THE RESPONSE OF PLANTS TO ILLUMINATING GAS

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 227

SARAH L. DOUBT

(WITH SIX FIGURES)

Introduction

Owing to increasing loss of plants in greenhouses, and of shade trees along city streets, it has seemed worth while to work out simple accurate methods by which gardeners, florists, and foresters may detect gas injury. This study falls into two divisions: (1) injury to greenhouse plants due to presence of gas in the air; and (2) injury to trees and bedding plants due to leakage in the soil. It is hoped that as a result of this work any florist or gardener may be able to determine readily the presence of illuminating gas in the air. The presence of gas in the soil as shown by injury to trees is more difficult to determine.

Considerable work has been done in this laboratory on the effect of illuminating gas and its various constituents upon plants. CROCKER and KNIGHT (1) showed that the buds and flowers of carnations are extremely sensitive to traces of illuminating gas in the air. Three days' exposure, 1 part in 40,000, killed young buds and prevented the opening of those which already showed the petals. The flowers were closed by 12 hours' exposure to 1 part in 80,000. One part ethylene to 1,000,000 parts of air prevented opening of the buds, and 1 part in 2,000,000 caused the flowers to close. Their work showed that ethylene is the constituent which is most toxic to plants. HARVEY and ROSE (6) showed that the relatively high toxicity of ethylene holds for many different species of plants. CROCKER, KNIGHT, and ROSE (2) found etiolated sweet-pea seedlings to be extremely sensitive to gas, and suggest the use of them as test plants for traces of gas. HARVEY (8) suggests the use of the castor bean for the same purpose.

Little is known about the effect of gas on trees. STONE (9) has made a number of observations in the field, which led him to conclude that many trees which are seriously injured by gas finally succumb to attacks of fungi or of insects. He believes these secondary causes are often blamed for the total injury.

Rather striking formative effects have been noted by a number of writers. STONE observed abnormal tissue in the cortex of stems of Carolina poplar, proliferation tissue in the lenticels of willow, and increased root development in cuttings of the willow exposed to gas. HARVEY and ROSE (6) found that gas and ethylene cause tubercle-like growths on roots of *Catalpa* and *Ailanthus*.

Methods

The gas used in this investigation was that of the Peoples Gas Light and Coke Company of Chicago. It averages about 4 per cent ethylene and about 25 per cent carbon monoxide. The ethylene used was generated from absolute alcohol and concentrated sulphuric acid and washed in the usual way. It contained 90 per cent ethylene and 10 per cent air impurities. The carbon monoxide was generated from oxalic acid and concentrated sulphuric acid, washed and analyzed. Each of these was mixed with air to give it the same volume percentage as exists in illuminating gas, and the air-gas mixtures were checked against the illuminating gas.

Three general methods of exposing plants to gas were used: (1) the flowers only were treated with gas; (2) potted plants were sealed in wardian cases and measured amounts of gas added; and (3) root systems were treated with a slow stream of gas in the soil.

1. To determine the limit of toxicity for the flower of the calla lily (*Zantedeschia ethiopica*) the method employed by CROCKER and KNIGHT (1) upon carnations was used. A 20 liter carboy was inverted over the flower bud and a rubber stopper fitted about the petiole and made gas-tight with vaseline. Gas was forced into this 20 liter bottle through a tube inserted in a second hole in the stopper. A measured amount (800 cc. or 4 per cent) of illuminating gas was forced in, and the pinchcock closed. A control plant was put under identical conditions, except that no gas was used. When the bottles were removed 11 days later, both flowers

opened and were of normal size. The one treated with gas showed slight discoloration on the spathe. Four per cent of illuminating gas, then, slightly injures the inflorescence of the calla lily. Further results on the calla lily are given later.

