that has been done on long term "low temperature" storage of fruits and vegetables, there are comparatively little data available on flower storage. Among the factors involved in a storage problem of this type are 1) inherent differences in flowers, 2) treatments previous to storage, 3) methods of handling in storage, 4) temperature, humidity, and atmosphere in storage, and 5) conditions prevailing upon removal from storage.

To be successful, stored flowers should meet high standards of quality. They should remain in good condition after removal from storage for a reasonable length of time, be free from disfiguring diseases, and retain original or pleasing color and fragrance. When these aims are realized, the industry will be greatly benefited.

Long Term Storage

It has been shown that flowers stored for short periods at low temperatures may last longer than freshly cut flowers when they are removed to room temperature. Long periods of storage will usually greatly shorten keeping qualities. Rose 1933 (30) stated that peonies can be held at 35° F for relatively long periods, although 30 days is usually the maximum storage period. Whiteman 1934 (35) reported that tulips held at 32° F for four months, were good in appearance if keeping qualities after storage were not important. Fresh cut buds were superior in keeping qualities to buds stored for any great length of time regardless of conditions used. Tulips held for five weeks at 32° F were in good condition when removed to room temperature, but their subsequent keeping qualities were materially shortened. Lilium erabu stored by Bowden (5) for 60 days, kept as well when removed to room temperature, as freshly cut lilies. Winsor 1936 (36) reported successful storage of peonies for two months at 30°-35° F. Neff 1939 (22) found that keeping qualities of carnations stored dry for 37 days were comparable to fresh carnations, and in some instances lasted longer than freshly picked flowers. In 1940 Honeywell, Gaylord and Fawcett (14) stored peonies in various ways for approximately one month with good results. Their figures clearly indicate a marked varietal difference as to ability to withstand prolonged storage.

Packing Methods

Rose 1933 (30) stated that cut flowers should be stored with the stems well submerged in water. Whiteman 1934 (35), using tulips, stored

one lot dry overnight and another lot in water, and then packed equal numbers (a) in waxed lined box (b) wrapped in newspaper over wax paper. Upon removal from storage the blooms in the waxed lined box were superior to those wrapped in waxed paper and then in newspaper. Winsor 1936 (38) bagged small peony buds in the field with brown paper bags, and cut the blooms when the outside petals began to loosen. The buds were placed in water for 1-2 hours, then dried and packed in cardboard boxes. Neff 1935 (21) pointed out that low turgor, brought about by storing without water, retarded maturity. He wrapped French Marigolds in wet cloth, wet moss, and waxed paper, and concluded that waxed paper was the most satisfactory. Neff 1939 (22) found that carnations stored dry (37 days) were comparable to fresh carnations, and superior to carnations stored in water. That there is little evidence in favor of soaking peony stems or sprinkling them with water previous to storage was shown by Honeywell, Gaylord and Fawcett 1940 (14). Hague and co-workers 1949 (12) were the first to use waxed boxes sealed in cellophane for the storage of cut flowers. They pointed out that the prerequisites of the film used for packaging are 1) transparency, 2) moistureproof, 3) low rate of gas transmission, 4) heat sealing, 5) water resistance, 6) sufficiently durable to withstand handling, and 7) relatively inexpensive.

Methods of Preservation

Low temperature is generally considered essential for the storage of cut flowers, but no one temperature is suitable for all flowers, (13). Neff 1939 (23) found that light, either from a screened arc lamp, direct from a mazda lamp, or filtered thru copper sulfate solution, was a great

aid in extending the life of stored flowers after they were removed to room temperature. This was specially true of those stored dry or with stems in a sugar mordant solution. That keeping qualities may be extended by exposing flowers to sunlight after removal from storage was shown by Bowden (5) using Lilium erabu. Roses stored with stems in a sugar-mordant solution under controlled conditions of light and temperature may remain turgid longer than fresh roses when placed at room temperature. Roses stored 18 days may remain turgid longer than those stored 8 days Neff 1942 (24).

In 1921 Fitting (11) reported premature withering of flowers in the presence of small amounts of CO_2 and other gases. Thornton 1930 (34) found that rose buds, when removed to warm air after a period of storage in 15% CO_2 for 7 days at $38^\circ\text{--}50^\circ\text{F}$, lasted as well as untreated roses which had been in cold storage without added CO_2 for 3 days. This treatment gave a possible gain of four days. Further work by Thornton 1930 (34) has shown that roses could be stored longer than 7 days in CO_2 and still remain in the bud stage, but upon removal to room temperature petals drop rapidly. Longley 1934 (19) stored several varieties of roses and carnations at $33^\circ\text{--}34^\circ\text{F}$ in atmospheres of carbon dioxide and hydrogen sulfide. Results varied widely depending upon kind and variety of flower. In general both CO_2 and H_2S retarded opening in storage and produced some fading. H_2S extended keeping quality of carnations but not roses. Carnation var. Spectrum, treated with H_2S for 2-3 hours were better than fresh flowers. This was not the case with all varieties. Neff 1934 (20) working with roses, peonies, iris, and verbenas found that CO_2 decreased the h-ion concentration of the cell

sap, and that this change was correlated with the change in petal color. It was pointed out that CO_2 may have a part in reducing fungal growth in storage Lin 1948 (18). He concluded that both low temperature and modified air with 5% CO_2 , 2% O_2 , and 95% N have retarding effects on fungal rots of apples. Brooks 1938 (7) showed that an atmosphere of 23% CO_2 retarded Botrytis and Rhizopus rots of strawberries, and that at 37% CO_2 their growth was completely inhibited.

