Station Bulletin 158. March, 1919

# Oregon Agricultural College
## Experiment Station

Division of Horticulture

# Pollination of Tomatoes

By
A. G. B. BOUQUET, Professor of Vegetable Gardening

CORVALLIS, OREGON

**Board of Regents of the Oregon Agricultural College and Experiment Station**

HON. J. K. WEATHERFORD, President ..... Albany
HON. N. R. MOORE, Secretary ..... Corvallis
HON. C. L. HAWLEY, Treasurer ..... McCoy
HON. JEFFERSON MYERS ..... Portland
HON. J. A. CHURCHILL, State Superintendent of Public Instruction ..... Salem
HON. BEN. W. OLCOTT, Governor and Secretary of State ..... Salem
HON. CHARLES E. SPENCE, Master of the State Grange ..... Oregon City
HON. CLARA H. WALDO ..... Portland
HON. WALTER M. PIERCE ..... La Grande
HON. M. S. WOODCOCK ..... Corvallis
HON. H. VON DER HELLEN ..... Wellen
HON. G. M. CORNWALL ..... Portland

## STATION STAFF

### Administration

W. J. KERR, D. Sc. ..... President
A. B. CORDLEY, D. Sc. ..... Director
E. T. REED, B. S., A. B. ..... Editor
J. M. CLIFFORD ..... Secretary to Director

### Department of Animal Husbandry

F. L. POTTER, B. S. ..... Chief in Animal Husbandry
E. J. FJELSTED, B. S. ..... Assistant Professor in Animal Husbandry
O. M. NELSON, B. S. ..... Associate in Animal Husbandry

### Department of Bacteriology

*T. D. BECKWITH, M. S. ..... Chief in Bacteriology

### Department of Botany and Plant Pathology

H. P. BARSS, M. S. ..... Chief in Botany and Plant Pathology
M. B. McKAY, M. S. ..... Associate Professor in Botany and Plant Patology
W. M. ATWOOD, Ph. D. ..... Associate Professor in Botany and Plant Pathology
W. E. LAWRENCE, B. S. ..... Assistant Professor in Botany and Plant Pathology
C. E. OWENS, M. A. ..... Assistant Professor in Botany and Plant Pathology

### Department of Agricultural Chemistry

J. S. JONES, M. S. ..... Chief in Agricultural Chemistry
R. H. ROBINSON, B. S. ..... Research Assistant in Agricultural Chemistry
H. G. MILLER, B. S. ..... Research Assistant in Agricultural Chemistry
N. E. BULLIS, B. S. ..... Research Assistant in Agricultural Chemistry

### Department of Dairy Husbandry

P. M. BRANDT, A. M. ..... Chief in Dairy Husbandry
V. D. CHAPPELL, M. S ..... Assistant Professor iu Dairy Husbandry
P. S. LUCAS, B. S ..... Assistant Professor in Dairy Manufacturing
L. W. WING, A. M. ..... Assistant in Dairy Production
S. FINE, A. M. ..... Assistant in Dairy Production

### Department of Entomology

A. L. LOVETT, B. S. ..... Chief in Entomology
*W. J. CHAMBERLIN, B. S. ..... Research Assistant in Entomology
*F. A. LATHROP, M. S. ..... Research Assistant in Entomology
LEROY CHILDS, B. S. ..... Entomologist, Hood River, Acting Superintendent
A. B. BLACK, B. S. ..... Research Asssitant in Entomology

### Department of Farm Crops

G. R. HYSLOP, B. S. ..... Chief in Farm Crops
B. F. SHEEHAN, M. S. ..... Assistant Professor in Farm Crops

### Department of Farm Management

H. D. SCUDDER, B. S. ..... Chief iu Farm Management

### Department of Horticulture

C. I. LEWIS, M. S. A. ..... Vice-Director, and Chief in Horticulture
W. S. BROWN, M. S. ..... Professor of Pomology
E. M. HARVEY, Ph. D. ..... Professor of Horticultural Research
A. G. BOUQUET, B. S. ..... Professor in Olericulture
A. E. MURNEEK, M. S. ..... Research Assistant in Horticulture
G. G. BROWN, B. S. ..... Research Assistant in Horticulture, Hood River

### Department of Poultry Husbandry

JAMES DRYDEN ..... Chief in Poultry Husbandry

### Department of Soils

W. L. POWERS, M. S. ..... Chief in Soils
C. V. RUZEK, B. S. ..... Associate Professor in Soils

### Department of Veterinary Medicine

B. T. SIMMS, D. V. M. ..... Chief in Veteriuary Medicine

---

ROBERT WITHYCOMBE, B. S. Supt. Eastern Ore. Branch Experiment Station, Union
D. E. STEPHENS, M. S. ..... Supt. Sherman County Dry-Farm Br. Exp. Station, Moro
HAROLD K. DEAN, B. S. ..... Supt Umatilla Branch Experiment Station, Hermiston
F. C. REIMER, M. S. ..... Supt. Southern Oregon Branch Exp. Station, Talent
OBIL SHATTUCK, B. S. ..... Supt. Harney County Branch Experiment Station, Burns
A. R. TAYLOR, B. S. ..... Act. Supt. John Jacob Astor Br. Exp. Station, Astoria

*On leave of absence for duration of war.

## SUMMARY

1. Previous literature concerning tomato production under glass has considered to a limited extent the importance of artificial pollination, the subject matter for the most part emphasizing the desirability of some means of pollination but containing little definite information as to the effects of the work.

2. Phases of tomato pollination previously discussed have dealt with the pollination of immature flowers, the effects of cross pollination of varieties, the value of varying amounts of pollen in pollinating, and a brief consideration of desirable means of pollination.

3. Commercial greenhouses in Oregon have produced large numbers of tomato plants which bear many barren or unfruitful blossoms, the proportion of unfruitfulness often being as high as sixty to seventy percent of the total number of blossoms, thus causing considerable financial loss.

4. In one tomato crop under observation, the plants of which were unpollinated, sixty percent of the blossoms were unfruitful, the average production of fruit for each plant being 3.3 pounds.

5. Records of all crops tabulated in this report show that the average yield for pollinated and unpollinated plants was 7.4 pounds and 4.4 pounds respectively.

6. There are several causes for the unfruitfulness of blossoms, the principal ones being, first, the absence of natural pollination agents such as insects; second, the relation of the several reproductive organs in the development of the flower; and third, the correlation of vegetative growth of the plant with the reproductive system.

7. Experiments have been conducted and observations made in the Oregon Station greenhouses during the past six years to determine from an economic standpoint the value of different methods of hand pollination in offsetting the number of unfruitful blossoms on clusters.

8. Cooperative experiments have also been carried on in commercial greenhouses, portions of which have been set aside by owners for experimental work.

9. In obtaining necessary data, a total of about eighty thousand tomato blossoms have been under observation.

10. Hand pollination of flowers has reduced the number of unfruitful blossoms from sixty-six percent to twenty percent of the total number of flowers produced, the percentage of reduction depending upon the comparative thoroughness of the pollination.

11. Records of plants typical of fifteen crops of tomatoes show that plants which were pollinated were fruitful to the extent of seventy-two percent, while the average fruitfulness of plants unpollinated was but thirty-six percent.

12. In one commercial greenhouse, a block of tomato plants regularly pollinated produced eighty percent of fruitful blossoms with a yield of nine pounds of fruit for each plant.

13. Of various methods of pollination tried, the emasculation method has been more widely used than any other and is recommended principally because of ease in applying pollen, prevention of duplication of pollination, and thoroughness of application at a time when the flower is most receptive.

14. Regularity and thorougness of pollination are conducive to high plant production, whereas inexperienced labor, haste, and irregularity in doing the work may not produce profitable net results.

15. Hand pollination of blossoms increases the earliness of fruiting, beginning with the rapid enlargement of the ovary after pollination in contrast to the comparatively slow development of many flowers which are self pollinated. Fruits produced from hand-pollinated flowers have been harvested as early as twenty-one days before fruit from plants not artificially pollinated.

16. Labor cost of pollination has been accounted for in relation to yields of pollinated and unpollinated plants. Statistics show that the cost of pollination during the season is approximately three cents a plant.

17. Results indicate that it pays to hand pollinate to the extent that the increased returns far exceed in value the labor cost of the work and leave a margin of profit. The plants which were pollinated at a cost of three cents showed a yield larger than those which were unpollinated by as many as 3 pounds for each plant, with a value of 38 cents.

18. The cost of pollination for the entire season may be covered by increased yields obtained from pollinated plants in the first two weeks of harvesting, when higher prices for fruit prevail. Records indicate that increased yields from pollinated plants will equal from one-half to the entire cost of production of plants when marketed, as compared with the production of plants unpollinated. In other words, in some cases pollination has paid the entire labor cost of production through increased yields.

19. The comparative net returns of plants after deducting the cost of pollination show an increased value of from sixteen to sixty-seven cents a plant or an average of thirty-eight cents in favor of pollinated plants. These returns are based on the cost of three cents a plant for pollination.