2. Exposure of entire potted plants was made in two wardian cases (each of about 1000 liters capacity); one case was used for exposure to gas and the other case was used for the control plants. The plants were placed in the cases by the removal of a pane of glass which was later sealed into place with the vaseline-clay mixture used by CROCKER and KNIGHT. The plants were kept under moisture conditions as nearly optimum as possible. During the winter season the temperature varied between 15 and 20° C. with day and night. The experiments were carried on from January to July. In April the temperature became so high in the cases as to injure the plants. The cases were then given a coat of whitewash. As the temperature again rose, the cases were moved outside and partly shaded. Plants were treated for 2 days, then the cases were opened, the plants removed, and the cases aired by means of an electric fan. After watering, the plants were returned to the case and following renewal of gas were left 2 days more. They were then removed and the immediate and the after effect of the gas noted. Since the control plants were in no case injured, it is clear that the response of the other plants was due to the gas.

Types of responses

1. *Leaf fall.*—In certain concentrations of ethylene or of illuminating gas, *Mimosa*, *Lycopersicum*, *Salvia*, *Datura*, *Coleus*, and *Hibiscus* dropped their leaves after a few hours' exposure. The abscission layer was probably formed. The older the plants, the less gas was required to cause the older leaves to drop. The youngest leaves were least affected.

2. *Rigor.*—*Coleus*, *Ricinus*, *Datura*, and *Mimosa* showed rigor when subjected to large amounts of gas. *Mimosa* showed imperfect rigor, lost sensitiveness to touch, but was somewhat injured by the gas. *Coleus* was completely anesthetized, with no ill aftereffects. FITTING (5) found that heat rigor or rigor from lack of oxygen will prevent gas injury to plants.

3. *Epinasty of petioles.*—Suitable concentrations of illuminating gas and of ethylene produced epinasty in petioles or flower stalks. In *Lycopersicum* and *Salvia* this response is often so marked as to produce complete spiral coils. The petioles of *Ricinus*, *Datura*, *Coleus*, and *Hibiscus*, and the flower stalk of calla lily also showed epinasty in traces of these gases. The bending may be near the blade or the bud, as in calla lily leaf and flower; all along the petiole, as in most younger leaves; or very near the stem, as in most older petioles (figs. 1–5).

4. *Proliferation tissue in lenticels, leaf scars, etc.*—In the presence of traces of illuminating gas or of ethylene, soft spongy tissue developed in the lenticels (*Hibiscus* and *Sambucus*), at leaf scars (*Lycopersicum*), or at more or less extensive regions along the stems. In the roots of the apple and pear the abnormal tissue developed just outside the vascular cylinder, but it is not determined whether it was produced by the cortex or the pericycle. Deep longitudinal cracks developed in the bark of the stem. These appeared on the apple, pear, ash, and *Hibiscus*, and to a less degree in *Sambucus*, *Grevillea*, and cottonwood.

5. *Root tubercles.*—Traces of these gases produced tubercle-like growths on the roots of *Grevillea*, *Sambucus*, *Populus*, apple, pear, and *Hibiscus*. In the tomato similar tubercles are produced by nematodes.

Results of treatments

In the following records, plants are arranged in the order of their sensitivity to gas. All amounts of gas indicated are in parts per million of air (ppm).

Lathyrus odoratus.—With 1000, 100, 75, and 50 ppm illuminating gas, the leaves turned yellow and died. Ethylene 8 ppm caused the leaflets to fall off; 5 ppm caused the leaves to become yellow and die; 2 ppm caused death of the older leaves; and 0.1 ppm still caused noticeable injury, although less than in the other cases.

Salvia splendens.—With 25,000 ppm illuminating gas, the older leaves fell off, while the younger ones showed epinasty; 9000 and 8000 ppm caused epinastic response of the petioles;[1] 1000 ppm

[1] In all cases of epinasty the leaves drooped, but the blades and petioles remained rigid. In some cases the halves of the blades folded together somewhat (fig. 4).

caused the oldest leaves at the base of the stem to fall off and the younger leaves showed epinasty; 100, 50, and 25 ppm still caused marked epinasty. With ethylene, 5 ppm caused some leaf fall, epinasty was marked, and some petioles showed a complete spiral coil (figs. 3, 4); 2 ppm caused epinasty but no leaf fall; 0.2 and 0.1 ppm still caused epinasty. With carbon monoxide, 50 and 12.5 ppm caused no response.

