BRIEF PAPER

THE PHOSPHORUS-IRON RELATIONSHIP IN GENETICAL CHLOROSIS

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Variegation of leaves is found widely distributed in the genera of the plant kingdom. Many forms are of great intrinsic beauty and are therefore a common feature in estates and gardens. The chlorotic areas usually appear as pale edges of varying width and regularity around and overlying an otherwise apparently normal green leaf, but very often whole leafy branches may appear colourless while others may grow out normally green, indicating that the variegated plant is in fact a chimaera. Some forms of variegation are due to a virus infection as in Abutilon striatum Thompsonii (5). Some types of virus infection cause a marked chlorosis of the leaf; sugar beet yellows being a case of such infection. In the case of June Yellows in Auchineruive Climax strawberry, no virus has so far been identified and this form of chlorosis has been suggested to be due to "genetical breakdown" (10).

Julius Sachs, using his classic method of growing plants in water culture, first demonstrated that plants required iron for chlorophyll formation; the application of an iron salt to the chlorotic leaves restoring the green colour.

Olsen (8) observed that the leaves of chlorotic plants invariably contained more phosphorus than did normal green plants and was of the opinion that iron in chlorotic plants was immobilized as insoluble ferric phosphate.

The discovery that chlorotic leaves often contained more iron than did green leaves tended to obscure Olsen's findings. This condition was often observed in plants growing on highly calcareous soils (17), and this type of chlorosis was accordingly termed "lime-induced." Lindner & Harley (6) were able to show that in lime-induced chlorosis there existed a definite ratio between the calcium and potassium contents of the leaves, healthy green leaves having high ratios while in chlorotic leaves the ratio was invariably low. For purposes of comparison they analysed the white and green leaves of Spiraea as an example of genetical chlorosis but could find no pertinent relation in the constituents of the ash.

De Kock and Strmecki (2), studying the growth-promoting effect of a lignite, obtained results which clearly indicated the existence of a phosphorus-iron ratio effect in mustard, the ratio being higher for chlorotic plants, while very low values indicated chlorosis due to iron toxicity. It has similarly been found that in mustard plants grown at pH 7.8 in the presence of various forms of iron, the trend in phosphorus-iron ratio was maintained, chlorotic plants having consistently higher ratios (1).

From examination of the work of other authors in which the iron and phosphorus contents of green and chlorotic leaves were given (6, 13, 14, 16, 17), it appeared that the same trend in the phosphorus-iron ratio occurred irrespective of the cause of chlorosis. Similarly, symptoms of phosphorus deficiency (3), or phosphorus toxicity (12) were in accordance with the expected phosphorus-iron ratio in each case. An examination of chlorosis due to genetical and virological causes was therefore undertaken to ascertain the trend in phosphorus-iron and calcium-potassium ratios.

Yellow, variegated and green leaves were taken from variegated herbs and shrubs in the gardens of the Macaulay Institute and from various greenhouses. These were washed in distilled water and gently dried with a clean glass cloth. If the leaves were sufficiently culticularised, as in Ilex, they were rubbed clean. They were dried at 80°C for 48 hours and then ashed in a muffle furnace at 460°C overnight. The ash was fused in "Analar" sodium carbonate in a platinum crucible and dissolved in redistilled hydrochloric acid. Iron was determined colorimetrically by aa' dipyrindyl and phosphorus by developing the phosphomolybdate blue complex with hydrazine. Calcium and potassium were determined by flame photometer (7).

The leaves analysed were taken from Abutilon striatum Thompsonii; Bougainvillea glabra variegata; Pelargonium Zonale var. Flower of Spring; P. zonale var. Rob Roy; Ilex aquifolium (4 variegated varieties) Spiraea japonica var. Anthony Waterer; Sambucus nigra variegata.

Table I gives the results of analyses for phosphorus, iron, calcium and potassium contents of the above leaves, together with the calculated phosphorus-iron and calcium-potassium ratios. It is clear that the value of phosphorus-iron ratio follows the degree of chlorosis observed, yellow leaves having the highest, variegated leaves intermediate and green leaves the lowest values. The calculated calcium-potassium ratios also show a definite correlation with the degree of chlorosis, being low for chlorotic leaves and high for green leaves.

The phosphorus-iron ratios for yellow and green leaves of Spiraea given by Lindner and Harley (6) do not substantiate those quoted here, the iron values for the chlorotic leaves being high. The calcium-potassium ratios do, however, agree with those here, as the authors themselves point out. Values for the iron content of yellow and green leaves of a variegated variety of pineapple (Ananas comosus) given by Sideris, Young and Krauss (13) are in line with the figures in Table I.

