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UPTAKE AND SOME PHYSIOLOGICAL EFFECTS OF MERCURY IN THE WATER HYACINTH, Eichhornia crassipes (!\tart.) Solm.*

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ABSTRACT

The study investigated the absorption and some physiological effects of mercury in water hyacinth (Eichhornia crassipes) plants found in Laguna de Bay. Plants ol approximately similar size and vigor were collected from' natural populations in the lake for the experiments. To assess the capacity of the plant to absorb mercury, plants were grown in a nutrient solution to which was added 1.0, 10.0, 20.0 and 50.0 ppm of the heavy metal for sx days Analysis of the mercury content of submerged and aerial tissues of the plant was done on the second, fourth and sixth day. Submerged tissues consistently accumulated more of the heavy metal than the aerial tissues. The higher the level of mercury in the growth medium, the higher was the concentration of the heavy metal in the plant tissue.

The physiological responses of the water hyacinth plant lo various levels of mercury in the culture solution was determined in terms of gain in plant fresh weight, root growth, leaf development and chlorophyll content, ramet production and visible leaf injury symptoms. The addition of mercury caused a decrease in fresh weight and an inhibited root growth and ramet production. The higher the level of mercury in the culture medium, the greater was the degree of growth inhibition. Leaf development, however, was not greatly affected by mercury. The addition of 0.005 and 0.01 ppm Hg even enhanced leaf area expansion. Only a slight reduction in chlorophyll content was noted in plants subjected to 0.005 and 0.01 ppm Hg. The chlorophyll content of the mature leaves of plants that grow under 1.0 and 2.0 ppm Hg was greatly reduced. Visible leaf injury in terms of drying tips and necrotic spots was noted in plants grown in culture solution containing various levels of mercury. The higher the concentration of mercury, the greater was the degree of injury.

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INTRODUCTION

The advancement of scicncc and tcchnology helps a lot in the growth of industrial activity and in the improvement of agricultural practices. It also leads to the greater use of mechanical equipments and to rapid population growth. There arc,however, negative factors that come along with progress that pose dangers to the biotic environment. For cxample, the ever-increasing demand by industries for water results in a corresponding rise in the volume of discharged effluents. Thesc effluents contain large quantities of organic matter, inorganic nutrients, hcavy metals, and a variety of other substances and are discharged into the aquatic environment, especially in lakes. rivers and coastal waters. Eventually. these water bodies become unit for fish and other aquatic habitats by hcay metals which through biological magnification pose serious health problems (Cocoros et al., 1983).

Laguna Lake. the largest freshwater body in the Philippines. scenes mainly as a natural water reservoir which receives water effluents from about forty small tributary streams along its entire coastline. The lake undergoes recurring seawater intrusions due to the back[low from the Manila Bay through the Pasig River and the Napindan Channel during dry months. The backflow also carries along heay metal-polluted waters from the Pasig River into the lake.

The presence of various industries along the coastal areas of Laguna de Bay, both large-scale and cottage or medium types which number more than a thousand, has largely contributed to the heavy metal pollution of the lake. Chemical, food, .and wood-based industries directly discharge heavy metal-laden wastes, including mercury, into the lake or indirectly through the number of tributaries. The average concentration of Hg in the lakewater had been reported at 1.0 and 0.02 ppm for sedimentary and water samples, respectively (LLDA, 1978). The widespread use of agricultural chemicals including organopesticides containing Hg in the farmcd areas along the lake's coastline has further aggravated the heavy metal pollution of the lakewater.

Although many of the hazards poscd by mercury and its compounds arc not new. it has since gained prominence in the well-documented massive mercury-poisoning of the people of Minamata and Niigata, Japan in 1953 and 1965, respectively. These poisonings were traced to the consumption of mercury-contaminated fish and shellfish caught from bays located in the two sites (Klein and Goldberg. 1970; McAullife, 1977).

Water hyacinth, Eichhornia crassipcs (Mart.) Solm.. an aquatic vascular plant which ecologists have traditionally considered as a serious aquatic wccd or pest. is slowly drawing attention as an effective and chcap means of removing heavy metals from polluted waters because of its remarkable absorbing capacity. The plant belongs to the Family Pontederiaceae under the Order Lilialcs. Il is at present widely distributcd in the tropical and subtropical regions of the world and considered as the most obnoxious freshwater wccd of the world (Gopal and Sharma. 1981). The species is a free-floating stoloniferous herb. consisting of a rhizomatous stem. a rosette of leaves and a number of pendulous roots (Fig. l). The stem or rhizome is made up of an axis with several short internodes. The nodes bear the leaves, roots, offshots as well as inflorescence. Long internodes called stolons are ofcn produccd which grow horizontally or, under crowded conditions, bear offshots at the distal portion. The leaves of the plant are spirally arranged on the rhizome and form a rosette. A leaf usually appears glossy and consists of a ligule, a float, an isthmus (which is the thin junction between the float and blade) and a blade. Under crowded conditions. the float is not formed but instead a long petiole develops with a less distinct isthmus. In their natural habitats, the plants exhibit two types of leaf morphology: short or small leaves with bulbous petioles and long leaves with narrow petioles. Those freely floating on the water receiving full sunlight are short and bulbous while those constituting a dense of water hyacinth mat exhibit both types of morphologies.

