so are many commercial lawn maintenance people. Adequate diagnosis is necessary if the quality of turfgrass is to be maintained. After proper diagnosis, good usage of chemicals for the specific problem will result in finer turfgrasses for both commercial and home-owned turf.

SOME SYMPTOMS OF MALNUTRITION IN ROSES

J. R. ILEY

Assistant Soils Chemist, Everglades Experiment Station

Belle Glade

T. W. YOUNG

Horticulturist, Sub-Tropical Experiment Station

Homestead

Interest in commercial and garden rose production has increased during the past few years in south Florida. A favorable climate which allows year-round production outdoors, the introduction of *Rosa fortuniana* rootstock (8) which has substantially increased yields in Florida, and a population increase, including retired persons, have all contributed to this increasing interest. However, both the commercial grower and home gardener sometimes attempt to grow roses under natural or induced conditions which lead to failure because of nutritional troubles. Recently, the Everglades and Sub-Tropical Experiment Stations initiated a joint investigation of nutritional requirements and disorders of roses to alleviate these troubles.

Deficiency symptoms for N, P, K, Ca and Mg have been described by Burkhart (2) and Allen (1); N, P, Fe and Mn by Butterfield (3); Fe, Mn and B by Laurie and Kiplinger (6); and B by Davidson and Biekert (4). Laurie and Kiplinger (6) also described symptoms associated with excess quantities of N and K and Marmon (7) has described those for excess Zn.

Nothing was found in the literature, however, on the concentration levels of various elements in rose plants at which symptoms of a deficiency or excess occurred. This paper is a report of progress on an investigation being conducted to produce these symptoms in rose plants on *R. fortuniana* rootstock, to determine the level of the elements in question in leaf tissue, and at the same time, determine if a common method of leaf tissue sampling can be used to detect these deficiencies by chemical analysis. The data reported here are from one experiment only and these results must be considered preliminary until further research is completed.

MATERIALS AND METHODS

A greenhouse pot-culture study was conducted using Pink Frill/*R. fortuniana* plants in randomized block design with 21 treatments and 3 replications. Treatments included Hoagland's No. 2 solution for check and 20 modificiations of this solution as shown in Table 1.

Three-gallon pots lined with polyethylene bags were used. One of the lower corners of the bag was pulled through the side drain hole at the bottom of the pot, the corner cut and a special polyethylene fitting connected. The solution reservoir, a dark polyethylene bottle, was attached to the special fitting with a flexible plastic tubing and all joints were made watertight. Thus, each pot had a separate reservoir which could be elevated and lowered to complete a watering cycle. Each pot was filled with 20 pounds of white silicon sand. Roots of the plants were thoroughly washed before transplanting to these pots where treatments were applied.

Plants were watered twice daily for about 3 weeks and daily thereafter, unless needed more frequently, with solutions which were renewed every 2 weeks.

All chemicals were reagent grade. The water supply was distilled and then passed through a demineralizer before using. When solutions were changed, each container was flushed with 2 liters of distilled and demineralized water and drained before the new solution was added. A relatively constant water level was maintained in the reservoir by adding water.

Kelthane was used for mite control until it gave only limited control. Then, malathion and nicotine sulfate were used one time each. After this, the plants were pruned and kelthane was used again. Following this pruning, additions equivalent to the control treatment were made to

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the minus N, P, and K pots for about two months in order to obtain enoughg rowth for leaf sampling.

After eight months, plus treatments of Mg, Fe, Cu, Mn and B were increased again (Table 1) since toxic symptoms were not present.

The first three compound leaves nearest the growing tip were taken for leaf tissue analyses. This tissue was analyzed by standard chemical methods (5, 9), with nitrogen being determined by a micro-kjeldahl method and potassium with a flame photometer.

Results and Discussion

Symptoms of malnutrition were observed only in part of the treatments. After ten months deficiency symptoms had not occurred in the -Fe, -Mn, and -Zn treatments. This could possibly be due to a contamination which had not been detected or small quantities were present within the plant at transplanting which sustained growth. Toxicity symptoms were observed only with increased Zn and B treatments.

Severe pruning to remove contamination from spray materials used, and to help induce deficiencies resulted in the loss of a number of plants and rendered statistical treatment of the chemical analyses questionable. Also, the small sample size, especially from deficient plants limited the number of determinations that could be made.

