CHAPTER IX

A STUDY OF THE EFFECT OF TRACE ELEMENTS ON THE GROWTH AND YIELD OF AMERICAN COTTONS

(a) General

The problem of the role of trace elements in plant nutrition has assumed great importance during the last 25 years and a great deal of literature has accumulated on the subject. This literature is summarised by Stiles (1946) in his small book on the effect of minor elements in plants and animals and a comprehensive bibliography has been compiled on this subject by Chilean Nitrate Educational Bureau (1948). The deficiency of any one of the trace elements like boron, copper, zinc, manganese, molybdenum etc., has resulted in the development of certain pathological symptoms in different crops. The cotton crop has been no exception as the crinkled leaf of cotton reported from Louisiana (Neal, E.S. and Lovett, H.G., 1938) has now been found to be caused by manganese toxicity on account of relative deficiency of calcium. Similarly, the sand drown disease of cotton in South Carolina (Cooper, H.P. 1931) has been attributed to the deficiency of magnesium. Except for these two cases no deficiency disease caused by a deficiency of trace elements is reported in the case of the cotton crop.

The availability of trace elements is known to be low under the alkaline conditions. The black cotton soils in the Malwa tract are known to be alkaline in reaction, the pH
of the soil being in the neighbourhood of 8.5 to 9.0. It was, therefore, considered necessary to undertake a study of the applications of various trace elements on the growth and yield of the American cottons under Malwa conditions. A similar study was undertaken by Dastur (1936) under irrigated conditions in the Punjab where the sandy loam soils were also alkaline in reaction but no effect of the application of any trace elements was visible in the different characters of the American cotton plant in that tract.

As the American cotton plant in Malwa tract is known to show reddening of leaves at the time of fruiting, it would also be interesting to study the effect of applications of different minor elements on the onset and the intensity of leaf reddening.

**Investigation**

The method of artificial or pot culture generally employed in these investigations was not used in this investigation as the results obtained with pot culture may not find applicability under field conditions. The main idea was to determine whether artificial additions of trace elements to the soil will increase their uptake by the crop and would result in better growth or yield.

**(b) Permanent mineral experiment.**

An experiment was arranged in the cotton season of 1947-48 to study the effect of applications of molybdenum,
boron, copper, magnesium, iron, manganese, zinc and chromium on the American Upland cotton (Ibore I). There were thus nine treatments including control. The layout was six randomised blocks of 9 plots each. The plot size was 7½' x 33'. (Though magnesium cannot be considered a trace element it was included in the investigation to study its effect on leaf reddening). The same experiment was repeated in 1948-49 and 1949-50 and half the quantity added in 1947-48 was added to the respective plots (Table XL) in the next two seasons. In 1950-51 and 1951-52 cotton seasons no fresh applications of these elements were made to see if there was any residual effect of these previous applications on the cotton yield in the succeeding seasons. This was important for the study of the economics of such applications as will be shown later.

The following Table XL gives the quantity of each element added in each year of the permanent experiment.

Table XL

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>nil</td>
<td>nil</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>14</td>
<td>7</td>
<td>7</td>
<td>nil</td>
</tr>
<tr>
<td>Boron</td>
<td>17</td>
<td>8½</td>
<td>8½</td>
<td>nil</td>
</tr>
<tr>
<td>Copper</td>
<td>25</td>
<td>12½</td>
<td>12½</td>
<td>nil</td>
</tr>
<tr>
<td>Magnesium</td>
<td>20</td>
<td>10</td>
<td>10</td>
<td>nil</td>
</tr>
<tr>
<td>Iron</td>
<td>25</td>
<td>12½</td>
<td>12½</td>
<td>nil</td>
</tr>
<tr>
<td>Manganese</td>
<td>15</td>
<td>7½</td>
<td>7½</td>
<td>nil</td>
</tr>
<tr>
<td>Zinc</td>
<td>20</td>
<td>10</td>
<td>10</td>
<td>nil</td>
</tr>
<tr>
<td>Chromium</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>nil</td>
</tr>
</tbody>
</table>

Sowing dates: 6th July 21st June 4th July 10th July
The salts of these elements after powdering and mixing with earth were spread uniformly by hand broadcast in the respective plots and thoroughly mixed with the soil by means of hand daura. As the crop was sown with rains, the sowing date differed in different years.

