STUDIES IN THE DISEASES OF MANGIFERA
INDICA LINN.

Part III. Investigation into the Effect of Sulphur Dioxide Gas
on the Mango Fruit

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I. Introduction

The necrosis (black-tip disease) of the mango fruit is popularly believed
to be due to the deleterious effect of fumes arising from brick kilns operating
in the vicinity of mango orchards. It was, therefore, thought advisable to
ascertain the effect of brick kiln fumes and their constituent gases on
the healthy mango fruits in orchards where black-tip disease is unknown.
Fumigation experiments, under controlled conditions, were therefore
carried out with both coal gas and sulphur dioxide gas which are known
to have harmful effects on the vegetation. The present paper deals
exclusively with the effect of sulphur dioxide gas on the mango fruits.

II. Material and Method

The investigation was carried out at the Government Horticultural
Gardens, Lucknow, in which locality the black-tip disease is not known
to occur. Mostly Safeda mangoes were utilised for the experiments as the
number of other varieties of fruits available were not sufficient for the pur-
pose. A number of Dasehri fruits were also used.

While still on trees the fruits were enclosed in a gas chamber inside
which a known quantity of SO₂ gas was produced by burning carbon
disulphide and absolute alcohol.

In the year 1938 a fumigation chamber after the pattern designed by
Haywood (1910) for testing effect of sulphur dioxide on young trees was
used (Pl. II, Fig. 1). This fumigation chamber measured 3 ft. × 3 ft. × 4 ft.
consisting of a wooden frame with glass panes on all sides except the top
which was left open. One end of a piece of good rubber sheet was fixed
round the open face, the other end of the rubber remaining free to be
tied round a twig bearing mango fruits. On one side of the chamber a small
window was made which could be closed tightly. But this type of chamber
proved inconvenient and had its limitations for our purposes. By using a
big chamber of this type only one concentration of sulphur dioxide could
be used in one setting and the manipulation took much time. Using the large
fumigation chamber preliminary experiments were made in the mango season of 1938 just to see the effect of sulphur dioxide gas on the fruits.
Systematic and more organised work was done in the summer of 1939 when
the authors designed their own fumigation chamber which could be worked
with more convenience and ease. The latter type of chamber (Pl. II, Fig. 2)
consisted of a small rectangular tin cannister measuring 22 cm. × 14 cm. ×
14 cm. fitted on one side with glass and on another with a window like ar-
rangement with an air-tight lid. The upper face of the tin cannister was kept
open. Round this open face, one side of a good rubber sheet was fixed by
means of a tightly screwed iron strip, the other side of the rubber sheet
remaining free to be tied round a twig bearing fruits (Pl. II, Fig. 2). The
volume of the chamber thus set up measured approximately 9,100 c.c. The
arrangement when set up was completely air-tight. These fumigation chambers
proved very convenient and useful because of their small size and portability.
Moreover on a single day many of these could be utilised using a varied
number of concentrations of sulphur dioxide.

Fumigation with Sulphur Dioxide.—For the production of sulphur dioxide
gas inside the chamber a mixture of carbon disulphide and absolute alcohol
in a given proportion was burnt in a procelain dish or a watch glass
kept inside the chamber through the window. The burning liquid could be
easily watched from outside through the glass panes. The fumes were allowed
to react with the fruits for durations needed; after this period the chambers
were removed. The observations were made at definite intervals after
the fumigation. In order to confirm results, a large number of twigs
bearing fruits were used for testing the effect of a single concentration of
sulphur dioxide.

Effect of burning Absolute Alcohol.—Since absolute alcohol was burnt,
mixed with carbon disulphide in the above experiments, it was thought desir-
able to find out the effect of burning alcohol on the fruits. The same
fumigation chambers were employed and alcohol was burnt in watch
glasses. No visible sign of any damage was noticed on the fruits. These
experiments along with those in which the fruits were merely enclosed in
the fumigation chambers without any thing being burnt inside served as
controls.

Study of the Effect of Sulphur Dioxide on the Internal Tissue of Fruits.—
Hand and microtomed sections of the affected and healthy fruits were cut
to study the effect of the gas on the tissues of the fruits. Epidermal peelings
were also utilised to aid the above study.
III. Fumigation with Sulphur Dioxide

During the mango season of 1938 the large fumigation chamber designed after Haywood was used. In order to see the effect of sulphur dioxide on the fruits, carbon disulphide mixed with absolute alcohol was burnt and it was noticed that the effect of the gas was in the production of brick red spots on the skin of the fruits. The spots increase in size as days pass off after the fumigation and in the cases when a large quantity of carbon disulphide was burnt these spots coalesce presenting a more or less uniformly affected surface of the fruit, leaving almost no characteristic green healthy surface. But this condition of the affected fruit in no way resembles the kind of necrosis termed as black-tip disease of mango.