Table 1. Treatments in malnutrition investigation with roses.

Element	Total Amount Per Treatment 1/		
		Modifications	
	Check	Minus 2/	Plus 3/
		ppm	
N	210	----	420
P	31	----	62
K	234	----	468
Ca	160	----	320
Mg	48	----	96 (192) 4/
Fe	0.5-1.0	----	5 (20) 4/
Cu	0.02	----	0.2 (0.4) 4/
Mn	0.5	----	5.0 (15.0) 4/
Zn	0.05	----	0.5
B	0.5	----	2.5 (5.0) 4/

1/ Molybdenum was applied to all treatments at a concentration of 0.05 ppm.

2/ These ten treatments contained the same concentration of all other elements as the control except they are deficient for the element as marked in this column.

3/ These ten treatments contain the same concentration of all other elements as the control except they contain the concentration for the element as designated in this column.

4/ Concentrations applied after eight months.

Nitrogen. Plants failed to make additional growth shortly after being placed in the nutrient solution without nitrogen. Leaves turned from green to pale green with some progressing to yellow. Angular necrotic areas appeared in the interveinal tissue of some leaves as the condition became more severe. Leaves had a glossy appearance and the margins showed a tendency to curl down. Use of nicotine sulfate spray in the greenhouse resulted in limited new growth on these plants.

Leaves of plants of the +N treatments were initially smaller compared to most other treatments and appeared to mature more slowly, as indicated by a lighter green color and a tender appearing leaf surface which lacked the sheen of mature leaves.

Phosphorus. After plants wer placed in the nutrient solution without phosphorus new growth emerged, but after this matured, the plants appeared to be in a dormant stage. The leaves became darker green than the check and plants of other treatments and had a hardened appearance as if they were made of wax. New growth did not appear until plants were sprayed with malathion. This flush was very small and of a short duration.

Phosphorus was added to this treatment for two months to stimulate growth for obtaining leaf tissue at a later date for analysis. This tissue was collected when all other treatments were sampled. At this time vigorous growth had been reduced as compared to the check and some of the other treatments, but it did not appear to be near a stage of severe limitation. Leaf tissue at this time contained 0.08, 0.09 and 0.11% phosphorus for the three replications compared to 0.35% for the check, a single plant, whose phosphorus value was similar to those of other treatments (Table 2).

There was a definite reduction in potassium uptake in the −P treatment. Replicate values of 1.27, 1.30 and 1.32% potassium were compared to a value of 1.85% for the check and similar values for most of the other treatments.

The +P treatment appeared to be one of the most vigorously growing treatments. There were not any noticeable adverse effects from this treatment.

Potassium. The introduction of plants to a nutrient solution without potassium resulted in a small flush of new growth that was severely chlorotic. Newly emerging leaves of this flush, which were normally a deep dark red, were yel-

Table 2. Leaf tissue analyses of minus and plus treatments with Pink Frill *R. fortuniana*. 1/

	P	K	Ca	Mg	Cu	Zn	Fe	B
	%				ppm			
1. Check	.35	1.85	1.62	.39	1.8	6.9	41	65
22. -N	.27	1.65	----	---	3.6	5.1	43	57
3. +N	.23	1.72	----	---	2.3	3.6	35	47
4. -P	.09	1.30	----	---	3.0	4.7	49	70
5. +P	.41	1.94	----	---	2.7	4.4	41	61
6. -K	.33	.33	3.74	.56	1.6	9.6	27	67
7. +K	.29	2.17	1.53	.28	2.8	6.1	48	68
8. -Ca	.33	1.72	----	.36	2.2	4.5	39	--
9. +Ca	.29	1.90	2.37	.33	2.4	4.0	51	56
10. -Mg	--	----	----	---	---	---	--	--
11. +Mg	.30	1.85	1.82	.36	2.2	4.6	46	56
12. -Fe	.29	1.72	----	---	3.2	4.8	47	57
13. +Fe	.27	1.96	----	---	3.1	6.1	75	58
14. -Cu	.31	1.82	----	---	1.5	4.6	47	63
15. +Cu	.30	1.99	----	---	6.4	4.6	40	58
16. -Mn	.24	1.88	----	---	2.2	3.5	35	52
17. +Mn	.31	1.85	----	---	2.1	5.0	42	50
18. -Zn	.22	1.63	----	---	2.4	3.3	181	44
19. +Zn	.26	1.66	----	---	2.9	9.7	50	54
20. -B	.24	1.66	----	---	3.0	5.0	73	56
21. +B	.27	1.66	----	---	3.1	4.0	47	114