A cursory survey of the Laguna Lake watershcd would indicate the abundance of water hyacinth populations which sometimes cover 5% of the lake surface (Fig. 2), notably at the junction of lakewater and its tributaries. Although the plant's potential as an undesirable wccd or as a beneficial accumulator of heavy metal pollutants in the lake ecosystem has often been mentioned (LLDA, 1978; ADB and LLDA, 1984), no experimental or field study has so far been published to assess its ecological role or importance in Laguna Lake.

OBJECTIVES OF THE STUDY

This study asscsscd the uptake and physiological cffccts of mercury in E. crassipes plants in Laguna Lake.

Specifically, the study determined the levels of mercury and its distribution in the submerged and emergent tissues of the plant as influenccd by varying levels of the heavy metal in the culture medium. It also evaluatcd some of th physiological effects of mer-

cury levels on the vegetative development of the plant in terms of fresh weight, leaf and root growth, leaf chlorophyll content, ramet fonnation and visible injury.

SCOPE AND LIMITATION

The ability of E. crassipes plant to absorb and accumulate other heavy metals has been documented by many authors. This study, however was concerned mainly with the determination of the Hg content of submerged and emergent tissues of water hyacinth plants exposed to varying levels of the heavy metal, namely, 1.0, 10.0, 20.0 and 50.0 ppm introduced into lake water as a nutrient solution or culture medium. The work was limited to the evaluation of some of the metal's physiological influences on the vegetative development the plant grown at different levels of Hg added to the culture medium, namely, 0.005, 0.01, 0.05, 1.0 and 2.0 ppm.

REVIEW OF LITERATURE

Mercury is an element that is found in the earth's crust, in sea, ground and rain water. Most importantly, all plant and animal species contain traces of the heavy metal which present either in an inorganic or organometallic form. Mercury entering an ecosystem originates basically from two sources: natural inputs, such as stream flowing through ore body, and artificial inputs, such as those arising from industrial and agricultural discharges and as a result of atmospheric pollution since mercury (as vapour and methylmercury) is scrubbed from the air by rain (McAuliffe, 1977).

The massive mercury poisonings in Minamata (1953) and in Niigata (1965), Japan were traced to the consumption of fish and shellfish with high mercury tissue levels. The heavy metal was shown to be a discharge from a chemical factory situated along the bay area using mercuric oxide as a catalyst. In Minamata Bay, the levels of methylmercuric chloride were very high (Klein and Goldberg, 1970; McAuliffe 1977).

Those tragedies have led to further studies which clearly demonstrated that mercury in the aquatic environment in an inorganic form is easily converted by hatural process to an organic form which can be taken in by living organisms and through time can accumulate in their tissues (Baez et al., 1976; Williams et all, 1976; McAuliffe, 1977; So, 1979). The metal becomes more concentrated as it passes from water to suspended matter,to plant life and to animal life (Frenet, 1981). In the food chain, it ends up in man as the ultimate recipient and sink (So, 1979).

Certain species of animals and plants can accumulate various toxic compounds without any harm or injury. These are often invariably referred to as biological indicators. The use of plant "monitors" (Harding, 1981) gives an integrated picture of pollution within a particular area and is cheaper than chemical monitoring over a long period (Christman, 1978).

Since estuarine and coastal waters not only serve as a source and habitat for a variety of commercial fishes but also receive industrial and municipal wastes, several studies have been done to assess the capability of various aquatic plants to absorb and accumulate various nutrients, especially heavy metals from the effluents.

Some studies have shown that submerged (Harding and Whitton, 1978; Harding, 1981; Duddridge and Wainwright, 1980; Tarifeno-Silva, 1982) and floating (Buddhari c! al., 1983; Haider et al, 1983; Prasad et al., 1983) freshwater plants absorb greater amounts of heavy metals as their concentrations in the aquatic medium were increased.

Christman (1977 and 1978) reported that water lily could absorb copper, cobalt, chromium and lead and that fresh water plankton easily accumulate copper, zinc, and cadmium from the polluted waters of six lakes in Southern California. Algae also absorb heavy metals. Prasinolladus tricornutum, a green platynomad and a pair of diatoms, Phalodactylum tricomutum and Chaetoceros simplex, have been shown to be the principal source of the high levels of cadmium in shellfishes utilizing these as food (Kerfoot and Jacobs, 1976).