20. The percentages of fruitfulness and unfruitfulness of individual clusters of a crop, given specific treatment, vary to a considerable extent, but total and average records indicate a remarkable mean of percentage of uniformity of all clusters.

# SOME ECONOMIC RESULTS IN THE POLLINATION OF GREENHOUSE TOMATOES

## INTRODUCTION

Pollination has long been recognized as an important factor in growing greenhouse tomatoes. Early writings regarding the production of this crop discussed the necessity of some means of artificial pollination.

Baily (1) writes that "in the short dull days of midwinter some artificial aid must be given flowers to enable them to set. Tapping the flowers with a stick is a practice which is perhaps better than nothing, but I am strongly of the opinion that it will pay the commercial grower to transfer the pollen by hand in midwinter." Watts (2) states that "artificial pollination seems to be necessary or at least advantageous in securing a full setting of fruit. On bright sunny days this additional labor is oftentimes unnecessary, but we believe the practice pays in every case." The experiments and findings of Munson (3) deal with the amount of pollen in its bearing on the amount and size of the fruit. Munson recommends that the flowers be pollinated in midwinter and that, as a source of profit, commercial growers transfer the pollen by hand. He also recommends jarring or shaking of the plant with a padded stick. He makes the assertion that more symmetrical fruit, having solidity, is produced by artificial pollination, which has a part in preventing one-sidedness of fruit. His determinations showed that the size of the fruit was in every case in direct proportion to the amount of pollen used.

Alwood (4) describes a test in which forty blossoms were bagged and allowed to remain until the period of receptivity of the stigma was passed. From the forty buds only two fruits set. The recommendations, based on the findings of the test, show that it is essential that the flowers be pollinated by hand. The author of these experiments also states that it is evident, if blossoms are exposed in the house where most of the blossoms are artificially pollinated, that a considerable portion of those not treated will be fertilized from pollen liberated in treating other blossoms. It was also noted that careful pollination appears to affect the size of the fruit. Fink (5) in a description of the methods of "pollination and reproduction of the tomato" notes that the amount of pollen influences to a very marked degree the size and shape of the fruit, his experiments proving that one sidedness of fruit results from lack of pollen in contrast to large, well-formed fruit resulting from large amounts of pollen. Beach (6) shows how the amount of pollen applied to the stigma influences the size and shape of the fruit, and its rapid development to maturity.

Mason (7), in his work in forcing tomatoes, at first practiced shaking or tapping of the vines, but finding this unsatisfactory went over the vines for the next two months pollinating every two or three days by lifting to the stigmas of the flowers a watch glass containing pollen. In trials as to various methods of pollinating, Jenkins and Britton (8) found that a majority of the blossoms set fruit in which the corolla of the flowers was pulled away after it had fully opened and that in the pulling the anthers were broken open and pollen escaped into the air

and lodged on the stigmas of the flowers. Experiments with the spoon method of pollinating showed that it took less time for operation and was more likely to affect cross fertilization, a factor desired in improving the strain. This seems to be somewhat disputed at the present time by the investigations of Troop (13), who found no increased results by cross pollination as compared with blossoms that were fertilized by their own pollen. Jordan (9) makes mention of using in his work the padded stick for the purpose of pollination of blossoms. Massey and Rhodes (10) tested with satisfaction the efficiency of the camel's-hair brush as a means of conveying pollen to the stigmas of flowers. In a test of efficiency of tapping the flowers daily at noon in contrast to fertilizing the flowers with the camel's-hair brush, the results indicate an imperfect setting of fruit and a rapid falling off in size where the blossoms were tapped in contrast to the increased yield caused by the use of the camel's-hair brush as a pollinating instrument.

Hartley (11) proves the fallacy of the opinion that when pollen is placed on the young immature stigmas, it will remain there, later fertilizing the flower when it finally becomes receptive. The necessity of pollinating every other day from December 1 to March 1 is discussed by Beal (12), who used and recommended the spoon method of collecting and applying pollen in his work. The subject of cross pollination has been touched upon to a certain extent by Troop (13) and by Fletcher and Gregg (18) who find no beneficial gain in yields by cross pollination as opposed to self pollination of the blossom. Green and Waid (14) used in their pollinating work home-made tools consisting of a small wooden ladle and, as a companion, a flat wooden spatula. The best results were obtained from daily pollination, although the authors state that satisfactory results come from pollinating half of the plants the first day and the other half the second day. As a result of their investigations it is stated that "success in tomato forcing depends more on thorough and careful pollination than on any other one thing."

Corbett (15) discusses the necessity of artificially pollinating tomato flowers, recommending the tapping of each open flower into a spoon or watch glass containing pollen. Figures are conspicuously scant with respect to the difference in the yield of plants which have been hand pollinated and those which have been self pollinated. Warren (17) observed that in a comparative test, plants which had been hand pollinated gave 48 percent more fruit and a slightly smaller percentage of ill-shaped fruit than those which were not pollinated. Fletcher and Gregg (18) contend that attention to pollination assures a large proportion of smoothly formed tomatoes, and that it pays to go over the plants on sunny days and sometimes on cloudy days to tap each blossom with a padded stick or the finger, holding in the left hand a glass slide or watch glass containing pollen which is brought into contact with the stigma of the flower. Experiments conducted by Sandsten (19) show that bright sunshine is more favorable to a large germination of pollen from tomato flowers than cloudy weather. The results obtained show an increase of from 25 percent to 50 percent of germination of pollen grains during a period of sunshine. Watts (24) plainly describes the tomato flower and emphasizes the need of hand pollination for thoroughness of work, arguing

that the increased yield will more than pay for the expense involved in pollination.

Kraus and Kraybill (25) show from a physiological study of tomato plants grown in different artificial soil mixtures that there is a close correlation between the amount of vegetative growth of the plant and the growth of the reproductive organs for fruit production. Plants with full, heavy, succulent foliage, classed as "markedly vegetative," were for the most part decidedly unfruitful, frequent instances being cited in which a large percentage of the blossoms failed to set fruit. Throughout all of the experiments conducted, plants grown in soil with an abundant supply of available nitrogen were distinctly unfruitful. Plants, too, which were markedly non-vegetative had a tendency to produce fruit early in their growth but failed later to do so in such proportion. The findings of the authors of this recent publication show that there is an important relation between the balanced nutrition of tomato plants and their fruiting, and that this is an important factor relative to the productiveness of the variety. It is especially desirable that plants be neither markedly vegetative nor non-vegetative, but that the nutrition furnish a happy medium between these two extremes.

## INVESTIGATIONS OF THE OREGON EXPERIMENT STATION

Investigations concerning the relation of artificial pollination to the fruitfulness of tomato plants grown under glass were begun in 1912. The subject was brought up in connection with the comparatively large number of tomato blossoms that were found to be unfruitful in the Station greenhouses and in some commercial greenhouses of the State.

### Preliminary Investigations of 1911 and 1912

The experimental work as first laid out and the results of the first year's findings are related in detail in the Biennial Crop Pest and Horticultural Report of 1911-12 as published in January, 1913. The phases of investigational work then partly covered were: first, a study of the comparative efficiency and economic value of different means of artificial pollination; second, a study of the variation of blossom clusters of different varieties determining the economic value of these varieties in producing marketable fruit.

In the first phase of the above investigations the following results were obtained:

1. Pollination by shaking the blossoms gave an average increased yield of early fruit of 160 percent over plants which were not pollinated, the variation being from 79 percent to 264 percent, the variety Bonny Best yielding an increase of 110 percent.

2. Pollination by hand for an average of four varieties gave an increased yield of early fruit of 270 percent over plants that were not pollinated, the variation being from 84 percent to 400 percent, Bonny Best yielding an increase of 180 percent.

3. Pollination by hand for an average of four varieties gave an increased yield of early fruit of 60 percent over plants that were jarred, the variation being from 6 percent to 150 percent, Bonny Best producing an increased yield of 33 percent.

4. For the entire marketing season plants hand pollinated yielded 17 percent more fruit than those shaken, and 42 percent more fruit than plants unpollinated. Plants shaken yielded 21 percent more fruit than those untouched.

### Continued Investigations of 1913 and 1914

Pollination studies made in the years 1911 and 1912, results of which were published in the Biennial Crop Pest and Horticultural Report of 1913-14 ([20]), were followed by further studies published in the corresponding report of January, 1915 ([22]). The results of the work of 1913 and 1914 are as follows:

1. Plants which were hand pollinated yielded, in the first month of harvesting, 164 percent more fruit than those which were untouched, the variety being Bonny Best. The average increased yield through pollination for all varieties under observation was 144 percent.

2. Through the first three weeks of marketing, plants that were hand pollinated were worth to the grower 16 cents apiece more than those which were shaken or tapped; while the latter were worth 26 cents apiece more than the check plants. Plants which were pollinated were more valuable to the extent of 42 cents apiece than those which were unpollinated.

