A SEARCH FOR METHODS OF PROLONGING THE LIFE OF CUT CARNATIONS

by

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INTRODUCTION

A survey of the floriculture industry based on the 1939 census gave as an estimate for 1946 total sales receipts, the figure $1,028,500,000. According to a survey made by Roses Inc. (1938) in the states of New York, Pennsylvania, Massachusetts, Illinois, Colorado, and Ohio alone there were approximately 10,000,000 square feet of valuable greenhouse space devoted to the production of carnations. One square foot of bench space planted with carnations in a year's time should produce about 62½ flowers. That would seem to indicate that in the six states previously mentioned about 625,000,000 were produced in one year. A letter from Leland T. Kintzele, Secretary-Treasurer of the Denver branch of the American Carnation Society states, "We estimate that the grower members of our Society represent about 40% of the carnation growers in the country, and these members have 4,893,000 square feet of bench space under cultivation. On this percentage basis, a reasonable estimate, therefore, for the entire country would be 12,232,500 square feet devoted to the production of carnations, which represents 30,000,000 or more plants." Another reasonable estimate would be that in a year's time an average carnation plant should produce

25 flowers. This would amount to a total of 750,000,000 carnations being produced in the United States each year. There is a discrepancy between these total figures. By accepting either one of these, however, it is still obvious that the growing of carnations is no small enterprise in the United States.

Refrigeration is the method now used universally for storing almost all cut flowers. This method is expensive to maintain, the necessary equipment is cumbersome, and the flowers cannot easily be displayed while so stored. Almost all imaginable methods have been tried to extend the life of cut flowers by other means. Many of these methods have had a measure of success, but to date none of them has superseded refrigeration.

HISTORICAL SUMMARY AND REVIEW OF LITERATURE

The search for the "fountain of youth" fills an important section of the history of the Americas. Man has long sought a means of extending his too brief stay on this earth. Because of new quick-freezing and dehydrating methods being introduced almost daily, the evolution of the preservation of food is still in a definite state of flux. However, until mankind had developed some spare time through mechanization, the preservation of flowers did not seem very important. Indeed, itwas not until 1907 when Perret (15) wrote an article advocating the use of low temperatures in storing flowers that any written scientific consideration was given to this matter. Shortly thereafter in 1911 Ducomet and Fourten (2) recommended the use of various salts of potassium at the rate of 100 ppm in a solution in which flower stems could be put to extend the flower's life. Knudsen (6) in 1914 claimed that a mixture of chlorides of calcium, strontium, and barium, or just zinc sulfate alone would delay the decay of african marigolds, Tagetes erecta (Linn.), and zinnias, Zinnia elegans (Linn.).

Low temperature and high humidity were recommended as factors in prolonging the life of cut flowers by Hitchcock and Zimmerman (4) in 1929.

A different attack on the problem was introduced when Thornton (21) in 1930 advocated the revolutionary procedure of using carbon dioxide for prolonging the flower's cut life. Dorner (1) in 1934 suggested that flowers be plunged in water immediately after cutting so that no air might enter their stems.

Wright and Griffiths (23) in 1934 made rather extensive experiments with tulips, Tulipa spp. (Linn.). They recommended storing them just above the freezing point for a limited period of time to get best results. They also discovered that there was a varietal difference in response to cold storage treatment.

A bacteriological approach to the problem was adopted by Ratsek (17) in 1935. He sponsored the use of copper containers for flowers. The slight amount of copper which apparently went into the water was sufficient to control most of the bacteria present.

As the result of considerable testing on the part of Neff and Loomis (14), in 1936, a method was announced for storing french marigolds, Tagetes patula (Linn.). They recommended keeping them dry-wrapped in wax paper at 33 degrees F.

Neff (12) wrote again in 1939 on flower storage. He advocated withholding water from cut carnations, Dianthus caryophyllus (Linn.), to give them an opportunity to wilt

a bit, packing them in containers without water, providing some means of aeration, and storing them at 33 degrees F. In a later article in 1939 Neff (11) placed the lower portions of the rose, Rosa hybrida (Tourn.) stems in a flask containing a "commercially available solution designed to maintain flowers in a fresh condition for a long time. Two and one-half times the amount of sugar recommended by the manufacturers was added to the solution." In this experiment he maintained a temperature of 34 degrees F., low humidity, aeration, and a Mazda light. The light served to minimize bluing of the rose petals. When they were removed after 165 hours of this storage and placed in water at a normal temperature, the flowers tended to have better keeping qualities than fresh roses.

Laurie's (8) investigation into the use of chemicals in the water in which plants were set showed that hydrazine sulfate and sugar would extend most flowers' lives. One quarter teaspoonful of boric acid in one quart of water made a solution in which cut carnations stayed fresh longer. A 10 percent to 15 percent sugar solution prolonged the life of China asters, Callistephus chinensis (Nees). He found that a solution consisting of ½ teaspoonful of potassium aluminum sulfate, ½ teaspoonful sodium hypochlorite, 1 pinch ferric oxide, and one teaspoonful of sugar to a quart of water made a solution in which roses, Rosa

spp. (Tourn.), kept very well.

The most comprehensive coverage of the problem of cut flower preservation was done by Tincker (21) in 1942. He reviewed the progress to that date on the subject and proceeded to add some observations of his own. He pointed out that there are several cultural practices which will help extend the cut flower's life. These are: no overforcing, optimum shading, and proper watering. He advised splitting milky stems; sealing succulent stems with heat; reductions in leaf surfaces; picking violets, Viola odorata (Linn.), only when fully open; picking daffodils, Narcissus spp. (Tourn.), in bud and allowing them to open in a gently heated shed; picking carnations, Dianthus caryophyllus (Linn.), before maturity and keeping them up to their necks in water until grading; and storing iris, Iris spp. (Tourn.), at 60 degrees F.

Once again in 1942 Neff (11) published some more results from his experiments concerning the effects of storage conditions on cut roses, Rosa hybrida (Tourn). His results were good when he stored his roses in solutions containing water, sucrose, and a salt of certain heavy metals. He suggested using ferrous sulfate, sucrose, water, and molybdic acid.