1/ All values are averages of three replications except treatments 8 and 15 which are averages of 2 replications. Values for treatments 1 and 6 are values for single plants only. Plant losses in treatments 1, 8 and 15 were due to severe pruning.

low with an orange tinge at the margins. When they grew older they exhibited a pattern that appeared to be that of iron defnciency (Fig. 1). As the condition progressed, the older leaves became necrotic. Slight new growth emerged after contamination with a nicotine sulfate spray. This new growth also was chlorotic. Potassium was added to this treatment for a two-month period, but only one plant survived. Later, leaf tissue was removed and analyzed. It contained 0.33% potassium as compared to 1.85% for the single check plant and similar values for the other treat-

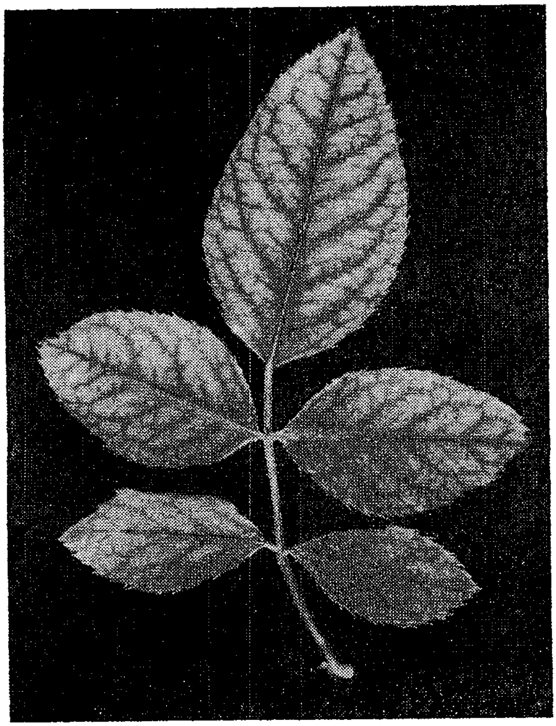

Figure 1.—Leaf symptom of plant where potassium was deleted from the nutrient supply.

ments. Reduced growth of this plant suggested that it was entering, or very near a potassium deficient period, although the symptoms previously described were not present. The calcium and magnesium content indicated that increased amounts of these bases had been taken up due to the lack of competition from potassium. This single plant also contained a high leaf zinc content when compared to other treatments, and a lower copper value. The low iron value found and the symptoms described indicated that there may be a relationship between potassium and iron.

The +K treatments grew vigorously with the red pigmentation of the new shoots being very bright in color. Adverse effects were not noted.

Calcium. Leaflet tissue of new growth of plants placed in a nutrient solution without calcium was reduced to a narrow margin around the midrib. Mature leaves became pale green to yellow with darkened areas of hardened tissue forming on the leaves. These areas contracted the tissue and gave it a puckered appearance. This condition also occurred in the treatments without magnesium during the summer and may have been an effect from a combination of the weakened condition of the leaf and the high temperature. There was very little new growth and the plants became progressively worse with leaves dying. Addition of calcium to these treatments did not revive the plants and new plants were placed in the containers after calcium had been added and then withheld from the nutrient supply. Leaf tissue samples were contaminated during a hurricane with whitewash used for greenhouse shading. Attempts to remove the contamination by washing the leaves were not successful.

The increase in calcium did not give visual differences, but the calcium content of the leaves was higher and was believed not to be due to contamination.

Magnesium. Growth was made by plants for a short period after they were placed in a nutrient solution without magnesium. Leaves of new growth were lighter in color and lacked the glossy appearance of leaves from plants of other treatments. The leaves appeared weak and lacking in vigor. A few of the older leaves exhibited an oval ring on the leaflets outlined by hardened tissue (Fig. 2). Darkening of the entire tissue of the leaflets except for the outer edges was more predominant. The leaves had more rounded tips than those of the check plants and other treatments.