Healthy and chlorotic leaves of the strawberry var. Auchineruive Climax affected with June Yel-

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1 Received November 30, 1954.
Table I

Analysis of the Ash of Leaves of Variegated Plants

<table>
<thead>
<tr>
<th>Plants</th>
<th>% P</th>
<th>% Fe</th>
<th>P/Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G* V* Y*</td>
<td>G V Y</td>
<td></td>
</tr>
<tr>
<td>Bougainvillea glabra</td>
<td>3.17 3.75 6.23</td>
<td>0.22 0.171 0.227</td>
<td>14.45 21.9 27.4</td>
</tr>
<tr>
<td>Sambucus nigra</td>
<td>2.84 3.97 4.05</td>
<td>0.092 0.054 0.050</td>
<td>30.9 73.5 81.0</td>
</tr>
<tr>
<td>Ilex aquifolium, Spiny Silver</td>
<td>2.68 3.36 3.74</td>
<td>0.084 0.050 0.049</td>
<td>34.4 80.0 91.0</td>
</tr>
<tr>
<td>Abutilon striatum Thompsonii</td>
<td>3.16 4.83 6.06</td>
<td>0.195 0.225 0.240</td>
<td>16.2 21.5 25.3</td>
</tr>
<tr>
<td>Spiraea japonica</td>
<td>2.37 3.74 2.23</td>
<td>0.102 0.107 0.129</td>
<td>20.6 40.2 45.0</td>
</tr>
<tr>
<td>Pelargonium zonale, Granite City</td>
<td>2.1 4.3 5.8</td>
<td>0.098 0.074 0.082</td>
<td>12.3 30.0 31.4</td>
</tr>
</tbody>
</table>

Plants

<table>
<thead>
<tr>
<th>Plants</th>
<th>% Ca Y</th>
<th>% K Y</th>
<th>Ca/K</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>G V Y</td>
<td>G V Y</td>
<td></td>
</tr>
<tr>
<td>Bougainvillea glabra</td>
<td>48.2 9.6</td>
<td>14.2 26.8</td>
<td>3.4 0.36</td>
</tr>
<tr>
<td>Sambucus nigra</td>
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<td>25.7 25.8 30.0</td>
<td>0.29 0.15 0.04</td>
</tr>
<tr>
<td>Ilex aquifolium, Spiny Silver</td>
<td>14.6 3.8</td>
<td>14.9 20.7</td>
<td>0.98 0.13 0.29</td>
</tr>
<tr>
<td>Abutilon striatum Thompsonii</td>
<td>16.4 11.8 7.3</td>
<td>12.9 20.7 25.6</td>
<td>1.27 0.57 0.29</td>
</tr>
<tr>
<td>Pelargonium zonale, Granite City</td>
<td>14.3 6.0</td>
<td>17.9 27.2</td>
<td>0.80 0.22 0.29</td>
</tr>
<tr>
<td>Spiraea japonica, Anthony Waterer</td>
<td>23.6 5.4</td>
<td>14.1 20.5</td>
<td>1.7 0.26 0.29</td>
</tr>
<tr>
<td>Abutilon striatum Thompsonii</td>
<td>17.2 13.6 2.3</td>
<td>15.5 18.3</td>
<td>1.1 0.74 0.45</td>
</tr>
</tbody>
</table>

* G = green; V = variegated; Y = yellow.

The ratio of phosphorus to iron and of calcium to potassium of chlorotic leaves of variegated plants show the same trends from those of normal leaves as is shown by other forms of chlorosis, the phosphorus-
iron ratio being higher, and the calcium-potassium ratio being lower than for normal green leaves. This also applies to chlorosis due to virological or pathological causes.

The writers wish to express their appreciation to Dr. R. L. Mitchell for the flame photometric results of calcium and potassium and assistance with the manuscript.

LITERATURE CITED


NEWS AND NOTES

GEORGE JAMES PEIRCE

George James Peirce died on October 15, 1954, aged 86. With him, American plant physiology lost one of its last remaining links with the great German tradition which so influenced its development in the first part of the twentieth century.

Peirce was born of American parents in Manila in 1867, attended the Lawrence Scientific School at Harvard from which he graduated in 1890. He was then awarded one of the first American travelling stipends, the Parker Fellowship of Harvard. His Wanderjahre included a year each in Bonn and Munich, where he studied, like so many other American botanists, with Strasserburger and Goebel. Then he moved to the great laboratory where Pfeffer was shaping the form and future of the new science of Plant Physiology. Peirce won his Ph.D. summa cum laude at Leipzig in 1894, his thesis being on the physiology of the parasitic flowering plant, Cuscuta, the dodder.

Returning to America, Peirce again spent a year at Cambridge, applied for the position at Smith Col- legé which was won by Ganong, and in 1895 went to Indiana University, in the then small and rather southern town of Bloomington. Indiana had just before this supplied David Starr Jordan, Douglas Houghton Campbell, and several other faculty members to the new university which Leland Stanford had endowed on his Palo Alto Ranch in California. It was not surprising, therefore, that, as botany grew at Stanford, Peirce should join Campbell. He became instructor in 1897, assistant professor in 1900, and remained in the department for all his career, taking over much administrative responsibility long before he became chairman in 1925. He retired in 1933.

The key to Peirce's research and teaching was in his title: Professor of Botany and Plant Physiology, which he always preferred to retain. While leaving to colleagues the exactitudes of taxonomy, he loved plants as such, especially out-of-doors, and he was more concerned with their relations to environment, their means of survival and response, and the correlation of structure and function, then he was with biochemistry, or the physical chemistry of protoplasm. It was the categories of Pfeffer's physiology which he taught, and incorporated in his own "Textbook of