FIGS. 1, 2.—Fig. 1, *Lycopersicum esculentum:* plant at left has been treated for 12 hours with 50 ppm carbon monoxide; plant at right has been treated for 12 hours with 8 ppm ethylene; the former appears perfectly normal, while the latter shows the distinct epinastic response characteristic of gas poisoning; note spiral coiling of one petiole; fig. 2, *Lycopersicum esculentum:* control at left; plant at right has stood for 18 hours in atmosphere containing 1000 ppm illuminating gas; a few hours longer would cause leaf fall, but as they stand the leaves show strong epinastic response; they are bent down, but are stiff.

Mimosa pudica.[2]—With illuminating gas, 60,000 ppm caused imperfect rigor;[3] 100 and 50 ppm caused folded leaflets and pulvinal movement; after a day the leaflets turned yellow and fell off; then some petioles fell; some of the youngest leaves were

[2] With *Mimosa* all amounts of gas used caused the plants to lose their sensitiveness to touch. After recovery they regained it.

[3] The leaflets folded and the leaves drooped as they do at night or after stimulation, but recovery was complete after removal.

uninjured. With ethylene, 8 and 5 ppm caused the same response as the preceding; 2 ppm caused some leaf fall but the injury was less; 0.2 ppm resulted in the fall of a few leaflets, but all leaves showed sensitiveness by folding together; 0.1 ppm caused some leaflets to fall. With carbon monoxide, 50 ppm caused a clear response; leaflets folded and petioles drooped; no leaflets fell; the plant lost its sensitiveness to touch; recovery was complete after two days in air.

Ricinus communis.[4]—With illuminating gas, 60,000 ppm caused imperfect rigor, some leaves falling; 100 ppm caused falling of the older leaves and epinasty of all others; 50 ppm caused marked epinasty but no leaf fall. With ethylene, 8 and 5 ppm caused most of the leaves to fall, the youngest showing epinasty; 2 ppm caused no leaf to fall, but all the leaves showed epinasty; 0.2 and 0.1 ppm caused a less marked response, but epinasty was still evident (fig. 5). With carbon monoxide, 50 and 12.5 ppm caused no response.

Datura Stramonium.—With illuminating gas, 60,000 ppm caused partial rigor; 4000 ppm caused all the leaves except the youngest to fall; 500 ppm caused falling of the oldest leaves; epinasty of the younger leaves was very similar to that of *Ricinus;* 50 ppm caused epinasty of the older leaves. With ethylene, 8 ppm caused the older leaves to fall, the younger leaves showing epinasty; 5 ppm caused less leaf fall, but the remaining leaves showed epinasty; with 2 ppm there was no leaf fall, but evident epinasty; with 0.2 and 0.1 ppm there was evident epinasty. With carbon monoxide, 50 ppm gave no visible response.

Lycopersicum esculentum.—With illuminating gas, 35,000 ppm caused the older leaves to fall, the root growth was stimulated on the stem above the ground, and epinasty occurred;[5] 26,000, 1000,

[4] The epinastic response is very striking in this plant. The cotyledons, leaf blades, and petioles, all show the characteristic turning. The petioles droop about 90° from their normal position, so that instead of making an angle of about 45° with the stem above the leaf, they droop until they make an angle of about 45° with the stem below the leaf. The blades and petioles are rigid after turning, and usually recover their normal position after a couple of weeks with no gas present (fig. 5).

[5] On the older leaves this was near the blade; on the younger leaves it was near the stem. In some cases this growth caused a spiral coil of the petiole (fig. 1).

75, and 50 ppm caused the same kind of response, but the degree was lessened somewhat. With ethylene, 8 and 5 ppm caused fall of the older leaves, the younger leaves showing epinasty (fig. 2), and proliferation tissue developed on the leaf scars; 2 ppm caused a few leaves to fall, but this amount was about the limit for causing leaf fall; 0.2 ppm caused evident epinasty; 0.1 ppm caused no response. With carbon monoxide, 12.5 ppm caused no response.