The crop was under observation all throughout the season in all these years and three observations were made on the crop in these four years. (1) The leaves of the plants in all the replicates of molybdenum plots turned turmeric in colour even from the seedling stage. The colour generally disappeared after heavy rains but reappeared later. (2) The leaves of plants in manganese, zinc and chromium plots were definitely greener in colour than the leaves of plants in the remaining plots. (3) The leaf reddening occurred under all treatments at the normal time. (4) The crop was definitely early in zinc, manganese and molybdenum plots as compared with the control and trace element treated plots.

Measurement of growth characters

The final height per plant, the internode number and the dry weight per plant were recorded for 10 randomized plants in each subplot of all the replicates for the years 1948-49, 1949-50, 1950-51. A study of these data showed no effect of any one of the trace elements on any growth character. As no statistically significant effect of any treatment was noticeable the results are not given here.
Similarly, the determinations of total number of bolls per plant and of weight of seed cotton per boll were also made on randomized plants in each subplot for all the four years. There was a significant increase in boll number in zinc and chromium plots in three seasons out of four and in manganese plots in 1950-51 season. In 1947-48 season, the increase in boll number in manganese plots was not on the verge of significance. Similarly boron, copper, magnesium and iron plots showed an increase in boll number per plant but these increases did not reach the level of significance.

Table XLII

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control</strong></td>
<td>2.20</td>
<td>2.10</td>
<td>1.64</td>
<td>0.98</td>
<td>2.56</td>
<td>2.14</td>
<td>1.93</td>
<td>1.75</td>
</tr>
<tr>
<td><strong>Molybdenum</strong></td>
<td>2.22</td>
<td>2.03</td>
<td>1.81</td>
<td>0.99</td>
<td>2.47</td>
<td>2.23</td>
<td>1.93</td>
<td>1.75</td>
</tr>
<tr>
<td><strong>Boron</strong></td>
<td>2.44</td>
<td>2.48</td>
<td>1.81</td>
<td>1.14</td>
<td>2.62</td>
<td>2.13</td>
<td>2.10</td>
<td>1.83</td>
</tr>
<tr>
<td><strong>Copper</strong></td>
<td>2.36</td>
<td>2.24</td>
<td>1.35</td>
<td>1.10</td>
<td>2.53</td>
<td>2.10</td>
<td>2.04</td>
<td>1.86</td>
</tr>
<tr>
<td><strong>Magnesium</strong></td>
<td>2.35</td>
<td>2.16</td>
<td>1.82</td>
<td>1.12</td>
<td>2.64</td>
<td>2.16</td>
<td>1.96</td>
<td>1.76</td>
</tr>
<tr>
<td><strong>Iron</strong></td>
<td>2.33</td>
<td>2.14</td>
<td>1.84</td>
<td>1.06</td>
<td>2.56</td>
<td>2.26</td>
<td>2.06</td>
<td>1.86</td>
</tr>
<tr>
<td><strong>Manganese</strong></td>
<td>2.59</td>
<td>2.27</td>
<td>1.88</td>
<td>1.47*</td>
<td>2.65</td>
<td>2.11</td>
<td>2.02</td>
<td>1.88</td>
</tr>
<tr>
<td><strong>Zinc</strong></td>
<td>2.66*</td>
<td>2.55*</td>
<td>2.06</td>
<td>1.22*</td>
<td>2.66</td>
<td>2.22</td>
<td>2.07</td>
<td>1.84</td>
</tr>
<tr>
<td><strong>Chromium</strong></td>
<td>2.63*</td>
<td>2.52*</td>
<td>1.95</td>
<td>1.42*</td>
<td>2.53</td>
<td>2.23</td>
<td>2.21*</td>
<td>1.90</td>
</tr>
</tbody>
</table>

There was some effect of trace elements on boll weight but this was not consistent from year to year. The effect on boll weight was significant only in the case of chromium 1948-49.

