Investigations on sugarcane chlorosis in Uttar Pradesh

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II. INFLUENCE OF IRON CHLOROSIS ON GROWTH, YIELD AND JUICE QUALITY

INTRODUCTION

IRON is an indispensible element for green plants. It is required in very small amounts but plays an important role in the synthesis of chlorophyll—the green pigment of leaves. Jacobson and Oertli (1956) claimed that a deficiency of iron progressivley impairs the chlorophyll producing mechanism till the point is reached when chlorophyll synthesis is limited not by the amount of iron but by the inability of leaf to produce it. Therefore, a good correlation was found between iron and chlorophyll under a continuous supply of iron but no relationship was observed under its intermittent supply. Almost similar results were obtained by Sideris and Young (1956) who claimed that following iron difficiency, the iron content had no correlation with chlorophyll content.

Carell and Price (1965) claimed that the rate of chlorophyll synthesis in *Euglena gracilis* was a linear function of the total iron content of the cell and during that part of growth curve, when its rate remained normal, the iron required for chlorophyll synthesis was about 1 microgram per mg. of protein nitrogen. When its content declined below this level, massive derangement occurred in the chloroplasts. As cell growth continues at this stage and the volume of the cell in which iron is required for distribution goes up, its concentration declines in cellular structures especially in the chloroplasts and the activity of the cell is reduced. This reduction in activity progressively impairs growth until it stops completely. Tomar *et al* (1965) observed marked reduction in sugarcane growth due to iron chlorosis during the tillering phase of the crop in Rajasthan.

As sugarcane chlorosis due to iron deficiency under field conditions had been seen for the first time in Uttar Pradesh, detailed observations on its effect on growth, yield and juice quality were made to determine the precise nature and extent of damage.

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MATERIAL AND METHODS

Investigations were undertaken in the field of Sri Lal Krishnakant Singh, of Village Daryapur, District Pratapgrah, where iron chlorosis had assumed serious proportions causing all the apical leaves to be completely bleached from their normal green colour. As the chlorosis was not uniform throughout the whole field and was in patches, 10 clumps of both normal looking and severely affected plants were tagged. At this stage, there was no distinct difference in apparent growth and the two sets of plants were only distinguishable by their green or chlorotic appearance. After about 4 months, observations for total length of millable cane, length of individual internodes of cane from 1 to 10, and weight of individual canes were recorded on the main shoot of both normal and affected plants. The juice of these canes was also extracted and its sucrose, purity coefficient and invert sugar contents were determined. The available sugar per cent. of cane was also ultimately worked out for both sets. The results obtained in respect of growth viz., cane height, average internodal length and weight of millable canes were analysed statistically and the differences of the normal and affected plants were judged at 1 per cent. probability level: The per cent. reduction of each factor under study caused by chlorosis was also determined to evaluate the magnitude of loss caused by chlorosis.

RESULTS AND DISCUSSION

The data pertaining to various characters are persented in Table 1.

TABLE 1—EFFECT FROM IRON CHLOROSIS ON SUGARCANE

S.N.	*Characters*	*Healthy plant*	*Chlorotic plant*	*C.D. at* 1%	% *Reduction/ increase due to chlorosis*
1	Cane height (cm.)	255.6	108.3	24.5	– 57.6
2	Internode length (cm.)	12.0	5.6	1.3	– 53.3
3	Cane weight (gm.)	657.0	171.0	60.0	– 74.0
4	Sucrose % in juice	17.5	10.2	—	– 41.7
5	Purity coefficient	89.0	70.6	—	– 20.7
6	Reducing sugars %	0.15	0.26	—	+ 73.3
7	Available sugar % in cane	12.12	6.21	—	– 48.7

The results show that the height of sugarcane was reduced due to iron chlorosis by 57.6%, which proved significant even at 1% probability level. This reduction in cane height was mainly due to reduction in the length of individual internodes, to the extent of 53.3% and was highly significant. Owing to the diminution in the cane length, weight of individual canes also declined sharply. This decline proved highly significant and reached the limit of 74.0 per cent. The relatively high percentage of reduction in cane weight as compared to the cane height indicates that the thickness of the cane also decreased due to iron chlorosis besides the length of the cane. Else the magnitude of reduction in cane weight should have been of a similar order to that of cane height. Since all these factors are parameters of the growth efficiency of plants, it may well be concluded that iron chlorosis caused very adverse effect on growth efficiency and reduced it very significantly. The large reduction in the ultimate yield of the crop was, therefore, to be expected.