Coleus sp.—With illuminating gas, 35,000 ppm caused rigor, no leaves fell, and after removal from the cases recovery was com-

3 4

FIGS. 3, 4.—Fig 3, *Salvia splendens:* plant at right was treated with 2 ppm ethylene; after 12 hours it showed distinct epinastic response; plant at left, appearing normal, received 12.5 ppm carbon monoxide; fig. 4, *Salvia splendens:* control plant and one which has been treated for 18 hours in 1000 ppm illuminating gas; epinastic growth of petioles is clear and leaf blades show a folding together of the sides, which is characteristic of presence of considerable gas.

plete; 25,000 ppm caused all the leaves to fall at the end of 24 hours exposure; 6000 ppm caused falling of about half the leaves, the older being the ones affected; 1000 ppm caused the oldest to fall, the younger showed epinasty, and the youngest were unaffected; 100 ppm caused slight epinasty of the younger leaves, and this is close to the limit of response. With ethylene, 5 ppm caused the oldest leaves to fall, while the younger, except those at the tip, showed epinasty; 2 ppm caused no leaf fall, and epinasty was slight; 0.2 ppm caused no response. With carbon monoxide 12.5 ppm caused no response.

Hibiscus rosa-sinensis.—With illuminating gas, 9000, 8000, and 4000 ppm caused all leaves to fall; new leaves developed in 2–3 weeks after removal from the case; the lenticels on the stem were filled with spongy white tissue; with 1000 ppm the older leaves fell, and the younger leaves showed epinasty; with 100 ppm only slight epinasty was evident. With ethylene, 8 ppm caused distinct epinasty; 2 ppm caused slight epinasty, but this is near the limit for response. With carbon monoxide, 12.5 ppm caused no response.

Acalypha tricolor.—With illuminating gas, 25,000 ppm caused some leaf fall, and other leaves showed epinasty; 8000 and 1000 ppm caused no leaf fall, but distinct epinasty.

Acacia horrida.—With illuminating gas, 8000 ppm caused fall of many leaves; 1000 ppm caused fall of some leaves several days after treatment.

Euonymus japonicus.—With illuminating gas, 20,000 ppm caused most of the leaves to fall; 8000 ppm caused the older leaves to fall; 1000 ppm caused a few of the older leaves to fall.

Citrus decumana.—With illuminating gas, 20,000 and 8000 ppm caused most of the leaves to fall after removal from the case; 1000 ppm caused the older leaves to fall.

Zantedeschia ethiopica.—With illuminating gas, 40,000 ppm caused the flower spathe to become somewhat discolored, but the plant seemed uninjured; 10,000 ppm caused epinasty in the young leaves, the petioles being arched next to the blade; 9000, 8000, and 1000 ppm caused the youngest leaf and the peduncle to show epinasty as above. With ethylene, 5 ppm caused slight epinasty of the youngest leaf; 2 ppm caused no response.

Pelargonium zonale.—With illuminating gas, 25,000 and 4,000 ppm caused no visible response during 4 days of treatment, but all leaves fell in 3–6 days after treatment had stopped;[6] 100 ppm caused no response. With ethylene, 8 and 2 ppm caused no response. With carbon monoxide, 12.5 ppm caused no response.

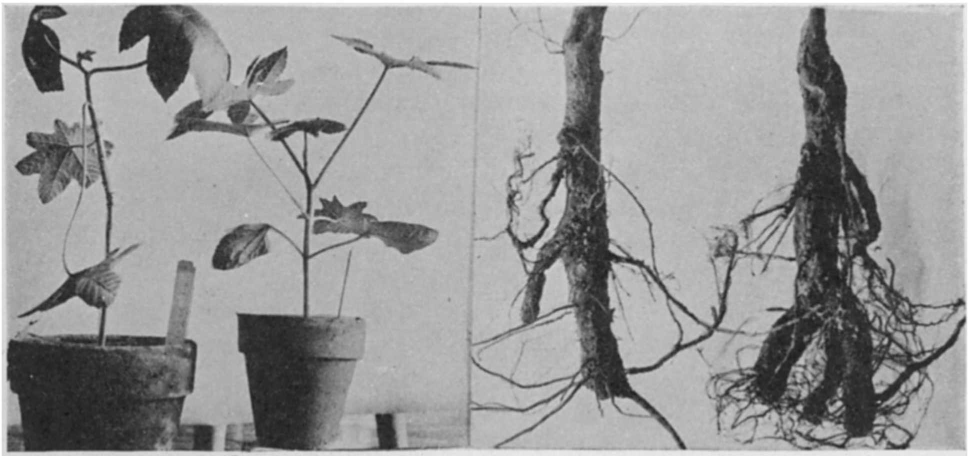
Begonia luminosa.—With ethylene, 8 ppm caused some epinasty at the base of the leaf blade. With carbon monoxide, 50 ppm caused no response.

