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A Study of the Influence of Micronutrients on the Growth of Sugar Cane and Tobacco.**

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Since 1922 several kinds of available minor elements were discovered, one after the other, to be essential for the growth of higher plants. Even though the seven elements: iron; manganese, boron, chlorine, copper, zinc and molybdenum are required in relatively small amounts, a few parts per million, they are as important for the nutrition of higher plants as the major elements such as nitrogen, potassium, magnesium, etc.

Hoagland & Arnon (1950), Arnon (1950, 1955), C. M. Johnson, P. R. Stout, T. C. Broyer and A.B. Carlton (1957) and many other scientists reported that if one of the minor elements nutrient was lacking to plants serious abnormal physiological symptoms occur and in some cases growth and development are suppressed. Moreover D. Emerton Williams and James Vlamis (1957) found that 5.0 ppm Mn to be toxic to barley plants causing necrotic spot symptoms to develop on the entire blade of leaves. D. R. Dilley & A. L. Kenworthy, E. J. Bense & S. T. Bass (1958) observed that when apple trees and Elberta peach trees were treated with higher concentration 315 ppm, 665 ppm chloride not only was growth in height and size of tree decreased but also the leaf size of chloride treated trees was smaller than that of untreated trees. From the results of those experiments it was obvious that the optimum concentration of micronutrient for enhancing the growth of plants should be determined. This experiment proposes to determine the optimum concentration of micronutrients such as iron, manganese and boron for the growth of sugar cane and tobacco, which are most important crops in the agriculture of Taiwan. Indeed the knowledge of these optimum concentrations will be profitably applied to increase sugar cane and tobacco production.

Materials, Chemicals and Methods:

Materials:

Seedlings of sugar cane (Variety F 134) and tobacco (Variety Hicks) are to be used in this study.

At first the tobacco seeds, which are very small, are placed for germination in sand to which nutrient solution is applied. Around a month is required for growth of seedlings a few centimeters tall.

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The nodes of the sugar cane stems are cultured in sand for vegetative propagation. When the seedlings have grown 2-3 centimeters they are cut off as clearly as possible from the tissue of the node stem, all the while being very careful that the root bud suffer no injury.

Chemicals:

Hoagland's solution is used to supply macronutrient elements. The stock solution are KNO_3 1 M, $Ca(NO_3)_2$ 1 M, $MgSO_4$ 1 M, KH_2PO_4 1 M.

A_5 stock solution is used to supply some of the micronutrients. This stock solution contains 4000 ppm Cl, 500 ppm B, 500 ppm Mn, 50 ppm Zn, 20 ppm Cu, and 10 ppm Mo.

The stock solution of Fe-EDTA (Ferric sodium ethylene diamine tetraacetate) is prepared by dissolving 4.84 gm of $FeCl_3$ $6H_2O$ and 6.46 gm Na EDTA in one liter of distilled water. The resulting solution thus contains 1 mg Fe/ml. NaOH was used to adjust to pH to 5.0. This solution is stored under refrigerator.

Iron:

Amounts of macronutrient element stock solutions added to each 2 gallon crock (1 gallon=3.785 liter) as follows.

KNO_3	1 M	38 ml
$Ca(NO_3)_2$	1 M	38 ml
$MgSO_4$	1 M	15 ml
KH_2PO_4	1 M	7.5 ml

Micronutrient elements A_5 stock solution 7.5 ml are added to each crock. Iron is added to the five crocks as follows.

No. I	No iron is added
No. II	0.38 ml of the 1 mg Fe/ml stock solution
No. III	2.3 ml of the 1 mg Fe/ml stock solution
No. IV	19.0 ml of the 1 mg Fe/ml stock solution
No. V	38.0 ml of the 1 mg Fe/ml stock solution

Boron:

The boron series are prepared as described above for iron the same amounts of macronutrient element of stock solution are added to each 2 gallon crock, except that the minus boron micronutrient stock solution is used in place of the complets A_5 solution. In addition 7.5 ml of a 5 mg Fe/ml stock Fe-EDTA solution is added to each crock. The series of boron concentration are prepared from a 1 mg B/ml stock solution. Boron is added to the five crocks in the same way and amounts as iron was added in the iron series.

Manganese:

The manganese series are prepared in the same way as the boron series, using the minus manganese micronutrient solution and 1 mg Mn/ml stock solution. Manganese is added to the five crocks as in the same manner and amounts as boron in the boron series.

Methods:

Five 2 gallon size crocks are used as containers in each series. Covers are placed over the crocks, 25 one-hole corks are procured to support the plants. They are rinsed thoroughly, first with tap water and finally with distilled water. Clean soft glass aerators are used when boron was to be studied. (Pyrex should not be used, since it is a borosilicate glass). One aerator is placed in each of the crocks. The aerator connected to compressed air line using a small plug of cotton at the top of the aerator to filter the air. (See picture No. 1) The air valves are adjusted so that a small stream of air bubbles through the culture solution to have the same strength of air bubbles in each series of five crocks. Otherwise the different root growth would occur. The crocks are filled to about three-fourths full with distilled water and stock salt solution of the macronutrients and micronutrients is added to each container to make full strength Hoagland's solution. The amounts are shown in the above table. It is advisable to stir the solution after each addition of stock solution in order to prevent precipitation due to local high concentration of salts. The aerator may be used as a stirring rod. Each crock is filled up to within ½ inch of the top.

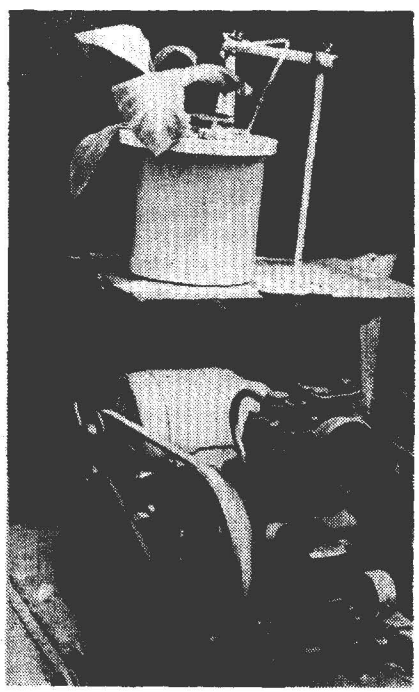


Fig No. 1 Showing apparatus set-up.

For one series of the five micronutrient concentrations, 25 single hole corks are prepared each with a seedling inserted it. Nonabsorbent cotton is used to hold the seedling in place and the covers are placed on the crocks.

After six or eight weeks, depending upon the weather, tobacco plants are harvested but sugar cane takes a longer time, two or three months.

The plants are harvested by severing to top from the root at the base of the plant just above the cork then weighed to find out the fresh weight of the tops and the roots. They are then dried in a ventilated oven at 60°～70°C. The dried samples are weighed and the yields are recorded.

Results

This experiment started in April, 1961, in the Department of Botany, Taiwan Provincial Chung Hsing University and ended in June 1963.

The effects of the micronutrients, such as iron, boron and manganese at several concentration on the sugar cane and tobacco growth were studied for the more than two years while this experiment was carried. During this time the study of each micronutrient series was repeated three times. The records showed that virtually the same results were obtained in different seasons. Thus report on any one experiment from each series will serve to illustrate adequately the influence of the elements concerned on the growth of sugar cane and tobacco.

I. Sugar Cane

A. Boron series.

Sugar cane was cultured in five different concentrations of boron for fifteen weeks, beginning on April 20, 1961, and ending on July 21 of the same year. At the beginning three seedlings of the same height (around 4 cm.) with two young leaves were planted in each of the crocks. After fifteen weeks, depending on boron concentration, the plant presented differences in appearance of both roots and tops, in size, in color, in leaf distortion, etc.

Table No. 1 *Record of differences resulting from variation in boron concentrations*

Observations / Boron Conc.	Height of top (cm)	Color of leaves	Number of leaves	Size of leaves length × width (cm)	Number of nodes	Length of internodes (cm)
Minus Boron	59.3	green color, with red brownish spots	10	55.5×2.4	8	8.47
0.05 ppm B	70.0	green color with light red brownish spots.	10—11	117×4.5	8	10
0.30 ppm B	112.8	green	13	130.6×4.9	11	11.6
2.50 ppm B	116.0	green	13—14	130.9×4.93	11	11.28
5.00 ppm B	93.0	green	13	130.2×4.0	11	9.36

The above records show that after fifteen weeks sugar cane growth in culture without boron top growth was slight, only ½ of that obtained in culture with 2.5 ppm, and the fresh weight was only ⅓ of the growth of the culture with 2.5 ppm boron. (Table No. 3). The boron deficiency symptom was observed on young and old leaves which had red-brownish spots scattered through entire the leaf blade. (Fig No. 4).

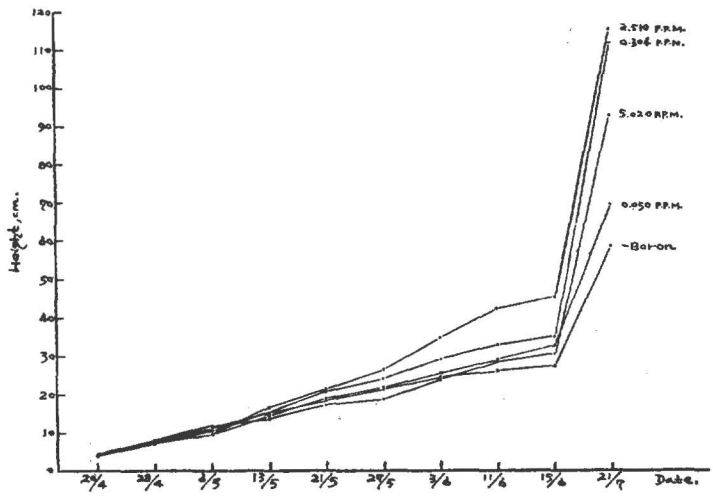
The sugar percentage in the stem was very much smaller than that obtained when boron was present.