The increased magnesium treatment did not appear to have any effect, visual or chemical, on the plants.

Iron. Plants grew vigorously in the treatments with and without added iron. From the analyses it appeared that a sufficient amount was present for growth. The sand medium may have contained traces which were sufficient for plant growth.

Copper. Plants placed in a nutrient solution without added copper did not appear to be adversely affected in growth. Later, one of three plants showed a persistent chlorotic leaf condition. Another plant developed this condition but it disappeared. The veinal area was dark green with the interveinal area presenting varying degrees of lighter green. This gave a mottled chlorotic appearance with a dull cast. The leaves appeared to be slightly smaller than those of the check plant. The copper content of leaf tissue at the time of sampling was 1.5, 1.7 and 1.3 ppm of copper for the three replications. This is not much less than 1.9 ppm of copper for the check plant but it was lower than most other treatments.

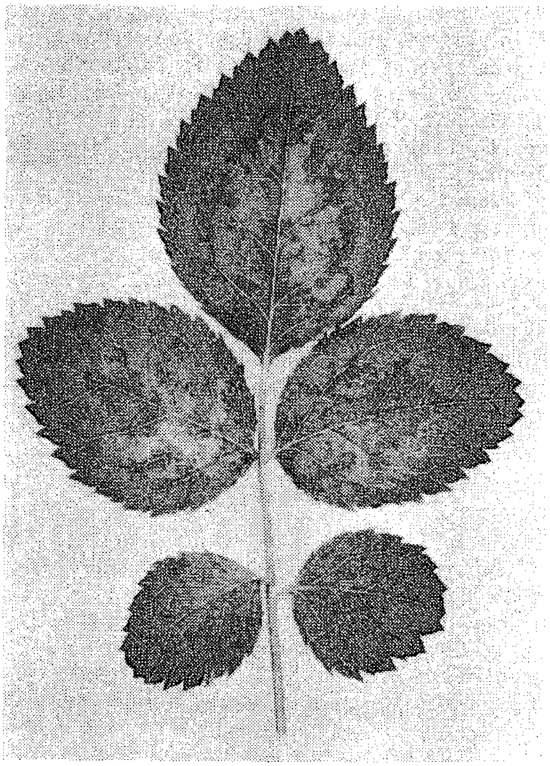

Figure 2.—Leaf symptom of plant grown in a solution culture without added magnesium.

The increased copper treatment did not appear to have a toxic effect on the plants. The copper content of leaf tissue of this treatment was 6.4 ppm.

Manganese. Plants in solutions with and without added manganese did not appear to be affected by these treatments. At times, the new growth of the +Mn treatment appeared to have more of a bluish hue than that of the check and other treatments.

Zinc. Plants placed in a nutrient solution without added zinc did not appear to be affected visually in any manner. The zinc content of leaf tissue was found to be lower than in most treatments. However, the iron content was much higher than in other treatments with 139 and 224 ppm of iron for the two surviving replications, as compared to 41 ppm of iron for the single check plant which was similar to other treatments. This high iron content was probably due to an accumulation of iron on the root surface in the absence of a higher zinc concentration and subsequent uptake due to mass action.

At first the high level of zinc did *not affect* plant growth. After approximately eight months the new leaves became cupped, very glossy and dark olive-green in color. This color was due to the retention of a red pigment which normally disappears as the leaf develops and approaches maturity. The newly emerging leaves had an abnormally small, narrow appearance. As the plants progressed, this condition became more and more like that of the minus boron treatment. The growth at the stem terminal was the area affected, with short internodes and deformed growth. The leaves sampled contained 5.2, 13.5, and 10.3 ppm zinc for the 3 replications as compared to 6.9 for the single check sample. Probably if the affected part of the plant had been sampled, higher values would have been obtained.