In the following year (1939 mango season) experiments were performed using the improved type of fumigation chamber described above and employing a wide range of sulphur dioxide concentrations. Each set of concentration was tried three times in order to confirm the results. The results are given in Table I.

<table>
<thead>
<tr>
<th>Volume of CS₂ burnt</th>
<th>Volume of absolute alcohol burnt</th>
<th>Volume of sulphur dioxide produced</th>
<th>Concentration of SO₂/100</th>
<th>Period of fumigation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>0.95</td>
<td>42.0</td>
<td>0.46</td>
<td>30</td>
<td>-</td>
</tr>
<tr>
<td>0.08</td>
<td>0.92</td>
<td>67.2</td>
<td>0.74</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>0.10</td>
<td>0.90</td>
<td>84.0</td>
<td>0.92</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>0.15</td>
<td>0.85</td>
<td>126.0</td>
<td>1.38</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>0.20</td>
<td>0.80</td>
<td>168.0</td>
<td>1.84</td>
<td></td>
<td>+ +</td>
</tr>
<tr>
<td>0.25</td>
<td>0.75</td>
<td>210.0</td>
<td>2.3</td>
<td></td>
<td>+ +</td>
</tr>
<tr>
<td>0.30</td>
<td>0.70</td>
<td>252.0</td>
<td>2.76</td>
<td></td>
<td>+ + +</td>
</tr>
<tr>
<td>0.10</td>
<td>0.90</td>
<td>84.0</td>
<td>0.92</td>
<td>30</td>
<td>-</td>
</tr>
<tr>
<td>0.11</td>
<td>0.89</td>
<td>92.4</td>
<td>1.01</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>0.12</td>
<td>0.88</td>
<td>100.8</td>
<td>1.10</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>0.13</td>
<td>0.87</td>
<td>109.2</td>
<td>1.20</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>0.14</td>
<td>0.86</td>
<td>117.6</td>
<td>1.29</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>0.15</td>
<td>0.85</td>
<td>126.0</td>
<td>1.38</td>
<td></td>
<td>+</td>
</tr>
</tbody>
</table>
It will be seen from the above Table that when mangoes are exposed to 0.92% SO\textsubscript{2} or below this concentration, no spots appear on the surface of the fruits; but at 1.38% SO\textsubscript{2} and upward concentrations the characteristic brick red spots appear.

As it seemed that the effect of sulphur dioxide would depend on the period of exposure, mangoes were subjected to one hour, one and a half hour, eight hours, twenty four hours and for eight continuous days' exposure to varying concentrations of sulphur dioxide. In the last named experiment a fresh supply of SO\textsubscript{2} gas was given every twenty-four hours, after the chamber had been ventilated with fresh air. For obvious reasons the longer the exposure the lesser were the concentrations used. Results of these experiments are given in Table II.

**Table II**

*Table showing effect of Period of Exposure for Varying Concentrations of Sulphur Dioxide on Safeda Mangoes*