This experiment shows the concentration of 2.5 ppm boron to be the best for sugar cane growth (Fig No. 2). However in another experiment the best results were obtained using a concentration of 0.3 ppm boron. From these two experiments

Table No. 2 *Shoot growth of sugar cane at various boron concentrations.*

Conc. of boron / Date	Minus Boron	0.050ppm	0.304ppm	2.510ppm	5.020ppm
20/4	4.3 cm	4.2 cm	4.0 cm	3.9 cm	4.3 cm
28/4	8.0 cm	7.5 cm	7.8 cm	7.8 cm	8.0 cm
6/5	11.5 cm	9.8 cm	11.3 cm	9.8 cm	11.8 cm
13/5	14.8 cm	14.5 cm	15.3 cm	16.3 cm	13.9 cm
21/5	18.0 cm	18.3 cm	20.9 cm	21.7 cm	17.0 cm
27/5	21.0 cm	21.6 cm	24.0 cm	26.3 cm	18.6 cm
3/6	24.3 cm	25.5 cm	29.2 cm	34.9 cm	23.9 cm
11/6	26.0 cm	29.3 cm	33.0 cm	42.6 cm	28.6 cm
15/6	27.5 cm	32.8 cm	35.4 cm	45.8 cm	30.6 cm
21/7	59.3 cm	70.0 cm	112.8 cm	116.0 cm	93.6 cm

can be concluded that optimum concentration for boron lies within range of 0.3~2.5 ppm. If boron concentration exceeded 5.0 ppm, the growth was repressed and fresh, dry weight were reduced. (Fig No. 2, 3, Table No. 3, 4).

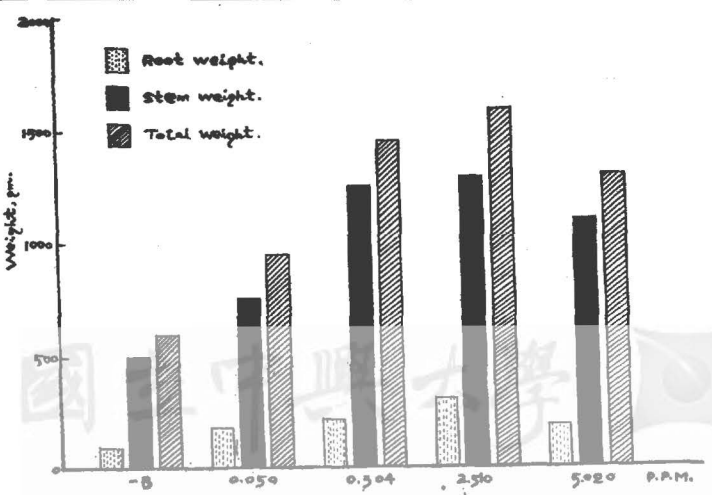


Date of measurement

Graph No. 1 Showing progress of sugar cane growth at various boron concentrations.

Table No. 3 ***The fresh weight of sugar cane at various boron concentrations***

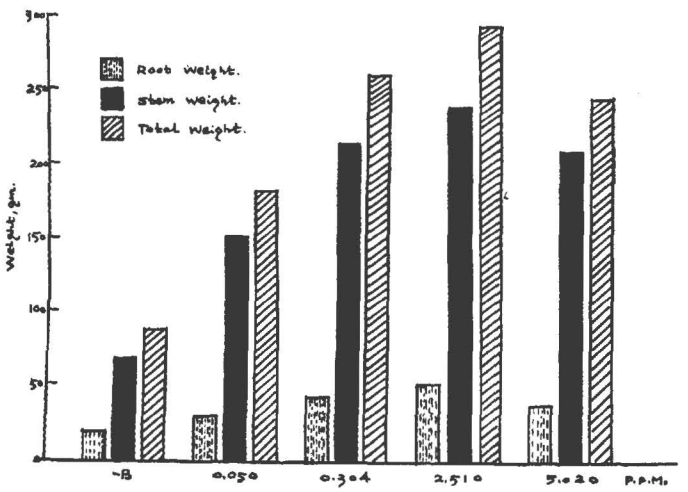
Part / Conc	Shoot of sugar cane fresh weight	Root of sugar cane fresh weight	Total fresh weight of shoot and root
Minus Boron	501.5 gm	101.0 gm	602.5 gm
0.050 ppm	794.5 gm	187.2 gm	981.7 gm
0.320 ppm	1,257.0 gm	225.6 gm	1,482.6 gm
2.510 ppm	1,286.0 gm	312.3 gm	1,598.3 gm
5.010 ppm	1,100.7 gm	193.0 gm	1,293.7 gm



Graph No. 2 Showing total fresh weight of sugar cane grown at various boron concentrations.

Table No. 4 *The dry weight of sugar cane at various boron concentrations*

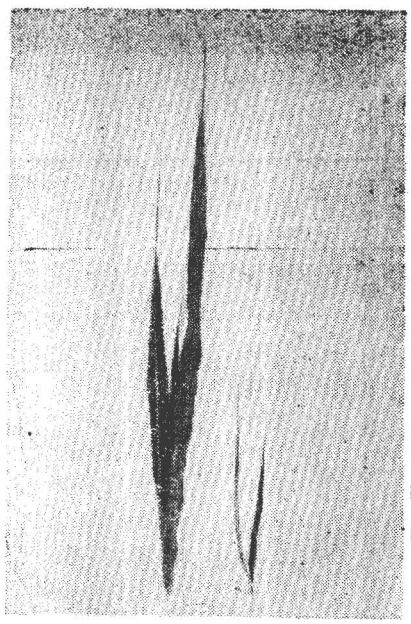
Part / Concentration	Shoot of sugar cane dry weight	Root of sugar cane dry weight	Total dry weight of shoot & root
Minus Boron	71.20 gm	20.80 gm	92.0 gm
0.050 ppm	153.00 gm	31.40 gm	184.4 gm
0.304 ppm	214.35 gm	44.30 gm	258.65 gm
2.510 ppm	238.74 gm	52.70 gm	291.44 gm
5.020 ppm	209.04 gm	34.30 gm	243.34 gm



Graph No. 3 Showing the dry weight of sugar cane at various boron concentrations.

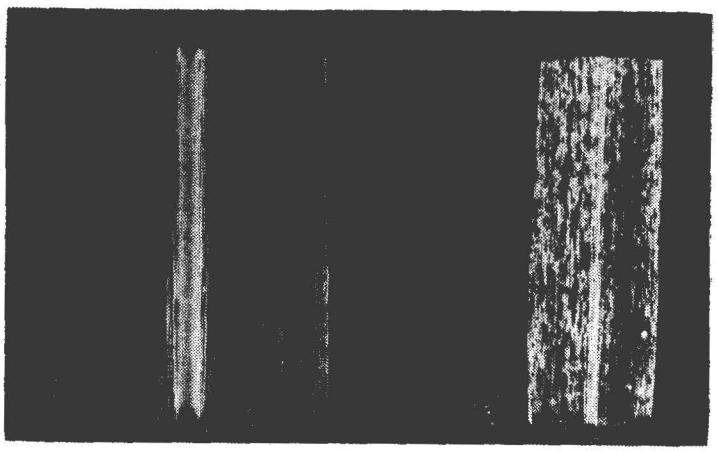
-B 0.050ppm 0.304ppm 2.510ppm 5.020ppm

Fig No. 2 Showing sugar cane growth at various boron concentrations.



2.50 ppm Minus Boron

Fig No. 3 Comparison of sugar cane bud growth at boron concentration 2.50ppm with that of minus boron.



2.50 ppm B Minus Boron

Fig No. 4 Comparison of sugar cane leaf growth at boron concentration 2.50 ppm with that of minus boron concentration.

The temperature of green house during this culture time are as follows:

Time / Temperature	8:00 A. M.	12:00 Noon	5:00 P. M.
Maximum	36°C	38.5°C	35°C
Minimum	18°C	20°C	18.5°C
Average	29.08°C	34.81°C	29.7°C

B. Iron series

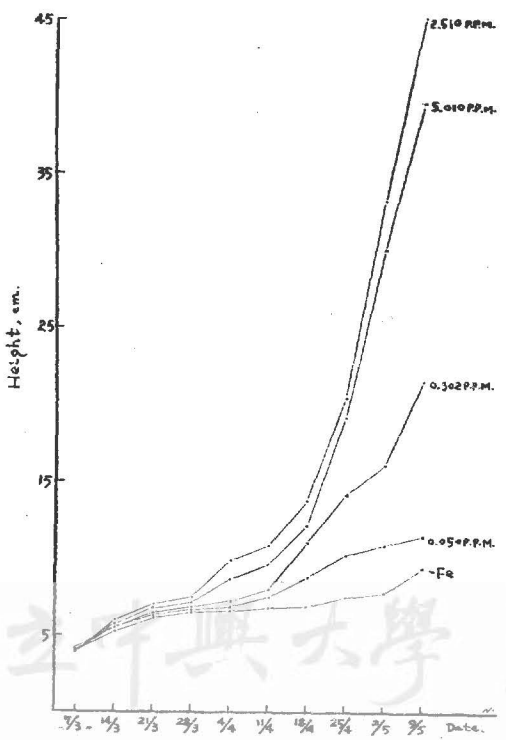
The iron series was studied on March 7, 1963, when plants were harvested after nine weeks of water culture. It was observed the sugar cane grown in solution without iron was much weaker, thinner and whiter than others (Fig No. 5) the whole body was small and specially the central leaves changed to white color exhibiting more serious chlorosis than any other older leaves (Fig No. 7) The size, thickness and color of leaves depended very much on the different concentration of iron. The leaves darkest green in color, largest in size and thickest grew at an iron concentration of 2.5 ppm (Fig No. 8).

The greatest number of roots and the longest roots were also obtained at an concentration of 2.5 ppm. When no iron was present very few roots grew and these were brownish in color, short and weak. (Fig No. 6). If iron concentration exceeded

5.0 ppm, the growth was repressed and fresh, dry weight was reduced, (Table No. 6, 7, Graph No. 5, 6) in the same way as when an excess of 5.0 ppm boron was present.