When the yields were determined it was found that almost all the trace elements had increased the yield per acre and
statistical analysis of the yield data revealed the effect on yield was significant in some cases. The yield per acre under each treatment and the percentage increases in yield are given in Table XLIII for all the four years.

Table XLIII

<table>
<thead>
<tr>
<th></th>
<th>Yield in maunds per acre</th>
<th>Percentage increase in yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>5.64</td>
<td>6.03</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>5.63</td>
<td>6.31</td>
</tr>
<tr>
<td>Boron</td>
<td>6.09</td>
<td>6.88*</td>
</tr>
<tr>
<td>Copper</td>
<td>6.38</td>
<td>6.83</td>
</tr>
<tr>
<td>Magnesium</td>
<td>6.39</td>
<td>6.53</td>
</tr>
<tr>
<td>Iron</td>
<td>6.47</td>
<td>6.30</td>
</tr>
<tr>
<td>Manganese</td>
<td>6.51*</td>
<td>6.52</td>
</tr>
<tr>
<td>Zinc</td>
<td>6.83**</td>
<td>7.08*</td>
</tr>
<tr>
<td>Chromium</td>
<td>7.12**</td>
<td>7.49**</td>
</tr>
</tbody>
</table>

In 1947-48 the application of chromium, zinc and manganese was found to increase the yield significantly while the increases due to boron, copper, magnesium and iron were not significant. In 1948-49 chromium and zinc again gave significant increases in yield while the increases due to manganese did not reach the level of significance. In addition, boron gave a significant increase in yield.

There was an increase in yield due to molybdenum but it was small and not significant. There was also an increase in yield, though not significant due to copper, magnesium and iron. In 1949-50 the five elements chromium, zinc, manganese, boron and copper gave significant increases in yield while the increases due to all the remaining elements were small...
and not significant. In the fourth year of 1950-51 trace elements were not added at all to study the residual effect of these elements on yield. A study of the results for that year would show a great fall in the general level of yield which have fallen to about three maunds per acre. This was partly caused by the delay in sowing in account of late break of the monsoon. There was also a partial failure of late rains which may be responsible for the lowering of the level of yield. The fall in the general level of the yield may also be due to cotton being grown in the same field for four consecutive years. This is evident from the level of the yield in 1949-50. On account of this fall in the level of the yield it is probable that the effect of trace elements on yield in 1950-51 was small and non-significant. It is also possible that the residual effect of these applications was smaller. The effects due to manganese and chromium were significant in that year while the increases in yield due to chromium was on the verge of significance. Zinc and boron did not give significant increases in yield. In spite of a great fall in the level of the yield there was some effect noticeable in yields of these trace element applications and this is clear from the percentage increases in yield for each year given in the Table.

The percentage increase in yield was highest in the case of chromium. The next best were zinc and manganese. There was about 15 percent increase in yield on an average due to copper and boron. The results for 1950-51 did not reveal
marked fall in the percentage increase in yield due to these five trace elements except in the case of chromium. This element is added in the least quantity of 2 lbs. per acre and it is possible the residual effect may be small and may decrease from year to year.

Molybdenum plots showed an increasing effect on yield from 1948 to 1950 as can be seen from the percentage increases in yield. There was a small percentage increase in yield due to iron and manganese but in no year these increases reached the level of significance.

The most promising elements from the economic point of view are boron and copper on account of their low cost and their availability in commercial form.

It is stated above that the crop was early in zinc and manganese and molybdenum plots. The percentages of the yield at first picking to total yield under all treatments are given in Table XLIV.