<table>
<thead>
<tr>
<th>Volume of CS\textsubscript{2} burnt</th>
<th>Volume of absolute alcohol burnt</th>
<th>Volume of sulphur dioxide produced</th>
<th>Concentration of SO\textsubscript{2}/100</th>
<th>Period of fumigation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05 c.c.</td>
<td>0.95 c.c.</td>
<td>42.0 c.c.</td>
<td>0.46 c.c.</td>
<td>1 Hour</td>
<td>-</td>
</tr>
<tr>
<td>0.06</td>
<td>0.94</td>
<td>50.4</td>
<td>0.55</td>
<td>&quot;</td>
<td>-</td>
</tr>
<tr>
<td>0.07</td>
<td>0.93</td>
<td>58.8</td>
<td>0.64</td>
<td>&quot;</td>
<td>+</td>
</tr>
<tr>
<td>0.08</td>
<td>0.92</td>
<td>67.2</td>
<td>0.74</td>
<td>&quot;</td>
<td>+ +</td>
</tr>
<tr>
<td>0.01</td>
<td>0.99</td>
<td>8.4</td>
<td>0.09</td>
<td>1\textfrac{1}{2} Hours</td>
<td>-</td>
</tr>
<tr>
<td>0.02</td>
<td>0.98</td>
<td>16.8</td>
<td>0.184</td>
<td>&quot;</td>
<td>+</td>
</tr>
<tr>
<td>0.03</td>
<td>0.97</td>
<td>25.2</td>
<td>0.28</td>
<td>&quot;</td>
<td>+</td>
</tr>
<tr>
<td>0.04</td>
<td>0.96</td>
<td>33.6</td>
<td>0.37</td>
<td>&quot;</td>
<td>+</td>
</tr>
<tr>
<td>0.05</td>
<td>0.95</td>
<td>42.0</td>
<td>0.46</td>
<td>&quot;</td>
<td>+</td>
</tr>
<tr>
<td>0.01</td>
<td>0.99</td>
<td>8.4</td>
<td>0.09</td>
<td>8 Hours</td>
<td>-</td>
</tr>
<tr>
<td>0.02</td>
<td>0.98</td>
<td>16.8</td>
<td>0.184</td>
<td>&quot;</td>
<td>+</td>
</tr>
<tr>
<td>0.03</td>
<td>0.97</td>
<td>25.2</td>
<td>0.28</td>
<td>&quot;</td>
<td>+</td>
</tr>
<tr>
<td>0.04</td>
<td>0.96</td>
<td>33.6</td>
<td>0.37</td>
<td>&quot;</td>
<td>+</td>
</tr>
<tr>
<td>0.05</td>
<td>0.95</td>
<td>42.0</td>
<td>0.46</td>
<td>&quot;</td>
<td>+</td>
</tr>
<tr>
<td>0.001</td>
<td>0.099</td>
<td>0.84</td>
<td>0.009</td>
<td>8 Hours</td>
<td>-</td>
</tr>
<tr>
<td>0.002</td>
<td>0.098</td>
<td>1.68</td>
<td>0.018</td>
<td>&quot;</td>
<td>-</td>
</tr>
</tbody>
</table>
It will be seen from the above table that on exposure for one hour no effect on the fruits is produced at 0.46% and 0.55% SO₂ but on one and a half hour's exposure, brick-red spots appear on the fruits. Again at 0.09% SO₂ concentration there is no effect when the fumigation lasts for one
and a half hour but after eight hours' fumigation the effect on the fruits is evident. It will be noticed that at certain concentrations, viz., from 0.009% to 0.082% SO$_2$ the increased period of exposure (varying from 8 hours to eight days) produces no effect. These facts lead to the conclusion that within certain limits of sulphur dioxide concentrations the effect produced on the fruits depends upon the duration of fumigation or vice versa, but at certain low concentrations the time factor has no influence.

Since moisture is always present in the atmosphere the possibility of sulphur dioxide gas combining with water and forming sulphurous acid is not remote. The acid thus produced might have something to do with the necrosis of the fruits. In order to find out if the presence of moisture on the surface of the fruit at the time of fumigation would produce any effect on the mango fruits, experiments were carried in which Safeda mangoes were fumigated in the usual way after the fruits were moistened by dipping into water. The results of fumigation of these fruits are given in Table III.

**Table III**
*Table showing Effect of Various Concentrations of Sulphur Dioxide Gas on Moistened Safeda Mangoes*

<table>
<thead>
<tr>
<th>Volume of CS$_2$ burnt</th>
<th>Volume of absolute alcohol burnt</th>
<th>Volume of sulphur dioxide produced</th>
<th>Concentration of SO$_2$/100</th>
<th>Period of fumigation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>c.c.</td>
<td>c.c.</td>
<td>c.c.</td>
<td>c.c.</td>
<td>Min.</td>
<td>−</td>
</tr>
<tr>
<td>0.10</td>
<td>0.90</td>
<td>84.0</td>
<td>0.92</td>
<td>39</td>
<td>−</td>
</tr>
<tr>
<td>0.11</td>
<td>0.89</td>
<td>92.4</td>
<td>1.01</td>
<td>&quot;</td>
<td>+</td>
</tr>
<tr>
<td>0.12</td>
<td>0.88</td>
<td>100.8</td>
<td>1.10</td>
<td>&quot;</td>
<td>+</td>
</tr>
<tr>
<td>0.13</td>
<td>0.87</td>
<td>109.2</td>
<td>1.23</td>
<td>&quot;</td>
<td>+</td>
</tr>
<tr>
<td>0.14</td>
<td>0.86</td>
<td>117.6</td>
<td>1.29</td>
<td>&quot;</td>
<td>+</td>
</tr>
<tr>
<td>0.15</td>
<td>0.85</td>
<td>126.0</td>
<td>1.35</td>
<td>&quot;</td>
<td>+</td>
</tr>
</tbody>
</table>

It will be seen from the above table and Table I that the brick-red spots appear at 1.01% SO$_2$ concentration whether the fruits are dipped in water or not. The results are the same in the two tables for the corresponding values of sulphur dioxide concentrations. Sulphur dioxide gas, therefore, does not produce any different effect on the fruits in presence of water.