3. Observations concerning the fruitfulness of blossoms in commercial greenhouses seemed to prove that, in the first case, the proportion of fruitful blossoms was 47 percent, the corresponding percentage of barren flowers being 52 percent. In the second case, the number of fruitful flowers was 37 percent and the number of unfruitful 63 percent. In each instance, the plants were not artificially pollinated.

4. The productivity of varieties was shown to be affected not alone by the number of blossoms produced on the clusters of the various varieties, but also by the percentage of fruitful or unfruitful blossoms on each plant. Statistics show the difference of varieties in this respect and also the condition of the style and stigma at the time of discharging pollen.

### Recent Investigations

Since the last publication in 1915, studies have been made covering the following economic phases of pollination:

1. Continued observations regarding the fruitfulness of tomato plants in commercial greenhouses.

2. Introduction of various methods of pollination in commercial establishments.

3. Relative value of blocks of pollinated and unpollinated plants, based on (a) earliness of yield, (b) total yield.

4. Labor cost of pollination as affected by various methods of pollination.

5. Net results of pollination.

## THE TOMATO FLOWER IN RELATION TO POLLINATION

In the following discussion concerning the economic effect of hand pollination, various botanical terms concerning portions of the flower are used which might be confusing to some readers who have not studied the make-up of the blossom, hence the relation of the different parts of the flower to pollination is here considered.

Fletcher and Gregg (18) plainly describe the flower and its functional parts as also does Watts (24). In a paper read at the Third Annual Convention of the Vegetable Growers Association of America, Gregg explains in detail the construction of a tomato flower and the relation, one to another, of its various parts.

Tomato flowers are borne on clusters averaging from five to twelve blossoms to the cluster. In the variety Bonny Best, which was observed more than other varieties, the number of flowers to a cluster averaged

Fig. 1. Cluster showing blossoms in various stages of development. (a) Flower in extreme left has opened and later closed its petals, being now in condition for emasculation and pollination. (b) Flower in upper right with petals reflexed is one from which pollen can be obtained in pollinating. Some flowers as shown in middle left have already become barren.

five to eight. The flowers on a single cluster develop at different times in the age of the plant, so that there are blossoms in various stages of development at the same time. Figure I shows a typical cluster of flowers in which each blossom is in a different stage of development. This fact makes it easier for the operator in hand pollination, inasmuch as it distributes the work of pollination over a longer period of time, and there is less danger of blossoms dropping before being pollinated.

Looking at a single blossom, it is noticed that the green star-like portion of the lower part of the flower is divided into several parts which are joined at the base. This part is called the caylx, which increases in size as the fruit enlarges and which remains attached to the portion of the stem of the fruit when the latter is harvested. The individual parts of the calyx are called sepals. The large green sepals, especially on the winter crop of fruit, are conspicuously showy in contrast to the crimson tomatoes. The yellow petals above the calyx are divided into lobes, all comprising the so-called corolla of the flower. The petals indicate by their appearance and development the maturity of the sexual organs of the flower. At first, when the blossom is in bud, the yellow petals are not in view, but later open until they are well reflexed or fully expanded, in which condition the pollen is freely discharged. Later on the petals close together, fade in color, and begin to shrivel and dry. After several days they will often dry quite hard and stiff, remaining persistent to the calyx for a short period before dropping.

The stage of development of the petals is a vital factor in the emasculation method of hand pollination described in this bulletin, inasmuch as the success of rapid emasculation and pollination of the stigma depends on the condition of the corolla. Details concerning troubles experienced in operating at any other time, except when the petals are in the right condition, is explained under "Methods of Pollination."

The stamens, which are the parts of the flower functioning as the male sexual organs, bear on the inner side small sacks, called anthers, in which pollen grains are held, and from which they are discharged. The erect central organ of the flower protruding through the stamens as they come together at the tip is the pistil, functioning as the female sexual organ. Its enlarged outer end is the stigma which has a sticky surface and which receives the pollen grains as they are shed from the anthers. At the base of the pistil is the ovary, containing ovules which afterwards become matured seeds when the stigma is properly fertilized by pollen grains.

Of the various crops of tomatoes cited in these pages, some seventy to eighty thousand blossoms have been under observation.

## Methods of Artificial Pollination

**Shaking the Plants.** There are several ways in which tomato flowers may be artificially pollinated, varying in time and labor and effectiveness of work. First, the quickest and simplest method consists in tapping or jarring the vines, clusters, or individual flowers of each plant. A padded stick or lead pencil may be used in this shaking, and, because

of the condition of the anthers for discharging pollen, only those flowers having well reflexed or fully expanded petals, or those having the petals but recently closed, should be tapped. Time would only be wasted in stopping to shake other blossoms.

**Spoon or Slide Method.** Second, pollen may be collected on spoon or glass slides from flowers with expanded corollas. As the operator passes from flower to flower, the pollen receptacle is held up to the stigma of the pistil protruding through the center of the flower so that a slight tapping of the blossom is sufficient to bring the stigma into contact with the pollen. There are disadvantages connected with this method which often preclude greatest efficiency for the time and labor employed. First, very often the pistil will not have developed sufficiently in some flowers so that the stigmatic surface can be touched by the pollen receptacle, in spite of the fact that the corolla may be fully reflexed. Second, there is no means of preventing duplication of pollination, since it is impossible to tell in pollinating a large number of blossoms whether a certain blossom has been previously pollinated. Third, flowers that have closed their petals following the full expansion cannot have their stigmatic surface pollinated without emasculation.

It is true, however, that this spoon or slide method of pollination may produce larger net yields than where no pollination is practiced. The method is rapid and effective in preventing large numbers of blossoms from becoming barren.

**Emasculation Method.** Pollen collected on the finger may be applied to stigmas of flowers which have been previously emasculated by the operator. This method has proved to be quick in performance and effective in results. Details of this method are as follows: Pollen is obtained from any flowers having their petals well reflexed, turned back, or fully expanded, in which stage of development the anthers are dehiscent or freely discharge pollen. The pollen is collected on the first, second, and, if desired, the third finger of the left hand in such quantities that the first joint of the fingers is well coated with pollen. Constant practice in collecting will soon enable the operator to observe at a glance which flowers are likely to discharge pollen. By carrying a quantity of pollen, a large number of flowers can be pollinated. The next step is to select the flowers to be pollinated. On each cluster there are certain blossoms which have opened fully and later closed their petals. These are the ones selected for pollination. The blossoms can be quickly emasculated (i. e., petals and stamens removed) with the thumb and third or fourth finger of the left hand, the right hand holding the flower back of the sepals in order to steady the operation as shown in Figure 2. The flower being emasculated, pollen can be quickly touched to the end of the pistil. (Figure 3.)

There are several advantages in this method of pollination. First, the stigma is in a receptive condition at the time the petals first close after having been previously reflexed. This assures fertilization when pollen is applied from the finger after emasculation. Second, the contact of pollen with stigma is sure, even, and ample, because the pistil can be seen and easily worked on following the removal of the flower. Third, there is no possibility of a flower being pollinated more than

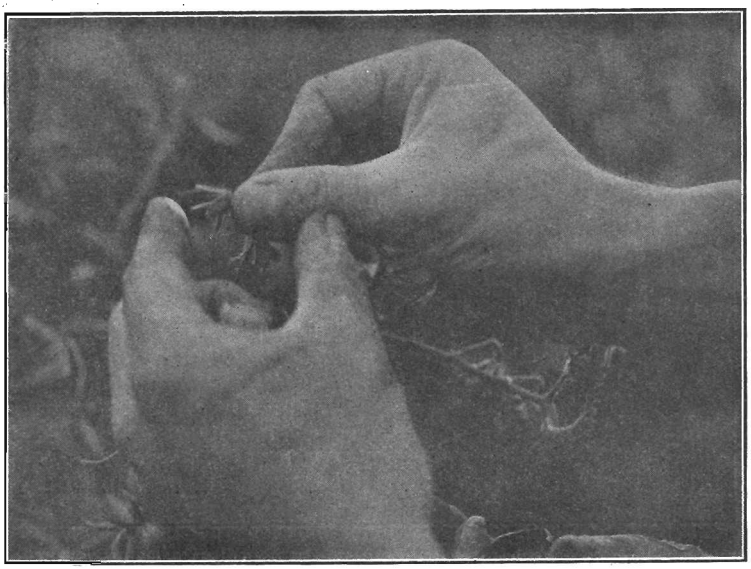

Fig. 2. Contact of pollen from finger to stigma. Abundance of pollen is carried on the finger so that many flowers may be pollinated before further collection of pollen becomes necessary.

Fig. 3. Petals of this flower are being removed for pollination of stigma. Note pollen on first joints of first and second fingers; thumb and third finger are pulling off the corolla, while the thumb and first finger on right hand steady the operation, holding the flower back of the sepals.

once, because all flowers found emasculated have been operated on and will be omitted by the operator in the next day's work. This makes sure a saving in time and labor impossible by other methods. It also leaves little chance that any flower will be passed by unnoticed; since the flowers with closed petals are easily distinguished from the others on a cluster.

