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Mineral Deficiency Symptoms of Waterhyacinth[1]

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ABSTRACT

Healthy waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) ramets of known size and weight were selected from a monoclonal population and transplanted to polyethylene tubs containing culture media deficient in either N, P, K, S, Mg, Ca, or Fe. The plants were observed daily, photographed after 4 weeks, and the visual mineral deficiency symptoms recorded. The most apparent symptom of the various deficiencies was the change in color; all plants grown in N-, P- and S-deficient media exhibited blue roots. Foliar chlorosis was observed in both N- and S-deficient plants, while P-deficient plants exhibited dark green leaves. Magnesium-deficiency resulted in a necrotic area first appearing at the apex of the leaves and then chlorosis spreading basipetally. Iron-deficient plants exhibited interveinal chlorosis. Potassium-deficient plants displayed brown bands across the mid to upper leaf region. Calcium-deficient plants exhibited brown spots on the leaves and petioles and then subsequent necrosis. The deficiency symptoms of waterhyacinth are discussed and presented in a tabular form similar to other mineral deficiency keys.

Key words: Eichhornia crassipes, nutrition, nitrogen, phosphorus, potassium, sulfur, magnesium, iron, calcium.

INTRODUCTION

Recently, interest in waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) has increased as their potential for use in removing nutrients from water bodies, particularly in wastewater treatment facilities, has become more widely recognized. Although the plant has not been studied as extensively as traditional crop plants, scientists have studied the ability of waterhyacinth to remove N and P. Phosphorus reduction values from 32 to 61% and N reduction values of 75 to 94% are reported (Clock, 1968; Sheffield, 1967; Reddy et al., 1982). However, the extent of nutrient removal is dependent on the growth rate of the plants, the detention time of the effluent in wastewater retention ponds, the water depth (Cornwell et al., 1977) and the nutrient content of the growth media. Apart from N, P and K, research conducted on other nutrients has emphasized correlations between plant tissue and the growth media nutrient concentrations (Gossett and Norris, 1971; Wolverton and McDonald, 1979; Boyd, 1976; Haller et al., 1970). Cooley et al. (1978) and Cooley and Martin (1980) used radioisotopes to conduct a more indepth study of waterhyacinth nutrition. They observed a positive correlation between root retention of various nutrients and the solubility of sparingly soluble salts such as metal carbonates. El-Sharkawi et al. (1980) investigated the nutrient fluxes of roots of waterhyacinth stressed by reduced water potentials. This was one of few studies which have examined S nutrition of waterhyacinth.

There are a number of potential problems associated with using waterhyacinth for nutrient removal. In a wastewater treatment system growing conditions for waterhyacinth are variable, and it is not known what conditions would maximize nutrient uptake and subsequent plant growth. For years agronomists have been able to diagnose plant nutritional problems related to soil fertility by observing symptoms plants display when nutrient stressed. Several comprehensive guides have been written which describe these symptoms (Chapman, 1966; Sprague, 1964). A key describing nutrient deficiency symptoms of waterhyacinth would be a useful tool not only as a means to rapidly determine possible nutrient imbalances in wastewater effluent, but also, it could be used to give an indication of the nutrient status of natural lakes within which waterhyacinth may be growing.

Desougi (1984) studied the growth and reproduction of waterhyacinth that were deprived of N, P, K, Ca, or Mg. The total nutrient concentration of these solutions varied considerably, and therefore it was not valid to make quantitative comparisons, and qualitative comparisons were not described. This paper qualitatively describes the symptoms displayed by waterhyacinth which were grown in nutrient deficient media.

MATERIALS AND METHODS

Healthy waterhyacinth plants approximately 4 weeks old were selected on the basis of uniform size and weight from a monoclonal population maintained in outdoor culture tanks. The stock plants were maintained in 900 l

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tanks containing 10% Hoagland's solution (Hoagland and Arnon, 1950) made with well water. The stock tanks were drained and fresh solutions were added every 2 weeks.

Three plants of known fresh weight were placed in each of eight polyethylene containers with 20 l of nutrient solution. Fresh weights were obtained by draining the plants for 4 minutes prior to weighing. The mineral deficient growth media (solutions) described by Hoagland and Arnon (1950), were made using deionized water. They were made at 20% full strength and were deficient in either N, P, K, S, Mg, Fe, or Ca. The control media contained 20% Hoagland's complete solution with no mineral deficiencies. All treatments and control solutions, contained full strength essential micro-nutrients. Iron was supplied in the chelated form (Sequestrene, 330 Fe, Ciba-Geigy). The pH of the culture media ranged from 5 to 7, well within the limits reported for active growth of waterhyacinth (Haller and Sutton, 1973). The plants and containers were placed in a greenhouse at the Agronomy Unit, located at Biven's Arm on the University of Florida campus. The plants were grown under ambient temperatures and prevailing light conditions. The volumes of the solutions were maintained by the daily addition of deionized water, and all the culture solutions were changed weekly to minimize algal growth and contamination.