[6] When new leaves developed, they were without the variegated zone.

Fuchsia speciosa.—With illuminating gas, 20,000 ppm caused some of the older leaves to fall; 8000 ppm caused epinasty.

Populus deltoides.[7]—With illuminating gas, 35,000, 25,000, and 10,000 ppm caused some leaf fall, and after removal from the cases other leaves died and fell off; 8000 ppm caused some leaf fall.

Ficus elastica.—With illuminating gas, 20,000 ppm caused the older leaves to fall during treatment; 8000 ppm caused some of the older leaves to fall about a week after treatment.



5 6

FIGS. 5, 6.—Fig. 5, *Ricinus communis:* plant at right, appearing normal, stood for 2 days in 50 ppm carbon monoxide; plant at left stood in 8 ppm ethylene for 2 days, and has dropped one leaf, all other petioles showing strong epinastic response; note that direction of leaf blades is altered as well as that of petioles; fig. 6, Roots (*Pyrus communis* at right; *P. Malus* at left): the 3-pronged root of pear has had 100 liters of illuminating gas forced into the soil during 40 days; notice swollen condition of underground parts, also numerous "tubercles"; the root of apple received 160 liters of illuminating gas in 62 days, its response, swelling and tubercles, being very similar to that of pear.

Croton tiglium var. Sanders.—With illuminating gas, 20,000 ppm produced some leaf fall of the older leaves; 8000 ppm caused slight epinasty.

Tulipa (several varieties).—With illuminating gas, 10,000 ppm caused injury of the flower buds and the tips of the younger leaves rolled up; 4000 ppm caused no visible injury.

[7] These were cuttings rooted in sand and grown in flower pots.

Hyacinthus (several varieties).—With the same quantities of illuminating gas, the responses were identical with those of the tulip.

Carica Papaya.—With illuminating gas, 20,000 ppm caused the older leaves to fall and the younger leaves to show epinasty.

Caladium esculentum.—This showed no response with 75 ppm illuminating gas, 8 ppm ethylene, or 50 ppm carbon monoxide.

Lupinus perennis.—This showed no response with 8 ppm ethylene or 50 ppm carbon monoxide.

Eriobotrya japonica, *Phoenix canariensis*, *Conocephalus* sp., *Canna* (King Humbert and other varieties), *Achyranthes Lindini*, *Cytisus canariensis*, and *Alternanthera* sp. showed no response with 20,000 ppm illuminating gas.

Polypodium, *Aspidium*, and *Asplenium.*—With illuminating gas, 60,000, 8000, and 4000 ppm caused no response.

The preceding data are summarized briefly in table I. The plants are grouped according to their sensitiveness to gas: very sensitive, less sensitive, and resistant. The minimum concentration necessary to produce a response is given in each case.

The following plants showed no response to illuminating gas or to ethylene in the concentration used: *Caladium esculentum*, *Lupinus perennis*, *Eriobotrya japonica*, *Phoenix canariensis*, *Conocephalus*, sp., *Canna*, *Achyranthes Lindini*, *Alternanthera* sp., *Cytisus canariensis Polypodium*, *Aspidium*, and *Asplenium*.

Root treatment of trees

Two or three year old trees were used for the root treatment. They were treated in flower pots during the winter and early spring, and then the work was carried on out of doors upon young trees which had been growing in the soil for a year or more.

The potted plants were set on tripods and glass tubing was run through the cork plug in the bottom of the pot. Connection was made with a wash bottle and the rate of gas flow through this wash bottle was controlled by means of a brass stopcock. The gas was forced out from the inverted carboys by means of water from a raised tank. All rubber connections with glass tubing were as short as possible, gas tight, and the gas was "water sealed" in the inverted carboys. By means of the brass stopcocks and glass tubes drawn out to a fine point in the wash bottles, the rate of flow of the gas could be regulated at will. To keep the soil from plugging the glass tube inserted in the pot, a small vial with a slit along the side of the cork was fitted over the end of the tube inside the flower pot. The pot was then dipped into melted paraffin in order to prevent too much escape of gas through the lower part of the pot.

