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AN ELECTRIC POLLINATOR FOR TOMATOES.

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INTRODUCTION.

The instrument described below was designed when it became desirable to carry out large-scale field pollination experiments in a study of winter blossom-drop in tomatoes; it simulates the behaviour of a native bee (*Anthophora pulchra*) visiting tomato flowers. Essentially it consists of a fine wire loop which is caused to vibrate within a glass pollen-collecting chamber. By placing the staminal cone of the flower in the loop, and causing the latter to vibrate, pollen is rapidly shaken from the anthers into the chamber. Pollination is effected in the same manner; if the stigma is protruding it will pick up pollen from the bottom of the chamber; if the stigma is only partly exposed pollen will be thrown up on to it; if the flower contains loose pollen the vibration will add to the pollen in the chamber and at least ensure selfing should the stigma be too deep within the flower to be reached by pollen from the chamber. The instrument is of especial value in hybridization studies, since it can readily be sterilized and enables pollen to be collected from a number of varieties in different localities for use where desired. It is thought that the instrument could be used in the commercial production of F_1 hybrids, since it greatly reduces the time required to effect a cross and is not affected by ordinary winds. Though designed for use with tomatoes, the instrument can be used in its present form for collecting pollen from other flowers, and, where necessary, could readily be modified.

ORIGINATION OF DESIGN.

For many years it has been customary to pollinate tomatoes in the glasshouse by the so-called "watchglass" method described by Bailey (1895), Schneck (1928), and other workers. In this method pollen is obtained by tapping flowers over a watchglass or glass slide; the protruding pistils of the flowers to be pollinated are then dipped into the pollen. The method suffers from several disadvantages: only a relatively small proportion of the available pollen is secured, great care must be exercised not to blow or brush the pollen off the glass, and the pistil must definitely protrude for rapid pollination; for field work it is out of the question since the least gust of wind will disseminate the pollen. It is usual in the field to pollinate by applying an opened anther to the

stigma, as described by Hadfield and Calder (1936), or to transfer pollen from an anther to the stigma by means of a needle scalpel in the manner described by Barrons and Lucas (1942). These methods, though excellent for small-scale work, are relatively slow and wasteful of pollen and can only be used satisfactorily on still days or in the mornings before the wind rises.

During the course of a field study of winter blossom-drop in tomatoes in 1944 the writer found that, when blossom-drop was taking place on apparently healthy plants during cold and cloudy weather, fruit could be made to set by pollinating flowers by one of the methods described above. It was therefore decided that, if possible, large-scale field pollination experiments should be carried out during the following winter. It was realized, however, that a more rapid method of pollination would be required and one which would not be affected by the winds which usually prevail at that time of the year.

It had already been observed that even during a bad blossom-drop period an occasional flower would set fruit. It had also been noticed that a native, blue-banded, solitary bee (*Anthophora pulchra*) was at times active on tomato flowers. It seemed possible that this bee might have been a factor in the partial fruit-setting which had been observed, and its behaviour when visiting tomato flowers was therefore closely studied. The bee would alight on the staminal cone of a flower and grasp it firmly with its legs in such a manner that the medial portion of its abdomen was situated immediately below the tips of the anthers; it would then rapidly vibrate its wings, thereby causing vibration of the flower and discharge of pollen, which the bee caught with the pollen-collecting hairs on its abdomen. Unfortunately, the varieties on which the bee was operating at the time did not have protruding pistils, but it seemed inevitable that had this been the case the stigmas would have picked up pollen from the bee. These observations suggested that it should be possible to develop a much more convenient method of pollination than those referred to earlier; after a number of experiments the instrument described below was produced and found to be very satisfactory.

CONSTRUCTION.

Materials Required.

For each instrument the following materials are required:—

1 low-pitched buzzer, DC 3V, AC 5V, 1.3A.
1 radio "C" battery, 4½V.
1 piece ⅛-in. sheet ebonite.
1 pair discarded car distributor breaker points.
1 piece clock spring about ·015-in. thick (or a discarded Model "T" Ford car coil trembler plate).
2 screws 3/16-in. with one nut to fit.
5 screws ⅛-in. with four nuts to fit. (All screws perferably brass).
1 small piece pressure rubber tubing about ¼-in. bore.
1½ yds. two-wire "flex."