On the recommendation of the Oregon Station this method of pollination has been tried by several growers, who have reported good results under thorough tests. Because of its general success, and the advantages specified, it is the method now most favored by this Station.

### Frequency of Pollination

Little time need be spent in pollination at the beginning of the blossoming season because of the few flowers then appearing; but as the number of clusters of each plant increases, the task of pollination requires more time. The pollination of 150 plants, for instance, might consume thirty to forty minutes, and any larger number of plants in like proportion, particularly at the time when blossoms were profuse on all clusters. Thorough methods of pollination, such as would be practiced by emasculation, naturally take more time than other methods in which the operator might pass more quickly from plant to plant. In the latter case the cost of pollination will no doubt be lessened, as is shown by Table XVI, but as far as these experiments are concerned, the amount of fruit obtained is decidedly smaller.

It has been the writer's custom to pollinate every second or third day, never leaving plants longer than three days without attention, lest the blossoms lack fruitfulness. Some growers in Oregon have practiced daily pollination with profit. Regularity of pollination is necessary, for irregularity will result in barren blossoms on the various clusters of the plant.

If the air in the house is dry, it is not necessary to wait until eleven or one o'clock before pollinating, nor does it seem absolutely necessary, from these experiments, that there be sunlight for favorable bursting of the pollen sacks and the consequent shedding of the pollen. It is undoubtedly true that when warm summer days prevail pollen will be discharged abundantly, but it has been found that it will also shed freely in somewhat cloudy weather provided the atmosphere in the house is dry and warm. Pollination has frequently been carried on with good results as early as nine o'clock in the morning and as late as four or four-thirty in the afternoon, although it has been customary to do most of the work at a regular hour in the forenoon or early afternoon. Thoroughness of pollinating is a more important factor than the time of day at which it may be done.

**Causes of Unfruitful Blossoms.** There are several factors responsible for the frequency of flowers which bear no fruit. First, there are no natural agents, such as insects, assisting in this pollination. While there is a circulation of air prevailing through the greenhouse, yet very seldom is this strong enough to cause the shaking of the blossoms in such a way as to assist in the scattering of the pollen. Second, the blossoms naturally hang in a downward position. This condition is responsible for the

fact that pollen grains, when discharged, fall past the stigmatic surface on the sides and lodge in the position explained in the next cause. Third, the enlargement of the pistil and the stigma is responsible to some extent for some blossoms not being self pollinated. The pollen in being discharged from the anthers is caught on the under side of the stigma or at the base of the enlargement of the pistil; is there held, and as a consequence, few if any grains may come into contact with the upper sticky stigmatic surface. Fourth, the elongation of the style of the pistil, which lengthens as it develops to maturity, may occur before the discharge of pollen from the anthers, thereby precluding the contact of pollen grains with the pistil at a favorable time for fertilization. Fifth, the corolla in falling may break the pistil before the ovary is fully fertilized, thus causing barreness. Sixth, flowers may be crushed or broken off by green-house attendants as they are passing through the rows of vines, thereby increasing the possibility of unfruitfulness. Seventh, the elongation of the style of the pistil may often occur after the discharge of pollen from the anthers, thereby rendering imperfect the correlation between the discharge of pollen from the male organs and the receptiveness of the female organs.

**Hand Pollination in Relation to Percentage of Fruitful Blossoms.** The question may arise, if hand pollination of all blossoms is undertaken, why is the percentage of fruitful blossoms not larger and the percentage of barren blossoms not smaller, if all blossoms supposedly receive attention? There are several causes for this condition. First, it is not always possible for the average grower, engaged in other farm work, to pollinate with absolute accuracy and regularity; hence a few blossoms will have been passed by unnoticed or will have dropped before being pollinated. In observations made in the Station greenhouses we have found this condition to be true, in spite of the fact that average precautions and care might have been exercised in pollination. Second, it is not possible to hand pollinate without breaking some pistls here and there on the vine. In these experiments many thousands of flowers have been pollinated, and the writer can vouch for the impossibility of regular pollination over many hundreds of plants without a small percentage of pistils being broken. He has yet to observe a tomato crop in which the blossoms showed higher than eighty percent of fruitfulness, for the reasons named above.

### Precautions Necessary in Pollination of Blossoms

1. Care should be taken that flowers are not allowed to become too far developed before being emasculated. If left for several days after the petals have closed, they will become dry and difficult to remove. There is danger of breaking the pistil from the ovary, if the flower is handled in this condition. The stigma is also past the receptive stage for fertilization.

2. In emasculation, the corolla should be pulled off straight from the calyx; that is, at no decided angle, otherwise the pistil is liable to be broken off.

3. Practice in emasculating several flowers will quickly show the operator the points of the work in which particular care is necessary.

Rapidity and efficiency of operation will result after many blossoms have been removed and stigmas pollinated by the methods described.

4. Double pistils may often be found on some flowers, in which case it has been customary to pinch off the entire flower, as fruit of unmarketable shape usually results from flowers with such pistils.

**Methods of Determining Percentage of Fruitful and Barren Blossoms.** In obtaining the data concerning the fruitfulness of the various crops of tomatoes the records of which are stated in this bulletin, it has been customary to select plants of a desired number to furnish material which would represent, as far as possible, the average of a greenhouse as a whole or a block of plants which had been given specific treatment. Following the harvesting of the crop of fruit from the plant and before the removal of the latter from the greenhouse, the clusters, usually six in number, were cut off at their attachment to the stem of the plant, each cluster being kept distinct as regards its place on the plant. A record was then made of the fruitfulness of each cluster by first observing the comparative number of pedicels which were enlarged at the tips showing the scar where the fruit had been picked with a portion of the stem and the calyx. The number of unfruitful blossoms was likewise observed by noting the pedicels which were straight, small in diameter, not enlarged at the tips, and showing no sign of a fruit scar. In some instances, at the time of collecting the clusters, there were a few fruits on the top clusters which had reached unmarketable size. These were included under the column of fruitful blossoms.

**Extent of Unfruitful Blossoms.** In the statements contained in the following tables relative to the percentage of fruitful and barren blossoms it will be noted that the percentage of unfruitful flowers is variable to a considerable extent, even among those plants which were pollinated or unpollinated as the case may be. In some cases the number of unfruitful flowers was so much as 79 percent and in other cases no more than 48 percent. The average percentage of barreness of blossoms of plants not pollinated was 63 percent, while the average percentage of unfruitful blossoms on pollinated clusters was 27 percent, this figure including records of all means of hand pollination used.

It is evident from observations made that the greatest degree of unfruitfulness is reached in the fall and winter crop of tomatoes when plants are not pollinated. In many cases the entire number of blossoms of a single cluster may be barren. In one crop recently observed, 50 percent of the second clusters of unpollinated plants produced no fruit at all. In another crop 22 to 37 percent of the clusters formed yielded no fruit, every blossom being barren. It is therefore evident that cases of 100 percent of unfruitfulness in individual clusters is not uncommon.

The extent to which all blossoms of single clusters may be barren is apparently not so marked in the late spring and summer tomato crop, the blossoming of which takes place during a time more suitable for natural self-pollination. Observations concerning the percentage of totally barren clusters of plants of a spring crop show that two percent of the first clusters, two percent of the second clusters, three percent of the third, two percent of the fourth, eleven percent of the fifth, and twelve percent of the sixth clusters were totally unproductive. The plants from which

the records were obtained were unpollinated. In this particular case, therefore, five to six percent of the entire number of clusters of a crop were totally unproductive. The percentage of total barreness of clusters of plants not pollinated seems to be more marked in the upper clusters, such as the fifth and sixth, than in the other clusters. If, on the one hand, the plant shows extreme vegetative vigor toward the end of the blossoming season or, on the other hand, lacks normal vitality, clusters will often appear later with no fruit.

Very few cases occur where there is a total barreness of individual clusters in greenhouses, the plants of which are pollinated. Our records show that this may be true only to the extent of eight barren clusters out of one thousand.

In the following tables concerning the percentage of fruitful blossoms, cluster 1 represents the first cluster produced by the plant and so on up the plant.