Burning the stem-end of wisteria, Wisteria sinensis

(Sweet.), and hydrangea, Hydrangea opuloides (Steud.), before arranging in water was suggested by Huttenlocher (5) in 1945. She also advised dipping stems in boiling water for several minutes to prevent bleeding of the following: poppies, Eschscholtzia spp. (Cham. in Nees) or Papaver spp. (Benth and Holt); gerberas, Gerbera jamesoni (Bolus); dahlias, Dahlia spp. (Cav.); poinsettia, Poinsettia pulcherrima (Willd.); heliotrope, Heliotropum peruvianum (Linn.); and sweet mignonette, Reseda odorata (Linn.). She advised crushing the hard stems on flowers such as chrysanthemum, Chrysanthemum morifolium (Ramat.), and roses, Rosa hybrida (Tourn.). A novel idea she brought forth was the soaking of calla, Zantedeschia aethiopica (Spreng.), leaves over night before arranging.

Hamner, Carlson, and Tukey (3) in 1945 developed a process whereby flowers were immersed in water, subjected to a vacuum treatment which, when the vacuum was removed, left the flowers looking water-soaked but longer-lasting.

About 1945 a radical departure was made from the time-honored custom of picking flowers early in the day. Lewis and Howland (10) reported that year that if roses were cut at 2:00 P. M., set in warm water, and later stored at 40 degrees F. to 50 degrees F. they would last longer. Immediately all other important cut flowers were given the same treatment, but all of the results were

negative. It seems that the rose is unique in that one respect.

Cut flowers such as camellias, Camellia spp. (Linn.), and gardenias, Gardenia florida (Linn.), need no water, but are benefited by a daily syringing of the foliage according to Platt (16) in 1946.

A few specific recommendations were made by Rowley (18) in 1947. She suggested cutting gladiolus, Gladiolus spp. (Tourn.), as soon as the second flower on the spike opens; cutting iris, Iris spp. (Tourn.), when the first bud is ready to open; forcing water into the stems of waterlilies, Nymphaea spp. (Tourn.), with a tiny syringe after they have stood in 2 to 3 inches of hot water for a half hour; splitting the stems of peonies, Paeonia spp. (Tourn.), 3 to 4 inches from the end; and singeing the hair from the stems of zinnias, Zinnia spp. (Linn.).

An entirely new method was found to be successful when Sherwin and Hamner (19) in 1948 reported the successful use of a plastic material, Geon 31X, as a dip. Gardenias, Gardenia florida, (Linn.), were dipped in a 20 percent solution of it and they lasted 20 to 36 hours longer than untreated gardenias.

The present flower handling practices are based on the findings of Laurie and Bryant (9) in 1948. They found that the keeping quality of cut flowers is extended by

storage in an atmosphere containing a carbon dioxide content between 5 percent and 15 percent, that a relatively high moisture content in the atmosphere immediately surrounding cut flowers reduces the water loss from plant tissues by the process of transpiration, and thus maintains the flower in a fresh and salable condition while avoiding wilting of petals and foliage. By storing the flowers with the stems out of water, the amount of water available to the cells of the plant tissues is greatly reduced, thus the rate of cell elongation and maturation as well as the physiological activity of the cell is retarded. They found that storage temperatures around 40 degrees F. were best.

OBJECTIVES OF THE PRESENT STUDY

The primary objectives of this search for methods of prolonging the life of cut carnations are as follows:

1. To discover a new chemical or combination of chemicals which, when placed around the carnations' stems in a certain concentration, will thereby significantly extend the carnations' salable life.

2. To investigate the use of a vacuum process whereby the chemicals used in objective #1 could be introduced into the tissues of the carnations and thereby significantly extend the carnations' salable life.

3. To determine what influence the cut stem length of the carnation has on its salable life.

4. To determine what effect the height of water on the cut carnation's stem has on its ultimate salable life.

5. To determine what effect the stripping of the lower leaves from the cut carnations' stems would have when the stems are placed in different depths of water.

METHODS OF PROCEDURE

EQUIPMENT AND MATERIALS

Containers, Pressure Guage, Stands, Vacuum Chamber, Thermometer

One 10-liter Shebler dessicator was used as a vacuum chamber with a 2-holed rubber stopper in the top. In one of the holes was placed a 3-way ground glass valve. This was used to control the amount of vacuum in the chamber. To one of the arms of the valve a 36 inch piece of high-pressure rubber tubing was fastened. The other end of the tubing connected with a vacuum pump. The pump had a capacity of 32 pounds pressure and was run by a belt from an electric motor. The other hole in the stopper of the Shebler dessicator had an L-shaped piece of glass tubing in it. This was connected by means of a short piece of high-pressure rubber tubing to a pressure guage which was mounted on a clamp stand.

A Fahrenheit thermometer with a range of 32 degrees to 100 degrees was quite adequate. Two 2-liter beakers were used to hold the various solutions and carnations for the many vacuum treatments. A 5 inch coverglass upon which was placed a partially filled 250 ml. Florentine flask served to hold the carnations down while they were undergoing vacuum treatments. A 500 ml. graduate was sufficient for all of the fluid measurements.

It was found that 12 oz. bottles such as are used for tomato catsup were excellent for placing the individual flowers in while the lengths of their salable lives were being observed. The mouths were just large enough to accomodate the calyx tube of the flower. This allowed the flower to rest without any pressure on its petals and the calyx tube was quite effective in preventing any evaporation from the solution in which the stem was suspended. One hundred 12 oz. catsup bottles were used.

Eight 1 quart mason jars were used for all the sequences which did not require any special processing or solutions.

Chemicals

It was found necessary to add a pinch of Vatsol to every 2 quarts of chemical concentrate when it was desirable to get penetration through the waxy epedermis of the carnation in the vacuum treatments. Ordinary cane sugar was used in preference to some which would be chemically pure. Ordinary cane sugar has but a fraction of 1 percent impurities, it is much cheaper, and so it was chosen. Other chemicals used were molybdic acid, ferrous sulfate, alpha naphthylene acetic acid, citric acid, ascorbic acid, and 2,4-D.

Greenhouse Space

An entire potting bench in the packing-shed of the Oregon State College Greenhouse range was reserved for the experiments. There the carnations were placed in their respective solutions and their salable lives measured. The bench was three feet wide by nine feet long. The windows were covered with a blue-green wrapping paper so as to minimize any injurious light effects.

A smaller bench on the opposite side of the packing-shed was used for the vacuum processing apparatus.

Storage Conditions

Conditions in the packing-shed were considered far from ideal. The temperature varied from 68 degrees F. to 78 degrees F., and the humidity was much lower than would be found in an ordinary house. These two factors undoubtedly shortened the life of every carnation which was tested.