Control of Fungus

Information concerning the control of fungus in storage is limited almost entirely to fruits where treatments usually consist of a fungicidal dip, fumigation before storage, or impregnated wrappers. Modifications of these techniques might warrant further investigation as applied to the storage of flowers, but none of these specific treatments were used at this time. Clayton 1941 (8) used paradichlorobenzene to control the blue mold disease of tobacco. It seemed as if this treatment might be applicable to the control of fungi on flowers in storage. The material is readily available, easy to apply, non-toxic to humans, and gives a continuous fumigation action over a long period of time. These features suggest that this material might function as a fumigant for controlling fungus on flowers in storage providing it was non-toxic to the flowers, and would inhibit the growth of the fungi. Fumigating action was obtained by Pentzer 1941 (27) working with the storage of grapes. Partial control of fungi was obtained with pellets made of sodium bisulphate and ammonium carbonate which were included with the packaged grapes. Fumigation before packing appears to offer some

possibilities. Pentzer 1941 (27) obtained outstanding results by fumigating grapes for 20 minutes previous to packing with a concentration of 1% by volume of sulphur dioxide at 70° F. Barger 1948 (3) obtained good results by fumigating cantaloupes with nitrogen trichloride. Ozone has been used rather extensively in apple storage. Smock 1941 (32) found it gave fair control of various rot organisms when introduced into the storage from 1-2 hours daily at the rate of 1-2 ppm.

Preservative Solutions After Storage

Many recommendations can be found in non-scientific journals suggesting the use of aspirin, salt, vinegar, clorox etc. in water to prolong the life of cut flowers. Ducomet 1911 (10) after testing the effect of varying concentrations of sugar and salt solutions on many different kinds of flowers, concluded that no one concentration was good for all flowers, and that the reaction varied with the genus, species and even the variety. Of the numerous solutions tested he considered sugar to be the most effective, and listed sodium chloride, dipotassium phosphate, "chloral", and magnesium sulfate as of some value. Knudson 1914 (16) was not able to substantiate the work of Ducomet. He worked mainly with flowers which normally are short lived, and pointed out that there should be greater possibilities of extending the life of flowers that normally have a long life period. By using any one of the following solutions he was able to prevent the putrifaction of marigolds and zinnias in water: .015% zinc sulphate, .05% strontium chloride plus .15% calcium chloride, .02% barium chloride plus .15% calcium chloride, .001% copper sulphate or .01% magnesium sulfate. In 1926 Pridham (29) reported on the use of

sulfurous acid by the Experiment Station in Hawaii. They found that a 6% solution increased the keeping quality of cut flowers. In 1926 an anonymous article (1) mentioned that sulfurous acid was of special value on hydrangeas and other heavy stemmed flowers. Hitchcock and Zimmerman 1929 (13) tested over 51 chemicals without any significant results, with the possible exception of ethyl alcohol. Both Phlox and Coreopsis lasted 1-2 days longer in a 1.5%-2.5% solution. They also pointed out that transpiration was reduced by many of the chemical treatments, but in all cases the flowers which remained in the best condition were those that lost the greatest amount of water daily. Arnold 1932 (2) found that a 5% glucose solution increased the life of several annuals, whereas dilute aspirin reduced their life in some instances. Contrary to the results of Hitchcock (13) he concluded that the lowering of transpiration by the sugar solution paralleled the longer life of the cut blooms. Workers in Ohio 1940 (26) found some benefit from the following; 1) hydrazene sulfate plus sugar, 2) potassium aluminum sulphate plus sugar, and 3) Santomerse penetrator plus sugar. Fifteen different amino acids were tested by Bowden (5), who found only one of these N- (β -hydroxyethyl)- β -Alanine to be beneficial. In addition several sugars, acids and aluminum potassium sulphate were tried alone and in various combinations with two commercial preservatives, "Floralife" and "Bloomlife", serving as controls. Results indicated that a combination of amino acid, sucrose, and aluminum potassium sulphate extended the keeping qualities of Better Times roses 3-5 days over commercial preservatives. Neff 1942 (24) obtained indifferent results with a number of solutions, but found solutions of ferrous chloride plus sugar, and ferrous sulphate plus sugar

materially increased the life of roses. In an attempt to prevent petal drop on a number of different genera of flowers by the use of solutions of the sodium salt of alpha naphthalene acetic acid, Whiteman 1949 (36) noted some beneficial effects at 50 ppm. on Peony var. Festiva maxima, and indifferent results with other varieties of peonies and several different kinds of flowers.

EXPERIMENTAL PROCEDURE

Cutting Methods

The peonies for this experiment were all obtained from the Cottage Garden Nursery of Lansing, Michigan. Cutting was begun on June 13, and was continued over a period of seven days. The majority of the peonies were cut between 8:00 A.M. and 12:00 noon. In some cases, however, in order to secure enough of one variety, it was necessary to cut a few during the afternoon and evening.

The following varieties of Paeonia officinalis were used; Felix Grousse (red), Reine Hortense (flesh color), Walter Raxon (coral pink), and Sarah Bernhardt (pink). These varieties were chosen because of their availability, and not necessarily because they were known to have lasting qualities.

The stage of maturity at which the buds were cut cannot be represented by inches of diameter, as this varied greatly even within a variety. Buds were cut when the outer layer of petals were just beginning to unfold, but before the center of the bloom was plainly visible. After five dozen peonies had been cut they were placed in containers of water in a closed truck. At no time were they allowed to remain in the truck for a period greater than four hours.

