Uptake Of Copper By Water Hyacinth[1]

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INTRODUCTION

Copper sulfate pentahydrate (hereinafter referred to as CSP) has been used extensively for the control of some aquatic vegetation since it was first recommended in 1904 (7). CSP is probably the most economical herbicide used in the aquatic environment.

Concentrations of CSP at 1.0 ppmw of copper or less will control most species of algae (2, 3, 9, 10). However, some species, i.e. *Pithophora* spp., are relatively resistant to CSP and require high concentrations, or repeated applications, or both for control. Some submersed species may be controlled with CSP at 100 to 500 lb/A (5, 6, 13). Many emersed species are resistant to the phytotoxic effect of CSP (9, 11),

Very little information is available on the effect of CSP on floating aquatic plants. Therefore, a study was initiated to determine the effect of CSP on the growth of water hyacinth (*Eichhornia crassipes*) (Mart.) Solms) and to measure the copper content of the plants after treatment.

Recent evidence indicates that some aquatic plants may contain high concentrations of copper after treatment with CSP. Concentrations of 300 to 4,820 ppmw were found in plants after treatment of an irrigation canal with a theoretical copper concentration of 0.17 ppmw for a 99-day period (1). Southern naiad (*Najas guadalupensis*) (Spreng.) Magnus) and hydrilla (*Hydrilla verticillata* Casp.) contained 1,430 and 2,650 ppmy of copper, respectively, 1 week after treatment of plants with CSP at 1.0 ppmw of copper in large plastic pools (12).

METHODS AND MATERIALS

Water hyacinth was collected from canals near Fort Lauderdale, Florida and placed in containers with fertilized pond water. After several weeks in the greenhouse these plants had vegetatively produced numerous daughter plants. Daughter plants in the four to five-leaf stage were selected for uniform size and then individually placed in aluminum foil-coated glass jars containing 900 ml of one-half strength Hoagland's Number 1 nutrient solution (4) with a chelated source of iron. The plants were allowed to grow in the greenhouse for 1 week, after which they were termed 1-week-old plants.

Root treatments with CSP in 900 ml of nutrient solution were conducted in the greenhouse during January and February of 1970. Plants 1 week old were selected for uniform shoot size and treatments applied according to a randomized complete block design. Each treatment concentration was replicated four times.

Water hyacinth was placed in treatment solutions containing CSP equivalent to 0.25, 0.5, 1.0, 4.0, 8.0, and 16.0 ppmw of copper. After 1 week the plants were removed from the solutions and separated into shoots and roots. The roots were rinsed in 1.0 l of distilled water for 1.0 min. After drying at 60 C, dry weights of the shoots and roots were determined. Copper in dry plant material was measured by atomic absorption spectrophotometry as described by Sutton, *et al.* (12). Transpiration of the plants was determined by volumetrically measuring the treatment solution and corrections were made for evaporation loss.

Another group of 1-week-old plants was treated with CSP equivalent to 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0 ppmw of copper. The treatment solutions were replaced at the end of 1 week and the plants harvested after 2 weeks. In this case the plants were separated into leaves, petioles, roots, and new shoots prior to analysis for copper content.

RESULTS AND DISCUSSION

Transpiration of water hyacinth was lower after the roots of 1-week-old plants were placed in solutions containing CSP at 4.0 ppmw of copper or higher for 1 week than in the control plants (Table 1). The shoot dry weight of these plants was reduced by CSP at 8.0 ppmw of copper or higher; however, the dry weight of the roots was reduced only by the 16.0 ppmw of copper treatment.

Increase in CSP in the root treatment solution from 0.25 to 2.0 ppmw of copper for 1 week did not increase the copper content of the shoots as compared to the control. These plants contained an average of 24 ppmw of copper after a 1-week treatment period. The shoots of those plants

TABLE 1. TRANSPIRATION AND PLANT DRY WEIGHT 1 WEEK AFTER ROOT APPLICATIONS OF CSP TO 1-WEEK-OLD WATER HYACINTH.

Treatment Concentration of CSP (ppmw of copper)	Transpiration[a] (ml)	Dry weight (g)[a] Shoot	Dry weight (g)[a] Root
Control	332 c	2.28 b	0.62 bcd
0.25	313 c	1.98 b	0.53 abc
0.50	311 c	2.05 b	0.56 abcd
1.00	343 c	2.32 b	0.75 d
2.00	345 c	2.38 b	0.69 cd
4.00	223 b	1.88 b	0.52 abc
8.00	66 a	1.36 a	0.42 ab
16.00	26	1.32 a	0.40 a

a/ Values in a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test. Each value is the mean of four replications.

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treated with CSP at 4.0, 8.0, and 16.0 ppmw of copper contained 66, 121, and 132 ppmw of copper, respectively, after 1 week of treatment. This increase of copper in the shoots appeared to depend primarily on the increase of CSP in the root treatment solution, but no increase occurred until the concentration of copper was above 2.0 ppmw.