**Earliness of Maturity Affected by Hand Pollination.** The rapid development of the ovary of the tomato and the quicker maturity of the fruit are the direct results of hand pollination of the stigma, thus greatly

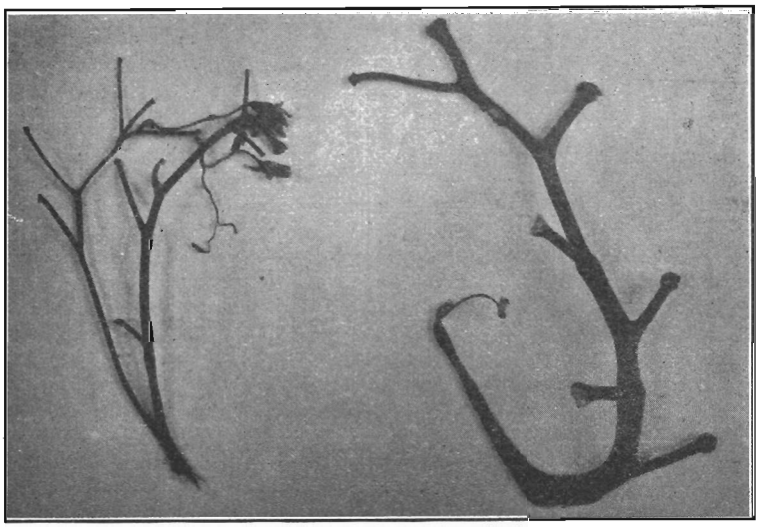

Fig. 4. Two individual clusters. the one on left showing almost total barreness, one on right being nearly 100 percent fruitful.

influencing a larger percentage of the crop in being ready for harvesting at a time when prices are comparatively high.

Observations covering a number of tomato crops have demonstrated beyond question that fruit from blossoms which have been hand pollinated will ripen from fourteen to twenty-one days earlier than the fruit from a majority of blossoms from check plants. Following the contact of pollen to the stigma by hand there is a rapid growth of the embryo tomato which results in earlier maturity.

Records show that plants which have been hand pollinated, as compared with those which have been unpollinated, have produced, during the first month of harvesting, an increase in early fruit varying from twenty-six percent to sixty-six percent. They show also that the hand-pollinated plants, as compared with those which have been jarred, have yielded increases of fifteen to thirty-seven percent of early fruit.

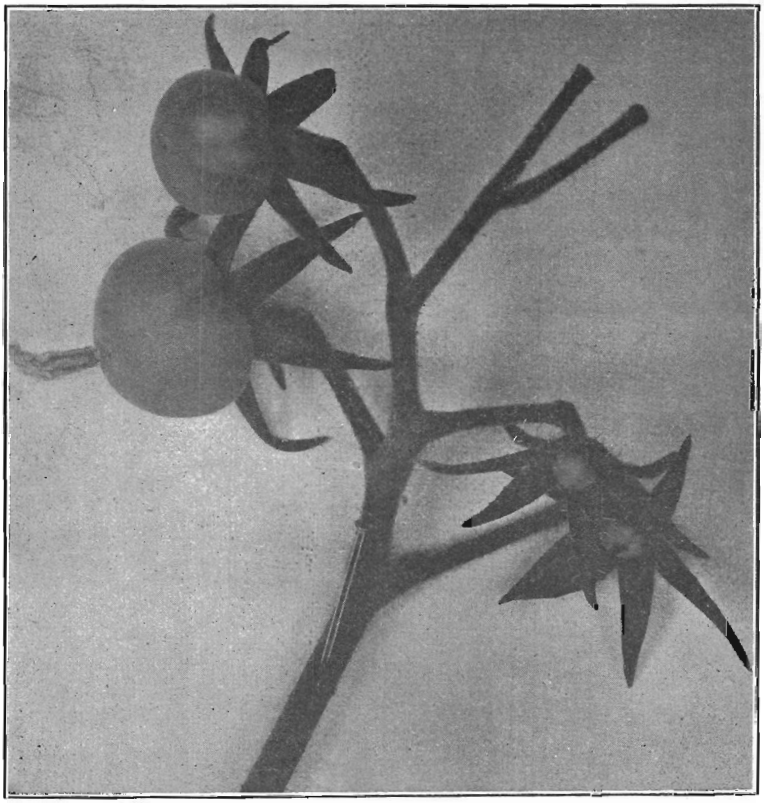

Fig. 5. Cluster showing rapid development of fruit from artificially pollinated stigmas. This cluster has six flowers, the two upper middle blossoms dropping, thus giving the cluster a 66 percentage of fruitfulness. This shows the necessity of regularity in pollination.

Increased yields from pollinated plants are more noticeable during the first month of harvesting than the yields of fruit at the end of the second month. This is largely because of the maturity of the fruit, from the second, third, and fourth clusters of unpollinated plants, which may bear during the second month of harvesting. Our records also show, however, that during May and June there was an increase of thirty-one percent of fruit harvested from a similar number of plants, hand-pollinated and unpollinated respectively.

The above figures and facts interpreted in terms of dollars and cents show (1) that a larger percentage of the crop which is hand pollinated will be sold on the market at a price of fifteen or twenty cents a pound and (2) that the cost of labor for pollinating plants, will be paid for by the increased returns produced through the early maturity of the plants, and that there will be left a profitable margin.

Siefert (23) shows in compilation of data concerning various crops of greenhouse districts of Portland, Oregon, the following summary:

TABLE I. COMPARATIVE VALUE OF THREE COMMERCIAL TOMATO CROPS
100 Plants Each

| No. of crop | Blossoms pollinated or uot | No. fruits set | Per-centage fruitful | Blossoms barren | Fruit produced | Fruit per plaut | Total value of crop |
|---|---|---|---|---|---|---|---|
| | | | % | % | lbs. | lbs. | |
| 1 | Yes (by hand) .. | 3810 | 80 | 20 | 944 | 9.4 | $117.00 |
| 2 | No ..... | 1447 | 34 | 65 | 361 | 3.6 | 45.12 |
| 3 | Yes (to some extent) ..... | 1672 | 34 | 65 | 418 | 4.1 | 52.25 |

### Explanation

1. Crop No. 1 was of unquestionable value as regards high percentage of fruiting. The plants and clusters were vigorous and the fruits uniform in size. Pollination was regularly done by the emasculation system. Note the high yield of fruit per plant.

2. Crop No. 2 received no pollination. The plants were less vigorous than those of Crop No, 1, in some cases the clusters dying before any fruit had set. Plants were trained to two leaders. The percentage of barren blossoms is unprofitably high.

3. The plants of Crop No. 3 were irregularly jarred. No account was available concerning the regularity of the work, but it probably was quite irregular. The plants were inferior in vigor to those of Crop No. 1. Plant vigor is necessary for strong clusters, rapid fruit development, and profitable size of fruit.

TABLE II. STATEMENT OF COMPARATIVE NUMBER OF FRUITFUL AND BARREN BLOSSOMS SPRING CROP. GROWER NO. 4, 1915

128 Plants

| Cluster No. | Number fruitful | Blossoms barren | Total number blossoms | Number blossoms per cluster | Percentage blossoms fruitful | Percentage blossoms barren |
|---|---|---|---|---|---|---|
| | | | | | % | % |
| 1 | 728 | 128 | 856 | 6.4 | 76 | 23 |
| 2 | 852 | 87 | 939 | 7.4 | 90 | 10 |
| 3 | 895 | 99 | 994 | 7.8 | 90 | 10 |
| 4 | 994 | 150 | 1144 | 8.8 | 86 | 13 |
| 5 | 759 | 263 | 1022 | 8.1 | 74 | 25 |
| 6 | 650 | 457 | 1107 | 8.6 | 58 | 41 |
| Average | 813 | 197 | 6062* | 7.8 | 79 | 20 |

*Total

### Explanation

1. The above plants under observation were hand pollinated, a further statement regarding the productiveness of the plants being included in Table I and its explanation.

2. The first clusters would have shown a greater percentage of fruitfulness had the operator exercised a little more care and regularity in pollinating.

3. The three following clusters show a remarkably high percentage of fruitfulness, the result of uniformity and regularity of pollination.

4. When the price of tomatoes began to decrease considerably, less care was used in pollinating the sixth cluster.

5. We consider this crop a good example of productiveness through careful and consistent pollination, the yield of plants being approximately nine pounds of ripe fruit.

6. The selection of plants for observation of their fruitfulness was made at random in this greenhouse, plants here and there throughout the entire house being taken.

TABLE III. STATEMENT OF COMPARATIVE NUMBER OF FRUITFUL AND BARREN BLOSSOMS, SPRING CROP. GROWER NO. 3, 1915

70 plants

| Cluster No. | Number fruitful | Blossoms barren | Total number blossoms | Number blossoms per cluster | Percentage blossoms fruitful | Percentage blossoms barren |
|---|---|---|---|---|---|---|
| | | | | | % | % |
| 1 | 253 | 294 | 547 | 7.8 | 46 | 53 |
| 2 | 228 | 336 | 564 | 8.0 | 40 | 59 |
| 3 | 128 | 416 | 544 | 7.7 | 23 | 76 |
| 4 | 191 | 361 | 552 | 7.8 | 34 | 65 |
| 5 | 99 | 316 | 415 | 5.9 | 24 | 75 |
| 6 | 71 | 274 | 345 | 4.9 | 20 | 79 |
| Average | 161 | 332 | 2967* | 7.0 | 31 | 68 |

*Total

## Explanation

1. The plants selected indiscriminately from this greenhouse show a high degree of natural unfruitfulness. No pollination was practiced.