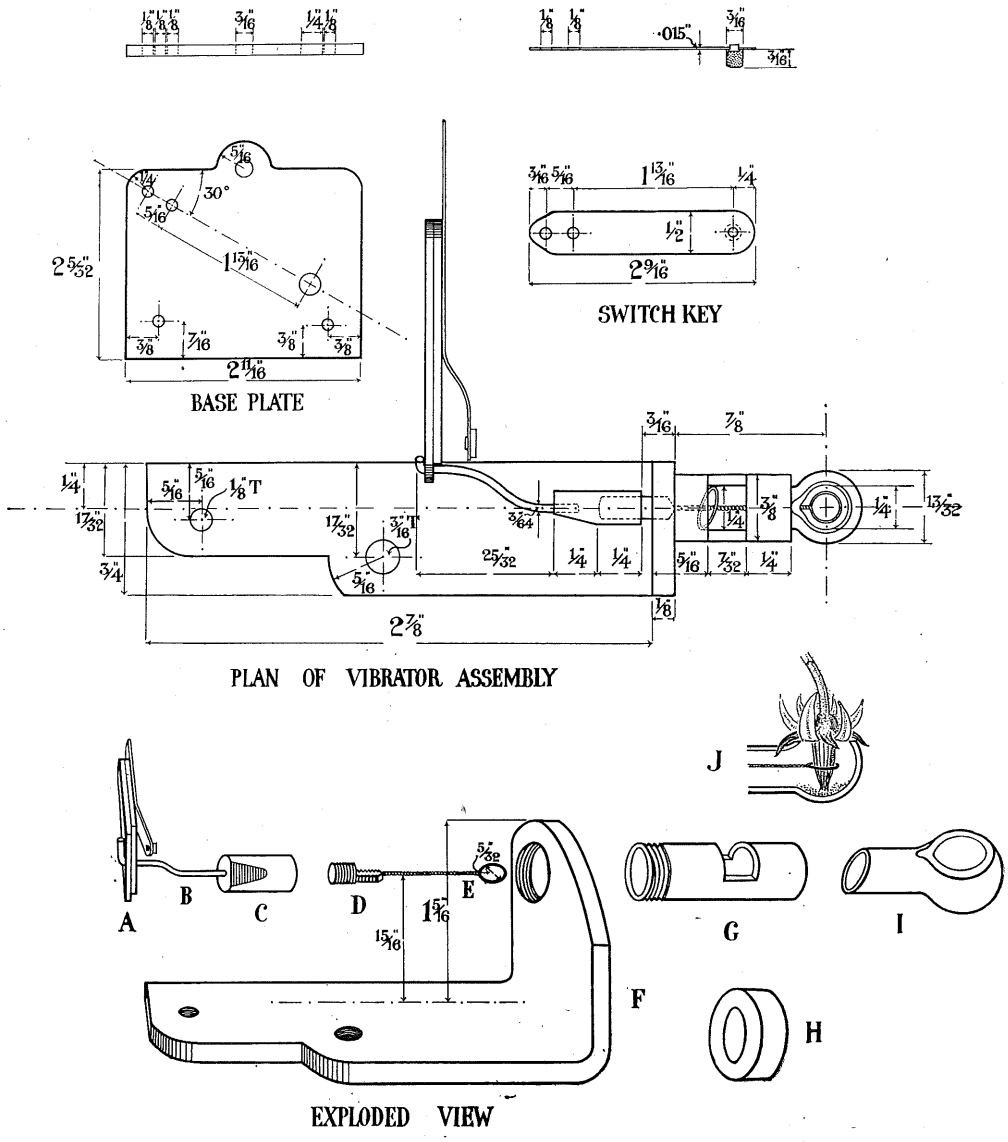


Figure 1.

Illustrating dimensions and disposition of parts of pollinator.

A Armature of buzzer.
B Connecting rod.
C Adaptor.
D Vibrator loop holder.
E Vibrator loop.
F Bracket support.
G Pollen chamber housing.
H Rubber ring.
I Pollen chamber.
J Position of flower during pollination or pollen extraction.

[*Drawings by William Manley.*]

$4\frac{1}{2}$ ins. copper or brass strip $\frac{1}{8}$ in. x $\frac{3}{4}$ in.
3 ins. fine steel wire 30-35 Imperial Standard gauge (Mandolin "E").
6 ins. soft glass tubing; minimum bore 3/16 in., maximum external diameter 9/32 in.
1-in. brass tubing; minimum bore 9/32 in., external diameter $\frac{3}{8}$ in.
3 ins. steel rod 3/64 in. diameter (hat pin).
$\frac{1}{2}$-in. brass rod $\frac{1}{8}$ in. diameter (or brass screw).
6 ins. brass rod 3/16 in. diameter.

Parts to be Made.

Following are given brief instructions regarding the making of parts and adjustments for the type of buzzer shown in Plates 1 and 2; letters given are those used in Figure 1.