Like growth, sucrose % and purity coefficient of juice was also reduced considerably due to iron chlorosis and this reduction amounted to 41.7% and 20.7% respectively. The reducing sugars in the juice, however, increased by 73.3% due to chlorosis and this increase was very marked. The reduction in sucrose and purity and the enhancement of the reducing sugar content of the juice can be expected to produce a marked decline in the available sugar percent. in cane. On being calculated this decline in available sugar worked out to 48.7% of the normal cane.

The results thus unmistakably point out that iron chlorosis caused serious damage to the sugarcane crop by inhibiting the growth, reducing the unit weight of canes and thereby the ultimate yield resulting in a great loss to the grower. It also seriously affected the quality of the cane, as the sucrose content and purity coefficient of the juice declined, while the reducing sugar content increased. Thus the available sugar per unit of cane declined causing serious losses due to low recovery.

The damaging effect of iron chlorosis on growth, yield and juice quality was not unexpected nor unusual. The photosynthetic process on which these heavily depended was no doubt hindered for want of chlorophyll and, therefore, the transformation of radiant energy into chemical forms was reduced, causing reduced plant growth and also adversely affecting sucrose accumulation.

SUMMARY AND CONCLUSIONS

Investigations were made to assess the influence of sugarcane chlorosis induced by iron deficiency on growth, yield and juice quality. The result revealed that cane height, cane weight, cane length of individual internodes were reduced very significantly by iron chlorosis. The magnitude of reduction in the three components was observed to be 57.6, 74.0 and 53.3 per cent. respectively as compared to the apparently healthy plant. Iron chlorosis also exercised profound adverse influences on the quality of sugarcane juice and caused serious reduction in sucrose and purity coefficient of juice, which amounted to 41.7 and 20.7 per cent. respectively at the same time reducing

sugar content increased in the juice by 73.3%, as compared to the normal plant. Owing to the reduction in sucrose and purity of juice, available sugar% in cane also declined by 48.7 per cent.

The results thus unmistakably showed that iron chlorosis caused serious damage to the sugarcane crop both by way of reduction in growth and yield and impairment in the quality of juice.

III. MODE OF CHLOROPHYLL DEVELOPMENT AFTER FOLIAR SPRAY OF FERROUS SULPHATE

INTRODUCTION

In earlier papers of this series, characteristic symptoms of iron chlorosis (Singh, 1971 *a*) and its influence on growth, yield and juice quality were discussed (Singh, 1971 *b*) in all essential details so that it may be possible to diagnose iron chlorosis by means of visual observations and reduce the magnitude of loss caused by it to the sugarcane crop by way of reduction in growth and yield and diminution in sucrose content and purity coefficient of juice. In this paper, mode of chlorophyll development and recovery from chlorosis after foliar spray of ferrous sulphate have been set forth indicating the manner of chlorophyll development and crop recovery from the chlorotic condition.

MATERIAL AND METHODS

As chlorosis has been known to be caused by the deficiency of one or several nutrient elements of which, iron, manganese and nitrogen are considered the more important, an experiment was conducted in the chlorosis affected crop at Pratapgarh. In a randomized block design eight treatments were replicated three times. Iron, Manganese and Nitrogen were sprayed on the crop through solutions of 2% ferrous sulphate, 0.5% mangaeese sulphate and 2% urea respectively—singly, as well as, in various combinations. The treatments thus comprised of the following :—

(1) Ferrous sulphate
(2) Manganese sulphate
(3) Urea
(4) Ferrous sulphate plus Manganese sulphate.
(5) Ferrous sulphate plus Urea
(6) Manganese sulphate plus Urea
(7) Ferrous sulphate plus Manganese sulphate plus Urea
(8) Control (Normal crop)

The sprayings of nutrient solutions were given twice at about 15 days interval beginning from the middle of September, when the newly emerged leaves of apex exhibited complete chlorosis. The rate of application of different solutions remained uniform at 1,000 litres per hectare. In treatments 4, 5, 6 and 7 where more than one nutrient solution was required to be applied, these were sprayed separately one after the other, allowing considerable time for complete absorption. Observations on the mode of chlorophyll development were carefully recorded from initiation to completion.