**IV. Effect of the Gas on the Fruit Tissue**

The external symptom of the gas effect is the production of brown to brick-red colouration around the lenticels on the skin of the fruit (Pl. II,
Fig. 3). This effect is not localised to any one region but extends all over the surface of the mango, wherever lenticels occur. When exposed to lower concentrations of sulphur dioxide gas or when the period of fumigation is less, the brick-red colouration remains restricted to the cells in the immediate neighbourhood of the lenticels having the intervening regions healthy green in colour (Pl. II, Fig. 3). In such cases the effect of fumigation, as revealed by the colouration, does not spread beyond the initial area occupied, even when the mangoes are kept under observation for a long period. In cases of fumigation with higher doses of sulphur dioxide gas (2.3% to 9.3% and over) the coloured spots referred to above are of bigger size and as days pass off after fumigation, these affected areas increase in size and coalesce with each other presenting more or less a uniformly affected surface of the fruit, leaving almost no characteristic green healthy portion. But, as pointed out elsewhere, this condition of the affected fruit in no way resembles the kind of necrosis termed as black-tip disease of the mango fruit.

Peelings of the skin of healthy and fumigated fruits were made and compared. These preparations confirmed the results mentioned above and revealed that the gas effect is localised in the beginning around the lenticels, the extent of localisation roughly depending upon the concentration or the period of fumigation of the gas. It was found that the tissue around the lenticels lose the green colour and become light-brown; the extreme periphery of the affected area is conspicuously dark and sharply delimits the latter from the unaffected green portion (Pl. II, Fig. 4). The peelings when examined under the microscope reveal that in the affected area the cells lose chlorophyll, become devoid of starch grains and their walls coloured brown; the cells here and there showing brown deposits. In cases of fumigation with high doses of sulphur dioxide gas all the affected cells show deposits, the latter being more conspicuous and heavier at periphery of the affected areas. Outside the affected region the cells retain chlorophyll and starch grains and remain healthy.

Microtomed and hand sections of healthy and fumigated fruits in various doses of sulphur dioxide gas (1.01%, 1.38%, 1.84%, 2.3%) were cut and studied. It was found that the effect of the gas was most marked just below the lenticels, where the extent of injury is deepest while on the sides it is comparatively less. The affected region thus presents a crescent shape in a section (Pl. III, Figs. 5, 6).

The affected area is more or less sharply marked off from the healthy one by the development of a cambial layer (Pl. III, Figs. 5, 7). The cells between the epidermis and the cambium show injurious effects of the gas;
these become empty, contain few starch grains, their walls coloured brown
and in some a brown substance is deposited, the deposition being heavier
in the epidermal cells and in the cells just outside the cambium (Pl. III, Figs.
6, 7). In fruits fumigated with a low concentration of sulphur dioxide (viz.,
1.01%), the deposits in the affected region are rather inconspicuous and the
starch grains continue to occur in the cells (Pl. III, Fig. 5). It is not usual
to find, particularly on application of high concentration of sulphur dioxide
gas, groups of the affected cells breaking down leaving empty spaces in
that region (Pl. III, Fig. 6).

The formation of the cambium results from the activity of the parenchymatous cells of the mesocarp dividing transversely and adding new cells in
which suberisation takes place (Pl. III, Fig. 6) thus forming a layer of
cells impervious to gaseous effects and consequently preventing the gas injury
from extending further into the deeper tissue of the fruit. The suberisation
is quite inconspicuous or even lacking when fruits are fumigated in low concen-
trations of sulphur dioxide (Pl. III, Fig. 5). The development of the
cambium is evidently in response to the injurious effect of sulphur dioxide
gas (Butler, 1918; Heald, 1937). It is a device of the tissue to protect itself
from the deleterious effect of the penetrating gas. In the case of lower
concentrations, when the diffusion of sulphur dioxide gas in solution with
the sap or water present in the cell or the cell wall is slow, the cambium layer
is formed superficially. When higher concentrations of the gas are applied,
the rate of diffusion is faster and before the activity of cambium formation
starts the gas has penetrated far inside the tissue and the formation of the
cambium takes place in deeper layers of the mesocarp. But whatever be
the concentration of the gas the impervious layer of cells are always formed
in a semicircle (Pl. III, Figs. 5, 6) around the lenticel, indicating that the
gas effect is the most just below the lenticel.

