THE EFFECT OF pH AND OF CERTAIN MINOR ELEMENTS ON THE GROWTH OF PINE-APPLES IN WATER CULTURES

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INTRODUCTION

Gumming is prevalent in many pineapple fields in Puerto Rico. A certain amount of yellowing affects pineapple plants and is the cause of considerable losses. In order to determine the effect of minor elements on these diseases water culture experiments were run at this Station for two years. In addition to minor elements the effect of pH was studied.

MATERIALS AND METHODS

One series of experiments was made to study the effect of different pH levels on growth of pineapple; a second series to determine the effect of certain minor elements on growth. In all, 13 treatments or 39 cultures were used. The various treatments are listed in tables 2 and 3.

Pineapple slips from a field near Manatí were used. They were "planted" in holes in lids covering 4 gallon pyrex jars containing the culture solutions. The slips were rooted in sand before the water culture was started. Two slips per jar were used in the pH study and one for the study of the minor elements. Three cultures were replicated for each treatment used.

Distilled water was used for the culture solutions. The greenhouse had open ventilation day and night. A steady flow of air from a central 30 gallon air compressor was bubbled through each of the cultures continuously. The flow was checked daily to make sure of good operation. Every second day 10 cc samples from the respective culture solutions were taken and tested for pH. If the value was different from the assigned value either $Ca(OH)_2$ or H_2SO_4 was added to bring it to the proper pH. The solutions in the jars were changed monthly. The fresh solutions for

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the three replicates of a treatment were made up together in a paraffined wooden mixing tank. The old solution from a culture was siphoned out and replaced by a fresh solution in a few minutes with one-inch rubber tubing.

The culture solutions were compounded from stock solutions of chemically pure salts. The composition of the nutrient solutions used is shown in Table 1. This is a modified form of the solution used by Sideris,

TABLE 1. *Formula for full nutrient of major and minor elements used in the water cultures.*

MAJOR ELEMENTS	MINOR ELEMENTS
N = 100 P P M	Cu = 2 P P M
P = 30	Zn = 2
K = 120	Mn = 2
* Ca = 80	B = 1
Mg = 40	Al = 1
S = variable	Fe = 5

* The amount of Ca was increased whenever $Ca(OH)_2$ had to be used to adjust the pH value.

Krauss and Young (2). In the pH series a complete formula of the major and minor elements was used. To this were added sufficient $Ca(OH)_2$ or H_2SO_4 to obtain the desired pH levels. In the minor element series a complete formula of the major elements was used and the pH value kept at 4.5. The minor elements were omitted one for each treatment as shown in Table 3.

Figure 1 shows the appearance of the cultures near the completion of the experiment.

EXPERIMENTAL RESULTS

A - Results of the pH experiment

In June, 1940, after 6 months of growth in water, one plant from each culture was removed for analysis. The general results from this study were reported in the 1939-40 Annual Report of the Station. The principal observations in this report were that no appreciable growth of either tops or roots occurred at pH 2.5. At pH 3.0 the tops made good growth and had exceptionally high dry weight but the roots were coarse.

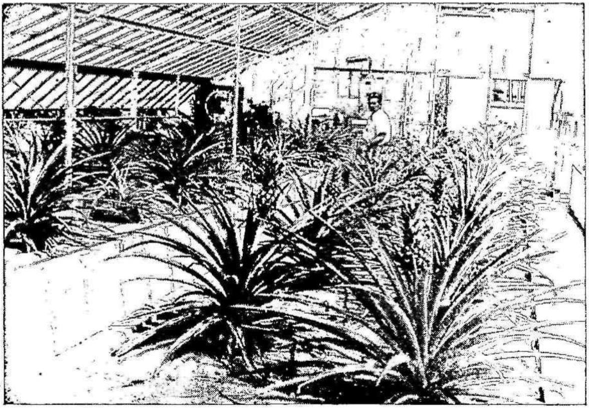

FIGURE 1. *The appearance of the pineapple cultures shortly before the first plants were harvested. The fruits are small due partly to the early flowering.*

At pH 5.0 to 7.0 the tops showed progressively increased chlorosis while the roots became more finely branched. By June there was a chlorotic condition observable with the cultures at pH 5.0, 6.0, and 7.0. In order to overcome the chlorosis these plants were sprayed with a 1% iron sulfate solution in June; also at several later dates whenever chlorotic symptoms appeared. This was done to prevent the death of the plants before the conclusion of the experiment. There was a strong tendency, especially during the first few days after changing solutions, for the solutions of the high pH cultures to become acid and considerable quantities of $Ca(OH)_2$ had to be added to keep the pH at the assigned values.