A. A 3/64-in. hole to be drilled through the armature of the buzzer close to its outer end and through its mid-axis.

B. *Connecting Rod.*—The thin steel rod to be softened and bent and cut to the shape and size shown in the drawings; both ends to be tinned with solder.

C. *Adaptor.*—A 3/64-in. hole to be drilled $\frac{1}{8}$-in. deep at one end of a $\frac{1}{2}$-in. length of 3/16-in. brass rod and a 3/32-in. hole $\frac{1}{4}$ in. deep to be drilled at the other; the latter hole to be tapped with $\frac{1}{8}$-in. Whitworth thread. The shoulder at one side of the non-threaded end to be filed away to avoid later fouling the buzzer cover.

D. *Vibrator Loop Holder.*—A piece of $\frac{1}{8}$-in. brass rod 7/16 in. long to be threaded with $\frac{1}{8}$-in. Whitworth thread at one end over $\frac{1}{4}$ in. of its length; a fine hole, say, 1/32 in., to be drilled $\frac{1}{8}$ in. deep at the other end. The unthreaded portion then to be filed down to give a central flat blade 1/16 in. thick and the shoulders of the blade to be rounded off. A $\frac{1}{8}$-in. Whitworth brass screw may be used in place of the brass rod.

E. *Vibrator Loop.*—The vibrator loop is made from fine steel wire, 30-35 Imperial Standard gauge. The new wire is first tinned with ordinary solder. Taking a piece about 3 ins. long a circular loop 5/32 in.-11/64 in. is now made at its centre. This is easily done by clamping a metal rod of suitable diameter in position over a flame and bending the wire around it quickly at a spot out of the flame where the rod is not quite red hot; removing the wire, its projecting ends are twisted together with the fingers to form a shank; the loop and its shank are now tinned once more.

F. *Bracket Support.*—This is a $\frac{1}{8}$-in. brass or copper strip $\frac{3}{4}$ in. wide cut, bent, and tapped as shown in the drawings. The tappings on the basal portion are $\frac{1}{8}$ in. and 3/16 in. Whitworth; that on the upright portion is $\frac{1}{8}$ in. gas.

G. *Pollen Chamber Housing.*—A piece of brass piping $\frac{3}{8}$ in. external diameter and 25/32 in. in length; one end to be threaded with $\frac{1}{8}$ in. gas thread over about $\frac{1}{8}$ in. of its length; the central portion to be slotted as shown in the

drawings; the other end may be countersunk to give good seating to the pollen chamber.

H. *Rubber Band.*—A slice cut from the pressure tubing; it is intended to fit around the pollen chamber housing and in the slot of the latter in order to hold the stem of the pollen chamber firmly.

I. *Pollen Chamber.*—A strong bulb with external diameter about 13/32 in. to be blown on the end of the soft glass tubing. The side of the bulb then to be opened; this is best done by grinding it down on a fine grinding wheel but it may be done by blowing and breaking off a second bulb on the side of the first one. The opening thus made should have a diameter of $\frac{1}{4}$ in. to 9/32 in. The depth of the chamber from this opening should be about 5/16 in. The tube is now cut $\frac{1}{2}$ in.-$\frac{5}{8}$ in. from the shoulders of the bulb to form a short stem, which is then ground obliquely so that it will later be easy to slip it below the rubber band around the pollen chamber housing. The edge of the opening in the bulb and the end of the stem are now carefully annealed without causing either to shrink any more than is unavoidable.

Base Plate.—This is made from $\frac{1}{8}$-in. sheet ebonite cut and drilled as shown in Figure 1.

Switch Key.—This is made from thin clock spring and presents little difficulty. Spring to be drawn flat by pulling around a smooth surface and a piece cut out with shears to the size and shape shown in Figure 1. The holes can now easily be made if their positions on the strip are each marked by a sharp blow on a centre punch; each mark will then show a "pimple" on the reverse side of the strip; each "pimple" then to be filed down until a small hole appears, which can be opened up by means of a fine rat-tail file. A press button is then made from 3/16-in. brass rod. Now a 3/16-in. hole is drilled in a piece of board and the button is placed in it with its flat end protruding slightly; then the spring strip is clamped on to the board with the single hole at one end pressing against the button and the latter soldered on to the strip through the hole. A contact point from an old car distributor breaker arm is then soldered on to the spring immediately above the press button. A small area of the spring is now to be tinned with solder immediately around the inner hole at the other end of the strip in order to provide a good contact when the switch key is later connected to the buzzer.