The cells of the mesocarp below the suberised layer remain healthy and
unaffected.

V. Discussion

Ranjan and Jha (1940) have recently shown that as a result of the effect
of a mixture of sulphur dioxide and air (1:1000) the mango fruit becomes
pulpy, the green colour gets bleached to some extent and the epicarp
becomes loose from the mesocarp, the latter becoming pulpy and brownish.
Loose nature of the epidermis was also seen in the control experiments. When
mangoes were treated with 0.1% sulphur dioxide for ten days, no blackening
was observed but the skin turned whitish through bleaching.
From the investigation carried out here on the effect of sulphur dioxide gas on the mango fruit, it has been seen that the injury produced is first exhibited as small brick-red spots round the lenticels on the skin of the fruit, and of the concentrations of sulphur dioxide, the minimum that produces the effect in 30 minutes' fumigation for one hour is $1.01\% \text{SO}_2$ (Table I). In higher concentrations of sulphur dioxide fumigation the coloured spots referred to above are of bigger size and as days pass off after fumigation, these affected areas increase in size and coalesce with each other presenting more or less a uniformly affected surface leaving almost no characteristic green healthy portion. The effect of sulphur dioxide on mango fruit as observed by the authors thus differs entirely from the observation of Ranjan and Jha (1940). The difference must be due to the difference in the experimental conditions. It is to be noted that the experiments by Ranjan and Jha were carried out with gathered mangoes while the authors have experimented with fruits on trees.

The first appearance of injury round the lenticels indicates that sulphur dioxide penetrates through the lenticels of the fruits. The effect of sulphur dioxide on the mango fruit will therefore largely depend upon the number, distribution and character of the lenticels. At present no data is available relating to the lenticels. The investigation on this point is being carried out by one of the authors. It should be realised that at that developmental stage of the fruit when the lenticels are present or when the lenticels found in the fruit are totally blocked for any penetration of the gas, the result will be greatly altered both with regard to the nature of the injury it causes and the relation between the minimum concentration of the gas and the period of fumigation required to produce the effect. The results presented here should therefore be true for a particular stage of maturity of the fruit. In a later communication, when the origin and development of the lenticels have been studied, it will be possible to find out the effect of sulphur dioxide gas at various stages of the development of the mango fruit and correlate with lenticel condition.

In the tissue the symptoms of injury consists in the deposition of light-brown substance in the cells and the colouration of the walls in the tissue below the lenticels. The affected region is always in the form of a semicircle in section, the deepest area lying just below the lenticel. The affected portion is sharply marked off from the healthy region by a cambium developed in response to the injurious effects of the gas. The formation of cambium in response to deleterious gases like sulphur dioxide and the invasion of parasitic fungi are well known (Butler, 1918; Heald, 1937). The region of
the tissue in which cambium layer is formed depends upon the concentration and probably the rate of diffusion of sulphur dioxide gas through the tissue. Smaller amount of sulphur dioxide diffusing along through the tissue will give the reacting cells enough time to produce the cambium in upper layers, whereas in the higher concentrations, the gas diffusing more rapidly, will penetrate deep below before the cambium layer is formed. The cambium cuts off one or more layers of cells in which suberisation takes place, the number of layers of these cells depending upon the concentration. The suberised cells prevent penetration of the gas further inside the fruit.