The plants were forced into premature flowering by applying to the crowns a small quantity of a solution made by adding 2 ounces of calcium carbide to 5 gallons of water in a closed tank. This was done between October 17 and November 9 so that the fruits matured at different dates and could be handled by the drying equipment.

The plants were harvested as soon as the bases of the fruits began to turn yellow. The plants that did not flower were among the last harvested. These were the plants growing at pH 2.5 and two of the plants at pH 7.0. One of the pH 7.0 plants had a very aborted fruit.

Since there were only three plants for each treatment it is difficult to draw conclusions. However, a few trends could be seen during the growth of the plants. These are reflected in the weight results given in Table 2. It appears that the plants grown at a pH of 2.5 made poor

TABLE 2. *The effect of pH on root, top and fruit development of pineapples in water cultures.*

pH	TOPS (EXCLUSIVE OF FRUIT AND CROWN)		ROOTS		FRUITS (EXCLUSIVE OF CROWN)	
	FRESH WT.	DRY WT.	FRESH WT.	DRY WT.	FRESH WT.	DRY WT.
	(GRAMS)	(GRAMS)	(GRAMS)	(GRAMS)	(GRAMS)	(GRAMS)
2.5	1163	197	122	24	0	0
3.0	5609	1001	560	63	2323	279
4.0	9442	1448	707	73	2940	369
5.0	4057	717	330	52	824	108
6.0	4631	725	433	58	1411	194
7.0	9169	1457	453	66	0	0

growth of both tops and roots. Those grown at pH 3.0 and 4.0, respectively, showed progressively better growth. At pH 5.0 the plants showed a poorer growth than at 4.0 or 6.0. The plants at pH 7.0 with the aid of iron sprays made good vegetative growth but probably did not store enough food for fruiting. The higher pH values seemed to promote a better, more fibrous root system while at pH 3.0 a short stubby root system formed. At pH values of 3.0 and 6.0 the most of the gumming occurred but it was not outstanding for some occurred at the other pH values also.

B - Results of the minor element experiments

The minor element cultures were not sprayed with iron sulfate to overcome chlorosis. The cultures without iron and those without aluminum were killed by severe chlorosis and had to be removed from the experiment. All the surviving plants were 'smoked" between October 17 and November 9 for the same reasons given above for the pH cultures.

The results of the fresh and dry weights of the minor element cultures are given in Table 3. The physical appearances of the plants during the experiment are important factors in interpreting these results. The

TABLE 3. *The effect of certain minor elements on root, top and fruit development.*

CULTURES FULL NUTRIENT EXCEPT MINOR INDICATED, ADDED TO CULTURES	TOPS (EXCLUSIVE OF FRUIT AND CROWN)		ROOTS		FRUIT (EXCLUSIVE OF CROWN)		RELATIVE VIGOR JUDGED BY SIZE AND COLOR OF THE PLANTS
	FRESH WT.	DRY WT.	FRESH WT.	DRY WT.	FRESH WT.	DRY WT.	
	(GRAMS)	(GRAMS)	(GRAMS)	(GRAMS)	(GRAMS)	(GRAMS)	
No minor elements*	17,300	2,860	832	70.30	-	-	+ + +
Minus Mn	6,925	1,214	605	67.60	2,309	307	+ +
Minus Zn	6,478	1,169	561	65.50	1,938	165	+
Minus B	5,421	933	424	56.00	1,092	148	–
Minus Cu*	1,924	370	113	22.60	735	114	– –
Minus Al**							– –
Minus Fe***							– – –

* The values given are 3/2-times the weight of two harvested plants. (See text).
** Plants started well but died later.
*** These plants were the first to be killed due to chlorosis.

various cultures, therefore, will be discussed separately in order to correlate physical appearance and weight of plants.