Table XLIV

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>47.7</td>
<td>42.8</td>
<td>44.3</td>
<td>38.4</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>49.3</td>
<td>52.8*</td>
<td>43.7*</td>
<td>42.6</td>
</tr>
<tr>
<td>Boron</td>
<td>43.8</td>
<td>46.8</td>
<td>43.9*</td>
<td>44.5</td>
</tr>
<tr>
<td>Copper</td>
<td>43.9</td>
<td>46.8*</td>
<td>48.1</td>
<td>41.7</td>
</tr>
<tr>
<td>Magnesium</td>
<td>46.4</td>
<td>42.8</td>
<td>43.5</td>
<td>39.2</td>
</tr>
<tr>
<td>Iron</td>
<td>47.4</td>
<td>45.1</td>
<td>44.3</td>
<td>39.4</td>
</tr>
<tr>
<td>Manganese</td>
<td>48.5</td>
<td>48.2*</td>
<td>44.9</td>
<td>44.2*</td>
</tr>
<tr>
<td>Zinc</td>
<td>49.3</td>
<td>47.6*</td>
<td>52.2*</td>
<td>45.1*</td>
</tr>
<tr>
<td>Chromium</td>
<td>46.2</td>
<td>44.1</td>
<td>45.8</td>
<td>40.2</td>
</tr>
<tr>
<td><strong>S.E.</strong></td>
<td><strong>1.89</strong></td>
<td><strong>2.01</strong></td>
<td><strong>1.87</strong></td>
<td><strong>2.13</strong></td>
</tr>
</tbody>
</table>

The crop was significantly early in zinc plots in three seasons out of four while it was significantly early in molybdenum and manganese plots in two seasons out of four. The copper...
(c) The effect of different doses of each element.

The dose of each trace element above was chosen arbitrarily in the absence of any previous information on the subject so the effect of two different doses of each of the five trace elements chromium, zinc, manganese, copper and boron which gave significant increases in yield even in any one year of experimentation was studied in a separate experiment which was laid out in 1949-50 and continued in 1950-51. The trace elements were added in 1949-50 only and the dose of each element is given below in the Table XLV.

This experiment would also provide information on the effect produced by these five elements in another field where the soil conditions especially the soil reaction may be slightly different.

The following Table gives the yields obtained along with percentage increases in yield.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Dose of each element in lbs. p. a.</th>
<th>Yield in maunds p. a.</th>
<th>% increase in yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>12</td>
<td>5.28</td>
<td>1.90</td>
</tr>
<tr>
<td>Copper I</td>
<td>18</td>
<td>6.61</td>
<td>2.21</td>
</tr>
<tr>
<td>Copper II</td>
<td>36</td>
<td>6.35*</td>
<td>2.10</td>
</tr>
<tr>
<td>Boron I</td>
<td>5</td>
<td>6.76</td>
<td>2.22</td>
</tr>
<tr>
<td>Boron II</td>
<td>10</td>
<td>6.53</td>
<td>2.59</td>
</tr>
<tr>
<td>Manganese I</td>
<td>20</td>
<td>6.78</td>
<td>2.09</td>
</tr>
<tr>
<td>Manganese II</td>
<td>40</td>
<td>6.98</td>
<td>1.94</td>
</tr>
<tr>
<td>Zinc I</td>
<td>15</td>
<td>6.63</td>
<td>2.19</td>
</tr>
<tr>
<td>Zinc II</td>
<td>30</td>
<td>6.42</td>
<td>2.01</td>
</tr>
<tr>
<td>Chromium I</td>
<td>2</td>
<td>5.72</td>
<td>2.13</td>
</tr>
<tr>
<td>Chromium II</td>
<td>5</td>
<td>6.82</td>
<td>2.24</td>
</tr>
</tbody>
</table>