It will be noted that in our experiments the minimum concentration of sulphur dioxide required to produce the symptoms of injury under the experimental conditions employed is 1.01% a value comparatively high to those obtained by Haywood (1910) and others. All the work known relates to the effect of sulphur dioxide on leaf. Haywood (1910) fumigated pine needles and leaves of cowpeas in the various concentrations of sulphur dioxide, giving various periods of fumigation and found positive results for 1.0, 0.1 and 0.01 percentages of sulphur dioxide gas for one hour repeating the fumigation six times, nine times and fifty times respectively. The result of the present investigation shows that the fruits were affected at 1.01% when fumigated for thirty minutes and once only, and 0.09% when fumigated for eight hours; but no effect was perceived in concentrations lower than 0.09% $SO_2$ even when the duration of fumigation was prolonged for as many as eight days. At certain critical concentration the effect is dependent on the period of fumigation. For example, 0.74% $SO_2$ for half an hour does not produce any effect, when the same concentration was employed for one hour the effect is evident. Similarly 0.46% $SO_2$ for one hour has no effect but the same concentration when employed for one and a half hour produces positive results. Below this critical concentration, the time of exposure seems to have no effect although the period of fumigation was sufficiently long. The fruit then appears to be more tolerant to very low concentrations of sulphur dioxide in comparison with leaves of pine and cowpeas. The results obtained with the leaves are not strictly comparable to those obtained with the fruits. Since it is known that the effect of sulphur dioxide on leaves is determined not only by the presence of stomata but also those factors which affect the opening of the same, such as light, temperature, humidity, etc. In the case of mango fruit the conditions are much different, in which the lenticels wherever they occur are not affected by the factors enumerated above. The authors are now investigating the minimum concentration of sulphur dioxide gas which will affect the leaves of Mangifera indica Linn. for
various periods of fumigation. The investigation will form a subject of later communication.

The deposits which are found in the epidermal and mesocarp cells of the mango fruit with sulphur dioxide gas, however, are externally comparable with those of the first etiolation stages of black-tip disease. It is difficult however to draw any definite conclusions from this superficial resemblance.

**Summary**

1. The black-tip disease of mango fruits is believed to be due to the fumes emanating from brick kilns situated near orchards. This paper deals with the effect of sulphur dioxide gas (one of the components of brick kiln fumes) on mango fruits.

2. The fruits while still on trees, were fumigated inside especially designed chambers with known concentrations of sulphur dioxide gas produced by burning a given amount of carbon disulphide mixed with absolute alcohol for varying periods ranging from 30 minutes to eight days. The effect of the gas on the fruits were noted and studied by making peelings of the skin and cutting sections of the tissue.

3. The first effect is the production of small brick-red coloured areas round the lenticels all over the skin of the fruit. In the affected region the epidermal cells lose chlorophyll, the starch grains become less in the mesocarpic cells, the cell walls are coloured brown and light brown deposits take place in the cell cavities. The effect of the gas on the tissue is the greatest just below the lenticel and comparatively less on the sides, thus in a section the affected region appears in a semicircle. The affected area is marked off from the healthy tissue by the development of a cambium which produces new cells in which suberisation takes place. This suberised layer is evidently developed in response to the injurious effect of the gas and protects the deeper tissue of the fruit from gas injury. At higher concentrations the formation of the cambium takes place at deeper layers of the tissue. Extent of injury appears to be proportional to the concentration and period of fumigation but after a certain minimum value the rule does not hold good.

**Acknowledgment**

The authors wish to express their thanks to the Director of Agriculture, U.P., for allowing the use of the mango orchard in the Government Horticulture Gardens, Lucknow, where the fumigation experiment was carried out.
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EXPLANATION OF FIGURES

PLATE II

Fig. 1. Large fumigation chamber designed after Haywood, enclosing mango twigs bearing fruits.

Fig. 2. Small fumigation chamber designed by the authors, enclosing a mango twig bearing fruits.

Fig. 3. An entire mango fruit showing the first visible effect of sulphur dioxide injury; H, the green healthy colour, S, the affected areas round lenticels.

Fig. 4. A diagrammatic representation of the affected area (S) on a large scale. L, lenticel. A, light brown area on the skin; B, a dark brown border line delimiting the affected area (S) from the unaffected area G1 and G2; G1, light green healthy skin, G2 dark green healthy skin.
PLATE III

FIG. 5. Section through a part of the tissue of a mango fruit fumigated for half an hour in 1·01% SO₂, showing (1) the affected region in a semicircle, the lenticel acting as the centre; (2) the early stage in the development of the cambium. × 115.

FIG. 6. Section through a part of the tissue of mango fruit fumigated with 2·3% SO₂ for half an hour showing (1) heavy deposits in the cells just outside the cambium and in the epidermis; (2) absence of starch grains in the cells of the affected region; (3) the suberisation of the new cells formed due to the activity of the cambium. × 55.

FIG. 7. Section through a part of the tissue of a mango fruit fumigated with 1·01% SO₂ for half an hour showing heavy deposits in the (1) epidermal cells, (2) the cells just outside the cambium. × 168.