Table No. 5 *Shoot growth of sugar cane at various iron concentrations:*

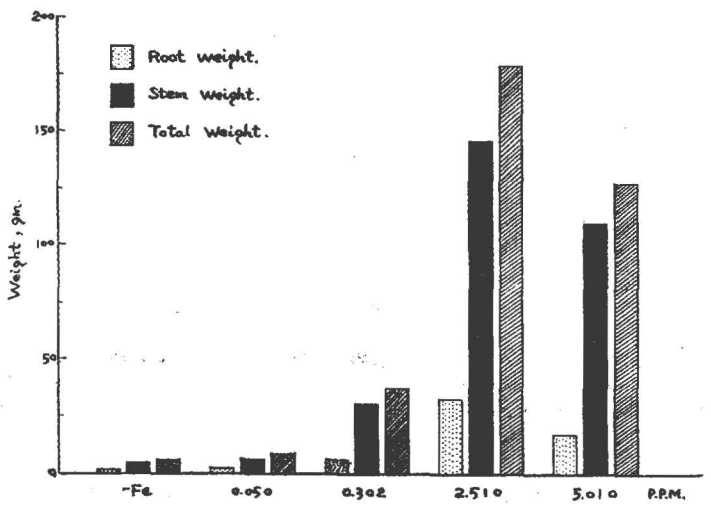
Conc / Date	—Iron	0.050 ppm	0.302 ppm	2.510 ppm	5.010 ppm
7/3	4.1 cm	4.1 cm	4.0 cm	3.9 cm	3.9 cm
14/3	5.3 cm	5.5 cm	5.5 cm	6.0 cm	5.8 cm
21/3	6.2 cm	6.3 cm	6.4 cm	7.0 cm	6.8 cm
28/3	6.5 cm	6.6 cm	6.8 cm	7.5 cm	7.2 cm
4/4	6.6 cm	6.8 cm	7.3 cm	9.9 cm	8.7 cm
11/4	6.8 cm	7.5 cm	8.0 cm	10.9 cm	9.6 cm
18/4	6.9 cm	8.8 cm	11.1 cm	13.8 cm	12.2 cm
25/4	7.5 cm	10.3 cm	14.2 cm	20.5 cm	19.2 cm
2/5	7.8 cm	10.9 cm	16.0 cm	33.2 cm	30.0 cm
9/5	9.4 cm	11.5 cm	21.5 cm	45.0 cm	39.5 cm



Graph No. 4 Showing progress of sugar cane growth at various iron concentrations.

Table No. 6 *The fresh weight of sugar cane at various iron concentrations:*

Part / Conc	Fresh weight of stem & leaves	Fresh weight of root	Total fresh weight of shoot & root (Only one plant)
Minus Iron	4.0 gms	1.4 gms	5.4 gms
0.040 ppm	6.45 gms	2.2 gms	8.65 gms
0.302 ppm	31.3 gms	6.4 gms	37.7 gms
2.510 ppm	145.8 gms	32.7 gms	178.5 gms
5.010 ppm	109.6 gms	17.4 gms	127.0 gms



Graph No. 5 Showing the fresh weight of sugar cane at various iron concentrations.

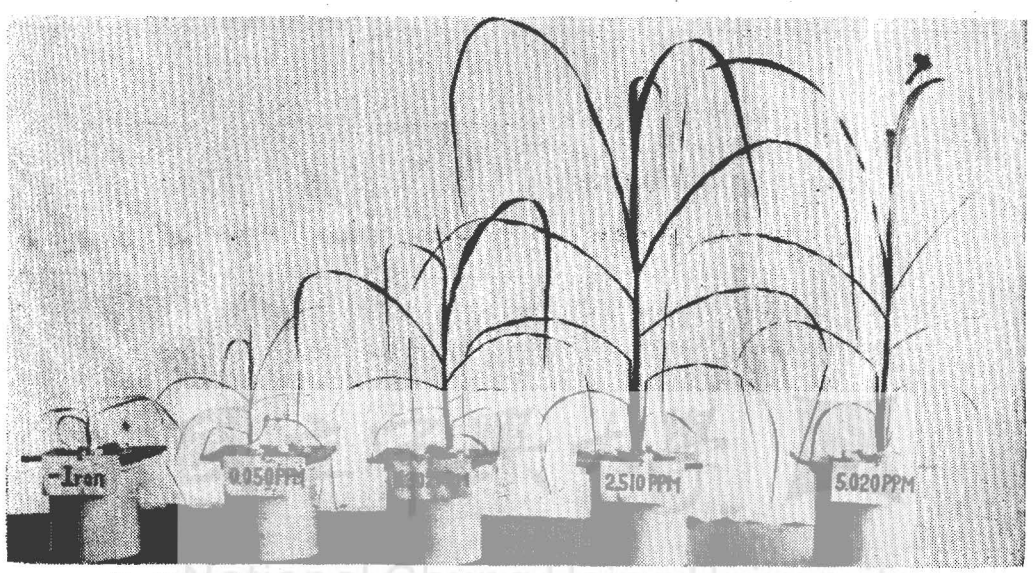
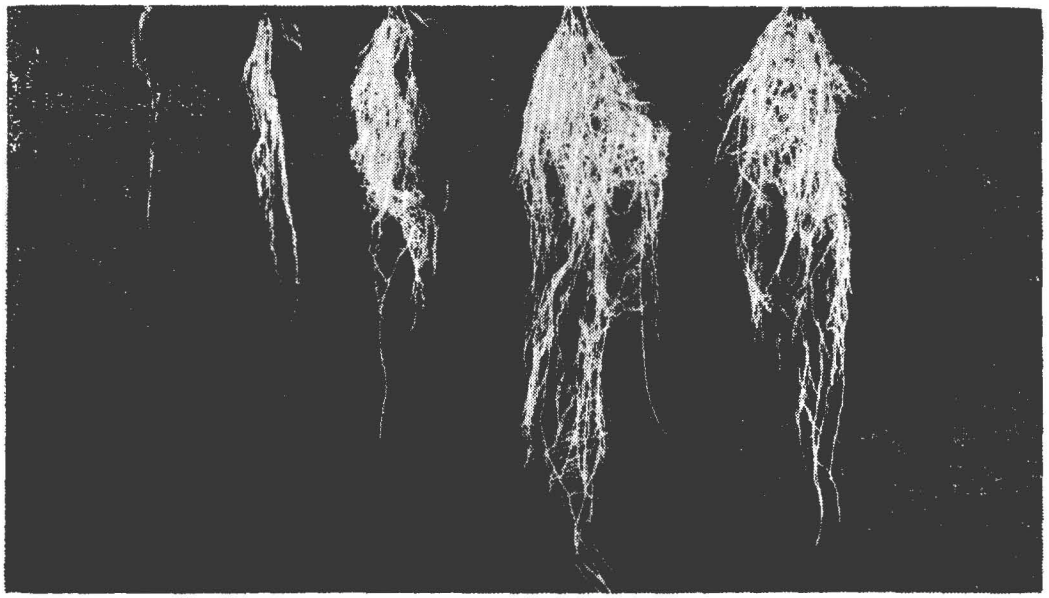


Fig No. 5 Showing sugar cane growth at various iron concentration

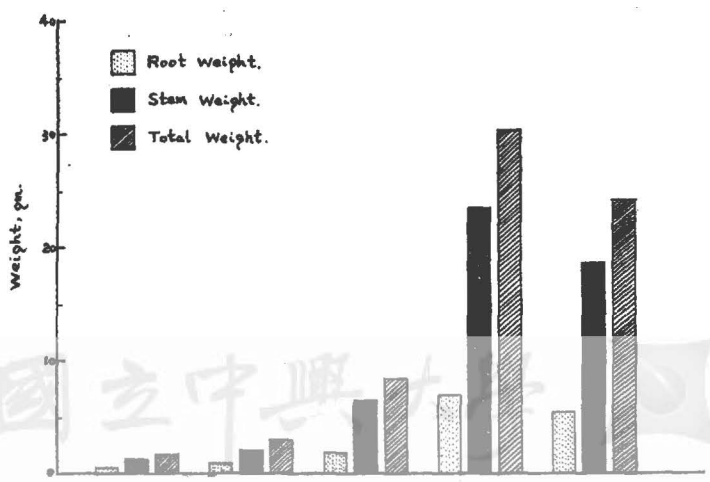


-Fe 0.05 0.3 02.50 5.0

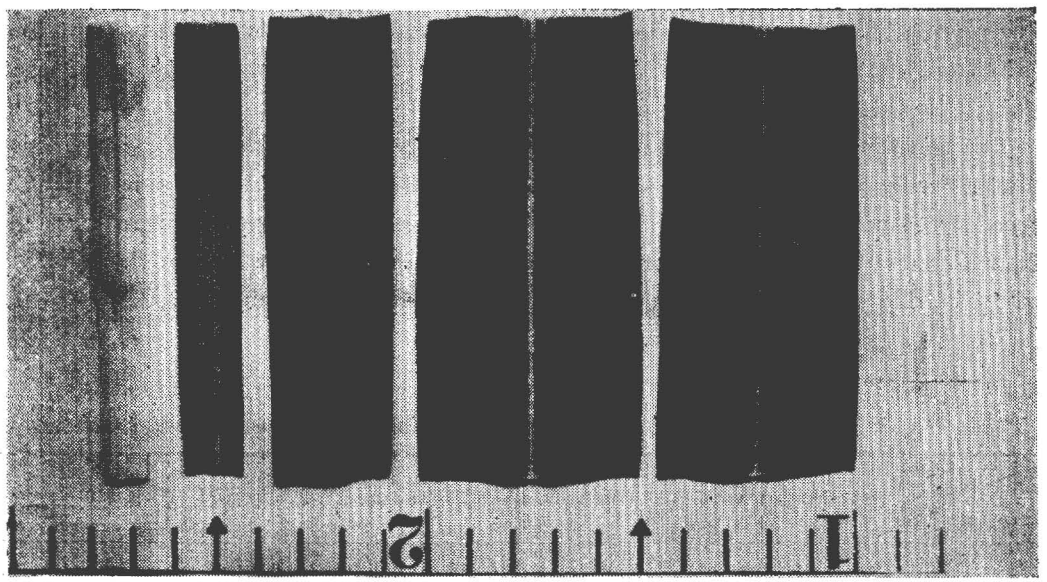
Fig No. 6 The root growth of sugar cane at various iron concentrations.

Table No. 7 *The dry weight of sugar cane at various iron concentrations*:

Part / Conc of iron	Dry Wt. of stem and leaves	Dry Wt. of root	Total dry Wt. of stem and root
Minus Iron	1.27 gms	0.52 gms	1.79 gms
0.050 ppm	2.07 gms	0.59 gms	2.66 gms
0.302 ppm	6.52 gms	1.91 gms	8.43 gms
2.510 ppm	23.44 gms	6.87 gms	30.31 gms
5.010 ppm	18.65 gms	5.42 gms	24.07 gms

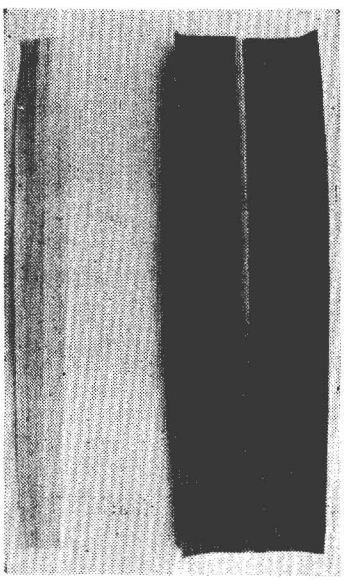


Graph No. 6 Showing total dry weight of sugar cane growth at various iron concentrations.