The minus minor element cultures were the most vigorous of all the cultures throughout the entire period of the experiment. One of the cultures was discontinued because it was infected with a root-rot fungus due to the lack of copper. A second plant was started in this jar after it was thoroughly cleaned and copper at the rate of 2 p.p.m. was added. This culture flourished like the two other minus minor element cultures thereafter. These cultures were extremely vigorous vegetatively but did not respond to the "smoking" treatment. Although no minor elements were given to these cultures it is probable that sufficient quantities were carried in the slips used in the experiments. (Figure 2 shows the appearance of one of the minus minor element cultures). The minus manganese cultures were second in vigor (of the minor element cultures). They showed no symptoms of chlorosis at any time.

The minus zinc cultures compared with the other cultures also were vigorous vegetatively and produced better than average fruits. The minus boron plants produced a good vegetative growth but not relatively large fruits. Two of these cultures showed symptoms of mild chlorosis. This may account for the smaller size of fruits. The minus copper plants were very stunted due to the growth of some fungus on the roots reducing them to soft, shiny threads. To the weakest of the three cultures copper at the rate of 2 p.p.m. was added after July 9. The root development and growth of tops increased rapidly on this culture and after 6 months of the copper treatment the plant regained its normal appearance.

The minus aluminum cultures began to show severe chlorotic symptoms the latter part of July and by September two of the plants were removed because the centers were dying. To the third culture aluminum was added at the rate of 2 p.p.m. after September 11. By October a new root development could be seen and by November 2 the center of the plant had made an appreciable new growth (see Figure 3). The new growth was of a pale green color but was a definite recovery.

The minus iron plants became chlorotic by May. They grew to one side and dead, dried areas formed on the older leaves. The immature leaves in the center of the plants seemed to rot off. (Figure 2 shows the appearance of such a severely chlorotic plant). All these plants were dying and were removed on July 1.

No correlation could be seen between minor elements and gummosis.

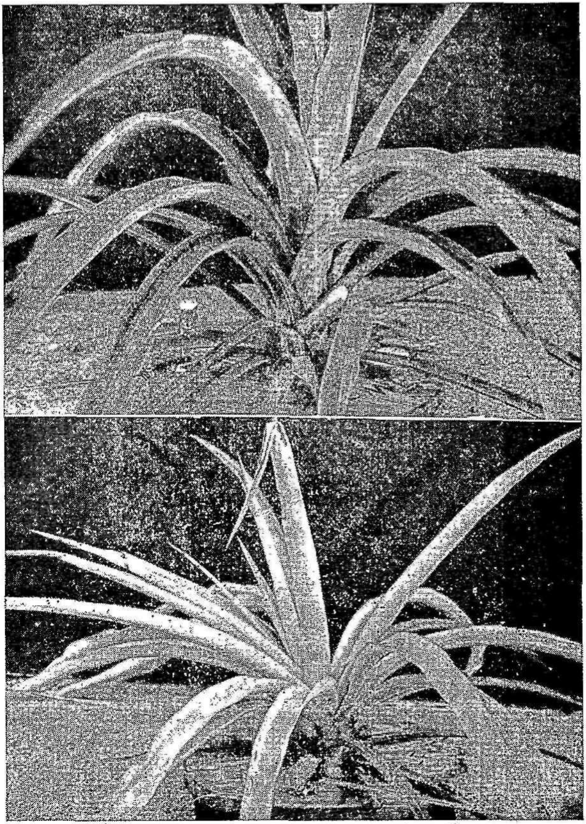

FIGURE 2. *Appearance of a plant receiving iron and no other minor elements (above) and one receiving all the minor elements except iron (below). Note growth to one side and dead areas on mature leaves of the chlorotic plant.*

FIGURE 3. *Response of a chlorotic, minus aluminum plant, to the addition of 2 p.p.m. of aluminum to the culture solution. The killed and injured areas near the tips of the center leaves were formed on growth before aluminum was added. The healthy, new growth below the injured tips resulted when aluminum was added to the culture solution.*

The minus zinc and minus copper plants tended to show the most gumming but there was some gumming on cultures of the other treatments also.