Plants were observed daily and changes in appearance, growth and coloration were noted. After 4 weeks all plants were visually inspected and the mineral deficiency symptoms recorded. The experiment was repeated at different times of the year (spring, summer and fall) to ensure the results were valid over the range of growing conditions in north central Florida.

RESULTS AND DISCUSSION

The elemental contents of the culture media in which the plants were grown are listed in Table 1. Data collected were qualitative, based on the appearance of the plants grown in the different solutions. The nutrient deficiency symptoms displayed by the plants were in many cases distinctly different from each other. A summary of the responses of waterhyacinth to the different nutrient deficient solutions is presented in Table 2. One most obvious difference among these symptoms is that of color; both roots and shoots exhibit distinct differences. The leaves and petioles of N- and S-deficient plants (Figure 1a) displayed an overall chlorosis. The roots were dark blue and extended.

Phosphorus-deficient plants (Figure 1b) also exhibited blue roots, however these were more irridescent in color and had a bushier appearance. The petiole of some plants exhibited a purplish coloration. In agronomic crops, P deficiency was found to result in sugar accumulation. High sugar concentrations often favor anthocyanin formation which produces a reddish color (Sprague, 1964; Meyer et al., 1973). Phosphorus-deficient plants differed from the N- and S-deficient plants by the healthy green appearance of the leaves and no sign of chlorosis.

Leaf and petiole chlorosis was particularly striking in plants deficient in Fe (Figure 1c). Due to the immobility of Fe within plant tissues, interveinal chlorosis of the newer leaves and the ramets occurred. Plants under severe Fe

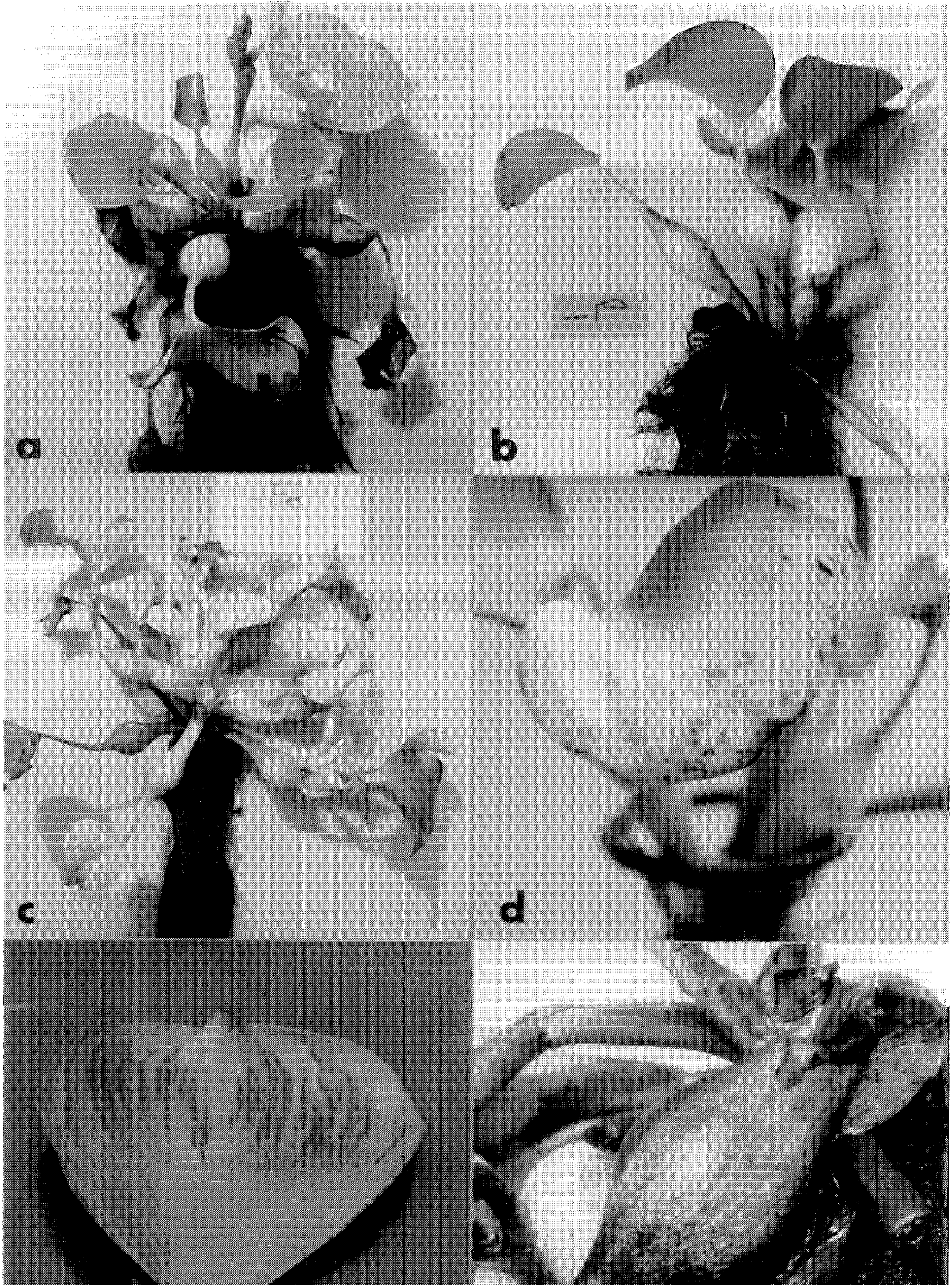
TABLE 1. CALCULATED INITIAL SOLUTION CONCENTRATIONS OF 20% HOAGLANDS MINERAL DEFICIENT SOLUTIONS IN WHICH WATERHYACINTH WERE GROWN TO DETERMINE DEFICIENCY SYMPTOMS.