Minus Fe 0.050 0.30 2.50 5.0 ppm iron

Fig No. 7 Comparison sugar cane leaf growth at various iron concentrations.



Minus Fe 2.5 ppm Fe

Fig No. 8 Comparison of sugar cane leaf growth at minus iron concentration (left) with that of iron concentrations 2.50 ppm. (right).

C. Manganese series

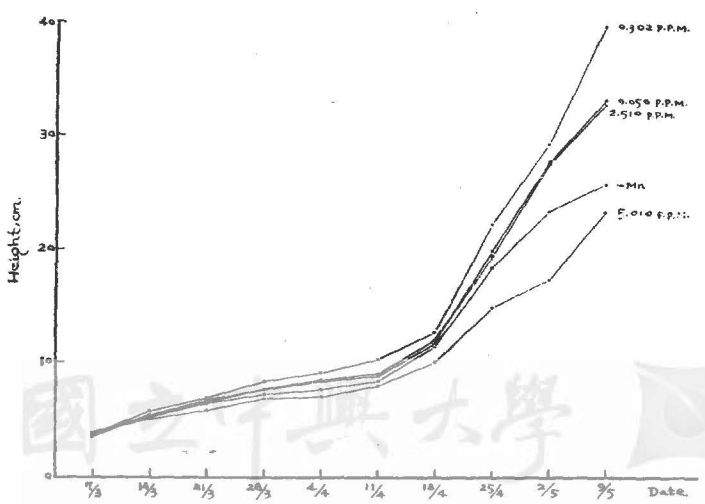
Sugar cane was cultured in five different concentrations of manganese, beginning on March 3, 1963, and ending on May 9, of the same year. After nine weeks the plants presented many differences, depending on manganese concentrations, in appearance of both tops and roots (Fig No. 9 and No. 10). In the sugar cane growth

in solution without manganese intermittent intervenal chlorotic streaks were observed throughout the leaves (Fig No. 12). The size of leaves was only ½ of that obtained in culture with 0.3 ppm manganese.

The records show the concentration of 0.30 ppm manganese to be the best growth for sugar cane (Fig No. 11, Table No. 8). If manganese concentration exceeded 2.5 ppm, the growth was repressed and fresh, dry weight were reduced. When a concentration of greater than 5.0 ppm even more so was growth repressed and fresh, dry weight were reduced (Table No. 9, 10 and Graph No. 8, 9).

Table No. 8 ***Shoot growth of sugar cane at various manganese concentrations:***

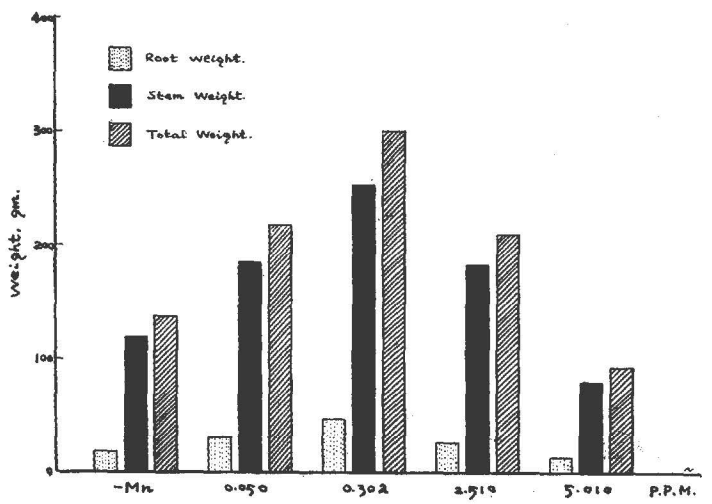
Conc / Date	-Manganese	0.050 ppm	0.303 ppm	2.510 ppm	5.010 ppm
7/3	3.6 cm	3.4 cm	3.6 cm	3.6 cm	3.7 cm
14/3	5.2 cm	5.3 cm	5.7 cm	5.4 cm	5.1 cm
21/3	6.3 cm	6.7 cm	6.8 cm	6.6 cm	5.9 cm
28/3	7.3 cm	7.7 cm	8.5 cm	7.7 cm	6.8 cm
4/4	7.6 cm	8.4 cm	9.2 cm	8.5 cm	7.1 cm
11/4	8.5 cm	8.9 cm	10.4 cm	9.1 cm	8.0 cm
18/4	11.5 cm	11.9 cm	12.8 cm	12.0 cm	10.2 cm
25/4	18.6 cm	20.0 cm	22.5 cm	19.5 cm	15.1 cm
2/5	23.5 cm	28.1 cm	29.5 cm	28.0 cm	17.5 cm
9/5	2.6 cm	33.5 cm	40.0 cm	33.0 cm	23.5 cm



Graph No. 7 Showing progress of sugar cane growth at various manganese concentrations.

Table No. 9 *The fresh weight of sugar cane at various manganese concentrations:*

Part / Conc of Mn	Fresh weight of stem & leaves	Fresh weight of root	Total fresh weight of shoot & root (Two Plants)
-Manganese	119.5 gms	19.1 gms	138.6 gms
0.050 ppm	185.7 gms	32.6 gms	228.3 gms
0.302 ppm	253.5 gms	46.8 gms	300.3 gms
2.510 ppm	155.7 gms	26.6 gms	182.3 gms
5.010 ppm	72.9 gms	13.6 gms	96.5 gms



Graph No. 8 Showing total fresh weight of sugar cane growth at various manganese concentrations.

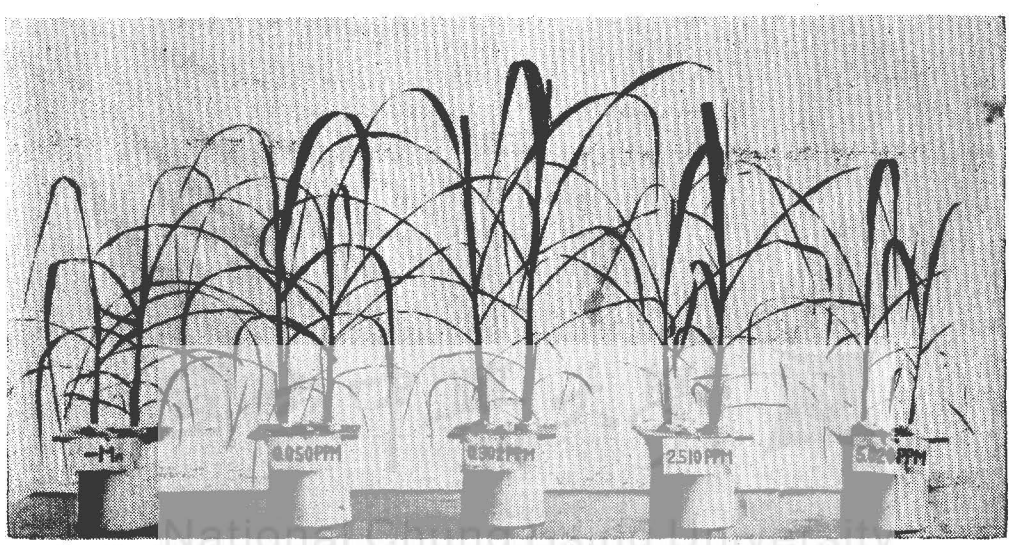
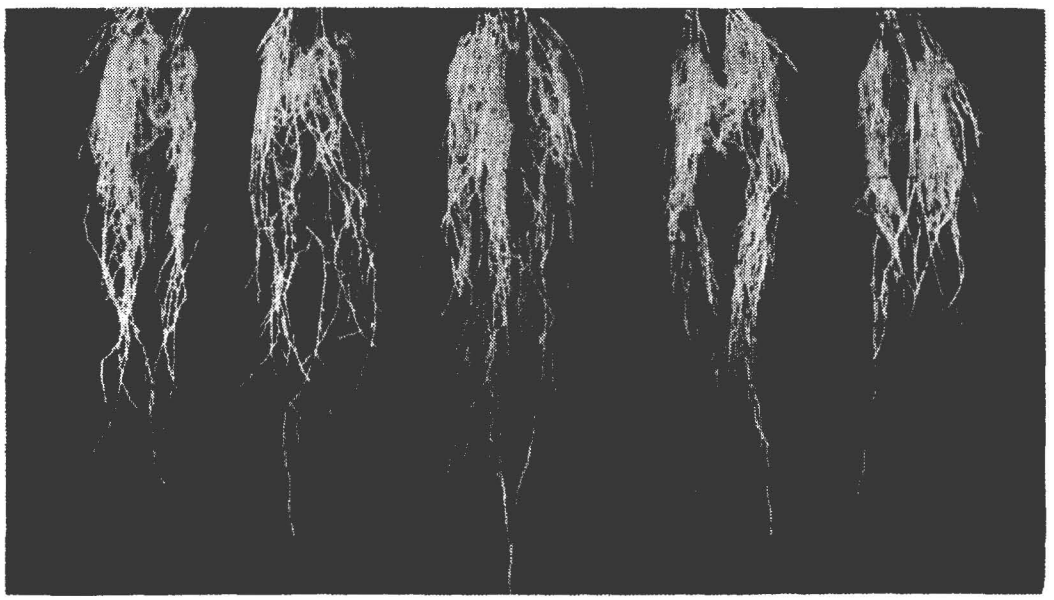


Fig No. 9 Showing sugar cane growth at various manganese concentrations.

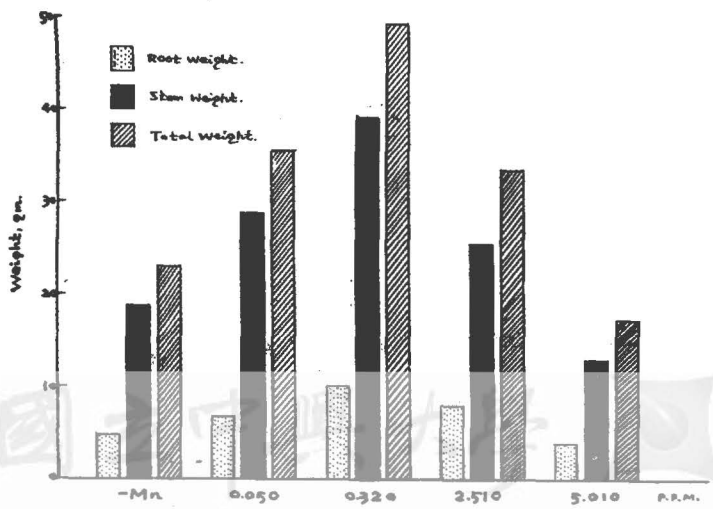


Minus Mn　　0.05　　0.30　　2.51　　5.02 ppm Mn

Fig No. 10 Root growth of sugar cane at various manganese concentrations.