Since the packing operation extended over a period of several hours, it was found necessary for most efficient operation and in order to prevent the opening of the buds, to store the peonies in water in the refrigerator (45° F) until such time as they could be packed. This period varied but was usually about 4 hours.

Pre-storage Treatment

Since no information seemed available concerning the control of fungus on cut flowers during storage, the various treatments were selected on the following basis. (Table 1) The peonies were dipped in solutions of Bordeaux mixture, zerlate, parzate, silver nitrate, and actidione. After dipping, the peonies were stood upright in a five gallon can to facilitate the draining of the excess solution. Paradichlorobenzene crystals were enclosed in 3" x 3" squares of double layer cheesecloth, and the ends were pulled together to form a bag that was stapled to the collar of the box. (Fig. 1)

Note: The application rate of paradichlorobenzene was increased over the rate recommended for use in tobacco seed beds Pinkard (1939) (28) at 50°-75° F to compensate for the lower rate of volatilization (9) that would occur at the temperature used for peonies (34°-36° F). The crystals used ranged in size from 1/16" - 1/8".

In order to obtain a preliminary check on the tolerance of peonies to paradichlorobenzene, buds from peonies that were forced in the Michigan State College greenhouses were packed in waxed, cellophane sealed boxes, 21" x 5" x 4", containing cheesecloth bags of paradichlorobenzene in 1,2,3, and 4 gram quantities. The boxes were placed in 34°-36° F storage, and after two weeks were removed for observation. Since at this time there was no apparent injury to the peonies when 4 grams were included in the box, this concentration of paradichlorobenzene was used in succeeding experiments.

Packaging

Peony varieties Felix Crousse, Reine Hortense, and Walter Faxon

PRE-STORAGE TREATMENTS

TREATMENT #	MATERIAL	RATE OF APPLICATION	METHOD OF APPLICATION	REASON OF CHOICE
1.	Acti-dione	10 ppm	Dip	Promising new anti-biotic;
2.	Silver nitrate	3.75 gms. per 3 gal. H ₂ O	Dip	Reported to be as effective as Bordeaux and to leave no residue.
3.	Bordeaux	56.5 gms. each of hydrated lime and CuSO ₄ in 3 gals. H ₂ O	Dip	Generally recognized as a standard in estimating the effectiveness of other fungicides.
4.	Zerlate (zinc base)	27 gms. per 3 gals. H ₂ O	Dip	Comparatively new and effective fungicide with wide application.
5.	Parzate (zinc base)	27 gms. per 3 gals. H ₂ O	Dip	Similar to Zerlate but often effective when Zerlate is not.
6.	Paradi-chloro-benzene	4 gms. per 105 sq. ins.	In box	Continuous fumigating action.
7.	Water	-----	Dip	Control
8.	None	-----	---	Control



Fig. 1

Peonies packed in waxed cardboard box which was sealed in cellophane. A cheesecloth bag containing paradichlorobenzene may be seen stapled to the collar of the box.

were packed in waxed cardboard boxes 21" x 5" x 4"* , and heat sealed in cellophane. Six peonies were placed in each box with three heads at each end. Fig. 1. Boxes were placed in storage at 34°-36° F.

In order to determine whether a simplified method of packaging might be adopted, twenty dozen untreated peonies of the variety Sarah Bernhard were tied in bunches of six, and wrapped in waxed paper. Half of these were placed in a cardboard carton 42.5" x 14" x 12", and the other half were placed in a similar carton containing paradichlorobenzene. The crystals were placed in a folded strip of cheesecloth, 1" in width, that ran the full length of the box and was stapled to the cover. Twenty grams of paradichlorobenzene were used, which was an increase of approximately 8 grams over the rate recommended by Pinkard for tobacco (28). These boxes were placed in storage at 34°-36° F.

Fungal Isolations

Isolations of fungi were made from peonies before they were placed in storage, and again upon removal from storage. The fungi were cultured on potato dextrose agar and later identified.

Effect of Paradichlorobenzene on Specific Fungi

Fungi isolated from peonies before storage, as well as those isolated from peonies after removal from storage, were plated on petri dishes containing potato dextrose agar. The colonies were allowed to grow at room temperature until the colonies were approximately 1" in diameter, at which time the extent of the colony was inked on the outside of the petri dish. The dishes were packed one to a box, in waxed cardboard

* These boxes were not designed specially for this project. A box measuring 27" x 6" x 4" or even longer would be more desirable.

boxes, in which paradichlorobenzene crystals contained in cheesecloth were included at the rates of two and four grams. The boxes were then sealed in cellophane and placed in storage at 34° - 36° F. Boxes without paradichlorobenzene were also included for comparative purposes. After twenty days, the outermost limits of growth were again marked on the dish, and the increase in area determined by the use of a planimeter.

EXPERIMENTAL RESULTS

One dozen of each treatment and of each variety was removed to room temperature (approximately 75° F) from storage at various intervals throughout July and August. The stems were cut, and equal numbers of each variety and treatment were placed in tap water, water plus "Floralife", and a solution of 50 ppm of the sodium salt of naphthalene acetic acid. After the first two series, (14 and 31 days in storage), the naphthalene acetic acid treatment was omitted because it significantly shortened the life of the peonies.

Data from flowers stored for 14 days have not been included. These flowers served to establish the method of making observations, and all data were compiled from the five succeeding series.

Since only an occasional flower opened after two days at room temperature, the total number of open and partly open flowers was recorded at this time. It was considered necessary to include partly open flowers because Var. Reine Hortense frequently failed to completely unfold the outer row of petals. Petal abscission after vigorous shaking of the flowers, or petal wilt, served as criteria for stating flowers were dead.