The Carnation Supply

All of the carnations in the Oregon State College Greenhouse were very kindly set at my disposal. With that great quantity at my disposal it was still difficult to get any large number of flowers of the same variety and at the same stage of maturity. In fact the tests concerning

correlation of stem length to long salable life was the result of a series of six different groups of carnations.

TECHNIQUE

Methods of Chemical Treatment

The sequence of tests followed rather a set pattern. Various concentrations of a chemical which were reportedly instrumental in extending the carnation's salable life were poured in marked containers, and the carnations' stems were placed in them, and the results observed and recorded. The next test duplicates the conditions of the first excepting the carnations are placed in their respective solutions and placed in a Shebler dessicating chamber. An electric motor which was connected with a vacuum pump was started. This evacuated most of the air from the chamber and in five minutes a vacuum of 32 pounds pressure was attained. It was held there for another five minutes at which time the motor was turned off and the vacuum was gradually relieved so that in ten minutes the pressure was back to normal. The flowers were thoroughly rinsed and then placed in carefully labeled 12 oz. catsup bottles so that the water in the bottle did not quite reach the bottom of the calyx tube of the carnation. The flowers were left there and their respective salable lives recorded.

Figure 1

Vacuum Processing Equipment For This Work in the Oregon State College Greenhouse

The third test was similar to the second excepting that instead of water in the bottles, there was the same chemical concentration in which they had just received their vacuum treatment.

For convenience in cataloguing, the tests are grouped by procedures, i. e. all tests which did not contain a vacuum treatment but which did involve the use of a chemical were placed in the first group, the tests involving vacuum treatment with a chemical were in the second group, and the others were in the third group.

DEFINITION

The term "mean salable life" is used in this thesis many times. For this reason it was thought advisable to explain more fully the exact sense in which it is used. The term "salable life" signifies that interval between the time when the outer petals are first perpendicular to the stem axis to the time when the carnation shows first signs of wilt or other deterioration. In most cases this term is applied to a group of carnations so the term "mean salable life" refers to the average of the "salable lives" in that group.

RESULTS

THE EFFECT OF PICKING CARNATIONS AT SPECIFIED INTERVALS FROM A DEFINITE BUD STATE ON THE LENGTH OF THEIR SALABLE LIFE

It was thought that perhaps there was a definite bud stage of the carnation at which it might best be picked for the longest salable life. A group of fifteen buds were selected with each bud just showing its first color. Two weeks later it appeared that the buds had matured enough that they might eventually fully open, so the first bud was picked with its stem 3½ inches long. It was set with the stem in water where its period of salability was observed and recorded. Each succeeding day another bud was picked and given the same treatment as the first. This method was followed until all of the flowers had been picked and their salable lives observed.

Looking at Table 1 it is easily seen that the best time to pick the carnations for longest salable life is about three weeks after the first bud coloration. There is a period of about six days where there is but one days' difference in the salable life. This may seem to indicate that there is considerable leeway in regards to the best picking time. In practice, however, it was found that an even more definite salable life could be maintained if the flowers were picked when the outer petals were first

perpendicular to the stem axis.

Refering to Table 1 again it can be seen that it is somewhat better to pick the flowers too late than it is to pick them too early.

Table 1

The Effects of Picking Carnations at Specified Intervals from a Definite Bud Stage on the Length of Their Salable Life

Interval between the first bud coloration and the time when the flower was picked	Salable life
days	days
14	1
15	1
16	1
17	1
18	1
19	3
20	4
21	4
22	5
23	5
24	4
25	4
26	3
27	3
28	3

Figure 2

Carnations Picked at the Same Interval From a Definite Bud Stage. Note the variation in blossom maturity.

THE EFFECT OF CHEMICAL CONCENTRATIONS ON THE PRESERVATION OF CUT CARNATIONS

Sugar

The practice of setting flowers with their stems in sugar solution in order to extend their salable life was suggested by Neff (11) and Laurie (8). Table 2 shows the result of an experiment whereby solutions ranging from one of pure water to one containing 200,000 ppm of sugar were placed in 12 oz. bottles into which carnations were set.

The flowers were all picked when the outer petals first were perpendicular to the stem axis. The stems were shortened to 3½ inches and placed in a bottle on which the quality of the contents were carefully labeled. Ninety carnations were used in this experiment.

An analysis of the results shown on Table 2 would show that the control had a mean salable life of 4.6 days which was about the average life of all of the controls. The mean salable life of all of the sugar treatments was 4.8 days. It will be noted that there was a definite increase in the mean salable life as the sugar concentrations were increased. An exception to this trend was the 100 ppm concentration which was no better than the control.

The result would indicate that the setting of carnations in a 20 percent sugar solution did extend their cut life appreciably.

Table 2

The Effect of Sugar Concentration on the Preservation of Cut Carnations

Concentrations of sugar solutions	Number of flowers	Number of flowers in salable condition after specified periods of treatments: (Days)								
		1	2	3	4	5	6	7	8	9
ppm										
Control	10	10	10	10	8	5	3			
12½	10	10	10	10	7	3	2			
25	10	10	10	10	6	5	3			
50	10	10	10	10	10	7	2			
100	10	10	10	10	10	5	1			
200	10	10	10	10	10	7	3			
50,000	10	10	10	10	10	6	4			
100,000	10	10	10	10	10	6	4	1		
200,000	10	10	10	10	10	7	4	2		

THE EFFECT OF CHEMICAL CONCENTRATIONS ON THE PRESERVATION OF CUT CARNATIONS

Ferrous Sulfate

The use of ferrous sulfate for prolonging floral life was first mentioned by Neff (11) in 1942 in his experiments concerning the effects of storage condition on cut roses. He used it as a "mordant" to retain the color in the petals of certain roses.

The carnations were all picked at the same stage of maturity for this test. The stems were all cut to 3½ inches and set in the bottles whose ferrous sulfate concentration contents were marked on the outside. The results were observed and recorded. The concentrations started at 400 ppm and were consecutively halved down to 12½ ppm. Seventy carnations were used in this experiment. The results are shown in Table 3. The mean salable life of the control was again 4.6 days. The mean salable life of all of the carnations in ferrous sulfate solutions was only 4.25 days.