2. The plants did not at any time attain normal vigor as compared with plants of other crops.

3. The vitality and size of the upper clusters was poor, and a normal number of blossoms per cluster was not produced. The percentage of fruitful blossoms was very small.

4. These plants show unprofitable production.

5. It will be noted that in comparing the fruitfulness of the blossoms of the fifth cluster in the above two crops, the percentage of barren and fruitful flowers is exactly reversed. In the plants in Table II, 75 percent of the blossoms were productive of fruit, while in the plants in Table III 75 percent were unproductive. The first-named plants, which were vigorous, were pollinated; while the plants in Table III, which lacked normal vigor, were unpollinated.

TABLE IV. STATEMENT OF COMPARATIVE NUMBER OF FRUITFUL AND BARREN BLOSSOMS, SPRING CROP. GROWER NO. 5, 1915

55 plants

| Cluster No. | Number fruitful | Blossoms barren | Total number blossoms | Number blossoms per cluster | Percentage blossoms fruitful | Percentage blossoms barren |
|---|---|---|---|---|---|---|
| | | | | | % | % |
| 1 | 109 | 225 | 334 | 6.0 | 35 | 64 |
| 2 | 161 | 310 | 471 | 8.5 | 32 | 67 |
| 3 | 203 | 312 | 515 | 9.3 | 39 | 60 |
| 4 | 152 | 317 | 469 | 8.5 | 32 | 67 |
| 5 | 147 | 265 | 412 | 7.2 | 35 | 64 |
| 6 | 90 | 222 | 312 | 5.6 | 29 | 71 |
| Average | 143 | 275 | 2513* | 7.5 | 32 | 65 |

*Total

**Explanation**

1. The above plants were not artificially pollinated.

2. The plants were of normal vigor except as regards the upper clusters, which were weak.

3. Of all crops under observation, this crop was second in unproductiveness.

TABLE V. STATEMENT OF COMPARATIVE NUMBER OF FRUITFUL AND BARREN BLOSSOMS. SPRING CROP. GROWER NO. 1, 1916

100 plants

| Cluster No. | Number fruitful | Blossoms barren | Total number blossoms | Number blossoms per cluster | Percentage blossoms fruitful | Percentage blossoms barren |
|---|---|---|---|---|---|---|
| | | | | | % | % |
| 1 | 550 | 490 | 1040 | 10.4 | 53 | 46 |
| 2 | 530 | 530 | 1060 | 10.6 | 50 | 50 |
| 3 | 560 | 700 | 1260 | 12.6 | 44 | 55 |
| 4 | 450 | 680 | 1130 | 11.3 | 40 | 60 |
| 5 | 250 | 580 | 880 | 8.8 | 28 | 71 |
| Average | 469 | 586 | 5370* | 10.7 | 43 | 56 |

*Total

**Explanation**

1. The first two clusters were pollinated by inexperienced greenhouse helpers, the pollination consisting of using a spoon in contact with the flower and also jarring. The work was somewhat hurriedly done, as is shown in a table found elsewhere in this bulletin discussing the time spent in pollination and the cost of the same. The above results show a comparatively small percentage of fruitful blossoms.

2. The third, fourth, and fifth clusters were unpollinated.

TABLE VI. STATEMENT OF COMPARATIVE NUMBER OF FRUITFUL AND BARREN BLOSSOMS, SPRING CROP. GROWER NO. 1, 1916

100 plants

| Cluster No. | Number fruitful | Blossoms barren | Total number blossoms | Number blossoms per cluster | Percentage blossoms fruitful | Percentage blossoms barren |
|---|---|---|---|---|---|---|
| | | | | | % | % |
| 1 | 430 | 510 | 940 | 9.4 | 45 | 54 |
| 2 | 600 | 680 | 1280 | 12.8 | 46 | 53 |
| 3 | 400 | 560 | 960 | 9.6 | 41 | 58 |
| 4 | 490 | 672 | 1162 | 11.6 | 42 | 57 |
| 5 | 320 | 850 | 1170 | 11.7 | 27 | 72 |
| Average | 448 | 654 | 5512* | 11.0 | 40 | 60 |

*Total

**Explanation**

1. All of the five clusters were unpollinated.

2. There is an evident uniformity in the percentage of barren blossoms of the first four clusters.

TABLE VII. STATEMENT OF COMPARATIVE NUMBER OF FRUITFUL AND BARREN BLOSSOMS, SPRING CROP. GROWER NO. 2, 1916

90 plants

| Cluster No. | Number fruitful | Blossoms barren | Total number blossoms | Number blossoms per cluster | Percentage blossoms fruitful | Percentage blossoms barren |
|---|---|---|---|---|---|---|
| | | | | | % | % |
| 1 | 287 | 304 | 591 | 6.5 | 48 | 51 |
| 2 | 322 | 328 | 650 | 7.0 | 49 | 50 |
| 3 | 303 | 322 | 625 | 7.0 | 48 | 51 |
| 4 | 264 | 410 | 674 | 7.3 | 39 | 60 |
| 5 | 187 | 490 | 677 | 7.4 | 27 | 72 |
| 6 | 166 | 500 | 666 | 7.4 | 25 | 75 |
| Average | 251 | 361 | 3883* | 7.1 | 39 | 60 |

*Total

**Explanation**

1. In the above greenhouse no pollination was practiced.

2. The yield per plant was 3.3 lbs., or about one-half to two-fifths of that obtained in other greenhouses.

TABLE VIII. STATEMENT OF COMPARATIVE NUMBER OF FRUITFUL AND BARREN BLOSSOMS, SPRING CROP. O. A. C. GREENHOUSE NO. 1, 1917

100 plants

| Cluster No. | Number fruitful | Blossoms barren | Total number blossoms | Number blossoms per cluster | Percentage blossoms fruitful | Percentage blossoms barren |
|---|---|---|---|---|---|---|
| | | | | | % | % |
| 1 | 554 | 147 | 701 | 7.0 | 79 | 20 |
| 2 | 442 | 200 | 642 | 6.4 | 68 | 31 |
| 3 | 445 | 260 | 705 | 7.0 | 63 | 36 |
| 4 | 279 | 376 | 655 | 6.5 | 42 | 57 |
| 5 | 200 | 400 | 600 | 6.0 | 33 | 66 |
| 6 | 124 | 445 | 569 | 5.6 | 21 | 78 |
| Average | 340 | 304 | 3872* | 6.4 | 51 | 48 |

*Total

### Explanation

1. The above plants were grown on raised benches ordinarily used for lettuce and seedling production. It was not difficult to pollinate the first three clusters; but after the fourth cluster was formed plants were growing too tall to be easily reached from the walk.

2. Pollination was discontinued after the third cluster.

3. While the average for the six clusters was 51 percent fruitful and 48 percent barren blossoms, yet the average for the first three clusters pollinated was 70 percent fruitful and 30 percent barren blossoms.

4. Average for last three clusters unpollinated 32 percent fruitful and 67 percent barren blossoms.

TABLE IX. STATEMENT OF COMPARATIVE NUMBER OF FRUITFUL AND BARREN BLOSSOMS, SPRING CROP, O. A. C. GREENHOUSE NO. 2, 1917

60 plants

| Cluster No. | Number fruitful | Blossoms barren | Total number blossoms | Number blossoms per cluster | Percentage blossoms fruitful | Percentage blossoms barren |
|---|---|---|---|---|---|---|
| | | | | | % | % |
| 1 | 300 | 75 | 375 | 6.2 | 80 | 20 |
| 2 | 295 | 115 | 410 | 6.8 | 72 | 28 |
| 3 | 288 | 115 | 403 | 6.7 | 71 | 28 |
| 4 | 282 | 131 | 413 | 6.8 | 68 | 31 |
| 5 | 175 | 208 | 383 | 6.3 | 45 | 54 |
| 6 | 146 | 237 | 383 | 6.3 | 38 | 61 |
| Average | 247 | 147 | 2367* | 6.5 | 62 | 37 |

*Total

### Explanation

1. In this greenhouse plants were grown on ground beds, all of the clusters being pollinated with the exception of the fifth and sixth.

2. Average for six clusters was 62 percent blossoms fruitful; 37 percent barren.

3. Average first four clusters was 72 percent blossoms fruitful; 27 percent barren.

4. Average fifth and sixth clusters was 42 percent blossoms fruitful; 57 percent barren.

TABLE X. STATEMENT OF COMPARATIVE NUMBER OF FRUITFUL AND BARREN BLOSSOMS, SPRING CROP, O. A. C. GREENHOUSE NO. 3, 1917

100 plants

| Cluster No. | Number fruitful | Blossoms barren | Total number blossoms | Number blossoms per cluster | Percentage blossoms fruitful | Percentage blossoms barren |
|---|---|---|---|---|---|---|
| | | | | | % | % |
| 1 | 482 | 267 | 749 | 7.4 | 64 | 35 |
| 2 | 630 | 217 | 847 | 8.4 | 74 | 25 |
| 3 | 682 | 176 | 858 | 8.5 | 79 | 20 |
| 4 | 624 | 220 | 844 | 8.4 | 74 | 25 |
| 5 | 507 | 395 | 902 | 9.0 | 56 | 43 |
| 6 | 531 | 544 | 1075 | 10.7 | 49 | 50 |
| Average | 576 | 303 | 5275* | 8.7 | 66 | 33 |

*Total

### Explanation

1. The plants in this greenhouse were grown on ground beds and the first four clusters were pollinated.

2. Average for first four clusters 72 percent blossoms fruitful; 27 percent barren. Average for fifth and sixth clusters 52 percent blossoms fruitful; 47 percent barren.