Spanner.—A small spanner for setting or removing the vibrator loop is made by cutting a 1/16-in. slot at the end of a short length of 3/16-in. brass rod.

Electrical Circuit.

A switch is included in the buzzer circuit in the manner shown in Plate 1. The screw which serves to hold in place the buzzer cover is taken out and its head filed down to leave a disc about 3/64 in. in depth, to the face of which is soldered another discarded distributor point. The longer end of the buzzer coil winding is now to be disconnected from its terminal and lengthened slightly if necessary; to this end is then soldered a $\frac{1}{8}$-in. brass nut after having

cut a small slot along its side to take the wire. The cover holding screw is now replaced and suitably connected with the terminal from which the coil winding was previously disconnected. A small piece of fine rubber insulating tube, which may be pulled off from the "flex," is then slipped over the other end of the coil winding to keep it separated from the end previously referred to. It will be found on assembling the instrument that the contact point on the switch key will come into position immediately below the contact point on the cover holder screw.

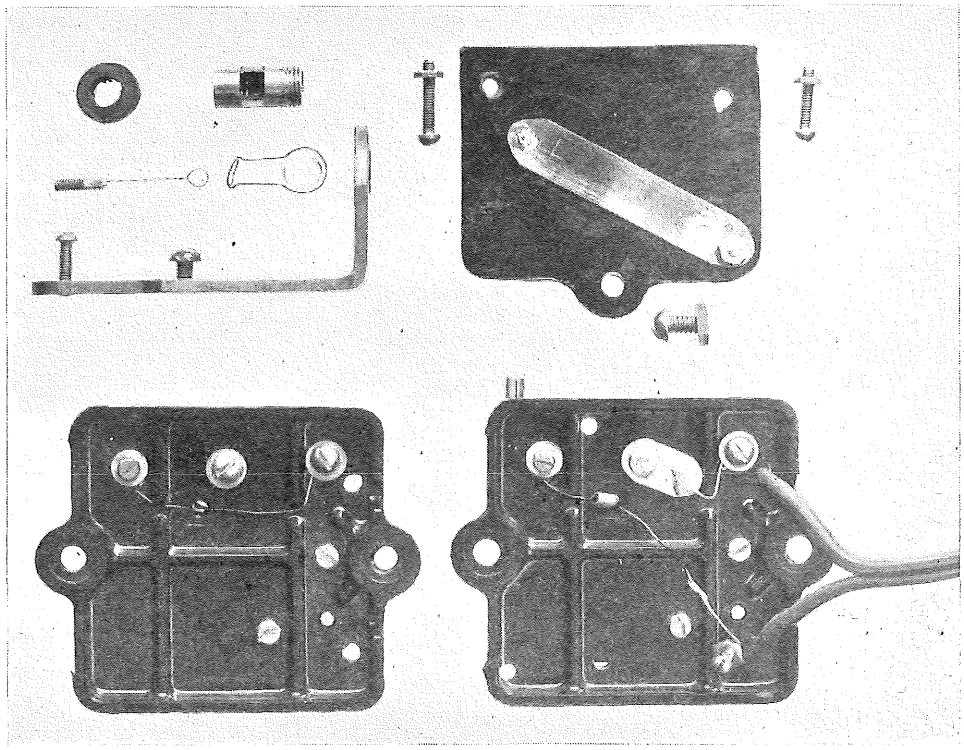


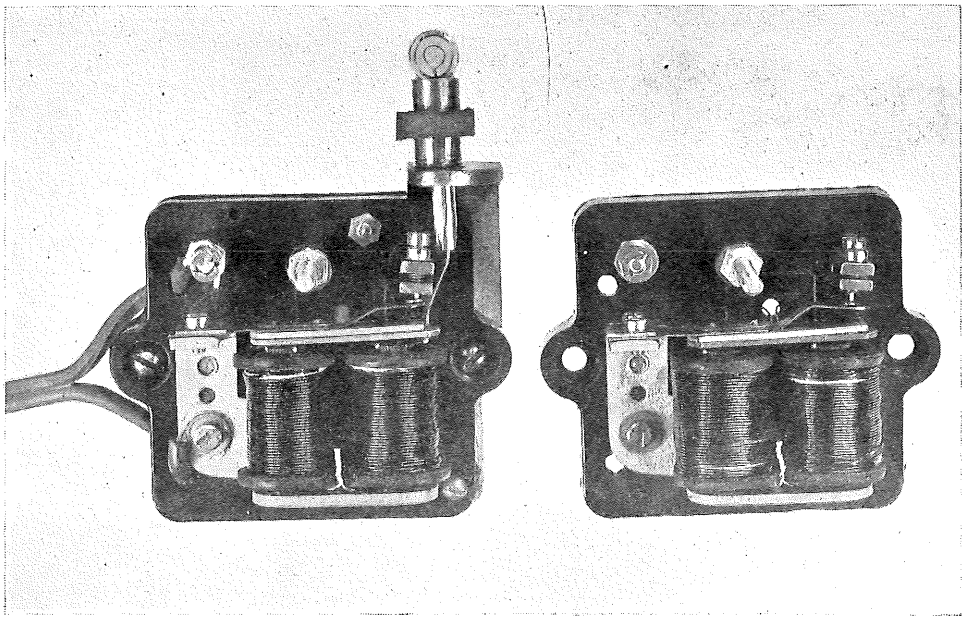
Plate 1.