There seems to be no definite trend as the difference between the lower concentration and upper concentrations is only .2 salable life days. No advantage in petal coloration was noted. The best result was from that group in the 100 ppm concentration. However, it was but .2 salable days longer than that of the control.

There does not seem to be any advantage to using this chemical by this method.

Table 3

The Effect of Ferrous Sulfate Concentrations on the Preservation of Cut Carnations

Concentrations of ferrous sulfate solutions	Number of flowers	Number of flowers in salable condition after specified periods of treatment: (Days)								
		1	2	3	4	5	6	7	8	9
ppm										
Control	10	10	10	10	10	5	1			
12½	10	10	10	10	7	4	1			
25	10	10	10	10	8	4	2			
50	10	10	10	10	7	5	1			
100	10	10	10	10	8	4	2			
200	10	10	10	10	7	3				
400	10	10	10	10	6	2	1			

THE EFFECT OF CHEMICAL CONCENTRATIONS ON THE PRESERVATION OF CUT CARNATIONS

Molybdic Acid

The use of molybdic acid in this test was the result of an arbitrary choice. Neff (1) recommended "--- one of the following promising salts: molybdic acid, cobalt, bismuth, lead, uranium, or tin." as one of the ingredients in a solution designed to maintain the color and turgidity in rose petals.

The carnations were all picked at the same stage of maturity for this test. The stems were cut to 3½ inches. The bottles were carefully labeled and filled almost to the top with their respective concentrations. The flowers were placed with their stems in bottles, and their salable lives were observed and recorded.

Seventy carnations were used in this experiment. As seen in Table 4 the mean salable life of the control was 4.6 days. The mean salable life of all of the carnations was 4.59 days. The results were uniformly better than the control with the exception of the 100 ppm concentration which had a mean salable life of only 3.8 days.

While the majority of the carnations lasted longer with the molybdic acid solutions than without, the increase was not significant and this method of introducing molybdic acid is not recommended.

Table 4

The Effect of Molybdic Acid Concentrations on the Preservation of Cut Carnations

Concentrations of molybdic acid solutions	Number of flowers	Number of flowers in salable condition after specified periods of treatments: (Days)								
		1	2	3	4	5	6	7	8	9
ppm										
Control	10	10	10	10	10	5	1			
12½	10	10	10	10	10	5	2	1	1	
25	10	10	10	10	10	6	2	1		
50	10	10	10	10	10	4	1	1		
100	10	10	10	8	6	2	2			
200	10	10	10	10	10	4	1			
400	10	10	10	10	9	5	3			

THE EFFECTS OF VACUUM TREATMENTS AND CHEMICALS ON THE PRESERVATION OF CUT CARNATIONS

Sugar With Vacuum Treatments

The practice of setting flower stems in sugar solutions in order to extend their salable lives was suggested by Neff (11) and Laurie (8). Hamner, Carlson, and Tukey (3) developed a vacuum process whereby the flowers were immersed in water, treated with a vacuum, relieved of the vacuum, and removed from the water.

These two processes were incorporated in this test in order that sugar might be drawn directly into the plant tissues to act as a nutrient.

The carnations were immersed in their respective 2 quarts of certain sugar concentrations to which a pinch of vatsol had been added to allow the solution to penetrate through the waxy cuticle covering both the carnation stem and petals. A weight was placed on the carnations to insure against their rising during the process. The 2-liter container holding both the solution and the carnations was placed in a Shebler dessicating chamber, the air was evacuated so that in 5 minutes there was a vacuum of 32 pounds which remained constant for the next 5 minutes. The vacuum was relieved during the next 10 minutes. The flowers were removed, gently washed and set with their stems in pure water, the salable life observed and recorded.

The flowers showed no ill effects from the vacuum. Most of them had a water-soaked appearance. Those which did not have that soaked appearance did not last as long.

Table 5 shows that the control had a mean salable life of 4.6 days. There were 170 carnations used in this test. The mean salable life of all which received the vacuum treatment with sugar was 5.1 days. The trend was fairly definite. The mean salable life varied directly with the higher sugar concentration. The one exception to that trend was that group in which there were 20,000 ppm of sugar. The mean salable life in this instance was 4.6 days.

Apparently this procedure holds promise. The 200,000 ppm concentration of sugar had a mean salable life of 5.7 days, over one day longer than the average control and .3 days longer than the same concentration without the vacuum treatment. The concentration containing but 200 ppm of sugar with the vacuum process gave the same result as the 200,000 ppm concentration of sugar did without a vacuum treatment.

Table 5

The Effects of Vacuum Treatments and Sugar on the Preservation of Cut Carnations

Concentration of sugar solutions in the vacuum treatment ppm	Number of flowers	Number of flowers in salable condition after specified periods from treatments: (Days) 1	2	3	4	5	6	7	8	9
Control	10	10	10	10	8	5	3			
12½	10	10	10	9	7	7	2			
25	10	10	10	8	8	7	4			
50	10	10	10	10	10	6	4			
100	10	10	10	10	9	7	5			
200	10	10	10	10	10	8	5			
400	10	10	10	10	9	9	5	1		
800	10	10	10	10	10	8	4			
10,000	10	10	10	9	8	8	5			
20,000	10	10	10	10	8	6	2			
25,000	10	10	10	10	10	7	4	1		
30,000	10	10	10	10	10	8	3			
40,000	10	10	10	10	9	6	4			
50,000	10	10	10	10	8	6	5	2		
100,000	10	10	10	10	9	7	6	3	1	
200,000	10	10	10	10	9	7	6	3	1	1
400,000	10	10	10	10	9	8	6	1		

THE EFFECTS OF VACUUM TREATMENTS AND CHEMICALS ON THE PRESERVATION OF CUT CARNATIONS

Sugar With and After Vacuum Treatments

This experiment was almost identical to the one preceding it. The essential difference was that after the flowers were washed, following the vacuum treatment, the carnations were set with their stems in the same solution in which they had received their respective vacuum treatments. The purpose of this was to give the flowers further opportunity to get sugar through their stems.

One hundred carnations were used in this experiment. The results are shown in Table 6. The mean salable life of the control group was 4.3 days. This still compares favorably with the mean salable life of the sugar-treated group which was but 2.76 days. At this stage these were the poorest results obtained through the use of sugar.