TABLE I

Plant	Gas used and amount in parts per million (ppm)	Response
	VERY SENSITIVE PLANTS	
Lathyrus odoratus.......	Illuminating gas, 25	Leaflets died and fell off
Salvia splendens........	Illuminating gas, 25	All leaves showed epinasty
Mimosa pudica.........	Illuminating gas, 50	Some leaflets fell; others showed epinasty
Ricinus communis........	Illuminating gas, 50	Epinasty shown by the leaves
Datura Stramonium.....	Illuminating gas, 50	Epinasty shown by the younger leaves
" "	Ethylene, 0.1	Close to the limit for the response
Lycopersicum esculentum	Illuminating gas, 50	Epinasty
" "	Ethylene, 0.2	Epinasty shown by the leaves
" "	Ethylene, 0.1	No response
	LESS SENSITIVE PLANTS	
Coleus sp..............	Illuminating gas, 100	Slight epinasty shown by the younger leaves
Hibiscus rosa-sinensis....	Illuminating gas, 100	Epinasty shown by the older leaves
Acalypha tricolor.......	Illuminating gas, 1000	Epinasty
Acacia horrida..........	Illuminating gas, 1000	Some leaves fell
Euonymus japonicus.....	Illuminating gas, 1000	Some leaves fell
Citrus decumana........	Illuminating gas, 1000	Some leaves fell
Zantedeschia ethiopica ...	Illuminating gas, 1000	Youngest leaf arched at the base of the blade
Pelargonium zonale......	Illuminating gas, 4000	Leaves fell several days after treatment
Begonia luminosa.......	Ethylene, 8	Slight epinasty
Fuchsia speciosa........	Illuminating gas, 8000	Epinasty
Populus deltoides.......	Illuminating gas, 8000	Some leaves fell
Ficus elastica...........	Illuminating gas, 8000	Some leaves fell
Croton tiglium..........	Illuminating gas, 8000	Slight epinasty
Tulipa (several vars.)....	Illuminating gas, 10,000	Flower buds somewhat injured
Hyacinthus (several vars.)	Illuminating gas, 10,000	Flower buds somewhat injured
Carica Papaya..........	Illuminating gas, 10,000	Older leaves fell, the younger showed epinasty.

When the trees were treated in the open ground, glass tubes 12–24 inches long, depending upon the size of the trees, were buried close to the side of the tree. The same precaution was used here to prevent clogging.

The following are the results for each tree or plant treated, the length of time treated, and the amount of illuminating gas passed into the soil. In no case could the odor of the gas be detected on a handful of the soil or escaping in the air. The temperature range was 12–20° C.

Acer Negundo.—A young tree was treated for 45 days and given 60 liters of gas. There was no visible effect above or below ground.

Acer saccharinum.—Treated 42 days and given 140 liters of gas, the parts above ground were unchanged. The stem below ground, however, was swollen, soft, and cracked longitudinally. A section showed proliferation tissue produced just outside the vascular cylinder.

Chrysanthemum hortorum.—One plant, being treated 42 days and given 80 liters of gas, was killed, no proliferation tissue being produced or other visible changes. A second plant was treated 28 days and given 60 liters of gas. Some roots grew up out of the ground, probably due to loss of geotropic response.

Fraxinus americana.—Treated for 42 days and given 120 liters of gas, the parts above ground were unchanged. Below ground the stem was swollen, soft, and cracked longitudinally. Sections showed that abundant proliferation tissue was produced just outside the vascular system.

Grevillea robusta.—One specimen was treated 33 days and given 40 liters of gas. After 2 weeks gummy matter exuded from a slight crack in the stem just above the ground. A second plant was treated 48 days and given 40 liters of gas; and a third was treated 31 days and given 19 liters of gas. The roots of all three showed spongy white masses of tissue at short intervals, with no epidermis. Many roots were dead. The underground parts of the stem were swollen, due to the development of spongy, white tissue.