Showing electrical circuit and component parts. In lower left corner is shown buzzer prior to modification.

[*Photograph by W. J. Sanderson.*

Assembly.

The parts of the instrument are now ready for assembly. First, the bracket support is screwed into position with a 3/16-in. screw. Next, the base plate is affixed with a 3/16-in. screw and nut so as to fit neatly against the bracket support. Now the positions are to be marked on the underside of the base of the buzzer for $\frac{1}{8}$-in. holes to be drilled to take the remaining screws for the base plate and bracket support. Having drilled these holes, after removing the base plate and bracket support, the two-wire "flex" is connected to the buzzer and the bracket support screwed into position again with its two screws. The switch key is now to be affixed to the base plate by means of a $\frac{1}{8}$-in. screw



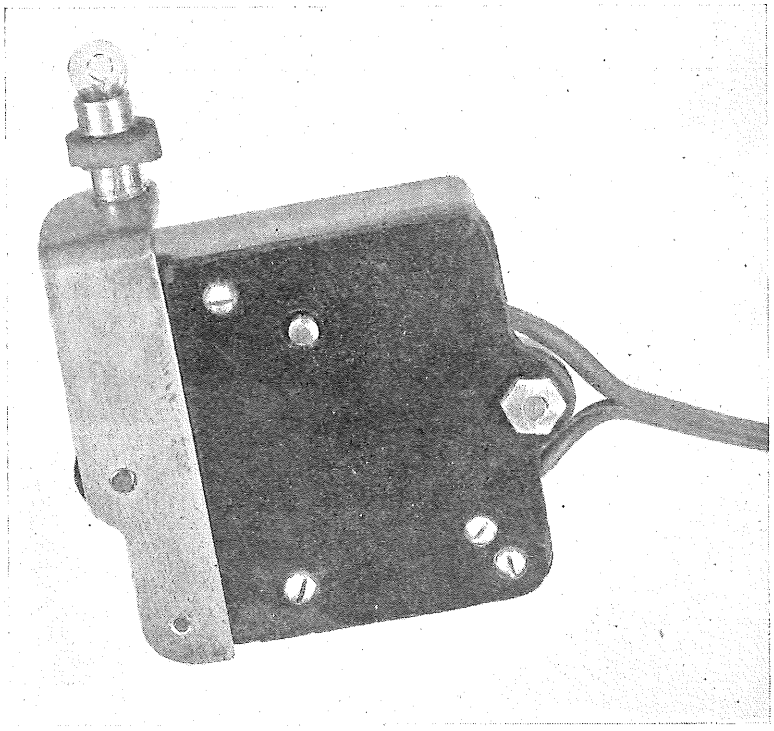


Plate 2.

Showing completed pollinator and unaltered buzzer without their covers, and underside of completed pollinator.