Table 6

The Effects of Vacuum Treatments Followed by Placement in Sugar Solutions on the Preservation of Cut Carnations

Concentrations of sugar solutions in the vacuum treatments	Concentrations of sugar solutions in the vacuum treatments	Number of flowers	Number of flowers in salable condition after specified periods from treatments: (Days)								
			1	2	3	4	5	6	7	8	9
ppm	ppm										
Control	Control	10	10	10	10	8	5				
12½	12½	10	10	10	5						
25	25	10	10	7	5						
50	50	10	10	10	9	9	7				
100	100	10	10	5	2						
200	200	10	5								
25,000	25,000	10	10	10	9	2					
50,000	50,000	10	10	10	7	4					
100,000	100,000	10	10	6							
200,000	200,000	10	10	10	8	6					

THE EFFECTS OF VACUUM TREATMENTS AND CHEMICALS ON THE PRESERVATION OF CUT CARNATIONS

Ferrous Sulfate With Vacuum Treatments

This experiment was based on the work of Neff (11) and Hamner, Carlson, and Tukey (3). The purpose was to introduce ferrous sulfate into the plant tissues through the use of the vacuum. It was hoped that the ferrous sulfate would act as a "mordant."

Seventy carnations were used in this experiment. As shown in Table 7 the mean salable life of the control group was 4.6 days. The mean salable life of all the tests using the vacuum treatment and ferrous sulfate was only 1.8 days. This means an average reduction of salable life of 2.3 days, a most significant loss.

It was rather obvious from the moment the carnations were removed from the vacuum that some of those in the higher concentrations were "burned." Inside of 24 hours the flower petals were completely plasmolyzed on some of them.

The trend was fairly obvious: the higher the concentration of ferrous sulfate in the solution, the shorter the salable life.

Apparently the vacuum process served to hasten the damaging effect of the ferrous sulfate.

Table 7

The Effects of Vacuum Treatments and Ferrous Sulfate on the Preservation of Cut Carnations

Concentrations of ferrous sulfate solutions in the vacuum treatments	Number of flowers	Number of flowers in salable condition after specified periods from treatments: (Days)								
		1	2	3	4	5	6	7	8	9
ppm										
Control	10	10	10	10	10	5	1			
12½	10	10	10	5						
25	10	10	10	5	2					
50	10	9	7	3						
100	10	8	4	1						
200	10	8	5							
400	10	8	2							

THE EFFECTS OF VACUUM TREATMENTS AND CHEMICALS ON THE PRESERVATION OF CUT CARNATIONS

Ferrous Sulfate With and After Vacuum Treatment

This experiment was identical to the preceding one excepting after the carnations were removed from the vacuum treatment and washed, instead of placing them with their stems in water, they were set in the same solution in which they had received their vacuum treatment. It was thought that it might be possible in this way to get even more ferrous sulfate into the carnation tissues to act as a "mordant."

The experiment proceeded as it did in the preceding one. The carnations which were given the vacuum treatment in the higher concentrations of ferrous sulfate showed immediate signs of plasmolysis. In 24 hours only 2 out of 10 of the carnations which had been vacuum processed in 400 ppm of ferrous sulfate were still in salable condition.

Seventy carnations were used in the experiment. The results of this experiment as shown on Table 8 shows another rather obvious trend in which the higher the concentration of ferrous sulfate in the solution, the shorter the flower's salable life.

The mean salable life of the control group was 4.6 days. The mean salable life of those which were chemically treated was 1.5 days. That was .3 days less than the

average of the preceding group in which the last solution in which the carnation stems were set was plain water, and 2.75 days less than the group in Table 3 that had no vacuum treatment.

The vacuum process seemed to accentuate the effects of the chemicals used so far. The returning of the carnations to the concentrations in which they had been processed seemed to have an injurious effect.

Table 8

The Effects of Vacuum Treatments Followed by Placement in Ferrous Sulfate Solutions on the Preservation of Cut Carnations

Concentrations of ferrous sulfate solutions in the vacuum treatments	Concentrations of ferrous sulfate solutions after the vacuum treatments	Number of flowers	Number of flowers in salable condition after specified periods from treatments: (Days)								
			1	2	3	4	5	6	7	8	9
ppm	ppm										
Control	Control	10	10	10	10	10	5	1			
12½	12½	10	10	8							
25	25	10	10	10	6	1					
50	50	10	10	10	5						
100	100	10	8	5	1						
200	200	10	4	1							
400	400	10	2								

THE EFFECTS OF VACUUM TREATMENTS AND CHEMICALS ON THE PRESERVATION OF CUT CARNATIONS

Molybdic Acid With Vacuum Treatments

This experiment was based on the work of Neff (11) and Hamner, Carlson, and Tukey (3). The special treatment was designed to maintain the color and turgidity of the carnation petals. Seventy carnations were used in this experiment.

The concentrations started with a 4 quart solution of 400 ppm molybdic acid. This was consecutively halved and the solutions brought up to 2 quarts apiece until there was a range from 400 ppm molybdic acid to 12½ ppm molybdic acid. A pinch of vatsol was added to each of these solutions so that they might penetrate the waxy cuticle which surround both the stems and flowers.

Seventy carnations were used in this test. In Table 9 the mean salable life of the control group was 4.6. The group which was treated with vacuum and molybdic acid had a mean salable life average of 4.8. That figure is slightly better than average but it is not a significant increase. The group which received the vacuum treatment with 200 ppm molybdic acid had a significantly longer mean salable life of 5.6 days. This was higher than the trend seemed to indicate. There was just a slight increase in

the mean salable life as the concentrations get higher,

The molybdic acid had a peculiar effect on the carnation petals. It caused the petals to roll outwardly from the side giving the petals a pointed effect.

The addition of the vacuum process in this experiment seems to have increased the mean salable life of the carnation by .2 days.

Table 9

The Effects of Vacuum Treatments and Molybdic Acid on the Preservation of Cut Carnations

Concentrations of molybdic acid solutions in the vacuum treatments ppm	Number of flowers	Number of flowers in salable condition after specified periods from treatments: (Days)								
		1	2	3	4	5	6	7	8	9
Control	10	10	10	10	10	5	1			
12½	10	10	10	10	9	6	1			
25	10	10	9	9	7	5	2			
50	10	10	10	10	8	6	3			
100	10	10	10	10	10	6	2	1		
200	10	10	10	10	10	6	3	2	2	2
400	10	10	10	10	10	5	2	1	1	

THE EFFECTS OF VACUUM TREATMENTS AND CHEMICALS ON THE PRESERVATION OF CUT CARNATIONS

Molybdic Acid With and After Vacuum Treatments

This experiment was identical to the preceding one excepting after the carnations were removed from the vacuum treatment and washed, instead of placing them with their stems in water, they were set in the same solution in which they had received their vacuum treatment. It was thought that it might be possible to get even more molybdic acid into the carnation tissues to maintain color and turgidity.