Culture Solution	Elemental content ($mg\ l^{-1}$)					
	N	S	P	K	Mg	Ca
–N	0	45.5	6.2	39.1	12.6	20.0
–K	28.0	16.7	6.2	0	12.6	44.1
–P	39.2	16.7	0	46.9	12.6	32.1
–Ca	14.0	16.7	6.2	46.9	12.6	0
–Mg	39.2	9.6	6.2	78.2	0	32.1
–S	46.5	0	6.2	54.7	12.6	32.1
–Fe	42.0	16.7	6.2	46.9	12.6	32.1
Control	42.0	16.7	6.2	46.9	12.6	32.1

TABLE 2. KEY TO THE NUTRIENT DEFICIENCY SYMPTOMS OF WATERHYACINTH GROUPED ACCORDING TO COLOR.

	I.	Plant light green to yellow green, not striated.
–N	i)	All leaves exhibit yellow-green color, more pronounced on older leaves. Retardation of growth, plant appears stunted. Roots extended growth, blue,dark blue-black color.
–S	ii)	Symptoms similar to nitrogen shortage, leaves uniform light yellowish-green, not as pronounced as nitrogen shortage over same time period. Retardation of growth, plant appears stunted. Roots extended growth, blue in color.
–Fe	iii)	Whole plant extremely chlorotic, advance case of Fe deficiency.
	II.	Plant normal to darker green.
–P	i)	Retardation of growth, smaller leaves and petioles. Petioles may have distinct reddish coloration at base. Roots, blue, shorter and bushier than those of N and S deficiency.
	III.	Overall color of plants is normal, have striations.
–Fe	A.	Plant exhibits longitudinal, interveinal chlorosis. Appears first in younger leaves, older leaves may still be green.
	B.	Leaf blades are spotted, freckled or have clear lesions.
–Mg	i)	Apex of leaf browns followed by yellowing of leaf from tip to base.
–K	ii)	A brown band forms in mid to upper region of leaf. Roots have extremely short branches.
–Ca	iii)	Small brown spots appear on leaf and petiole spotting becomes abundant. Roots have extremely short branches. Severe deficiency leads to quick death of the plant.

Figure 1. a—upper left. Nitrogen-deficient plant showing reduced growth and leaf chlorosis. b—upper right. Phosphorus-deficient plant exhibiting shortened leaves and petioles and deep green leaf coloration. c—center left. Typical iron deficiency symptoms of waterhyacinth include overall chlorosis and yellow striations of the leaf. d—center right. Magnesium-deficient waterhyacinth leaves typically first show a necrotic spot, followed by chlorosis advancing from the leaf tip toward the petiole. e—lower left. Potassium deficiency symptoms are characteristic brown bands on the distal end of the waterhyacinth leaf. f—lower right. Calcium deficiency symptoms appear rapidly with brown spots occurring on the leaves and petioles, which soon turn black and die.


a
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deficiency appeared almost bleached-white on the youngest organs. In contrast to Fe, where chlorosis was distinct on both leaf and petioles, Mg deficiency was apparent only on the leaf blades (Figure 1d). Initially Mg deficiency was observed as a discrete brown spot at the apex of the leaf. As the symptoms became more pronounced the brown spot expanded into a chlorotic area which then spread basipetally.

The final two deficiency symptoms studied, K (Figure 1e) and Ca, (Figure 1f) were both characterized by brown lesions. A brown band appeared in the mid to upper region of the leaf in K-deficient plants. The height, petiole diameter and root branches were also reduced in size or stunted.

However, of all the symptoms observed, Ca-deficient plants displayed the most dramatic response. In all other treatments the plants were still actively growing at the end of the experimental period, while plants grown in Ca-deficient solutions died within 2 weeks. Further research has been conducted on the Ca nutrition of waterhyacinth (Newman, 1987).

This study clearly demonstrated that nutrient deficiency symptoms can be observed visually in waterhyacinth. However, care should be taken when using qualitative data such as these because they are based upon the deficiency of a single element. Combined elemental deficiencies may result in different visual symptoms. These data, however, do provide an initial step for diagnosing nutrient deficiencies in waterhyacinth.

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