Table No. 10 *The dry weight of sugar cane at various manganese concentrations*:

Part / Conc of Mn	Dry weight of stem & leaves	Dry weight of root	Total dry weight of shoot & root
-Manganese	18.68 gms	5.09 gms	23.77 gms
0.050 ppm	28.8 gms	6.67 gms	35.47 gms
0.302 ppm	38.26 gms	10.14 gms	48.4 gms
2.510 ppm	25.4 gms	8.02 gms	33.42 gms
5.010 ppm	12.97 gms	4.06 gms	17.03 gms



Graph No. 9 Showing the dry weight of sugar cane at various manganese concentrations.

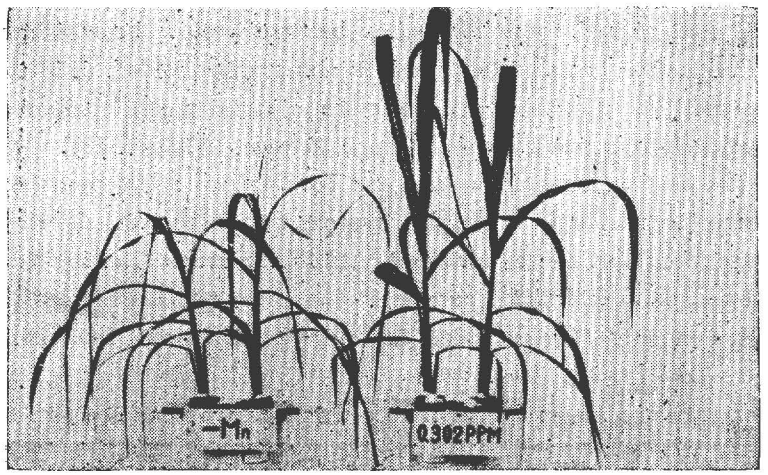
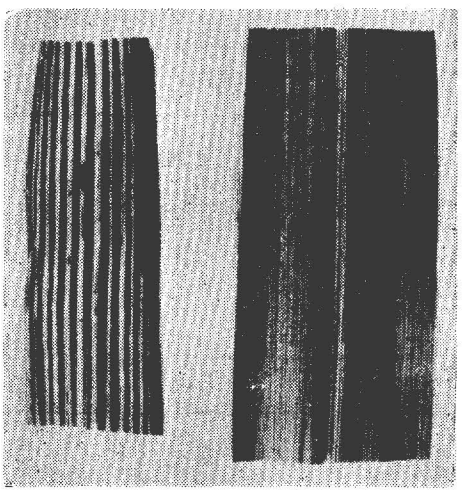


Fig No. 11 Comparison of sugar cane shoot growth at minus manganese concentration (left) with that of Mn concentration 0.302 ppm. (right).



Minus Mn 0.302 ppm

Fig No. 12 Comparison of sugar cane leaf growth at minus Mn concentration (left) with that of manganese 0.302 ppm. (right).

II Tobacco

A. Boron series

Tobacco was cultured in various concentrations of boron around six weeks beginning on May 6, 1961 and ending on June 15. Sand germinated tobacco seedling 2 cm in height with four leaves were used. Each seedling was inserted in a hole of a cork.

The tobacco growth in culture without boron after six weeks had dwarfish shoots about 4 cm tall just $^{1}/_{13}$ the growth in culture with 2.5 ppm boron (Fig No.

13). The apical central bud, growing point, became yellow brownish color, dried and folded. Third leaf shows shrinking and is abnormally folded. (Fig No. 14, 17).

These abnormalities stand out all the more clearly when compared with the vigorous leaf growth at boron concentration 2.50 ppm. (Fig No. 15).

Therefore the best concentration of boron for tobacco is 2.5 ppm (Graph No. 10) but the picture (No. 13) shows the root system not to be well developed because faulty aeration throughout the experiment. Another picture (No. 16) shows the root well developed because under good aeration.

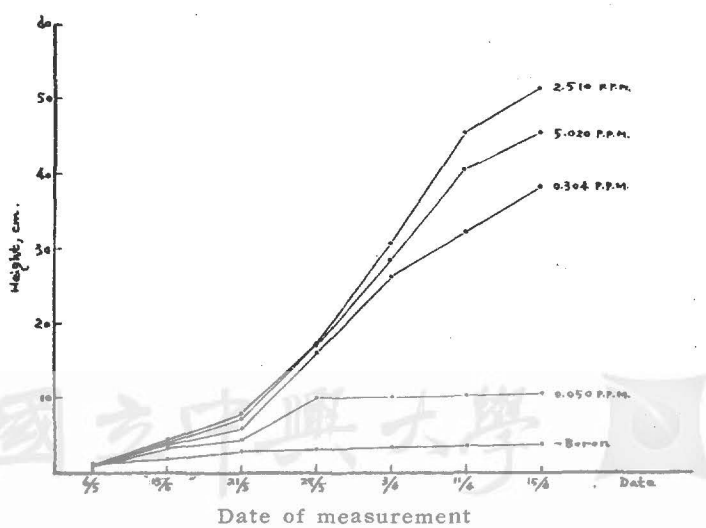
When boron concentration exceeded 5.0 ppm growth was reduced. (Table No. 12, 13).

The temperatures of green house during this culture time are as follows:

Time / Temperature	8:00 A. M.	12:00 Noon	5:00 P. M.
Maximum	33°C	38.5°C	31.5°C
Minimum	18°C	20°C	18.5°C
Average	28°C	33.8°C	28.3°C

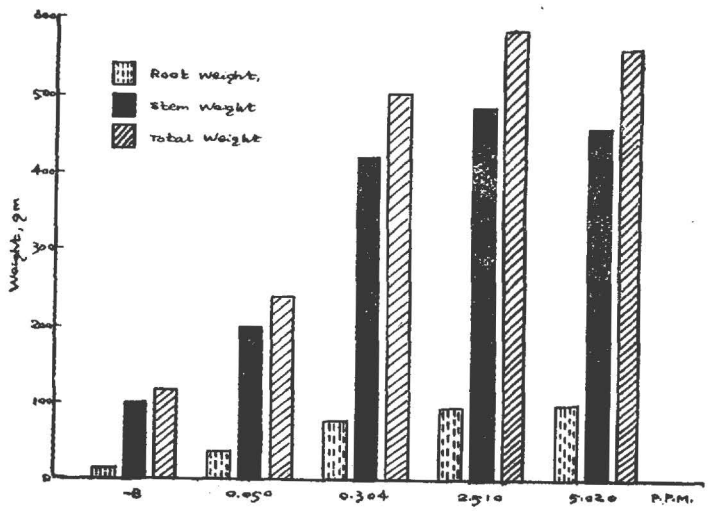
Table No. 11 ***Shoot growth of tobacco at various boron concentrations***

Conc of Boron / Date	Minus Boron	0.050 ppm	0.304 ppm	2.510 ppm	5.020 ppm
6/5	1.3 cm	1.1 cm	1.0 cm	1.0 cm	1.2 cm
13/5	1.9 cm	3.3 cm	3.8 cm	4.5 cm	4.0 cm
21/5	3.0 cm	4.5 cm	6.0 cm	8.0 cm	7.5 cm
27/5	3.1 cm	10.0 cm	16.1 cm	17.5 cm	17.2 cm
3/6	3.5 cm	10.06 cm	26.2 cm	30.9 cm	28.6 cm
11/6	3.8 cm	10.2 cm	32.3 cm	45.3 cm	40.5 cm
15/6	4.0 cm	10.8 cm	38.4 cm	51.4 cm	45.2 cm



Date of measurement

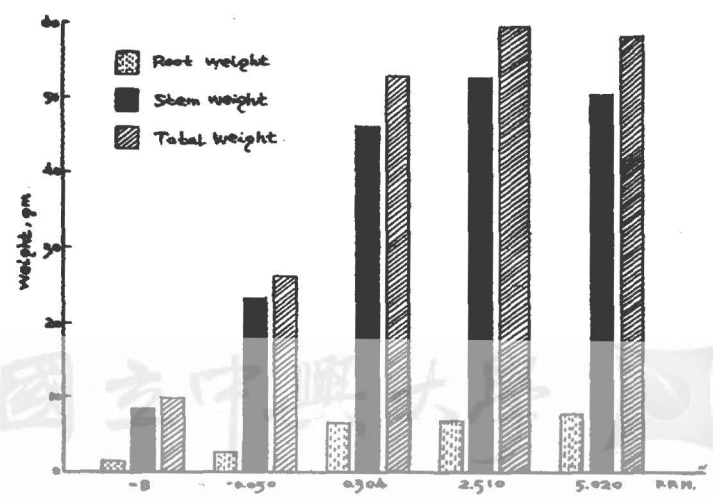
Graph No. 10 Showing progress of tobacco shoot growth at various boron concentrations.



Graph No. 11 Showing total fresh weight of tobacco growth at various boron concentrations.

Table No. 12 *The fresh weight of tobacco at various boron concentration*

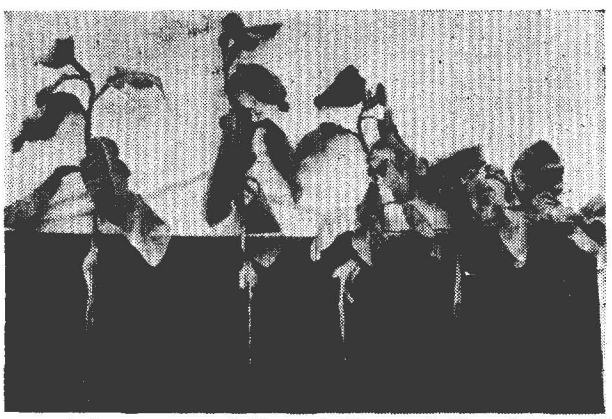
Part / Conc.	Fresh weight of shoot	Fresh weight of root	Total of fresh weight
Minus Boron	102.0 gm	17.8 gm	119.8 gm
0.050 ppm	201.8 gm	39.8 gm	241.6 gm
0.304 ppm	424.0 gm	81.5 gm	505.5 gm
2.510 ppm	489.1 gm	97.0 gm	586.1 gm
5.020 ppm	461.0 gm	100.5 gm	561.5 gm



Graph No. 12 Showing total dry weight of tobacco growth at various boron concentrations.