Seventy carnations were used in this experiment. As can be seen in Table 10 the results left much to be desired. The mean salable life of the control group was 4.6 days. For the rest of the carnations in this experiment the mean salable life was 4.1 days. The trend indicated that the lower concentrations seemed to survive the final added process better than the higher concentrations.

Table 10

The Effects of Vacuum Treatments Followed by Placement in Molybdic Acid Solutions on the Preservation of Cut Carnations

Concentrations of molybdic acid solutions in the vacuum treatments	Concentrations of molybdic acid solutions in the vacuum treatments	Number of flowers	Number of flowers in salable condition after specified periods from treatments: (Days)								
			1	2	3	4	5	6	7	8	9
ppm	ppm										
Control	Control	10	10	10	10	10	5	1			
12½	12½	10	10	10	10	10	7	2			
25	25	10	10	10	10	10	4	2			
50	50	10	10	10	10	9	6	3			
100	100	10	10	10	10	10	5				
200	200	10	10	10	6	4	1				
400	400	10	10	10	7	3	2	1			

RECOMMENDATIONS FOR FUTURE EXPERIMENTS

The ten experiments which had been completed so far have indicated that the practice of returning the carnations to the solutions in which they had received their respective vacuum process was detrimental to their salable life. For this reason that technique was discarded. The practice of setting the carnations in a chemical solution without any vacuum processing was also discontinued. It was felt that while the latter technique did have its value, it was neither as quick nor as beneficial as the process whereby the concentrations were introduced into the carnation tissues with the aid of a vacuum and then the carnations were set with their stems in water. Undoubtedly there are many exceptions to the latter statement, but by keeping but one process, it did simplify the work. It made possible the testing of several chemicals which, because of the limited supply of carnations and time, would have been impossible otherwise.

THE EFFECTS OF VACUUM TREATMENTS AND CHEMICALS ON THE PRESERVATION OF CUT CARNATIONS

Sugar and Molybdic Acid With Vacuum Treatments

This is the logical merging of two experiments which have previously given some measure of success. Theoretically it meant combining of a plant nutrient and a tissue "mordant" in the tissues of the carnation.

In this experiment thirty carnations were used. Table 11 shows the two solutions besides the control that were used. The control group had an average salable life of 5.0 days. Neither of the solutions even equalled that figure.

This experiment gave very disappointing results. It is thought that this experiment should be replicated several times before any recommendations are made.

Table 11

The Effects of Vacuum Treatments with Sugar and Molybdic Acid on the Preservation of Cut Carnations

Concentrations of sugar and molybdic acid solutions in the vacuum treatments	Number of flowers	Number of flowers in salable condition after specified periods from treatments: (Days) 1	2	3	4	5	6	7	8	9
ppm										
Control	10	10	10	10	8	6	4	2		
100,000 sugar 200 molybdic acid	10	10	10	10	8	4	2	1		
200,000 sugar 200 molybdic acid	10	10	10	10	9	5	2	1	1	

THE EFFECTS OF VACUUM TREATMENTS AND CHEMICALS ON THE PRESERVATION OF CUT CARNATIONS

Citric Acid With Vacuum Treatments

Dr. E. J. Kraus (7) suggested the use of citric acid in these experiments. He pointed out that it was a comparatively cheap substance which seems to be an important chemical in most fruits. He further stated that some success had been had by merely setting the stems of flowers in a dilute acid solution. The purpose of this experiment, then, is to find a concentration of citric acid which, when introduced into the tissue of carnations, will extend their salable life.

The concentrations ranged from 1 ppm to 128 ppm in successively doubled concentrations. Two quarts of each concentration were made and to each a pinch of vatsol was added to achieve better tissue penetration. Each concentration had ten carnations in it. They were each given the prescribed vacuum treatment, rinsed, and set with their stems in water.

Ninety carnations were used in this experiment. The mean salable life of the control was 4.9 days. The mean salable life of all the citric acid treated flowers was 4.8. On the surface this seemed to indicate that the process was of no value, but by referring to Table 12 it was readily noted that a definite trend was present. It

appeared that a concentration of 16 ppm of citric acid was best. It resulted in a mean salable life of 5.6 days, a significant increase over the 5.0 days which the control had achieved. A concentration of either more or less than 16 ppm resulted in a decrease of the mean salable life.

This was the most encouraging experiment to date. The obvious recommendation then was to test citric acid with sugar.

Table 12

The Effects of Vacuum Treatments and Citric Acid on the Preservation of Cut Carnations

Concentrations of citric acid solutions in the vacuum treatment ppm	Number of flowers	Number of flowers in salable condition after specified periods from treatments: (Days)								
		1	2	3	4	5	6	7	8	9
Control	10	10	10	10	10	6	2	1		
1	10	10	10	10	10	5	2			
2	10	10	10	10	10	6	2			
4	10	10	10	10	10	8	3	2		
8	10	10	10	10	10	8	4	2	1	
16	10	10	10	10	10	8	5	2	1	
32	10	10	10	10	10	5	2			
64	10	10	10	10	6	4	1			
128	10	10	10	10	9	5	4	1		

Figure 3

Experiment 12, The Effects of Vacuum Treatments with Citric Acid on the Preservation of Cut Carnations

THE EFFECTS OF VACUUM TREATMENTS AND CHEMICALS ON THE PRESERVATION OF CUT CARNATIONS

Sugar and Citric Acid With Vacuum Treatments

This was the logical sequence to the previous experiment. The best citric acid concentration was incorporated with the concentration of sugar which had previously given the best result. It was wondered at this time if the vacuum treatment was influencing the results, so an extra group of controls was run using plain water but receiving the vacuum treatment. Since there were but three sets of treatments, it was decided to double the amount of flowers in each group making a total of 60 carnations used in this experiment.

The results are shown in Table 13. The control and the control plus a vacuum process had almost identical mean salable lives of 4.95 days each suggesting that the vacuum treatment by itself was neither injurious nor beneficial. The solution containing 200,000 ppm sugar and 16 ppm citric acid had a mean salable life of 5.9 days, a very significant increase. This was the longest mean salable life of any group in the entire search.