Roots of the control plants contained 22 ppmw of copper. As the concentration of CSP in the treatment solution was increased from 0.25 to 16.0 ppmw of copper, the copper content of the roots of water hyacinth increased from 41 to 14,801 ppmw of copper (Figure 1). The increase in copper content in the roots was almost a linear relationship depending on the concentration of CSP in the root treatment solutions.

During a 2-week treatment period, transpiration of water hyacinth was reduced by CSP at 2.0 ppmw of copper (Table 2). However, CSP at 3.5 ppmw of copper or higher was required to reduce growth (Table 3).

Some acropetal movement of copper in water hyacinth had occurred by the end of the 2-week treatment (Table 4). The copper content of the control plants was the same for each plant section analyzed. As the concentration of CSP was increased from 1.5 to 4.0 ppmw of copper, the copper content of these plants increased. In general, the distribution of copper in the plants was highest in the roots, lower in the petioles, and the leaves and new shoots contained the least amount. The maximum uptake of copper by the roots occurred with the 3.5 ppmw of copper treatment and the greatest movement of copper with the 4.0 ppmw treatment.

SUMMARY

Transpiration of water hyacinth under greenhouse conditions was reduced after root applications of CSP at 2.0 ppmw of copper or higher. Growth, as determined by dry weight, was inhibited by CSP at 3.5 ppmw of copper or higher. The copper content of these plants after root applications was highest in the roots. Some acropetal movement of copper occurred, the amount depending on the length

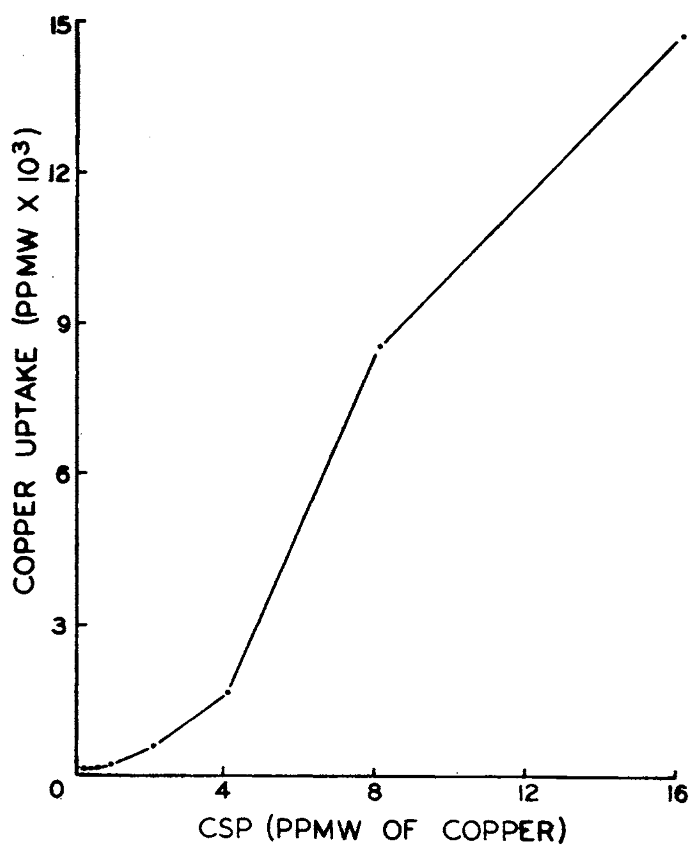

TABLE 2. TRANSPIRATION OF WATER HYACINTH AFTER TREATMENT OF 1-WEEK-OLD PLANTS WITH CSP AT VARIOUS CONCENTRATIONS OF COPPER.

Treatment Concentration of CSP (ppmw of copper)	Transpiration (ml)[a] Weeks after Treatment 1	2
Control	176 a	420 e
0.5	176 a	414 e
1.0	168 a	373 de
1.5	129 a	377 e
2.0	138 a	309 cd
2.5	139 a	299 bc
3.0	170 a	276 bc
3.5	159 a	238 b
4.0	109 a	138 a

a/ Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test. Four plants were used for each treatment concentration. Values for the second week do not include the first week.

TABLE 3. GROWTH OF WATER HYACINTH AFTER TREATMENT OF 1-WEEK-OLD PLANTS WITH CSP AT VARIOUS CONCENTRATIONS OF COPPER.