DISCUSSION

For pineapples a pH range of about 4.0 or slightly higher seemed to give the best growth in the water cultures. At pH values above 5.0 the development was hindered by severe chlorosis and at pH values of 3.0 the root development was of a poorly branched, stubby type.

The principal observable effect of the minor elements on the growth of the pineapple was causing or preventing a chlorotic condition. It was found that manganese, and to a lesser extent, zinc, tended to cause a chlorosis. On the other hand aluminum, and to a lesser extent, boron, tended to prevent the chlorosis induced by the presence of manganese. Since the chlorosis was similar to that observed in the field, which could be overcome by spraying iron sulfate on the plants, it seems that the observed effects of the minor elements are indirect. In other words, the minor elements made iron more or less functionable for chlorophyll formation in the pineapple plants. Since iron is an element that is readily oxidized or reduced it is possible that one function, at least, of the minor elements, and perhaps of some ions of the major elements, is to cause a certain degree of oxidation or reduction of the iron in the plant. In a field fertilizer experiment (Schappelle: 1) with pineapples where manganese probably caused a chlorotic condition, the plants were greener where only ammonia rather than nitrate nitrogen was used.

Certain plants may not be very sensitive to the degree of oxidation or reduction of iron while certain ones like the pineapples are. Pineapples seem to require a reduced form of iron. Manganese or some manganese derivative may have caused a certain degree of oxidation of the iron which prevented its normal functions in chlorophyll synthesis. Since aluminum caused the opposite response from that of manganese it may be concluded that aluminum may effect some degree of reduction of the iron which was efficacious to chlorophyll synthesis. It is not impossible that citrus chlorosis and the color of *Hydrangea* flowers are also caused by the indirect effect of certain minor elements, zinc and aluminum, respectively, on the function of the iron in the plant tissue.

The effect of copper on the iron functioning could not be determined in this experiment because of the stunting of the plants, caused by a root-rotting fungus.

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SUMMARY AND CONCLUSIONS

1. A pH value of 4.0 to 4.5 was found to be favorable for the growth of the pineapple plant in water cultures.

2. At pH values above 5.0 chlorosis became increasingly severe.

3. The higher pH values promoted excellent root development while those below 4.0 caused a short, stubby root system.

4. Manganese and zinc tended to cause chlorosis which is due to the nonfunctioning of iron in the plant.

5. Aluminum and boron tended to counteract the effect of the manganese and zinc and tended to cause a normal condition of the pineapple plants.

6. Copper added at the rate of 2 p.p.m. controlled a root fungus that caused stunting of the pineapple plants.

7. No correlation between pH value or minor element composition and gummosis of the fruit could be determined.

SUMARIO

La Acción del pH y de Ciertos Elementos Menores Sobre el Desarrollo de la Planta de la Piña en Cultivos Hidropónicos

1. Quedó demostrado que un valor pH de 4.0 a 4.5 fué muy favorable al desarrollo de la planta de la piña en cultivos hidropónicos.

2. En valores de pH de 5.0 se notó clorosis de la planta en forma muy severa.

3. Los valores de pH de 4.0 produjeron un sistema radical muy reducido, mientras que en los valores más altos de 4.0 el sistema radical fué sumamente favorable.

4. El magnesio y el zinc produjeron una clorosis como resultante de la incapacidad del hierro en entrar en función con respecto a la planta.

5. El aluminio y el borax ejercieron una función protectora en contra de la acción desfavorable del magnesio y zinc y promovieron condiciones normales en las plantas de piña.

6. El cobre empleado a razón de 2 partes por millón limitó el riesgo de un hongo de la raíz que había venido causando perjuicios a las plantas.

7. No se estableció ninguna correlación entre los valores pH o los elementos menores de la solución y la gomosis de la fruta de la piña; con lo que se infiere que es preciso buscar otra causa a esta nueva enfermedad de la piña que viene causando ya estragos en las piñas de exportación.

LITERATURE CITED

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