In the following discussion Vars. Felix Crousse, Reine Hortense, and Walter Faxon will be referred to as Vars. 1, 2, and 3 respectively.

Effects of Pre-storage Treatments

The fungal growth was first evident directly under the bud on the margins of the bracts, as well as on blasted axillary buds. For periods longer than 66 days in storage, the fungus had progressed to the leaves, and in a relatively few cases had advanced to the flowers. Fifty five

percent of peonies representing all treatments showed visible fungal growth when removed from the boxes after a two week storage period. The quantity of fungus was not sufficient to make these peonies unmarketable. Four weeks after storage this was increased to 76%, and for periods longer than four weeks fungal growth was observed on 87%. Paradichlorobenzene completely prevented fungal growth even after 73 days in storage. This fact caused the percent of diseased flowers to be lower for all treatments, and is therefore not a representative average. There was no visible difference in control between the other treatments.

Silver nitrate caused some browning on the margins of the petals of the light colored varieties, and a white streaked appearance in the dark variety. Parzate left a white residue on flowers and foliage. Bordeaux mixture gave a blue tinge to the petals of the light varieties, and on the dark variety left a white residue. The residue on the foliage was not sufficient to be objectionable.

Paradichlorobenzene caused injury that was apparent after two weeks in storage. At that time the leaves appeared to be watersoaked when held to the light, but again this injury was not sufficient to be objectionable. After 45 days in storage the leaves showed signs of severe drying and yellowing. (Fig. 2) This was particularly noticeable on Vars. Walter Faxon and Reine Hortense which for this reason no longer had foliage that could be considered of commercial quality. After 66 days the foliage of Felix Crousse showed severe injury, and after 73 days the petals were slightly browned. The natural fragrance was masked by the odor of paradichlorobenzene which disappeared after several hours of exposure to room temperature.



Fig. 2

Shriveling and drying of foliage resulting
from the use of paradichlorobenzene.

The turgidity of the foliage varied slightly depending on the pre-storage treatment. Both turgor and color were excellent (except paradichlorobenzene) after 73 days in storage. A slight wilting was noted in the Bordeaux treatment and the dry control, but turgidity was quickly regained when the stems were placed in water.

Keeping Qualities of Cut Flowers at Room Temperature

There is a marked varietal difference as to the number of flowers opening, and to the rapidity at which this opening takes place when the flowers are removed from storage and placed at room temperature. The flowers of Var. 1 (Felix Brousse) opened most rapidly to the full bloom stage. (Fig. 3) In sharp contrast to Var. 1 the buds of Var. 2 (Reine Hortense) and Var. 3 (Walter Faxon) opened more slowly. The flowers of Vars. 2 and 3 showed a tendency to remain cupped so that the outer rows of petals assumed a more vertical than a horizontal position in relation to the stem axis. (Fig. 4) This condition was occasionally apparent in Var. 1 after 66 days in storage.

After 31 days in storage approximately 100% of the flowers of Var. 1, and 94% of Var. 3 opened when placed in water. (Fig. 5) Var. 2 showed a marked tendency to remain in bud. (Fig. 6) After 66 days in storage, records for this variety were discontinued because all flowers failed to open. After 66 days in storage several flowers of Var. 1 opened on one sector only, and appeared wilted, but after 24 hours in water they regained turgor and opened in a normal manner. (Fig. 7) In general, fewer flowers of all three varieties opened as the length of the storage period increased. (Fig. 5)

Fig. 8 shows the influence of the pre-storage treatments on the



Fig. 3

Flowers of peony Var. Felix Crousse showing fully opened condition.



Fig. 4

Flowers of peony Var. Walter Faxon showing "cupping" of petals.

% OF FLOWERS OPENING AFTER 2 DAYS AT ROOM TEMP.