Hibiscus rosa-sinensis.—A plant was treated 15 days and given 40 liters of gas. The leaves showed epinasty for 2 days and then fell off. After 4 days' treatment, white spongy tissue developed in the lenticels just above ground. The underground parts were enlarged to three times their normal size. The cortical tissue was white and spongy. The bark split longitudinally and dropped off. Small tubercles developed on many roots. The xylem and phloem appeared normal. These results with *Hibiscus* agree with those of HARVEY and ROSE (6).

Lycopersicum esculentum.—One plant was treated 24 days and given 20 liters of gas, while a second plant was treated 18 days and given 20 liters of gas. After a few hours' treatment, the lower leaves began to show the epinastic response, falling after 2 days. Many more roots developed on the stem above ground than on the control plant. Roots grew up out of the ground, probably due to loss of geotropic sensitiveness. Tubercles occurred on the roots. The control plants showed some tubercles, but the number was greatly increased upon the treated plants. Nematodes were present in many of these tubercles.

Poa pratensis.—One sod was treated 38 days and given 60 liters of gas; a second 25 days with 60 liters; a third 5 days with 40 liters; and a fourth 8 days with 40 liters. There was no response in any case.

Populus deltoides.—Treated 81 days and given 60 liters of gas, the roots developed many small "tubercles," being swollen to twice the normal size at these points. The tissue was soft and spongy. The stem showed no visible effect above ground; below ground it was swollen and rigid.

Pyrus communis.—Treated 40 days and given 100 liters of gas, there was no visible response above ground, but all underground parts were swollen. Longitudinal cracks appeared, in which was soft spongy tissue. All the roots were irregularly enlarged, all the proliferation tissue being in the cortex (fig. 6).

Pyrus Malus.—Treated 62 days and given 160 liters of gas, the response was very similar to that of the pear (fig. 6).

Ricinus communis.—Treated 45 days and given 80 liters of gas, all leaves except the youngest fell. The underground part of the stem was swollen and cracked longitudinally.

Salvia splendens.—One plant was treated 18 days and given 20 liters of gas, and another plant was treated 42 days and given

80 liters of gas. Some leaves fell and others showed epinasty; but the underground parts showed no effect.

Sambucus canadensis.—Treated 60 days and given 60 liters of gas, the roots were killed. Some roots which were still living showed "tubercles" similar to those upon *Populus*. The stem below ground was somewhat swollen, due to the development of spongy white tissue in the lenticels.

Ulmus americana.—Treated 90 days and given 180 liters of gas, after 3 weeks the bark cracked vertically just above the surface of the ground. After 6 weeks, 2 small limbs died and were removed. About half the leaves fell during the treatment. Near the close of the treatment the underground parts were dead and cracks extended throughout the bark and cortical tissue. There was a small amount of proliferation tissue just outside the vascular system.

Practical suggestions for florists

To detect illuminating gas in a greenhouse, the florist should provide himself with some vigorous plants of one of the following: tomato, castor bean, scarlet sage, Jimson weed, or sensitive plant. These should be grown in pots so that they may readily be handled, and should have from 6 to 12 or more leaves. They must also be in vigorous condition; otherwise they may not respond should illuminating gas be present. These should be placed at various locations throughout the greenhouse and left 24–48 hours with poor ventilation. All the plants named will respond to traces of illuminating gas within this period at ordinary temperatures.

With only a trace of gas present in the air, the epinastic response of the leaves will be very noticeable if these plants are compared with normal plants without gas. This bending down of the leaves will increase with the concentration of the gas present in the air. All these plants will drop their leaves with a concentration below the limit of the odor of gas. The older leaves fall first, the younger leaves being retained until there is 1 part of illuminating gas to 1000 of air.

Summary

1. The following plants are admirably adapted for use as test plants for illuminating gas in greenhouses: *Lycopersicum escu-*

lentum, *Salvia splendens*, *Mimosa pudica*, *Ricinus communis*, *Datura Stramonium*, and *Dianthus Caryophyllus*. The response of each is definite, striking, and not easily mistaken.