Table No. 13 *The dry weight of tobacco at various boron concentration*

Part. / Conc.	Shoot of dry weight	Root of dry weight	Total of dry weight
Minus-Boron	8.4 gm	1.5 gm	9.9 gm
0.050 ppm	23.3 gm	2.8 gm	26.1 gm
0.304 ppm	46.0 gm	6.7 gm	52.7 gm
2.510 ppm	52.3 gm	6.8 gm	59.1 gm
5.020 ppm	50.1 gm	7.8 gm	57.9 gm



5.0 2.50 0.30 0.05 Minus Boron

Fig No. 13 Showing tobacco growth at various boron concentrations.

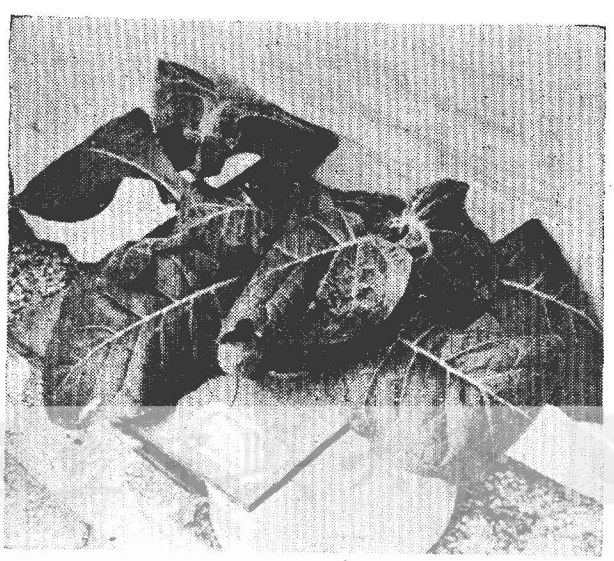


Fig No. 14 Showing the apical central bud dried and folded at minus boron concentration.

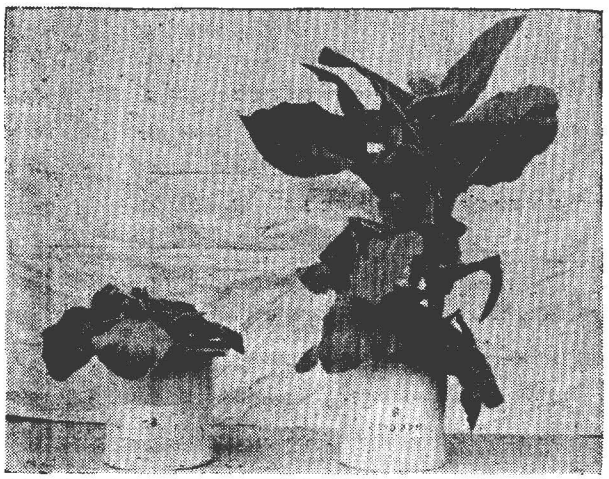
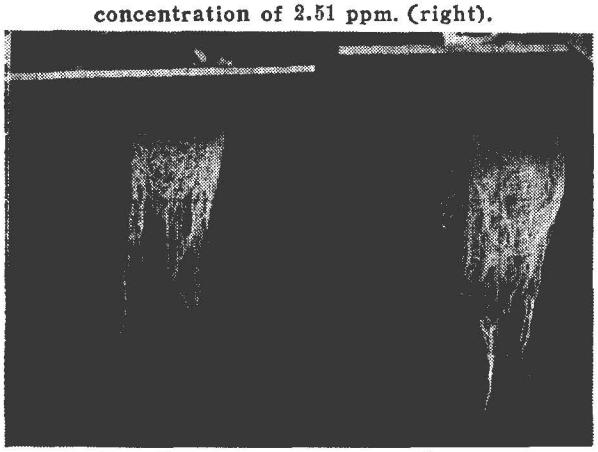
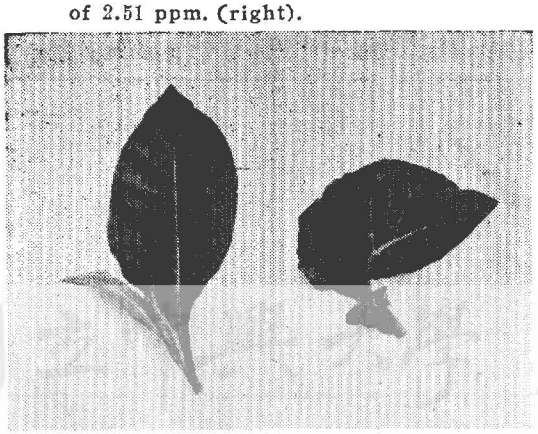


Fig No. 15 Comparison of tobacco shoot growth at minus boron concentration (left) with that of boron concentration of 2.51 ppm. (right).



minur Boron 2.510 ppm B

Fig No. 16 Comparison of tobacco root growth at minus boron (left) with that of boron concentration of 2.51 ppm. (right).



2.51 ppm B Minus Boron

Fig No. 17 Comparison of tobacco leaf growth at boron concentration 2.51 ppm (left) with that of minus boron. (right)

B. Iron series

The iron series was started on March 27, 1963. When plants were harvested after five weeks of water culture. The record shows that the tobacco shoot grown in solution without iron was much whiter and weaker than other plants (Fig No. 18). The central leaves became white exhibiting more serious chlorosis than the older leaves. A green network of fine veins was distinct in early stages. (Fig No. 20).

The root system showed an especially development, the lateral roots of iron-deficient tobacco plants were many branched and stubby with club tips. This is in contrast with the normal fibrous type roots when plants are cultured, in iron concentration of 2.5 ppm. The best growth both in tops and roots were 2.5 ppm iron concentration. The leaves are dark green in color, thick and soft in mesophyll (Fig No. 19, 20, 21).

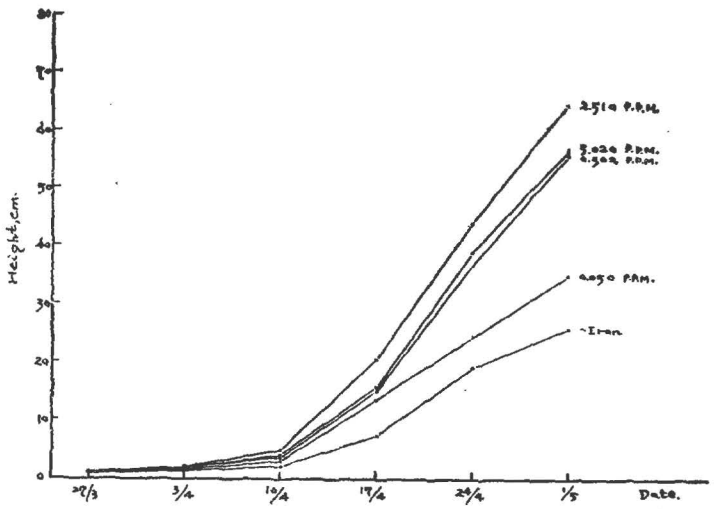
When the iron concentration exceeded 5.0 ppm the growth of tobacco was repressed and fresh, dry weight was reduced (Tab. No. 15, 16. Fig No. 18, 19 Graph No. 14, 15).

The temperature of green house during this culture time are as follow:

TIME / TEMPERATURE	8:00 A. M.	12:00 Noon	5:00 P. M.
Maximum	26.0°C	32.0°C	27.0°C
Minimum	21.0°C	23.0°C	22.0°C
Average	23.5°C	27.5°C	24.5°C

Table No. 14 ***Shoot growth of tobacco at various iron concentrations:***

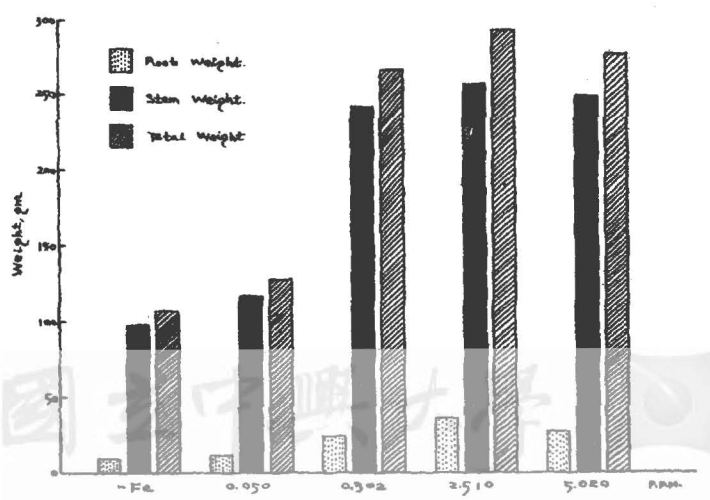
Conc. / Date	Minus Iron	0.050 ppm	0.302 ppm	2.510 ppm	5.101 ppm
Before Culture	1.0 cm	1.2 cm	1.2 cm	1.1 cm	1.3 cm
April	1.2 cm	1.5 cm	1.8 cm	2.0 cm	1.9 cm
April 10	2.5 cm	3.0 cm	3.5 cm	5.0 cm	4.0 cm
April 17	7.5 cm	13.5 cm	15.0 cm	20.5 cm	15.5 cm
April 24	19.0 cm	24.5 cm	37.0 cm	44.0 cm	39.0 cm
May 1	26.0 cm	35.0 cm	56.0 cm	65.0 cm	57.0 cm



Graph No. 13 Showing progress of tobacco growth at various iron concentrations.