Table 13

The Effects of Vacuum Treatments with Sugar and Citric Acid on the Preservation of Cut Carnations

Concentrations of solutions used in vacuum treatments	Number of flowers	Number of flowers in salable condition after specified periods from treatments: (Days)								
		1	2	3	4	5	6	7	8	9
ppm										
Control	20	20	20	20	18	14	6			
Control plus vacuum	20	20	20	18	18	14	6	2	1	
200,000 sugar 16 citric acid	20	20	20	20	20	17	12	7	3	

THE EFFECTS OF VACUUM TREATMENTS AND CHEMICALS ON THE PRESERVATION OF CUT CARNATIONS

Ascorbic Acid with Vacuum Treatments

Dr. E. J. Kraus expressed an interest in what would happen if ascorbic acid were used with this vacuum process on carnations. He explained that this substance seems to effect the rate of respiration in some plants. This experiment, then, was to find if there was a concentration of ascorbic acid which would exert a beneficial effect on the respiration of the carnation if it were introduced by by the vacuum process.

Sixty carnations were used in this experiment. Table 14 shows that the mean salable life of the control was 4.8 days. The mean salable life for the carnations receiving ascorbic acid by means of the vacuum process was not quite 4.0 days. The trend seemed to be for comparatively longer salable lives for the lesser concentrations of ascorbic acid, but even at 1 ppm the ascorbic acid reduced the life of the cut carnation by .3 days.

It seems that ascorbic acid introduced into the tissue of carnations was toxic in all concentrations.

Table 14

The Effects of Vacuum Treatments and Ascorbic Acid on the Preservation of Cut Carnations

Concentrations of ascorbic acid solutions in the vacuum treatments	Number of flowers	Number of flowers in salable condition after specified periods from treatments: (Days)								
		1	2	3	4	5	6	7	8	9
ppm										
Control	10	10	10	10	9	7	2			
1	10	10	10	10	8	6	1			
2	10	10	10	10	4	2	1			
4	10	10	10	7	2					
8	10	10	5	3						
16	10	10	10	8	2					

THE EFFECTS OF VACUUM TREATMENTS AND CHEMICALS ON THE PRESERVATION OF CUT CARNATIONS

Sodium Salt of 2,4-Dichlorophenoxy Acetic Acid With Vacuum Treatments

While this plant hormone has gained much popularity for its use in weed control, it has not as yet been fully tested. It seems to be somewhat specific in the plants it affects. It is supposed to increase the metabolic plant processes to a point where the plant kills itself by overgrowing. That is apparently what happens on the plants on which it is effective; but there was no available information on its effect on carnations.

This is one of the cheapest of plant hormones; and it was thought that if it did happen to have a beneficial effect, here would be the cheapest substance for the job of extending the salable life of the cut carnation.

Sixty carnations were used for this experiment. Table 15 shows the result. The control showed a mean salable life of 4.8 while all of those with 2,4-D treatment averaged a salable life of 4.0. The trend seems to show that the higher concentrations were slightly more toxic than were the lower concentrations.

The results were somewhat of a surprise. A more drastic result was expected one way or the other. The ferrous sulfate solution of the same concentration exhibited a much greater damaging effect.

Table 15

The Effects of Vacuum Treatments and the Sodium Salt of 2,4-Dichlorophenoxy Acetic Acid on the Preservation of Cut Carnations

Concentrations of 2,4-D solutions in the vacuum treatments	Number of flowers	Number of flowers in salable condition after specified periods from treatments: (Days)								
		1	2	3	4	5	6	7	8	9
ppm										
Control	10	10	10	10	10	6	2			
1	10	10	10	10	10	5	1			
2	10	10	10	10	10	4				
4	10	10	10	9	9	4	1			
8	10	10	10	8	5					
16	10	10	10	8	5	3	1			

THE EFFECTS OF VACUUM TREATMENTS AND CHEMICALS ON THE PRESERVATION OF CUT CARNATIONS

Alpha Naphthylene Acetic Acid With Vacuum Treatments

This plant hormone has been receiving much favorable publicity as the result of the discovery of new uses for its peculiar power. It tends to inhibit the formation of an abscission layer on leaf or fruit petioles. It is sprayed on fruit trees to prevent premature dropping of the fruit, it is sprayed on holly to prevent the leaves from falling, and it has been sprayed on fruit trees to make them hold their blossoms longer. It seemed reasonable to expect that there might be some benefit by introducing it into the tissues of the carnation by means of the vacuum process.

Sixty carnations were used in this experiment. The mean salable life of the control was 4.9 days. The mean salable life of the carnations receiving some alpha naphthylene acetic acid by means of the vacuum process was 2.3 days. A glance at Table 16 shows that again we have a situation where the the mean salable life of the cut carnation flowers varied inversely with the amount of alpha naphthylene acetic in the solution.

It would appear that this chemical is toxic when used as it was here.

Table 16

The Effects of Vacuum Treatments with Alpha Naphthylene Acetic Acid on the Preservation of Cut Carnations

Concentrations of A. N. A. acid solutions in the vacuum treatments ppm	Number of flowers	Number of flowers in salable condition after specified periods from treatments: (Days)								
		1	2	3	4	5	6	7	8	9
Control	10	10	10	10	10	6	3			
1	10	10	7	6	4	2	1	1		
2	10	10	6	6	5	3	1			
4	10	9	8	4						
8	10	9	8	3						
16	10	9	5	1						

THE INFLUENCE OF THE CUT STEM LENGTH ON THE PRESERVATION OF CUT CARNATIONS

This experiment deals with exactly that which the title specifies. It was the purpose of this experiment to find whether a long stem or a short stem was more beneficial to the carnation's cut life. There was also the possibility that there was no correlation between these two factors.

It was necessary to have the flowers as near alike as possible. Only the variety King Cardinal was used. To be eligible for testing the individual blossom had to have a stem over 21 inches long. Of course all were picked at as near the same stage of maturity as possible. The group with the longer stems were tied with the blossoms held loosely together so as to have uniform bunching. The shorter stems were achieved by cutting off portions of the long stems.

This was not a single experiment but the result of six separate tests. This was necessary because of the limited number of available flowers at the same stage of maturity.

One hundred and ninety two carnations were used in this experiment. The results on Table 17 are curiously misleading. It would appear that the longer stems were conducive to longer salable lives. Closer examination will show that the opposite is true. The longer stemmed

flowers tended to have a more irregular length of salable life.