[*Photographs by W. J. Sanderson.*

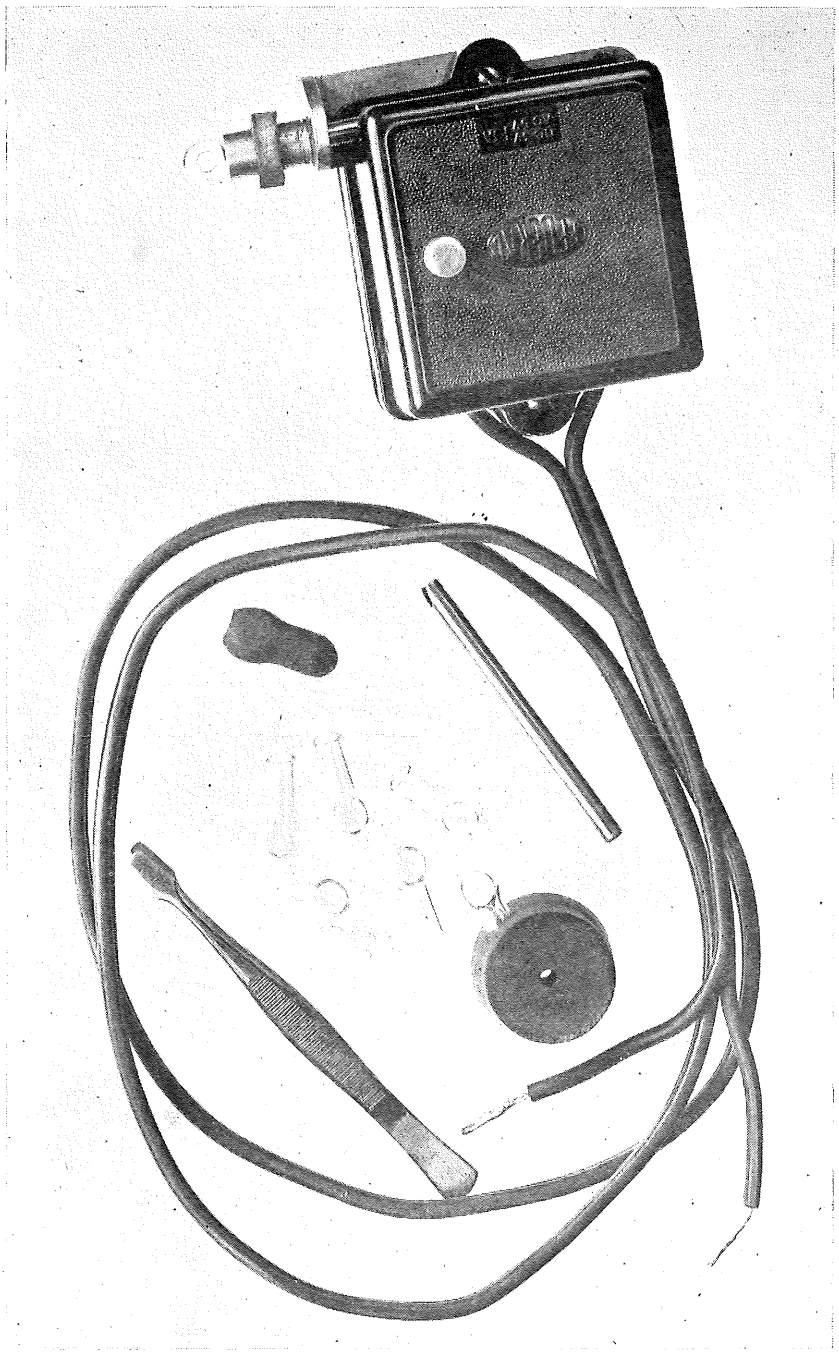


Plate 3.

Showing completed pollinator, together with small spanner, spare pollen chambers, pollen chamber in rubber sheath, hybridizing forceps, and pollen chamber held in rubber stopper.

[*Photograph by W. J. Sanderson.*

and nut through the end hole; then a second screw is passed through the remaining hole and screwed into the nut which was soldered to the end of the coil winding. The base plate can now be screwed into place with its 3/16-in. and two $\frac{1}{8}$-in. screws and nuts, all screws having previously been shortened where necessary. The connecting rod is then to be soldered on to the armature and the adaptor to the connecting rod.

Next the vibrator loop holder is to be screwed tightly into position in the adaptor and the pollen chamber housing screwed finger-tight into the bracket support. The buzzer should then be tested and adjusted as necessary to give a strong and fairly high frequency vibration. The vibrator loop holder should work freely in the centre of the inner end of the pollen chamber housing: if necessary, it can readily be adjusted by bending the connecting rod slightly. The vibrator loop should then be tried in position in its holder and, if necessary, its shank shortened so that the loop will be centred in and approximately level with the pollen chamber opening when at rest. Removing the pollen chamber housing, the shank is then soldered into position with the loop in a plane parallel to the base plate. If it is later found that the vibrator loop holder tends to become loose when the instrument is in use, the adaptor should be slotted for about two-thirds of its length with a fine jeweller's saw and the two sides pressed slightly together in a vise so that they will act as a spring clamp when the vibrator loop holder is again screwed into position. Having satisfactorily adjusted and fitted the vibrator loop, the rubber band is forced into position around the pollen chamber housing, the latter again screwed finger-tight into position, and the pollen chamber thrust home. The vibrator loop should now be at rest a little below the pollen chamber opening; if necessary, its shank can be bent at its base to bring it into this position. It now remains only to cut a slot in the corner of the bakelite cover of the buzzer to allow complete freedom of movement to the adaptor and the instrument is ready for use.