TABLE XI. STATEMENT OF COMPARATIVE NUMBER OF FRUITFUL AND BARREN BLOSSOMS, SPRING CROP, GROWER NO. 2, 1917

**55 plants**

| Cluster No. | Number fruitful | Blossoms barren | Total number blossoms | Number blossoms per cluster | Percentage blossoms fruitful | Percentage blossoms barren |
|---|---|---|---|---|---|---|
| | | | | | % | % |
| 1 | 254 | 82 | 336 | 6.0 | 75 | 24 |
| 2 | 271 | 112 | 383 | 6.0 | 70 | 29 |
| 3 | 282 | 125 | 407 | 7.0 | 69 | 30 |
| 4 | 219 | 134 | 353 | 6.5 | 62 | 37 |
| 5 | 249 | 193 | 442 | 7.5 | 58 | 41 |
| 6 | 218 | 130 | 348 | 7.0 | 62 | 37 |
| Average | 248 | 129 | 2269* | 6.6 | 66 | 34 |

*Total

### Explanation

1. These plants were grown as a cooperative experiment in a commercial greenhouse.

2. All of the clusters were pollinated, this being the first experience of the grower in performing this operation.

3. Average for the first three clusters 71 percent blossoms fruitful; 29 percent barren.

4. Average for the last three clusters 60 percent blossoms fruitful; 39 percent barren.

5. Here, again, it is to be noted that the pollination of all clusters, especially towards the top of the plant was responsible for a larger percentage of fruitful blossoms than is ordinarily obtained where no pollination is practiced.

TABLE XII. STATEMENT OF COMPARATIVE NUMBER OF FRUITFUL AND BARREN BLOSSOMS, SPRING CROP, GROWER NO. 2, 1917

**42 plants**

| Cluster No. | Number fruitful | Blossoms barren | Total number blossoms | Number blossoms per cluster | Percentage blossoms fruitful | Percentage blossoms barren |
|---|---|---|---|---|---|---|
| | | | | | % | % |
| 1 | 147 | 125 | 272 | 6.4 | 54 | 45 |
| 2 | 160 | 78 | 238 | 5.6 | 64 | 35 |
| 3 | 168 | 130 | 298 | 7.0 | 58 | 41 |
| 4 | 146 | 81 | 227 | 5.4 | 63 | 36 |
| 5 | 113 | 109 | 222 | 5.0 | 51 | 48 |
| 6 | 103 | 103 | 206 | 5.0 | 50 | 50 |
| Average | 139 | 104 | 1463* | 5.5 | 57 | 42 |

*Total

## Explanation

1. More or less pollination was practiced in this greenhouse at irregular times.

2. The yield of these plants was considerably less than that obtained from plants in Table XI.

TABLE XIII. STATEMENT OF COMPARATIVE NUMBER OF FRUITFUL AND BARREN BLOSSOMS, SPRING CROP. O. A. C. GREENHOUSE NO. 1, 1918

87 plants

| Cluster No. | Number fruitful | Blossoms barren | Total number blossoms | Number blossoms per cluster | Percentage blossoms fruitful | Percentage blossoms barren |
|---|---|---|---|---|---|---|
| | | | | | % | % |
| 1 | 787 | 312 | 1099 | 6.2 | 71 | 28 |
| 2 | 809 | 319 | 1128 | 6.5 | 71 | 28 |
| 3 | 778 | 365 | 1143 | 6.5 | 68 | 31 |
| 4 | 774 | 327 | 1101 | 6.3 | 70 | 29 |
| 5 | 710 | 342 | 1052 | 6.2 | 67 | 32 |
| 6 | 706 | 331 | 1037 | 6.2 | 68 | 31 |
| Average | 760 | 332 | 6560* | 6.3 | 68.5 | 31.5 |

*Total

## Explanation

1. The plants in the above tables were grown to two main stems per plant.

2. All six clusters were pollinated as regularly as possible consistent with the care of other necessary vegetable work.

3. Average for the first three clusters pollinated 70 percent fruitful; 30 percent barren.

4. Average for last three clusters pollinated 68 percent frutiful; 31 percent barren.

5. Note that the top clusters were unusually fruitful in contrast to the percentage of barren blossoms found on other clusters unpollinated.

In these experiments it has been found that blossoms are not so accessible for pollination where there are two main stems in contrast to the pollination of plants grown to a single stem, as may be noted by contrasting Tables XII and XIV.

TABLE XIV. STATEMENT OF COMPARATIVE NUMBER OF FRUITFUL AND BARREN BLOSSOMS, SPRING CROP. O. A. C. GREENHOUSE NO. 2, 1918

116 plants

| Cluster No. | Number fruitful | Blossoms barren | Total number blossoms | Number blossoms per cluster | Percentage blossoms fruitful | Percentage blossoms barren |
|---|---|---|---|---|---|---|
| | | | | | % | % |
| 1 | 605 | 139 | 744 | 6.4 | 81 | 18 |
| 2 | 607 | 206 | 813 | 7.0 | 74 | 25 |
| 3 | 656 | 218 | 874 | 7.5 | 75 | 24 |
| 4 | 617 | 200 | 817 | 7.0 | 75 | 24 |
| 5 | 609 | 253 | 862 | 7.4 | 70 | 29 |
| 6 | 599 | 251 | 850 | 7.4 | 70 | 29 |
| Average | 615 | 211 | 4960* | 7.1 | 74 | 25 |

*Total

### Explanation

1. The plants in the above table were trained to single stems.

2. All clusters were pollinated.

3. Average for the first three clusters 76 percent blossoms fruitful; 23 percent barren.

4. Average for last three clusters 71 percent blossoms fruitful; 28 percent barren.

5. Note that the top clusters were unusually fruitful in contrast to the percentage of barren blossoms found on other clusters unpollinated.

TABLE XV. STATEMENT OF COMPARATIVE NUMBER OF FRUITFUL AND BARREN BLOSSOMS, FALL AND WINTER CROP. O. A. C. GREENHOUSE NO. 2, 1918-19

| Cluster No. | Number fruitful | Blossoms barren | Total number blossoms | Number blossoms per cluster | Percentage blossoms fruitful | Percentage blossoms barren |
|---|---|---|---|---|---|---|
| | | | | | % | % |
| 1 | 311 | 201 | 512 | 4.7 | 60 | 40 |
| 2 | 122 | 403 | 525 | 4.8 | 30 | 70 |
| 3 | 162 | 414 | 576 | 5.3 | 28 | 71 |
| 4 | 296 | 556 | 852 | 8.0 | 37 | 62 |
| 5 | 416 | 480 | 896 | 8.2 | 40 | 60 |
| 6 | 333 | 558 | 891 | 8.2 | 37 | 62 |
| Average | 273 | 435 | 4252* | 6.5 | 38 | 61 |

*Total

### Explanation

1. The first cluster of the above crop was pollinated, but due to high temperature and rapid plant growth, pistils of flowers were very brittle and easily broken. The percentage of fruitful blossoms is therefore comparatively low.

2. The increase in number of blossoms per cluster on the fourth, fifth, and sixth clusters is due to the elongation of the clusters through unfavorable light conditions.

### Cost of Pollination

Investigations of the cost of hand pollinating have been made from time to time in the Oregon Experiment Station greenhouses and in commercial greenhouse establishments, the owners of which have cooperated in the experiments to test the cost of pollinating a tomato crop grown on a commercial scale.

Tabulated statements are herewith given showing records of pollination costs. The hourly cost of labor varies according to the locality, and therefore cannot be accurately stated to meet all sections. In view of the importance of the work of pollination, it is necessary to have constant, careful workers who understand the nature of the operation and appreciate the value of thoroughness.

For the most part the labor costs of pollination for crops grown in the Experiment Station greenhouses coincide very closely with those obtained from data on crops in commercial houses.

Costs will vary according to the manner of performing the pollination, as is shown in Table XVI.