Table No. 15 *Fresh weight of tobacco at various iron concentrations*:

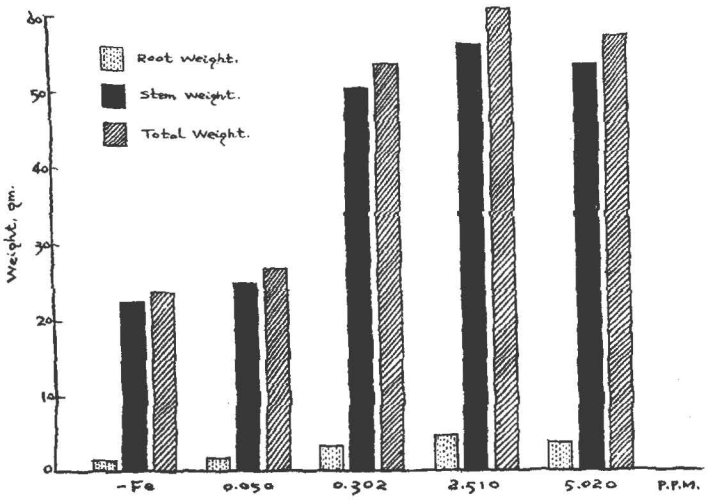
Part. / Conc.	Fresh wt. of stem and leaves	Fresh wt. of root	Total fresh wt. of shoot and root
Minus iron	98 mg	9.5 mg	107.5 mg
0.050 ppm	116 mg	12.3 mg	128.3 mg
0.302 ppm	242 mg	24.5 mg	266.5 mg
2.510 ppm	258 mg	36.0 mg	294.0 mg
5.020 ppm	251 mg	27.8 mg	278.8 mg



Graph No. 14 Showing the fresh weight of tobacco at various iron concentrations.

Table No. 16 *Dry weight of tobacco at various iron concentrations*

Part / Conc.	Dry wt. of stem and leaves	Dry wt. of root	Total dry wt. of shoot and root
Minus Iron	22.5 g m	1.3 gm	23.8 gm
0.050 ppm	24.7 gm	1.8 g m	26.5 gm
0.302 ppm	50.2 g m	3.1 g m	53.3 gm
2.510 ppm	55.9 g m	4.6 gm	60.5 gm
5.020 ppm	53.2 g m	3.8 gm	57.0 gm



Graph No. 15 Showing total dry weight of tobacco growth at various iron concentrations.

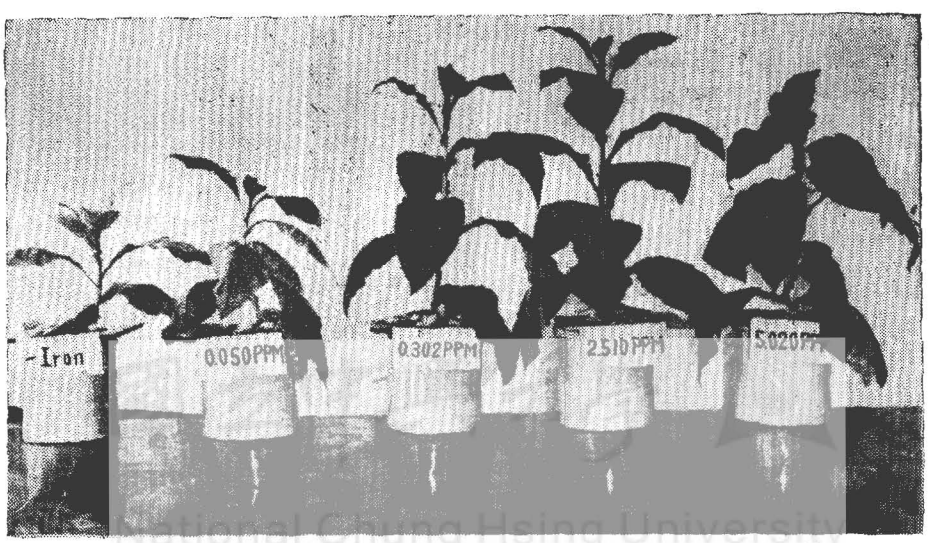
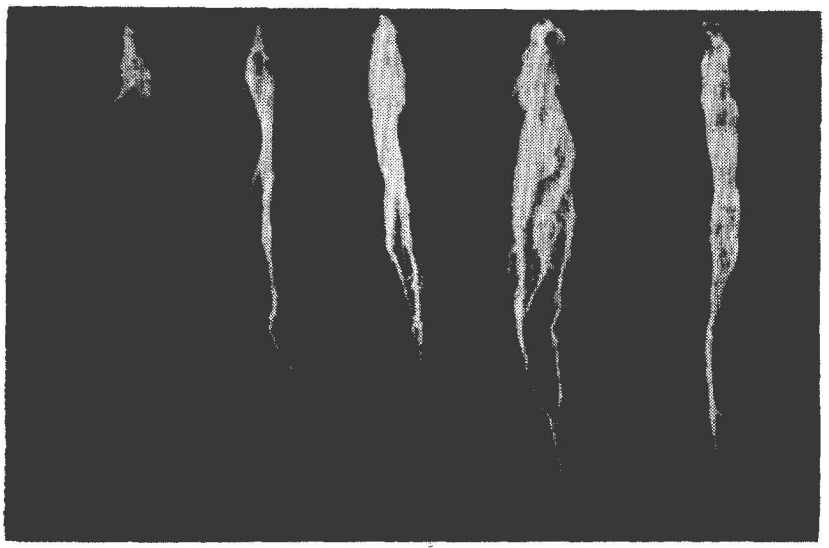
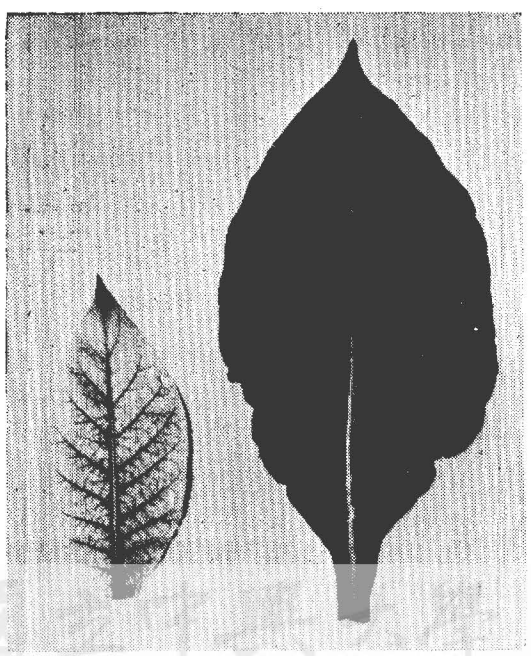


Fig No. 18 Showing tobacco growth at various iron concentrations.



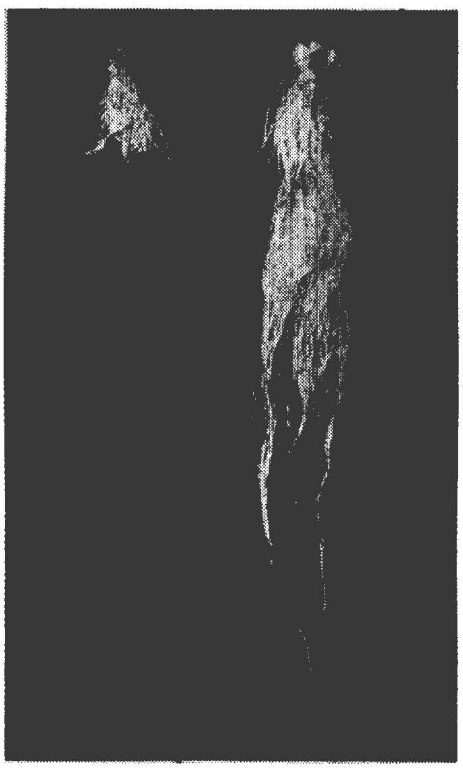
Minus Fe 0.05 0.30 2.51 5.02 ppm

Fig No. 19 The root growth of tobacco at various iron concentrations.



Minus Fe 2.510 ppm Fe

Fig No. 20 Comparison of tobacco root growth at minus iron concentration (left) with that of iron concentration 2.51 ppm. (right).



Minus Fe 2.510 ppm

Fig No. 21 Comparison of tobacco leaf growth at minus iron (left) with that of 2.510 ppm. iron concentration (right).

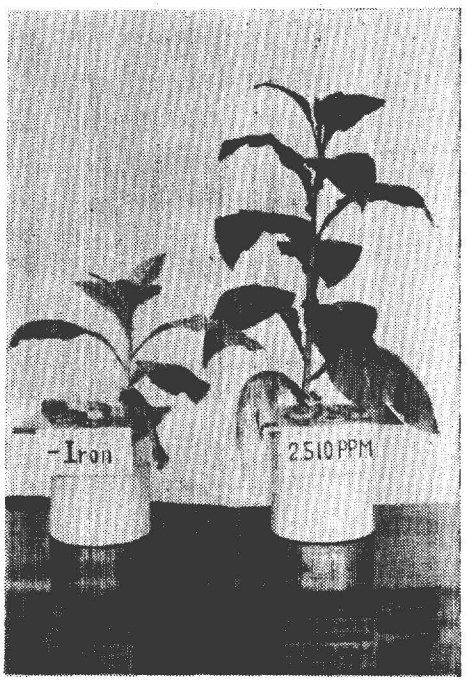


Fig No. 22 Comparison of tobacco shoot growth at minus iron concentration (left) with that of iron concentration of 2.51 ppm. (right).

C. Manganese series

Tobacco was cultured in various concentration of manganese around five week beginning on March 27, 1963, and ending on May of the same year.

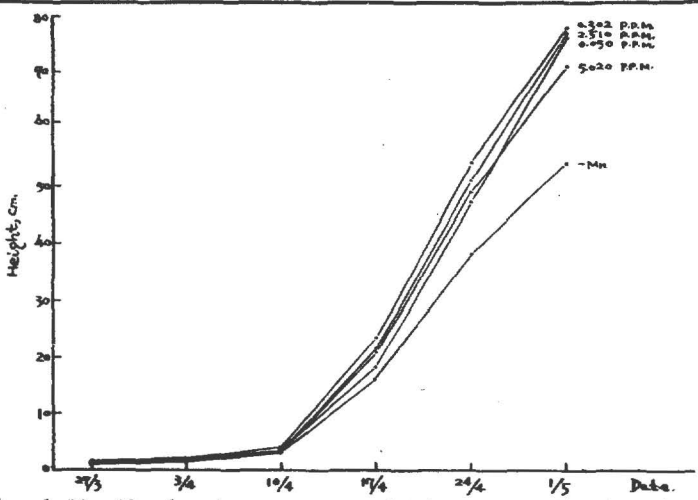
After two weeks manganese deficient plants were a light green in central leaves. After four weeks was observed a somewhat faint intervenal chlorosis beginning near margins of the leaves. Comparison with leaves of plants grown at a 0.302 ppm manganese, illustrates clearly the symptoms of manganese deficiency (Fig No. 26). However not many dfferences were observed in root growth at various managnese concentrations.