METHODS OF USE.

The instrument may be used as either a pollen collector or a pollinator. The methods of use for each purpose are given below.

Use as a Pollen Collector.

The instrument is designed for use in the field, glasshouse, etc., on growing plants; but, of course, it can equally well be used for collecting pollen from flowers brought into the laboratory. When it is used on growing plants, the wire flex is connected to the battery, one, two, or three cells being tapped according to the force of the vibration required; for tomato flowers the writer taps three cells, or $4\frac{1}{2}$ volts. The battery is then carried in the pocket, in a belt pouch, or in some other convenient manner. The instrument is held horizontally in the right hand with the thumb over the cover and the fingers on the underside in such a way that the tip of the second finger rests lightly on the switch press button. Continuing to hold the instrument more or less horizontally, it is placed

below the flower to be treated. Grasping the peduncle of the flower between the thumb and first finger of the left hand, as shown in Plate 4, the flower is brought into a vertical position and the staminal cone lowered into the vibrator loop as shown at "J" in Figure 1; a light press on the press button will then set the loop in motion and most of the loose pollen of the flower will be shaken into the pollen chamber in a few instants without injuring the flower or impairing its ability to set fruit. The whole operation takes only a few seconds, so the rate at which flowers can be treated is usually restricted only by the number of suitable flowers available. The best stage of anthesis at which to collect pollen is when the petals are about fully reflexed. One good flower of the Break o' Day variety of tomato will yield about 0·0006 gm. of pollen, or about 150,000 pollen grains, in a single

Plate 4.

Showing method of using pollinator in the field. Position of hands is a matter of convenience and will depend on position of flower.

[*Photograph by W. J. Sanderson.*

treatment; some varieties—e.g., Rouge de Marmande—will yield considerably more. The yield of pollen is influenced by the weather and the age and health of the plant; cluster varieties are far less affected by weather in this respect than are the larger-fruited varieties.

When sufficient pollen has been collected, or the pollen chamber has been sufficiently filled, the latter is removed from its housing, its stem plugged with a small piece of cotton wool, a rubber "policeman" or sheath slipped over it (see Plate 3) in order to prevent the pollen from falling out, and a clean pollen chamber fitted to the instrument. In a single test the writer was able successfully to fertilize emasculated flowers with pollen kept in a chamber and sheath for 30 hours at ordinary room temperatures; the percentage of viability was, however, not determined. As a matter of interest, pollen has been collected from a number of other flowers, including sweet pea, Iceland poppy, wallflower, citrus, custard apple, and papaw, using the instrument in its present form. It could easily be modified for special purposes, its basic principle being the shaking of anthers within a collecting chamber.

Use as a Pollinator.

As a pollinator in field or glasshouse the instrument, after being charged with pollen, is used precisely as described above. If the pistil of the flower is short and the anthers contain loose pollen, selfing at least will be ensured. If the pistil is longer and the stigma partly exposed, pollen will be thrown on to the latter by the rapid motion imparted to the anther tips by the vibrator loop. If the pistil is long and the stigma protrudes the latter will pick up pollen from the bottom of the chamber. When a variety which, owing to weather conditions other than rain, has a scanty supply of pollen is being pollinated, an ample supply of pollen can usually be obtained from a cluster variety such as Prosperity if cross fertilization is of no consequence and fruit production only is desired. Experiments are at present in progress to determine to what extent, under such circumstances, pollen is driven up the staminal cone to reach a short pistil.

Used for experimental hybridization the pollen chamber, charged with pollen, is removed from its housing and its stem plugged with cotton wool, or removed from its rubber sheath if the pollen has been collected elsewhere and transported. Its stem is then thrust into a hole cut in the side of a medium-sized rubber stopper for ease of handling, as shown in Plate 3. Emasculation of the flower to be pollinated is best carried out by seizing the bases of two petals together by means of a pair of flat-nosed forceps and gently pulling out the corolla with the staminal cone as described by Barrons and Lucas (1942). The exposed pistil is then dipped into the pollen in the pollen chamber. It should be noted that the ready accessibility of the pollen chamber, the pollen chamber housing, and the vibrator loop make it an easy matter to sterilize these with alcohol where it is necessary to ensure purity of pollen in genetical studies. For large scale hybridization the charged pollen chamber can very conveniently be used in the following manner:—Two holes are bored close together and at right angles to each other and to its axis through a small rubber stopper.