Boron. Plants were not affected until approximately eight months after they were placed in a nutrient solution without boron. Leaves at terminal growth became severely chlorotic, starting with the midrib and progressing toward the outer edge of the leaflet. This chlorotic pattern was due to the dying petiole (Fig. 3). This condition became more severe, resulting in necrotic

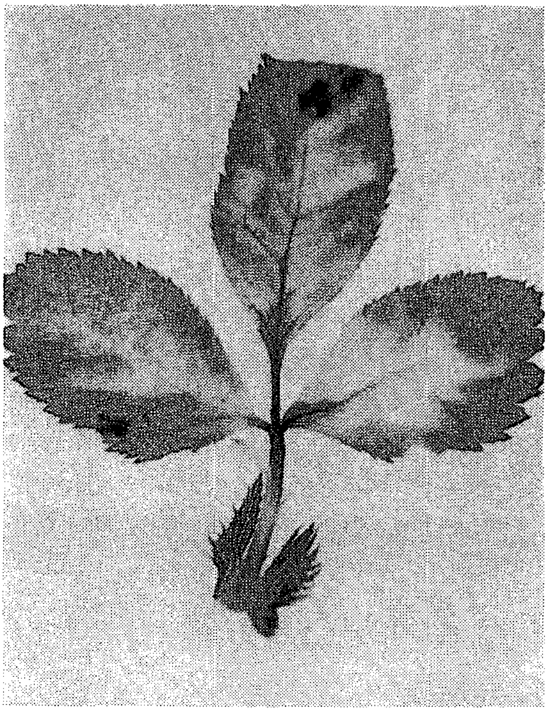

Figure 3.—Dying petiole of leaf where boron was deleted from the nutrient supply.

leaves at the stem terminals. Multiple sprouting at the terminals, with deformed new growth and sometimes cupped leaflets, occurred. Analysis of the first fully mature leaves from the growing point gave boron values of 48, 55, and 66 ppm for the 3 replications. This was not different from the single check plant which contained 65 ppm boron, or most of the other treatments which contained similar values. Apparently the leaves sampled were not from the correct part of the plant to determine this deficiency by chemical analysis.

The plants of the 3 replications of the plus boron treatment developed a chlorotic marginal ring on the older leaves about two months after being placed in this solution (Fig. 4). The outer edges of the leaves became necrotic and this chlorotic condition progressed slightly inward. With vigorous growth this condition disappeared. At the time of sampling this condition did not exist. The leaves of the 3 replications contained 96, 113 and 132 ppm boron. This concentration would probably be greater in the older leaves of the plant.

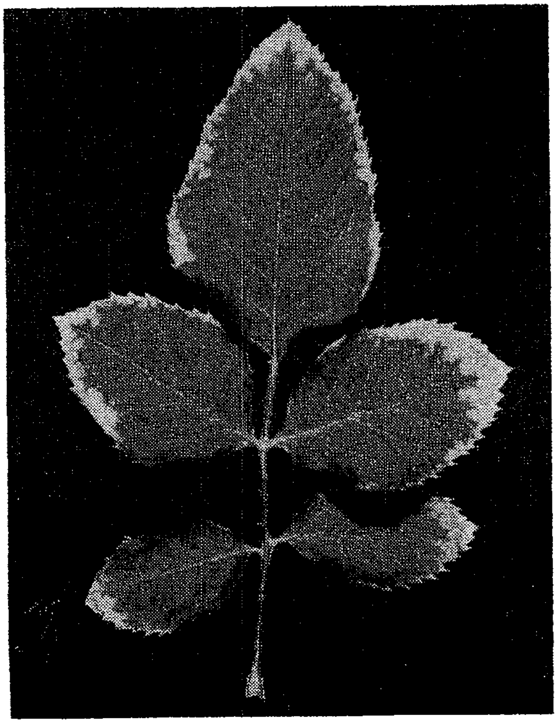

Figure 4.—Chlorotic marginal ring of leaf from plant where boron level was increased.

From the results of this one experiment it is suggested that the part of the plant to sample for the chemical detection of deficiencies or toxicities would be the one affected by the element in question.

The values reported here for copper and zinc are relatively low compared to values of other plants. Zinc was found to be very toxic while the concentration of copper used did not affect the plants on this particular rootstock.

Summary

Roses (Pink Frill *R. fortuniana*) were grown in replicated series of sand culture with Hoagland's No. 2 solution and 20 modifications of this solution in which N, P, K, Ca, Mg, Cu, Mn, Fe, Zn, or B were omitted or increased. Deficiency symptoms of N, P, K, Ca, Mg, B, and possibly Cu, and toxicity symptoms of Zn and B were observed and described.

Leaf tissue samples were analyzed quantitatively for these elements. The results obtained, together with comments on deficiency or toxicity symptoms in the plants, are given.

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