S.E.  0.29  0.168
As in the previous experiment the yields per acre were low in 1950-51 season. In 1949-50, a double dose of copper and chromium gave significant increases in yield while the increases due to single dose of boron, zinc, manganese and chromium were on the verge of significance. In the succeeding year in the same field the increase due to double dose of boron (10 lbs. p.a.) gave highly significant increase in yield while the increase in yield produced by a single dose of copper, boron and zinc and by a double dose of chromium just fall short of significance. So the double dose of 5 lbs of chromium and 10 lbs of boron proved optimum while in the case of copper, manganese and zinc single dose proved as good or better than the double dose. Thus 10 lbs. of boron or 18 lbs. of copper per acre would probably prove suitable dose for Mulwa conditions if the residual effect of these applications persists for three years. These two elements have given consistent increases in yield in the two experiments.

(d) The effect of different combinations of trace elements.

It was necessary to determine indirectly whether the effect of each of the five trace elements was, from physiological point of view, specific or all the trace elements produced the same effect on the plant metabolism.

An experiment was, therefore, laid out to determine the effect of combinations of two elements in comparison to a single trace element application. From the results of
yields obtained no conclusion could, however, be drawn and
the results are, therefore, not discussed here.

(a) The study of the residual effect of
trace elements on cotton yields.

In order to determine the residual effect of these
trace elements on the yield of cotton an experiment was laid
out in 1947-48. The same dose of each element
that was applied to cotton in 1947-48 was
added to the respective plots of the experiment which consisted
of three randomized blocks of nine plots each in which the
same nine treatments were randomized. Wheat was sown in
November 1947 and the cotton was planted in the Khurif of
1948-49. The yields obtained in the experiment are given
below in Table XLVI.

Table XLVI
Yield in pounds per acre
Block size = 64 x 40'; Plot size = 6' x 40'

| Dose of each | Yield of seed. |
| treatment in | cotton in lbs. per acre |
| lbs. per acre | per acre |
| Control | ** | 5.51 |
| Molybdenum | 14 | 5.57 |
| Boron | 20 | 6.52 |
| Copper | 24 | 7.35** |
| Magnesium | 40 | 6.00 |
| Iron | 30 | 6.46 |
| Manganese | 15 | 6.39 |
| Zinc | 20 | 6.42 |
| Chromium | 2 | 6.49 |

S.S. 1.0.307
In this case copper alone had significantly increased the yields while the increases due to boron, manganese, zinc, iron and chromium were not significant.

(f) The effect of application of small doses of trace elements on cotton yield.

(1st year of experiment)

A second trial to verify the results obtained with the use of these five trace elements was conducted in another field. It was a randomized block design with five replications of each treatment. The amounts of the elements added and yields obtained are given below in Table XLVII. Only five trace elements are included in this study.

Table XLVII

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Element in lbs. per acre</th>
<th>Yield in bds. per acre</th>
<th>% increase in yield over control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td>6.16</td>
<td></td>
</tr>
<tr>
<td>Boron</td>
<td>10</td>
<td>6.88</td>
<td>11.7</td>
</tr>
<tr>
<td>Copper</td>
<td>20</td>
<td>6.74</td>
<td>10.2</td>
</tr>
<tr>
<td>Manganese</td>
<td>20</td>
<td>7.14</td>
<td>15.9</td>
</tr>
<tr>
<td>Zinc</td>
<td>20</td>
<td>6.70</td>
<td>8.8</td>
</tr>
<tr>
<td>Chromium</td>
<td>2</td>
<td>6.28</td>
<td>1.9</td>
</tr>
</tbody>
</table>

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The doses of the trace elements were considerably reduced than in the previous experiments copper, boron and manganese gave an increase in yield averaging from 10 to 15 percent of the normal, while the increases due to zinc and chromium were very small and negligible.
It is clear from the Table jolt that if these elements are to be applied every season, their use on a field scale be very uneconomical. It was, therefore, necessary to examine the economics of such applications. These figures for the five elements were worked out giving the cost of chemical applied per year as an average of three years, the average increase in yield obtained and the profit and loss incurred on account of these applications.