RESULTS AND DISCUSSION

Fig. 1 shows the effects of different treatments on the development of chlorophyll in the leaves after the first spraying. It is observed that in treatments 1, 4, 5 and 7 where iron had been applied alone or in combination with other elements, chlorophyll commenced developing within two days of spraying and became quite evident in the short period of 15 days. In treatments 2, 3 and 6, however, where manganese, nitrogen or both of these were applied, the plants continued to remain chlorotic and absolotely no chlorophyll development occurred in leaf tissues. As the chlorophyll also developed in the tissues, which actually received iron from the spray mists, a mosaic like appearance with green and white tissues spreading throughout the leaf surface became visible in the intial stages and the density of green colour depended on the intensity of coverage by the spray mist. The results thus indicated that in order to assure uniform supply of iron to all the cells, complete drenching of the leaves with nutrient solution is absolutely necessary. Efforts should, therefore, be made to bathe the leaves completely by sprays.

Fig. 2 shows the different stages of chlorophyll development in leaves from initation to completion. On the extreme left (0) is the leaf which had been completely bleached of normal green colour. The leaf next to it (1) shows the initial stage of chlorophyll development in tissues, which actually received iron from the spray mists leaving other adjoining tissues chlorotic as before. The third leaf from the extreme left (2) shows the second stage of chlorophyll development in which chlorophyllous tissues are coalescing together and forming a uniform colour pattern on the leaf surface. The fourth leaf (3) shows the third stage of chlorophyll development, when stripes became evident due to different degrees of pigmentation in veins and interveinal areas. The leaf on the extreme right (4) shows the final stage when chlorophyll development attained uniformity throughout the leaf imparting a normal green colour to it.

The mode of chlorophyll development and recovery of crop from chlorosis after foliar application of ferrous sulphate as stated above makes it abundantly clear that the etiolated condition was caused by the deficiency of iron as had been observed earlier by Jacobson and Oertli (1956), Sideris and Young (1956) and Levitt (1969). It became further established that the leaf tissues had lost their normal ability to synthesize chlorophyll in the absence of iron and as soon as iron became available, they regained their power of synthesis with the result green pigments developed in tissues receiving iron from the spray mists in a short period. This finding confirmed the earlier observations of Jacobson and Oertli (1956) who had claimed that a deficiency of iron progressively impairs the chlorophyll producing mechanism to the point that the leaves become incapable of synthesizing green pigments. This fact is further borne out by the manner in which chlorosis developed progressively resulting in different degrees of chlorosis during different stages of plant development viz. no chlorosis in the basal leaves, partial chlorosis with green and white stripes in the leaves of middle portion and complete chlorosis in the leaves of the apical portion of the plant (Singh, 1971 *a*). Such a feature of progressive development of chlorosis in the event of iron deficiency was possibly due to the fact that root growth did not keep pace with the increased demand of iron of the growing shoot meristems and, therefore, resulted in internal stravation which increased with increase in the age of the plant resulting in progressive development of chlorosis.

SUMMARY AND CONCLUSIONS

An experiment was conducted in the chlorosis affected field of sugarcane at Pratapgarh. Ferrous sulphate, magnanese sulphate and urea were sprayed on the plants at 2%, 0.5% and 2% concentrations respectively singly and in combination with each other. As all treatments supplying iron caused favourable effect on the alleviation of chlorosis and resulted in progressive recovery of plants from this malady, close observations on the mode of chlorophyll development were recorded from the initial to the last stages of chlorophyll development in leaves.

The results showed that within two days of ferrous sulphate application, chlorophyll commenced developing and became quite evident within 15 days. In the initial stages, tissues receiving iron from the spray mists only showed chlorophyll development and others remained chlorotic as before. Gradually, these green tissues coalesced together and formed a more or less uniform pattern throughout the leaf surface. Owing to different degrees of pigmentation in the leaf veins and interveinal areas, however, alternate green and whitish green stripes became evident within a few days. Further development of chlorophyll resulted in uniform green colour throughout the whole leaf surface as evidenced in normal leaves. The mode of recovery from chlorosis thus unmistakably pointed out that the chlorotic condition was caused by simple iron deficiency and as soon as iron became available to the tissues, the leaves commenced turning green due to the onset of chlorophyll synthesis. It was further established that owing to the deficiency of iron, tissues had lost their ability to synthesize chlorophyll and had become inactive. The spraying of ferrous sulphate thus activated the synthesis of chlorophyll, thereby causing the recovery from chlorosis.