As with sugar cane was the concentration of 0.302 ppm manganese to be the best for tobacco growth (Fig. 23, 24).

When manganese concentration exceeded 2.5 ppm the growth was repressed and fresh, dry weight was reduced (table No. 18, 19, Graph No. 17, 18).

Table No. 17 *Shoot growth of tobacco at various manganese concentrations*:

Conc. / Date	Minus Manganese	0.050 ppm	0.302 ppm	2.510 ppm	5.020 ppm
Before Culture	1.0 cm	1.2 cm	1.4 cm	1.3 cm	1.4 cm
April 3	1.5 cm	1.7 cm	2.0 cm	1.9 cm	1.8 cm
April 10	3.0 cm	3.5 cm	4.0 cm	3.3 cm	3.2 cm
April 17	16.0 cm	18.5 cm	23.0 cm	21.5 cm	21.0 cm
April 24	38.0 cm	47.0 cm	54.0 cm	51.0 cm	49.0 cm
May 1	54.0 cm	76.0 cm	78.0 cm	77.0 cm	71.0 cm



Graph No. 16 showing progress of tobacco growth at various manganese concentrations.

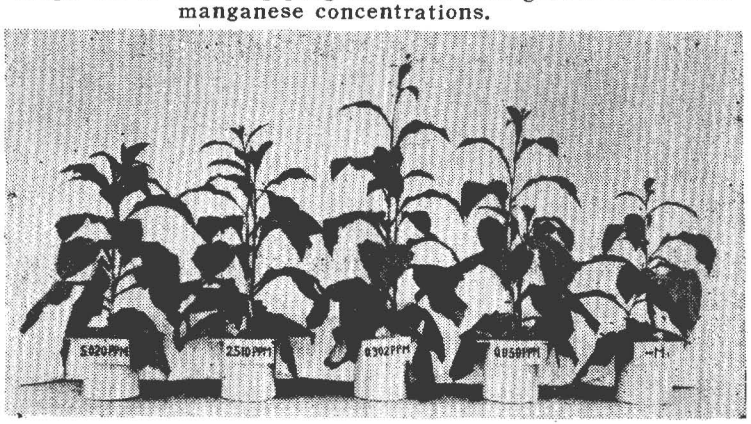
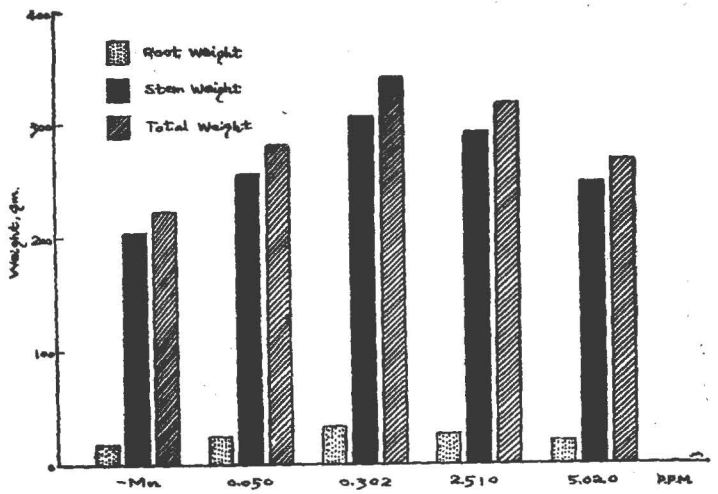


Fig No. 23 Tobacco growth at various manganese concentrations.

Table No. 18 *Fresh weight of tobacco at various manganese concentrations*:

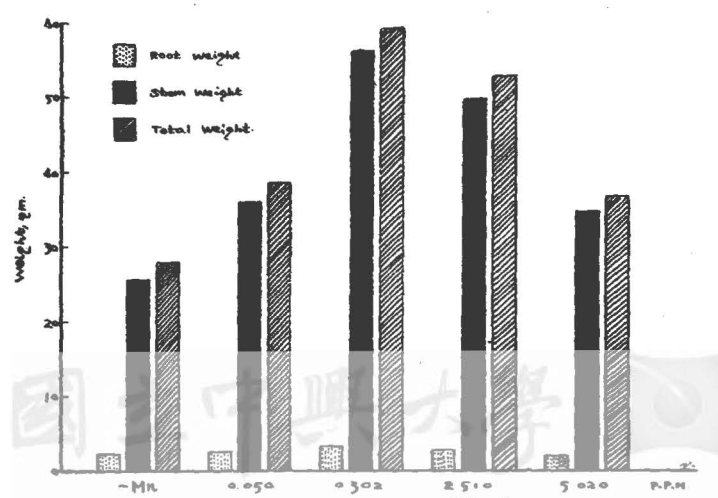
Part / Conc.	Fresh wt. of stem and leaves	Fresh wt. of root	Total fresh wt. of shoot and root
Minusg Manganese	204 gm	18.5 gm	222.5 gm
0.050 ppm	255 gm	25.3 gm	280.3 gm
0.302 ppm	305 gm	34.3 gm	339.3 gm
2.510 ppm	290 gm	26.5 gm	316.5 gm
5.020 ppm	246 gm	20.2 gm	266.2 gm



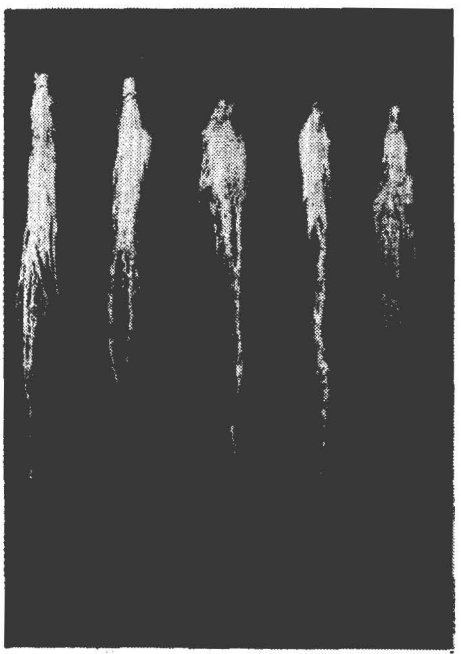
Graph No. 17 Showing total fresh weight of tobacco growth at various manganese concentrations.

Table No. 19 *Dry weight of tobacco at various manganese concentrations:*

Part / Conc.	Dry wt. of stem and leaves	Dry wt. of root	Total dry wt. of shoot and root
Minus Manganese	25.5 gm	2.3 gm	27.8 gm
0.050 ppm	35.8 gm	2.5 gm	38.3 gm
0.302 ppm	55.7 gm	3.2 gm	58.9 gm
0.510 ppm	49.5 gm	2.8 gm	52.3 gm
5.020 ppm	34.5 gm	2.0 gm	36.5 gm



Graph No. 18 Showing total dry weight of tobacco growth at various manganese concentrations.

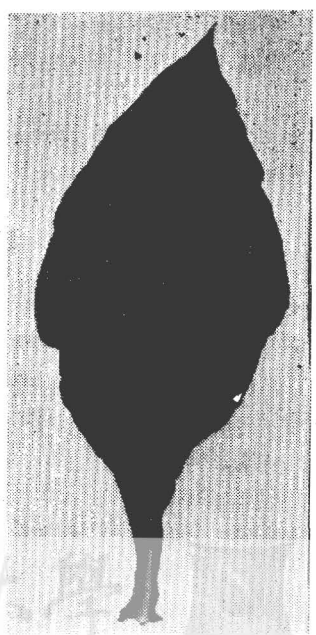


5.0 2.510 0.302 0.05 Minus Mn

Fig No. 24 The root growth of tobacco at various manganese concentrations.

Fig No. 25 Comparison of tobacco shoot growth at minus Mn concnetration (left) with that of manganese concentration 0.302 ppm. (right).

Minus Mn



0.302 ppm Mn

Fig No. 26 Comparison of tobacco leaf growth at minus manganese concentration (left) with that of Mn 0.302 ppm (right).

Summary

When sugar cane and tobacco were cultured at various concentrations of the micronutrients, such as boron, iron and manganese, concentration of micronutrients was found to have an important effect upon their growth.

The records showed that sugar cane and tobacco growth depend on the kind and concentration of micronutrient, and various concentrations of micronutrient produce differences in appearance of both roots and tops, in size, in color, in leaf distortion, etc.

Both sugar cane and tobacco grown in culture without boron, iron and manganese showed deficiency symptoms but in a much different degree in each plant and with each micronutrient. When micronutrient, iron, boron and manganese exceeded a 5.0 ppm concentration growth was reduced which was manifested by decreases in fresh, dry weight of sugar cane and tobacco.

The best concentration of micronutrient for growth of both top and roots differ with plants grown and micronutrients used. If the concentration used is higher or lower than the best concentration, growth is reduced. This is shown quite clearly in the graphs correlating concentrations of micronutrients and plant growth.

2.5 ppm iron concentration is the best for growth in sugar cane and tobacco. From without iron up to 2.5 ppm iron concentration growth gradually increased but the growth is reduced at concentration of iron greater than 2.5 ppm.

The best boron concentration was 2.5 ppm in tobacco and sugar cane but at boron concentration of 0.3 ppm growth in sugar cane was also very good. Therefore we may state that the best boron concentration in sugar cane is between 0.3 ppm~ 2.5 ppm.

The best concentration of manganese was 0.3 ppm for sugar cane and tobacco growth. If a higher or lower than 0.3 ppm is used the growth notably reduced.

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微量元素影響甘蔗與烟草之生長研究**

易　希　道*

甘蔗及烟草行精細之水中培養試驗，結果發現各種濃度不同之鐵，硼錳等微量元素，對此等植物之生長有重大影響，其根、莖、葉等部分發生顯著不同徵狀。

倘缺乏鐵、硼、錳等微量元素，或用量不足，則甘蔗及烟草之生長均受阻，並引起生理上之病徵。但如用量超過 5 ppm，則無論鐵、硼或錳對該等植物之生長與發育均將降低。而最適濃度可促進根、莖、葉等部分之發育與生長，及新鮮與乾燥重量之增加。因此低於或高於最適濃度，生長率均將降低。

鐵之最適濃度爲 2.510 ppm，在甘蔗與烟草之結果相同。

硼之最適濃度在烟草係 0.302 ppm，但在甘蔗則爲 0.302～2.510 ppm，之間。

錳之最適濃度無論甘蔗或烟草均爲 0.302 ppm。

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** 本研究之完成得國家長期發展科學委員會之補助，謹此深致謝忱。