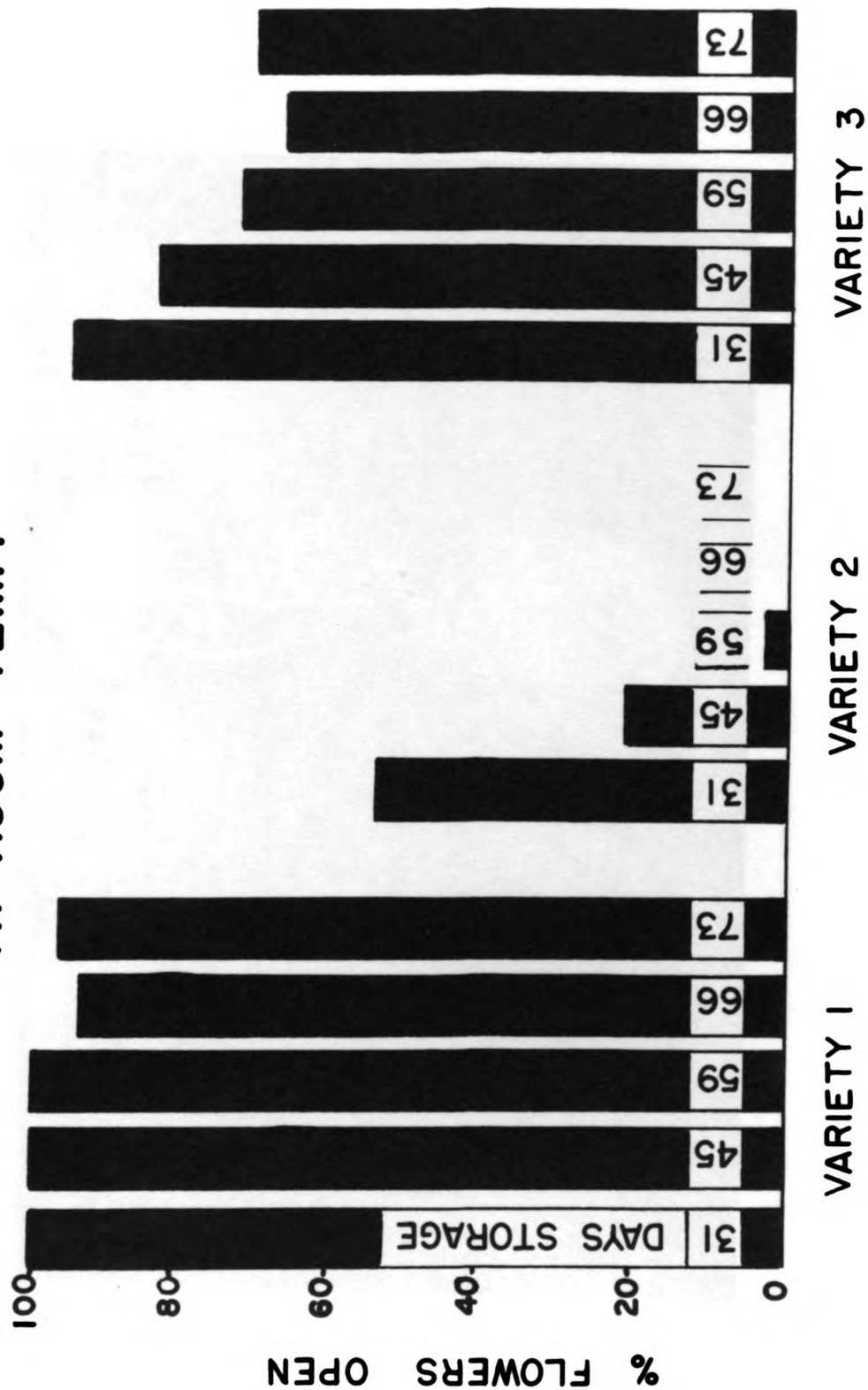




Fig. 6

Flowers of peony Var. Reine Hortense showing failure of buds to open.



Fig. 7

Var. Helix Crouse showing opening of flower on one-sector only. This condition was noted after 56 days in storage.