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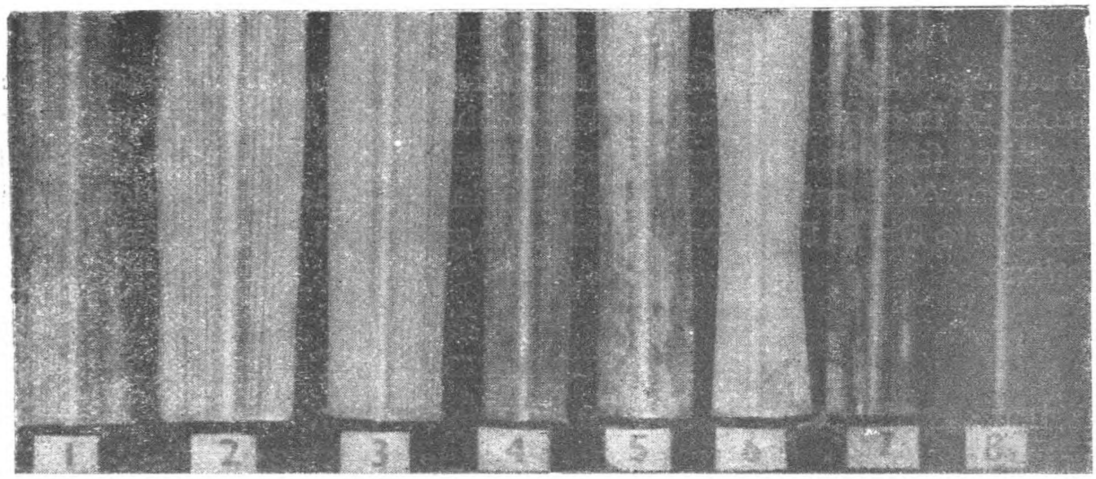

Fig. 1 showing effects of different treatments. From the extreme left are the leaves sprayed with the following:—

(1) Ferrous sulphate
(2) Managnese sulphate
(3) Urea
(4) Ferrous sulphate plus manganese sulphate
(5) Ferrous sulphate plus urea
(6) Manganese sulphate plus urea
(7) Ferrous sulphate plus manganese sulphate plus urea.
(8) Normal green leaf

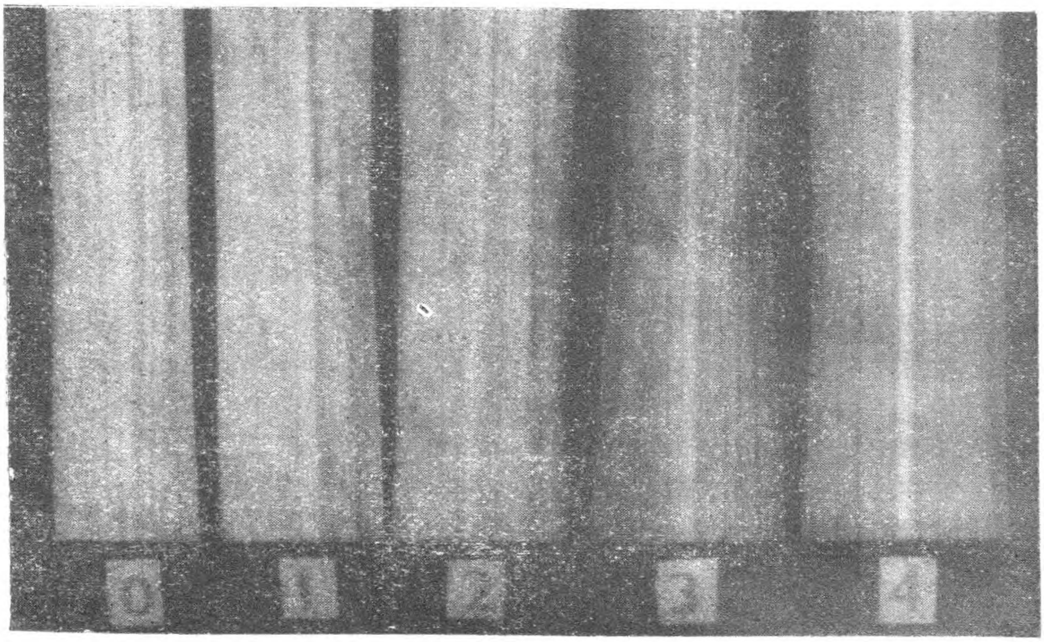

Fig. 2 showing different stages of chlorophyll development and fate of chlorosis after foliar spray of ferrous sulphate. From the extreme left are —

(0) Completely chlorotic leaf
(1) Chlorotic leaf showing chlorophyll development in tissues obtaining iron
(2) Chlorotic leaf showing chlorophyllous tissues coalescing together
(3) Partially recovered leaf showing green and whitish green stripes
(4) Normal green leaf of uniform colour