Treatment Concentration of CSP (ppmw of copper)	Dry weight after 2 weeks of treatment (g)[a] Leaves	Petioles	Roots	New Shoot	Total
Control	0.76 bc	0.86 a	0.55 bc	1.11 a	3.28 c
0.5	0.79 c	0.86 a	0.61 c	1.00 a	3.26 c
1.0	0.74 bc	0.70 a	0.66 c	0.78 a	2.88 bc
1.5	0.64 ab	0.63 a	0.51 bc	0.74 a	2.52 abc
2.0	0.71 bc	0.70 a	0.52 bc	0.70 a	2.63 abc
2.5	0.69 bc	0.82 a	0.44 ab	0.58 a	2.53 abc
3.0	0.63 ab	0.88 a	0.44 ab	0.82 a	2.77 abc
3.5	0.54 a	0.61 a	0.34 a	0.54 a	2.03 ab
4.0	0.54 a	0.68 a	0.34 a	0.36 a	1.92 a

a/ Means in a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test. Four plants were used for each treatment concentration.

TABLE 4. COPPER CONTENT OF WATER HYACINTH 2 WEEKS AFTER ROOT TREATMENT OF 1-WEEK-OLD PLANTS.

Treatment Concentration of CSP (ppmw of copper)	Copper content of dry plant material (ppmw)[a] Leaves	Petioles	Roots	New Shoots
Control	15 a	16 a	16 a	12 a
0.5	14 a	26 a	66 a	16 a
1.0	15 a	39 a	106 ab	20 a
1.5	22 ab	96 b	184 b	30 b
2.0	28 bc	101 b	655 c	41 cd
2.5	33 bc	114 b	876 d	38 bc
3.0	38 c	142 b	1,175 e	48 d
3.5	38 c	145 b	1,452 f	42 cd
4.0	69 d	247 c	1,190 e	58 e

a/ Means in a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test. Four plants were used for each treatment concentration.

of treatment time and the concentration of CSP. Petioles contained higher amounts than either the leaves or the new shoots. The leaves and new shoots contained essentially the same concentration of copper after root application of CSP.

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Extraction Of Protein From Water Hyacinth[1]

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Efforts are being made to clear water hyacinth (Eichhornia crassipes) from Florida waterways. Research is being conducted to find commercial uses for the plant and to help defray removal and disposal costs. Some work has been done to determine the nutritional value of aquatic plants, including hyacinth (1). An earlier paper from this laboratory reported on the protein and amino acid composition of the whole hyacinth plant (10). This study indicated that the protein might be nutritionally useful for man or monogastric animals, if it could be extracted from the fiberous plant.

Extraction of leaf protein has been championed by Pirie in England (7) and techniques for extracting crude protein from field crops has been accomplished on a pilot scale (8, 6). Byers (4) and Dalta et al. (5) have conducted studies on the preparation of protein concentrate from the leaves of water hyacinth. The extraction of protein from the leaves only is not practical under the present system for removal of the hyacinth from waterways. Thus the present investigation was initiated to determine the feasibility of extracting protein from the whole plant.

MATERIALS AND METHODS

This investigation consisted of three phases: (1) crude protein was determined in chopped plant material and press juice collected from a mechanical harvester, (2) entire plants were harvested by hand and subjected to different extraction procedures and (3) the most effective protein extraction procedure from the above trials was evaluated in terms of recoverability of essential amino acids from the whole plant.

PHASE 1

The press juice collected from the Hiller machine operating in a phosphate pond in Lakeland, Florida was obtained in January 1969. The machine chops the plants into coarse particles which are passed through a screw press, the press juice is expelled and the residue is dehydrated by a gas fired rotary dryer. The juice obtained from the machine process was transported to the Food Science Laboratory at the University of Florida and refrigerated at 1°C until processed. Prior to protein precipitation the press juice was clarified in an Electro E-500 Centrifuge Clarifier. Two kg aliquots were acidified with concentrated HCl to pH 3.8 and then heated to 80°C. The juice was then refrigerated 36 hours at 1°C. The sedimented precipitate was separated from the supernatant by filtration through a Buchner funnel. The whole plant, acid supernatant, and residue were analyzed for crude protein in order to follow the efficiency of the extraction procedures.

PHASE 2

Whole hyacinth plants were collected in March from Lake Alice on the University of Florida campus. Various techniques to determine the most effective method of extraction of the protein from the water hyacinth solids were attempted on chopped hyacinth samples which had been refrigerated overnight. These procedures are outlined in Figure 1.

PHASE 3

Whole hyacinth plants were harvested from Lake Alice in June. Replicate one-kg samples of fresh chopped hyacinth (whole plant) were comminuted in a commercial 4-liter capacity Waring blender with 3 kg of 0.05*N* NaOH at low, medium, and high speed for 20 seconds each. The slurry was passed through a screw press fitted with a 0.020 inch screen. The juice was then clarified, acidified to pH 3.7 and heated to 80°C. The acidified solution was refrigerated overnight at 1°C and the precipitate separated from the supernatant on a Buchner funnel. The sediment from the clarified was added to the extracted residue.

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