Table XLVIII
The economics of trace element applications

<table>
<thead>
<tr>
<th>Element</th>
<th>Quantity added per year in lbs.</th>
<th>Total cost of chemical per acre (3 years' average) in Rs.</th>
<th>Average increase value of chemical in yield in Rs. per year</th>
<th>Average increase loss in Rs. per year</th>
<th>Profit or loss in Rs. per acre 0.30/-</th>
<th>Profit or loss in Rs. per acre 0.44/-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium</td>
<td>2.0</td>
<td>55</td>
<td>1.46</td>
<td>44</td>
<td>-21</td>
<td>-21</td>
</tr>
<tr>
<td>Zinc</td>
<td>13.3</td>
<td>53</td>
<td>1.00</td>
<td>30</td>
<td>-23</td>
<td>-23</td>
</tr>
<tr>
<td>Manganese</td>
<td>10.0</td>
<td>101</td>
<td>0.72</td>
<td>22</td>
<td>-79</td>
<td>-79</td>
</tr>
<tr>
<td>Copper</td>
<td>13.0</td>
<td>32</td>
<td>0.77</td>
<td>23</td>
<td>-9</td>
<td>-9</td>
</tr>
<tr>
<td>Boron</td>
<td>11.3</td>
<td>37</td>
<td>0.78</td>
<td>23</td>
<td>-14</td>
<td>-14</td>
</tr>
</tbody>
</table>

It is clear from the Table XLVIII that if these elements are to be applied every season their use on a field scale would be very uneconomical. It was, therefore, considered that if the effect of one application could last for three or more seasons, the application of these elements would certainly be economical and the yield of cotton would be increased by 10 to 25 percent of the normal every year. Out of the five elements copper, boron, zinc and chromium would be the most suitable as the figures given in the above Table would show.
The price of manganese sulphate is prohibitive and it would have to be left out of consideration. Copper and boron are the cheapest chemicals and their use may prove very economical. They are also available in a commercial form while that is not the case with chromium. The last trace element is to be used in very small amount and it would also prove difficult for a cultivator to apply uniformly such a small quantity.

(h) Practical application of the results.

It appears from the results that applications of 18 lbs. of copper which will be equivalent to 75 lbs. of copper sulphate and 10 lbs. of boron equivalent to 88 lbs. of borax may ultimately prove economical. It may not be necessary to apply these elements every year and the effect of one application may last for several seasons. The price of copper sulphate is 8 annas a pound while that of borax is about 7 annas a pound. Thus the cost of one application of any one of the two elements would be about 8.38/- per acre. This cost can be more than recovered in two years, depending on the seasonal conditions.

It is also possible that other crops in rotation with cotton may be benefited by these applications.

(i) The effect of trace elements on the rate of oxidation of organic matter of the soil.

Observations on the crop indicated the greater availability of nitrogen. It was, therefore, surmised that the
application of these elements increased the rate of oxidation of organic matter of the soil and make more nitrogen available to the crop. An attempt was, therefore, made to determine this point by measuring the oxidation-reduction potential of the soil.

Soil samples up to a depth of six inches were, therefore, collected at the end of the season from all the 54 plots of the field where the trace element experiment was conducted and the soil samples were sent to the chemical laboratory of the physiological section for the determination of oxidation-reduction potential by the indicator method as electrometric apparatus was not available. The following Table MLIX gives the percentage values of the ratios of the soil solution to the standard for the control and treated plots from which it was apparent that generally there was no constant and consistent difference between the control and treated soils.