For longest mean salable lives it is recommended that the stems on carnations be cut to a length of 3 inches.

Table 17

The Influence of the Cut Stem Length on the Preservation of Cut Carnations

Cut stem length	Number of flowers	Number of flowers remaining in salable condition after a specified period of days										Average salable life: (Days)
		1	2	3	4	5	6	7	8	9	10	
3 inches	48	48	48	48	48	33	15	1				5.0
9 inches	48	48	47	46	45	37	8	4	2	1		4.9
15 inches	48	48	47	47	43	12	10	8	7	3		4.7
21 inches	48	48	46	43	38	16	15	8	7	3	1	4.5

THE EFFECTS FROM VARYING THE AMOUNTS OF BOTH LEAVES AND WATER ON THE STEMS OF CUT CARNATIONS

It is a comparatively unknown, though not particularly new theory, that flowers last longer when only the tips of the stems are in the water. The explanation is rather simple. Practically no water can be absorbed through the sides of the stems. That can be easily proven by plugging the stem end and setting it in the water. The flower will not last any appreciable length of time longer than one which was picked and left with its stem out of water. The more water there is on the stem, the more bacteria can go from the stem into the water, and the bacteria seem to have a detrimental effect on the flowers. If the leaves are left on the stem of the flower and the water covers the lower leaves, there is just that much more surface from which the germs may come to get into the water. This experiment was intended to demonstrate the foregoing theories.

Forty carnations were used in this test. The long-lived variety, Virginia, was used. The first group of ten were placed in 6 inches of water in a mason jar. The next group, like the first, had all the leaves left on; but there was only one inch of water in the bottom of the mason jar. The third group had the lower leaves stripped off and was placed into six inches of water in the mason

jar. The fourth group had all of the lower leaves stripped off before placing them in a mason jar which had but one inch of water in the bottom of it.

The figures shown in table 18 give the results. The first group had a malodorous solution when they were removed at eleven days. Obviously, the last group received the most beneficial treatment.

Table 18

The Effects from Varying the Amounts of Both Leaves and Water on the Stems of Cut Carnations

Stem Treatment	Number of flowers	Number of flowers remaining in salable condition after a specified period of time: (Days) 6	7	8	9	10	11	12	13	Average salable life: (Days)
All leaves on, water 6" deep	10	10	9	8	6	6	6			9.5
All leaves on, water 1" deep	10	10	9	8	7	7	5			9.6
Lower leaves off, water 6" deep	10	10	10	7	7	7	7	4		10.2
Lower leaves off, water 1" deep	10	10	9	7	7	7	7	7	3	10.7

SUMMARY AND CONCLUSIONS

The majority of the experiments in this search concerns the use of chemicals with or without a vacuum process. A total of 1,234 carnations were used, 180 of which acted as controls. The mean salable life of the controls was 4.7 days.

Some of the procedures or chemicals were definitely injurious to the carnations. All procedures involving placement of the carnations in the concentrations in which they had just been vacuum processed proved quite injurious. The use of ferrous sulfate, ascorbic acid, alpha naphthylene acetic acid, and the sodium salt of 2,4-dichlorophenoxy acetic acid produced negative results in every case.

The use of molybdic acid gave varying results. In most cases it seemed to have a neutral effect. In one test, however, where 200 ppm of molybdic acid was used in the vacuum process and the carnations then set with their stems in water, a mean salable life of 5.6 days was achieved by a group of ten carnations. That is a 20 percent increase in the salable life over the controls.

Four other methods of attaining longer life for the carnations follow in the order of their ascending values. Merely placing the flowers with their stems in a 20 percent sugar solution resulted in a mean salable life of 5.3 days, a 13 percent increase in mean salable cut flower

life. A 16 ppm solution of citric acid used in the vacuum process where the flowers were eventually set with their stems in water produced a mean salable life of 5.6 days, a 20 percent increase in the mean salable life. Using the latter process but substituting a 200,000 ppm concentration of sugar in place of the citric acid resulted in a mean salable life of 5.7 days, a 22 percent increase in the mean salable life. The best results were obtained when 16 ppm of citric acid was included in a solution with 200,000 ppm of sugar. This gave a mean salable life of 5.9 days, an increase of 25 percent over the mean salable life of the controls.

Apparently the carnation's cut life varied inversely to the length of the stem. Comparing with the mean salable life of the controls, 4.7 days, the 3 inch stems allowed the flower .3 days more mean salable life, while the 22 inch stems seemed to shorten the mean salable life by .2 days.

The stripping of leaves from the lower portion of the stems and keeping just enough water about the base of the stem to keep it covered kept the long-lived variety, virginia, alive for 1.2 days longer than the group which retained all its leaves and had 6 inches of water about the stems.

RECOMMENDATIONS

This search is admittedly not a comprehensive research of the problem. There were too many factors over which the author had no control such as time, quantity of flowers, light, and those previously mentioned.

It is the hope, however, that an indication of the possibilities of this problem has been demonstrated.

This was but one way of attacking the problem. It ignores the bacteriological approach, the physicist's approach, the geneticist's approach, etc. The search was purposely kept simple so that more material could be investigated.

The effects of molybdic acid were not sufficiently investigated here. It is felt that there are some potentialities for it in the preservation of cut flowers.

The vacuum process as used here seemed to be a good method of introducing the various chemicals into the plant tissues. It is comparatively quick both in administration and in exhibiting the effects. It is not a complicated process and it is cheaply administered.

The mixture of sugar and citric acid in the right porportions and applied by the forementioned vacuum process is hereby recommended.

Apparently the 3 inch stem extended the life of the cut carnation, but it is realized that florists would

ordinarily find it difficult to sell carnations with stems so short.

It should be standard procedure for anyone picking carnations to strip the lower leaves from the stem and place them in just enough water to cover the end of the stems.

All of the methods of prolonging the lives of cut flowers which were mentioned in the review of literature seem to be of value.

It is felt that the greatest possibility for extension of the life of cut carnations lies in the use of plant hormones such as phenylacetic, indolacetic, and indolepropionic acids. Perhaps naphthaleneacetamide, or some of the phenoxy compounds such as 2,4, phenoxypropionic acid, orthochlorophenoxy acetic acid, and orthochlorophenoxy propionic acid might be the final answer.

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