EFFECT OF PRE-STORAGE TREATMENT ON KEEPING QUALITY OF FELIX GROUSSE

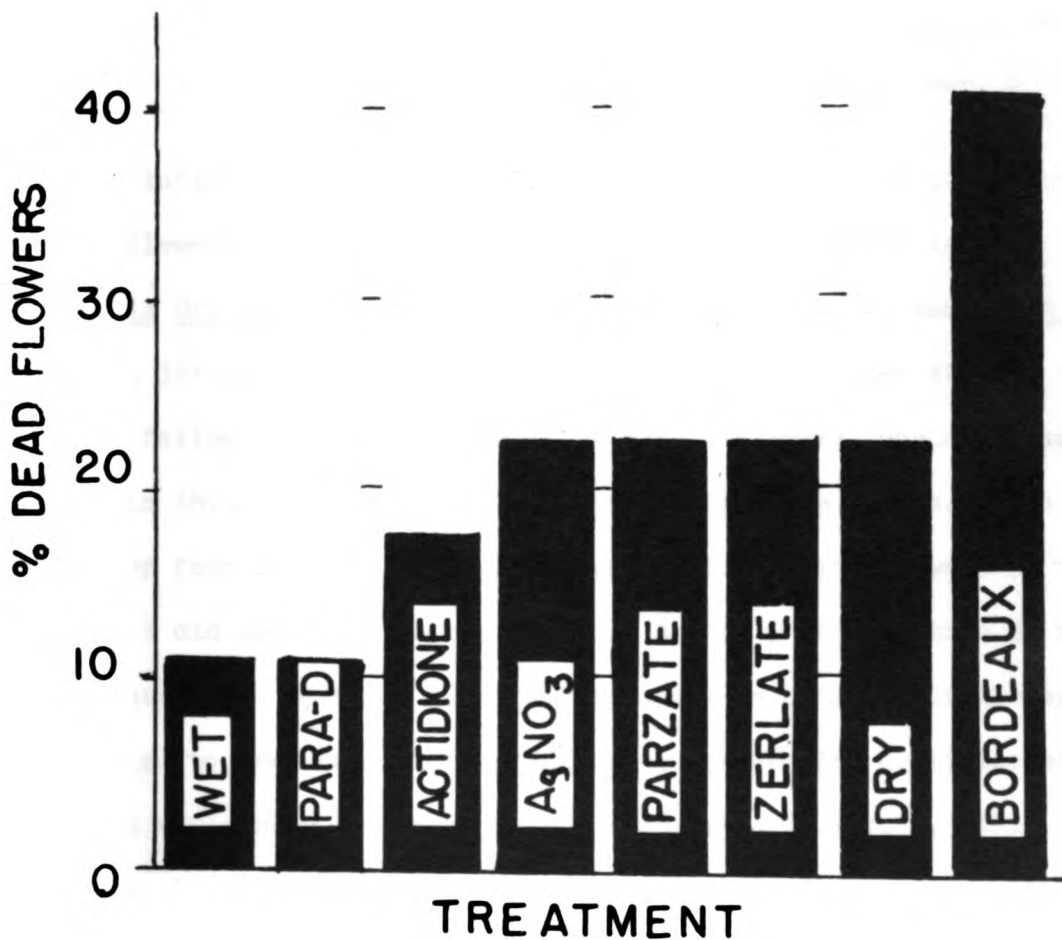


Fig. 8

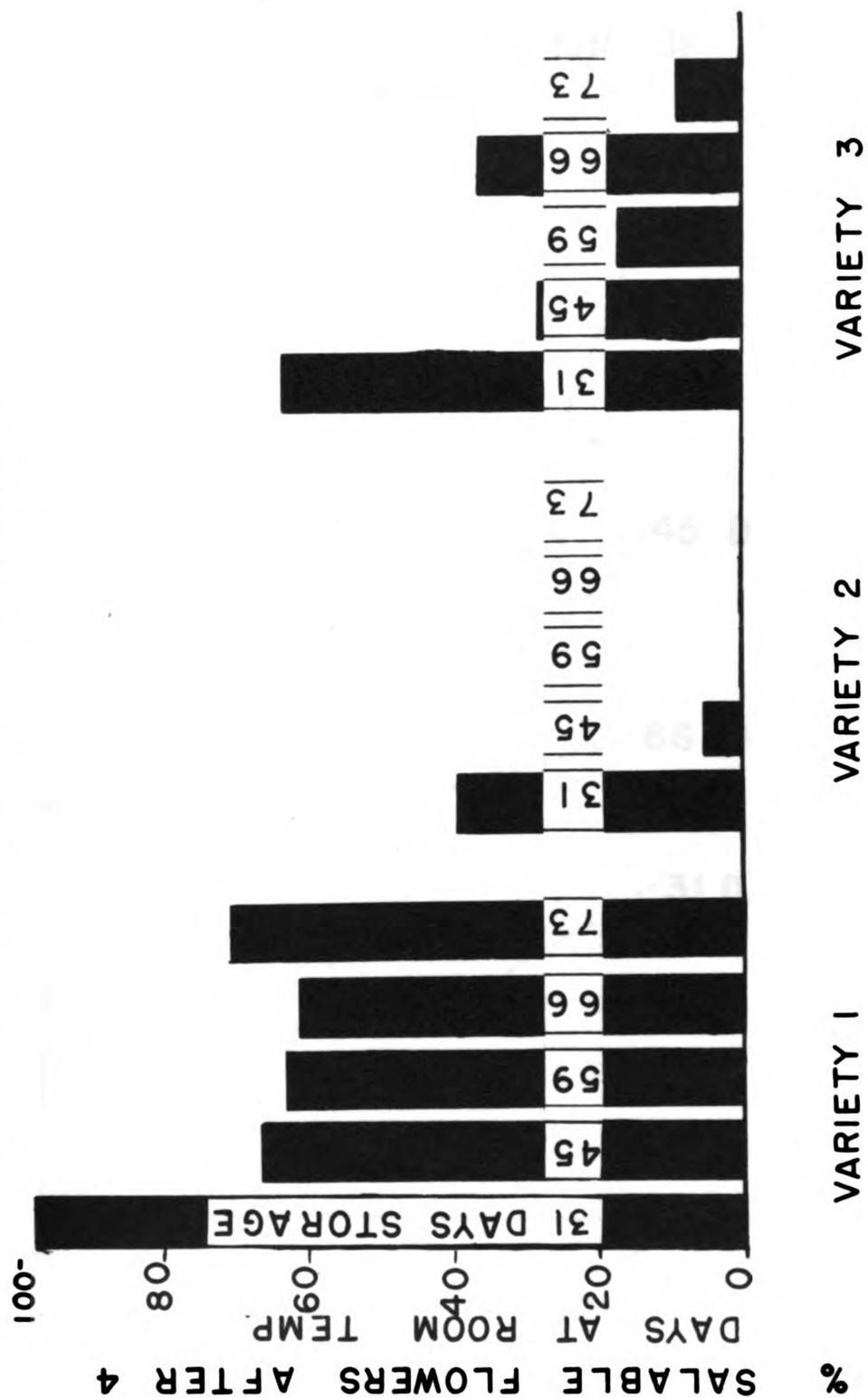
keeping quality of Felix Crousse when removed to room temperature. This variety opened more buds in a more normal manner than the others, and consequently is more representative. Bordeaux mixture was most detrimental, paradichlorobenzene and the "wet" control were most favorable, and the other treatments were uniformly injurious. The percent dead flowers is averages for 31, 45, 59, and 66 days in storage, and were obtained in the following manner:

$$\frac{\text{number flowers dead (after 5 days at room temp.)}}{\text{number flowers open (after 2 days at room temp.)}} \times 100$$

The influence of the length of the storage period on the number of salable flowers after 4 days at room temperature is shown in Fig. 9. With Felix Crousse approximately 60%, Reine Hortense 0%, and Sarah Bernhardt 35% of the flowers were salable after four days at room temperature following 45 to 66 days of storage. Flowers considered as not salable in this chart are those that did not open as well as those that died after four days. Since a large proportion of the flowers in Var. 2 and Var. 3 did not open the chart is not a true representation of the keeping qualities of those flowers that actually opened. If flowers that failed to open had not been included, the keeping qualities of these varieties would have been more nearly comparable to Var. 1. This chart represents the overall storage value of a variety from a commercial standpoint.