<table>
<thead>
<tr>
<th>Table MLIX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Percentage ratio of the soil solution to the standard</strong></td>
</tr>
<tr>
<td>Replicate nos.</td>
</tr>
<tr>
<td>Control</td>
</tr>
<tr>
<td>Molybdenum</td>
</tr>
<tr>
<td>Boron</td>
</tr>
<tr>
<td>Copper</td>
</tr>
<tr>
<td>Magnesium</td>
</tr>
<tr>
<td>Iron</td>
</tr>
<tr>
<td>Manganese</td>
</tr>
<tr>
<td>Zinc</td>
</tr>
<tr>
<td>Chromium</td>
</tr>
</tbody>
</table>

This indicates that there was no change in the oxidation and reduction potential of the soils treated with trace elements.
or if there was any change, it was not possible to measure it by the
method adopted.

(j) The effect of applications of trace
elements on the uptake of nitrogen.

It was pointed out that the plants in zinc, manganese
and chromium plots were greener in appearance than the plants
in control plots and the crop in zinc and manganese plots was
earlier than in the control plots. The appearance of green
colour and earliness were also found to be the features of
crops in plots which were treated with ammonium sulphate.

It was, therefore, undertaken to have the nitrogen contents
of the leaves determined before the fruiting stage to study
if there was greater availability of that nutrient as a result
of trace element application.

The nitrogen contents of the leaves of plants collected
in October from the six replicates are given below in Table I.

Table I

Percentage nitrogen content of the leaves of
control and plants treated with Zn, Mn,
Cr in 1950.

<table>
<thead>
<tr>
<th>Replicate</th>
<th>Control</th>
<th>Mn</th>
<th>Cr</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>2.69</td>
<td>2.70</td>
<td>2.63</td>
</tr>
<tr>
<td>II</td>
<td>2.77</td>
<td>2.87</td>
<td>2.88</td>
</tr>
<tr>
<td>III</td>
<td>2.69</td>
<td>2.60</td>
<td>2.64</td>
</tr>
<tr>
<td>IV</td>
<td>2.64</td>
<td>2.96</td>
<td>2.72</td>
</tr>
<tr>
<td>V</td>
<td>2.55</td>
<td>2.58</td>
<td>2.48</td>
</tr>
<tr>
<td>VI</td>
<td>2.77</td>
<td>2.67</td>
<td>2.64</td>
</tr>
<tr>
<td>Mean</td>
<td>2.702</td>
<td>2.781</td>
<td>2.682</td>
</tr>
<tr>
<td>SE</td>
<td>0.0617</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The differences between treatments were not significant and there was no indication of an increase in the nitrogen content of the leaves as a result of any one of these trace elements.

(k) The effect of application of trace elements on their absorption by the plant.

It was necessary to see if the plants absorbed more of these trace elements as a result of their application to the soil. The leaves of plants from zinc and copper plots were analysed for zinc and copper along with the leaves of control plots for the same two elements. The results of zinc and copper concentration in the leaves of plant from control, zinc and copper plots are given in Table LI.

Table LI
Percentage of zinc and copper at the time of fruiting in the leaves of control plants and of plants treated with zinc and copper

<table>
<thead>
<tr>
<th></th>
<th>(a) percentage of zinc in leaves in gms.</th>
<th>(b) Percentage of copper in leaves in gms.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Zn treated</td>
<td>Cu treated</td>
</tr>
<tr>
<td>I</td>
<td>0.0039</td>
<td>0.0042</td>
</tr>
<tr>
<td>II</td>
<td>0.0036</td>
<td>0.0042</td>
</tr>
<tr>
<td>III</td>
<td>0.0042</td>
<td>0.0039</td>
</tr>
<tr>
<td>IV</td>
<td>0.0042</td>
<td>0.0043</td>
</tr>
<tr>
<td>Mean</td>
<td>0.0039</td>
<td>0.0042</td>
</tr>
<tr>
<td>S.E.</td>
<td>±0.001</td>
<td>±0.001</td>
</tr>
</tbody>
</table>

It will be seen that there is a small increase in
concentration of copper and zinc in the leaves of plants treated with these trace elements. The increase though small is statistically significant. It is possible that these elements play some part in the enzymic activity of the leaves and when they are absorbed in slightly larger amounts, they increase the metabolic activity of the plant.