TABLE XVI. LABOR COST IN HAND POLLINATION

| Crop No. | Number plants poll. | Date First poll. | Date Last poll. | Total No. hours spent on poll. | Total cost | Cost per plant | Blossoms of the crop fruitful | Blossoms of the crop barren |
|---|---|---|---|---|---|---|---|---|
| | | | | | | cents | % | % |
| 1 | 144 | April 1 | May 20 | 11 | $2.75-$3.30 | 1.9-2.3 | 60 | 40 |
| 2 | 180 | Mar. 20 | May 18 | 16 | $4.00-$4.80 | 2.2-2.6 | 71 | 29 |
| 3 | 1066 | Mar. 15 | May 30 | 104 | $31.20 | 3.0 | 66 | 33 |
| 4 | 100 | Mar. 18 | May 12 | 10½ | $3.15 | 3.1 | 72 | 27 |
| 5 | 1900 | April 4 | May 18 | 51½ | $16.80 | 0.8 | 51.5 | 48.5 |

### Explanation

1. Pollination of the first five crops in Table XVI was done by the emasculation method, the thoroughness of pollinating varying in each case, and, as a consequence, the cost, as well as the percentage of fruitfulness.

2. The average cost of pollination per plant of the first four crops in Table XVI was from 2.5c to 3.0c.

3. Pollination of Crop No. 5 was done partly by the spoon method and partly by shaking the blossoms. The records of this crop as regards fruitfulness are explained under Grower No. 1, where mention is made of the inexperienced labor employed in the pollination and the hasty manner, for the most part, in which the work was done.

### Labor Costs of Pollination Covered by Increased Earliness of Fruit Production

Cooperative trials concerning the relative yields of pollinated and unpollinated plants during the first part of the marketing season have shown that the greater yields of the pollinated plants not only cover the cost of pollinating during the entire blossoming season, but also leave a margin of profit. The following tabulated records give ample evidence of these facts. In some instances it has been found that the labor cost of pollinating may be paid for as early as the end of the first week of harvesting, or again, as early as the end of the second week, through the increased yields of pollinated plants.

TABLE XVII. COMPARATIVE NET RETURNS OF PLANTS AFTER DEDUCTING COST OF POLLINATION

| Crop No. | No. plants poll. and check resp. | Yield Poll. plants | Yield Check plants | Value fruit Poll. | Value fruit Check | Cost of poll. | Net returns after deducting labor cost total per plant | Net returns after deducting labor cost total per plant |
|---|---|---|---|---|---|---|---|---|
| | | | lbs. | lbs. | | | | cents |
| 1 | 80 | 515 | 370 | $ 77.25 | $55.50 | $2.40 | $19.35 | 24 |
| 2 | 144 | 823 | 662 | 123.45 | 99.30 | 4.32 | 24.15 | 16 |
| 3 | 100 | 944 | 389 | 117.00 | 46.68 | 3.15 | 67.17 | 67 |
| 4 | 100 | 864 | 450 | 107.00 | 56.25 | 3.00 | 47.75 | 47 |
| Average | 106 | 789 | 467 | 106.17 | 64.43 | 3.21 | 39.60 | 38 |

### Explanation

1. The above records show the value of pollinated plants to be an average of 38 cents more than those unpollinated, the variation being from 16 to 67 cents.

2. Pollination of Crop No. 2 was somewhat delayed at the beginning of the blossoming.

3. Crop No. 3 was exceedingly productive with an average of 9.4 pounds to the plant.

4. Cost of labor by the hour for pollination averaged 30 cents.

TABLE XVIII. STATEMENT SHOWING INCREASED YIELDS FROM POLLINATED PLANTS, COVERING LABOR COST OF POLLINATION

180 plants

| Yield in lbs. end of 2nd week of harvesting | | Value of yield of plants | | Labor cost of pollination entire season | Increased value poll. over unpoll. plants | Margin profit after deducting labor cost |
|---|---|---|---|---|---|---|
| Poll. | Unpoll. | Poll. | Unpoll. | | | |
| 160.2 oz. | 61.8 oz. | $32.00 | $12.30 | $5.40 | $19.70 | $14.30 |

### Explanation

1. The cost of pollination was based on previous findings of 3c a plant, records of which are given elsewhere in this publication.

2. Table XVIII shows that in the early part of the marketing season the yield from pollinated plants may be so much greater than that from unpollinated plants as to make it possible to pay for the entire labor cost of pollination before the expiration of the second week of harvesting.

### Relation of Increased Yields to Labor Cost of Crop Production

Determinations have been made cooperatively with commercial growers regarding the extent to which the value of the increased returns from pollinated plants may offset the cost of growing the crop as a whole. Records of such a relation as deduced from a commercial crop, a like number of plants of which were hand pollinated and unpollinated respectively, are as follows:

TABLE XIX. YIELDS OF PLANTS IN RELATION TO PRODUCTION COST

| Total yield lbs. | | Value plants | | Labor cost production 1146 plants | Increase in value poll. over unpoll. plants |
|---|---|---|---|---|---|
| poll. plants | unpoll. plants | poll. | unpoll. | | |
| 6588 | 5320 | $939.72 | $768.97 | $180.00 | $170.75 |

### Explanation

1. The labor cost for the above number of plants is figured from the preparation of the soil for the plants up to the packing of the first crates. The figures represent pre-war prices. At prevailing prices there would be an increase of possibly one-third in the labor cost.

2. The increased value of the pollinated plants was almost equal to the labor cost of production at the pre-war wage or at the present time would have paid for at least one-half to two-thirds of the labor cost, not including the labor cost in marketing.

3. The comparatively small investment of pollinating 1146 plants, totalling approximately $30 to $34, was responsible for the increased gross returns of $180 to the grower, or nearly 600 percent.

## ACKNOWLEDGMENTS

Considerable assistance has been rendered by W. I. Spencer, Gresham; F. B. Chase, Eugene; R. B. Bodley, Portland; W. H. Dunham, Portland, and others, in furnishing records of their crops from which data have been obtained concerning the influence of pollination. Without this co-operation much reliable information would have been unavailable. The author's thanks are extended to them for their helpfulness in furnishing data, and in permitting the use of portions of their greenhouses for experimental purposes.

## BIBLIOGRAPHY


(1) L. H. Bailey—Experiments in the Forcing of Tomatoes. N. Y. (Cornell) Agr. Exp. Sta. Bul. 28, 1891.

(2) R. L. Watts—Tomato Culture under Glass. Tenn. Agr. Exp. Sta. Bul. 4, 1892.

(3) W. M. Munson—Secondary Effect of Pollen. Maine Agr. Exp. Sta. Rept., 1892.

(4) W. B. Alwood—Tomatoes under Glass. Va. Agr. Exp. Sta. Bul. 59, 1895.

(5) B. Fink—Pollination and Reproduction of Lycopersicum esculentum. Survey Geol. and Nat. Hist. Minn. Bul. 9, 1896.

(6) S. A. Beach—Forcing Tomatoes. N. Y. (Geneva) Agr. Exp. Sta. Bul. 125, 1897.

(7) S. C. Mason—Forcing Tomatoes. Kan. Agr. Exp. Sta. Bul. 7, 1897.

(8) E. H. Jenkins and W. E. Britton—Experiments with Tomatoes. Conn. Agr. Exp. Sta. Rept., 1899.

(9) A. T. Jordan—Forcing Tomatoes. N. J. Agr. Exp. Sta. Bul. 141, 1899.

(10) W. F. Massey and A. Rhodes—Winter Forcing of Tomatoes. N. C. Agr. Exp. Sta. Bul. 170, 1900.

(11) C. P. Hartley—Injurious Effects of Premature Pollination. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 22, 1902.

(12) A. C. Beal—Forcing Tomatoes. Ill. Agr. Exp. Sta. Bul. 81, 1902.

(13) J. Troop—Cross Pollination of Tomatoes. Ind. Agr. Exp. Sta. Rept., 1904.

(14) W. J. Green and C. W. Waid—Forcing Tomatoes. Ohio Agr. Exp. Sta. Bul. 153, 1904.

(15) L. C. Corbett—Tomatoes. U. S. D. A. Farmers' Bul. 220, 1905.

(16) L. H. Bailey—The Forcing Book. 1906.

(17) G. F. Warren—The Forcing of Tomatoes. N. J. Agr. Exp. Sta. Rept. 1906.

(18) S. W. Fletcher and O. I. Gregg—Pollination of Forced Tomatoes. Mich. Agr. Exp. Sta. Spec. Bul. 39, 1907.

(19) E. P. Sandsten—Some conditions which influence the Germination and Fertility of Pollen. Wis. Agr. Exp. Station. Res. Bul. 4.

(20) A. G. B. Bouquet—Greenhouse Tomato Investigations. Ore. Exp. Sta. Hort. and Crop Pest Rept., 1913.

(21) L. C. Corbett—Garden Farming, 1913.

(22) A. G. B. Bouquet—Greenhouse Tomato Investigations, Ore. Agr. Exp. Sta. Hort. and Crop Pest Rept., 1915.

(23) H. W. Siefert—Pollination of Greenhouse Tomatoes, Ore. Agr. Exp. Sta. Thesis, 1916.

(24) R. L. Watts—Vegetable Forcing, 1917.

(25) E. J. Kraus and H. R. Kraybill—Vegetation and Reproduction with Special reference to the Tomato. Ore. Agr. Exp. Sta. Bul. 149, 1918.