Through the lower hole is passed a rubber band and the two protruding loops of the latter are slipped over the middle of the first finger of the left hand so as to hold the stopper across the inside of the finger; the rubber band should be of a size suitable to hold the stopper comfortably on the finger without its feeling tight. The pollen chamber stem is then thrust into the upper hole in the stopper,

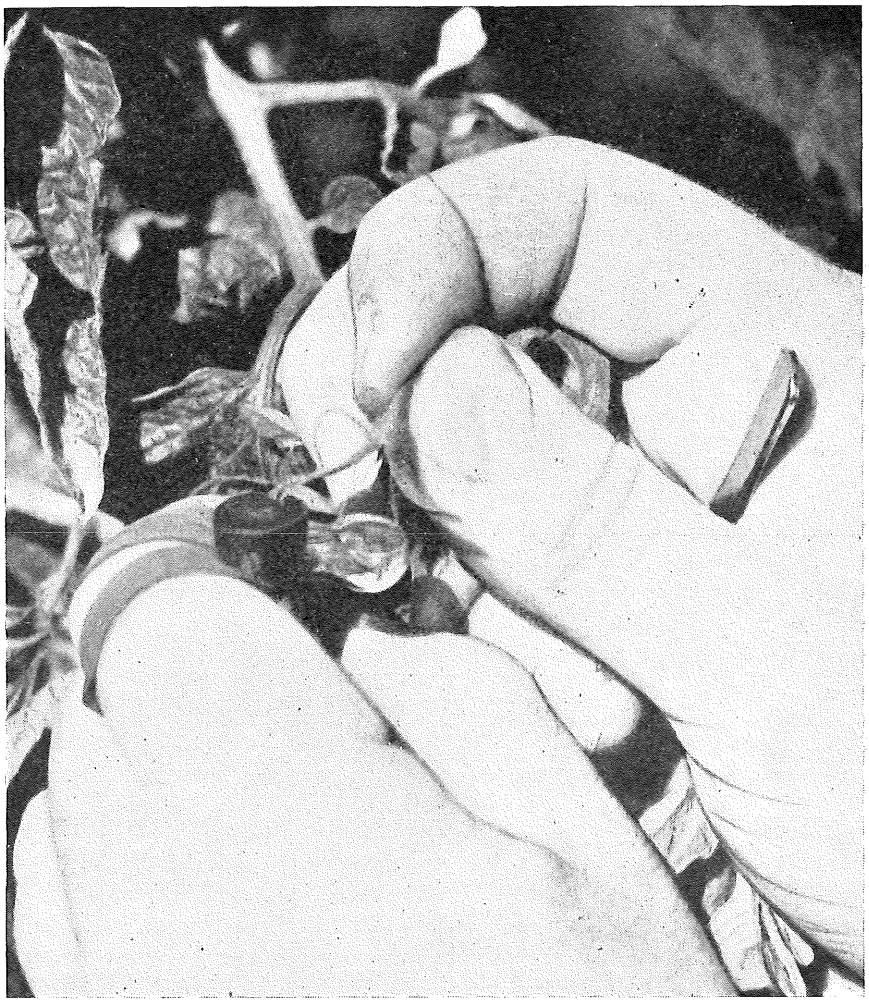


Plate 5.

Showing method of using pollen chamber in large scale hybridization. Pistil of emasculated flower is about to be dipped into pollen in the pollen chamber.

[*Photograph by W. J. Sanderson.*

where it can safely and conveniently be carried. Emasculation of each flower is carried out as described in the previous paragraph and is not interfered with by the presence of the pollen chamber. Immediately after each emasculation the forceps in the right hand are moved into the palm of that hand, the peduncle

of the flower seized with the fingers and the pistil dipped into the pollen chamber as shown in Plate 5. The whole of this operation occupies from seven to 15 seconds according to the ease with which the corolla may be removed from the flower. The latter operation is best performed just before dehiscence, since the corolla is then easier to remove and the stigma is more receptive than in younger flowers. The right stage at which to emasculate is soon determined at the commencement of the work by examining a few flowers for dehiscence with a 10x hand lens. It should also be mentioned that the work is simplified if the female parent plants are staked and pruned to one stem and if a group of male parent plants is grown nearby to provide a convenient source of pollen.

This method of hybridizing tomatoes is a great deal more rapid than any other known to the writer and is not affected by ordinary winds; the instrument may therefore prove useful with this crop in the commercialization of hybrid vigour, the advocacy of which periodically appears in the literature. It is perhaps of interest to mention that experiments are under way to determine whether successful cross-pollination of varieties with protruding pistils can be accomplished without emasculation, as this would further reduce the time factor in commercial hybridization.

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