Results indicate that in general keeping quality is reduced as the storage period increases. This relationship is shown for Var. 1 (Felix Crousse) in Fig. 10. It can be seen that the number of flowers dead on

% SALABLE FLOWERS AS INFLUENCED BY DURATION OF STORAGE



**KEEPING QUALITY AT ROOM TEMP. AS
INFLUENCED BY DURATION OF
STORAGE**

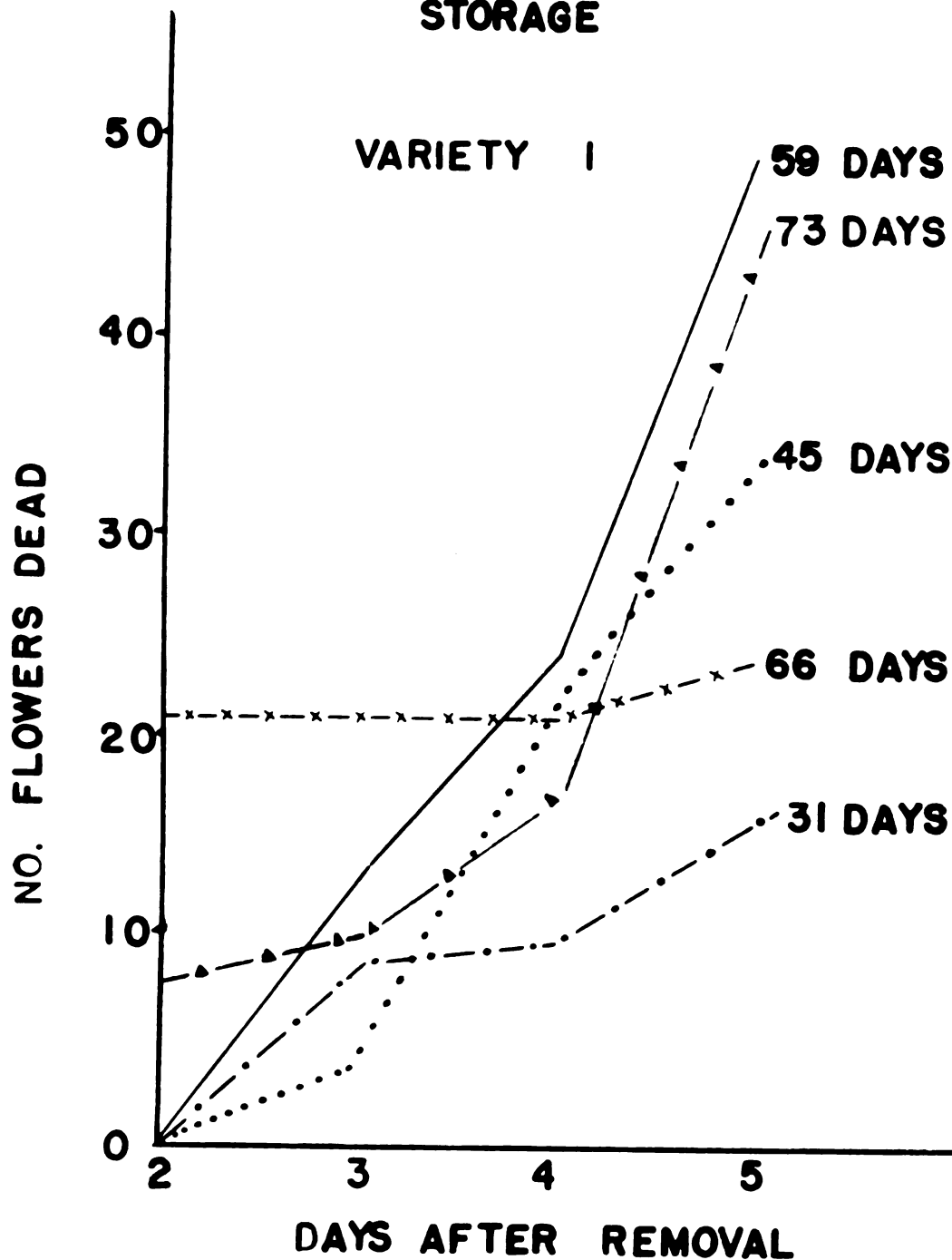


Fig. 10

the second day at room temperature increases with the length of storage, with the exception of the 73 day series. This relationship on the 3rd and 4th day is not as clearly defined, but appears to be re-established on the 5th day.

The life of peonies has not been greatly increased by using various chemicals in the water. The sodium salt of naphthalene acetic acid seriously decreased keeping qualities, and its use was discontinued. "Floralife" appeared to be of some value on Var. 3 (Walter Faxon), but more extensive trials would be necessary to justify this conclusion. The opening of the flowers was apparently not influenced by the use of "Floralife".

Peonies Stored in Large Cartons

After 45 days in storage the large cardboard cartons were opened for observation. At that time all the paradichlorobenzene crystals had volatilized, and the gas had escaped from the non air-tight box. This test was considered of no further value, and was discontinued since the flowers were as seriously damaged by fungus as were those packed dry in a carton without paradichlorobenzene.

Identification of Fungi

The fungi isolated from the peonies before storage were found to be the same as those producing the visible fungal growth on the peonies in storage. The fungi were identified as Fusarium sp. and Alternaria

Effect of Paradichlorobenzene on Specific Fungi

No growth of Fusarium sp. was evident in the petri dishes that were

placed in the refrigerator. It was assumed that 35° F was too low a temperature for normal growth of this fungus. However, a colony of Alternaria humicola almost tripled in area unless 2 or 4 grams of paradichlorobenzene had been included in the box. When this was done, there was no increase in the size of the colony. Upon removal to room temperature, colonies of both fungi made normal growth.