2. Traces of gas (50 ppm of air) cause the epinastic growth of the petioles of all these plants, with the exception of the last. The flower buds of the carnations are blighted by these amounts. One part of illuminating gas per 1000 of air causes leaf fall in the following plants: *Lycopersicum esculentum*, *Salvia splendens*, *Mimosa pudica*, *Datura Stramonium*, *Ricinus communis*, *Coleus* sp., and *Hibiscus rosa-sinensis*. Both the amounts (50 ppm of air and 1 part per 1000 of air) are far below the limit of odor. Repeated trials showed that it was impossible to detect less than 0.25 per cent of illuminating gas (1 part to 400 of air) by the sense of smell.

3. Amounts of ethylene corresponding to the gas mixture gave similar responses; 2 ppm of air caused epinastic growth of the petioles of *Lycopersicum esculentum*, *Salvia splendens*, *Mimosa pudica*, *Ricinus communis*, and *Datura Stramonium;* 8 ppm of air (equivalent to 200 parts of illuminating gas) caused some leaf fall in the 5 plants named.

4. *Poa pratensis* and *Acer Negundo* are very resistant to gas, having shown no response to concentrations injurious to all other forms tested.

5. The following plants are not noticeably injured by gas unless there is enough present to be detected by odor: *Caladium esculentum*, *Lupinus perennis*, *Eriobotrya japonica*, *Phoenix canariensis*, *Conocephalus* sp., *Canna*, *Achyranthes lindini*, *Alternanthera* sp., *Cytisus canariensis*, *Polypodium*, etc.

6. The following trees are rather sensitive to gas escaping into the soil: *Pyrus Malus*, *P. communis*, *Fraxinus americana*, *Ulmus americana*, *Sambucus canadensis*, *Grevillea robusta*, *Catalpa speciosa*, *Populus deltoides*, and *Tilia americana*. Apple, pear, ash, elm, *Catalpa*, and *Sambucus* showed proliferation tissue in the cortex of the stems below the surface of the ground. Elm, ash, and cottonwood showed longitudinal cracks in the bark just above the surface of the ground.

7. The following bedding plants are injured by gas escaping into the soil: *Lycopersicum esculentum*, *Salvia splendens*, *Ricinus communis*, and *Chrysanthemum hortorum*. *Chrysanthemum* is

killed outright; the others drop their leaves or show epinastic growth of the petioles.

8. Young trees at least are injured by leakage of illuminating gas too slight to be detected by odor. The foliage shows no injury, and one would not be likely to suspect gas poisoning from the appearance of the tree above ground. Judging from my results with trees, their killing by illuminating gas is a very slow process, going on for months or years. It is certain that enough gas to cause an odor in the vicinity of trees would be enough to injure them seriously.

I am indebted to Dr. WILLIAM CROCKER for suggestions and help during the progress of the work.

WINONA FEDERATED COLLEGE
WINONA LAKE, IND.

LITERATURE CITED

1. CROCKER, WM., and KNIGHT, L. I., Effect of illuminating gas and ethylene upon flowering carnations. BOT. GAZ. **46**:259–276. 1908.
2. CROCKER, WM., KNIGHT, L. I., and ROSE, R. C., A delicate seedling test. Science N.S. **37**:390. 1913.
3. ———, A new method of detecting traces of illuminating gas. Science N.S. **31**:636. 1910.
4. ———, Effect of various gases and vapors upon the etiolated seedling of the sweet pea. Science N.S. **31**:635–636. 1910.
5. FITTING, HANS, Untersuchungen über die vorzeitige Entblätterung von Blüten. Jahrb. Wiss. Bot. **49**:187–263. 1911.
6. HARVEY, E. M., and ROSE, R. C., The effect of illuminating gas on root systems. BOT. GAZ. **60**:27–44. 1915.
7. HARVEY, E. M., Some effects of ethylene on the metabolism of plants. BOT. GAZ. **60**:193–214. 1915.
8. ———, The castor bean and laboratory air. BOT. GAZ. **56**:439–442. 1913.
9. STONE, G. E., Effect of escaping illuminating gas on trees. Mass. Exper. Sta. Report pp. 180–185. 1906.
10. ———, Effects of illuminating gas on vegetation. Mass. Exper. Sta. Report pp. 45–60. 1913.