DISCUSSION

The reason for the failure of the buds of Reine Hortense to open when placed in water at room temperature is not entirely clear. It is possible that water was not being translocated in sufficient quantity. A red dye (acid fuschin) was readily transported up the stem and into the flower petals, but this was no indication of the quantity of water absorbed. Little difference was found between the quantity of water absorbed by one variety in relation to another, but no quantitative records were taken. The arrangement of the petals in Var. 1 (Felix Crousse) as contrasted to Var. 2 (Reine Hortense) may explain the difference in opening. In Var. 1 the flower is of the bomb type, that is the central petals are in an upright position, and these are surrounded by a single layer of petals which are folded over the inner petals. In Var. 2 the petals are tightly overlapped, and after storage the margins of the petals have a tendency to cling together, thus making it more difficult for the flower to expand. In Var. 1 opening only involves the unfolding of the outer layer of petals, whereas in Var. 2 all the petals must unfold.

It was interesting to note that in all cases the first signs of visible fungal growth appeared in the vicinity of the buds rather than on the foliage. The margins of the modified green petals that surround the bud in its earliest stages of growth were the first to show fungal activity. A sugar gel is found on young peony buds, which makes a natural media for fungal growth. Ants are often found feeding on this material, and may carry fungus spores. Leech 1938 (17) found that the most commonly occurring spores in the infrabuccal pellets of ants found associated with peony buds were those of Alternaria sp.. A species

of this same fungus has been shown to be present on peonies in the present investigation, and it is believed to be the most serious source of infection at this time. This suggests that a control program designed to eliminate ants might lower the incidence of Alternaria.

The use of paradichlorobenzene did not prove to be commercially practical in these experiments. It is true that control of fungi was obtained without disfiguring injury to the foliage for a period of 4 to 6 weeks. The amount of fungus growth in the untreated boxes for a similar period was probably not sufficient to be objectionable.

It is probable, however, that since the cellophane cover over the boxes almost completely eliminated loss of the paradichlorobenzene gas, a much lower concentration of paradichlorobenzene might give effective control without injury to the flowers. It seems likely that an optimum amount of paradichlorobenzene could be established to guarantee fungus control without causing injury to the peony. It might be practical to pack the peonies in such a manner that intermittent fumigation could be practiced.

No satisfactory explanation has yet been offered for the control of downy mildew of tobacco with paradichlorobenzene. Horsefall (15) suggests that since it has been found that fumigation must be repeated at frequent intervals, the fungus is probably not killed but rather sporulation has been retarded, and that this inhibition of sporulation may be caused by a disturbance in the spindle formation of mitosis. Horsefall bases this suggestion of the mechanism of inhibition of sporulation on some work by Berger 1944 (4) who treated onion root tips with benzene, and found that spindle formation was interfered with and diplo-chromosomes and tetraploid

cells resulted.

Since the vapours of paradichlorobenzene go into solution when they are in contact with water on the surface of the leaf, dipping the stems in a wax preparation previous to packing might reduce injury. The wax should lower the quantity of vapor that enters the leaf, therefore substantially reducing the injurious effects. It is conceivable that the fungus might grow under the wax coating or that its' use might have other detrimental effects. This modification in the use of paradichlorobenzene warrants further investigation, along with other materials that would provide a similar action.

The various fungicidal dips used to control fungus were apparently without benefit. Since at least two of the causal organisms have now been identified, it would appear practical in any future work to use the technique suggested by Nielson 1942 (25) to determine the effect of various fungicides on these organisms. This method consisted of spraying individual leaves with fungicide, adding spores, and incubating in a moist chamber.

Some explanation should be offered for the detrimental effects of Bordeaux mixture. Conflicting claims have been made about the influence of Bordeaux mixture on transpiration. Horsefall (15) believes that these claims are probably all correct, since Bordeaux sometimes increases, sometimes decreases, and sometimes has no effect on transpiration. He further points out that in general, Bordeaux increases cuticular and reduces stomatal transpiration. Since in cold storage the stomates would be closed, no reduction of stomatal transpiration could occur, and if Bordeaux caused an increase in the cuticular transpiration this might be

valid reason for explaining the detrimental effects observed. This reason is further strengthened by the fact that upon removal from storage the foliage of the peonies treated with Bordeaux were less turgid than those in the other treatments. On the other hand, the peonies in the paradichlorobenzene treatment showed a severe loss of turgidity, and yet were superior to the other treatments in keeping qualities. With this in mind it would seem necessary to explain the effects of Bordeaux mixture on some other basis.

SUMMARY

Variety Felix Crousse is superior to either Reine Hortense or Walter Faxon for long term storage at 35° F.

Storing peonies in waxed boxes sealed in cellophane appears to increase their storage life.

In general, keeping qualities after removal from storage to room temperature, varies inversely with the length of the storage period.

After 60 days in storage 61% of Felix Crousse, 0% of Reine Hortense, and 36% of Walter Faxon were in a salable condition after 4 days at room temperature.

Fungi isolated from the peonies in storage were identified as Alternaria humicola and Fusarium sp.. Low temperature (35°F) apparently prevented further growth of Fusarium sp. but not Alternaria humicola.

Paradichlorobenzene completely controlled fungal growth on peonies in cellophane sealed wax boxes stored at 35° F for over 73 days. Paradichlorobenzene used at 2 or 4 grams per 420 cubic inches, prevented the growth of Alternaria humicola but did not prove lethal. Paradichlorobenzene caused severe injury to the foliage but not to the flowers. This injury was not sufficient to be objectionable until after 59 days in storage.

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