Wolverton (1975 and 1978) proposcd that water hyacinth could be an answer to the problem of water pollution by toxic heavy metals in the aquatic habitat in major Asian countries since the plant readily absorbs effluents polluted with gold, cobalt, strontium, cadmium, nickle, lead and mercury. The first large-scale field demonstration of the water hyacinth's ability to remove heavy metals from domestic wastewater was done in 1978 at Coral Spring, Florida (Christman, 1978).

In experiments using industrial waste effluents, water hyacinth not only absorbed or removed as much as 80% of dissolved chromium within 16 days (Prassad et al.. 1983) and 97% of cadmium and nickle (Wolverton, 1975) but also could continuously accumulate mercury until it withers completely (Haider gt al, 1983).

Measurements on the decrease in the substrate concentrations of heavy metal accompanying the growth of water hyacinth (Wolverton, 1975) and on the quantities recoverable from the plants (Sutton and Blackburn, 1971; Wolverton, 1978) clearly showed that the plant can accumulate heavy metals at concentrations greater than that in the surrounding medium.

The toxicological effects of mercury and its derivatives depend not only on the dose and extent of their relative distribution in the aquatic environment (Frenet, 1981) but also on its interaction with thiol, selenidem phosphate, amino and carboxyl groups of such cellular components as amino acids, proteins, enzymes, nucleic acids and lipids (Arcenas, 1976; McAulifTe, 1977; Rosell, 1985).

In search for a plausible explanation of the remarkable ability of the water hyacinth to absorb metal ions, Haider ct al. (1983) were able to synthesize in laboratory experiments complexes of the amino acids, proline and glutamic acid, in collagen with copper, nickle, cobalt, iron, zinc and chromium.

METHODOLOGY

Preparation of Plant Materials and Culture Medium

Ramets of approximately similar vigor and size (8-10 cm in height; 4-5 leaf stage) and carefully severed from the mother plant were collected from the coves of the West Bay of the Laguna Lake and acclimated in concrete tanks with lake water for two days. Sample plants were then gathered and washed thoroughly with tap water before these were transferred into 5 plastic basins half filled with lake water collected from sites where the plant materials were collected.

Experiments were conducted under natural field conditions at the Binangonan Freshwater Station of the Aquaculture Department of the Southeast Asian Fisheries Department Center (SEAFDEC) at Tapao Point(Fig.3). Cultures were brought indoors during rainy days.

Uptake of Mercury

For the experiment on the uptake of mercury, four levels of the element were introduccd as mercuric chloride into lake water,namely, 1.0, 10.0, 20.0 and 50.0 ppm.

These concentrations which were many-a-fold higher than the reported levels of mercury in the Laguna Lake, had been selected primarily to determine the capacity of the plant to accumulate the toxic element. Plants grown in the same lake medium but to which no mercury had been added served as the control. There were three replicates for each level of mercury and each replicate or 5 basins contained 3 plants. The culture period was one week. Water loss through evaporation and transpiration was replenished everyday with lake water. After 2 days, plant samples from the different treatments were collected for the analysis of the mercury contents of submerged (root) and emergent (petiole and leaf) tissues. The analysis was repeated twice after every two days during a six-day culture period.

Physiological Responses

For the experiments on the physiological responses of the plant to different levels of mercury in the lake medium, five levels of mercury in the form of mercuric chloride were used, namely. 0.005, 0.01, 0.05. 1.0, and 2.0 ppm. These concentrations were based mainly on the reported levels of the heavy metal in the Laguna Lake ecosystem.i.e.. 0.02 mg of lakewater and 1.0 mg/k of lake sediment (LLDA, 1978). Plants grown in the same lake medium but without exogenously added mercury served as the control. There were three replicates for each treatment and 3 plants for each replicate. Waterlevels in the culturebasins were maintained everyday by adding lake water.

Growth was measured weekly in terms of root and leaf lengths and leaf area. Leaf length was measured from the base of the flOat to the tip of the blade. Leaf area was determined planimetrically. The freshweight of each plant was also determined every week. The total chlorophyll content of leaf tissues was determined spectrophotometrically using the method of Mckinney (1941) and Aron (1949). A sample of 0.2 gram of the cut mature leaf materials was ground and extracted with 90% acetone. The extract was concentrated and the chlorophyll level was determined spectrophotometrically at 645 nm.

Determination of Mercury In Plant Tissues

About 0.2 gram of fragmented plant tissues, i.e. roots and shoots with leaves were ground. Digestion of plant samples **was based** on the methods used by Uthe et al. (1970). The plant samples were digested with sulfuric acid at 50-60C. Digested samples were submitted to the Chemistry Department of Industrial Technology Development Institute of the Department of Science and Technology for the determination of the levels of mercury in the digested tissues using Flameless Atomic Absorption Spectroscopy.

RESULTS

The uptake of Hg by the water hyacinth plant was monitored only for six days because after this period, some of the plants, especially those exposed to higher levels, started to wilt. Table I presents the Hg content of the submerged and emergent tissues of E. crassipes plants grown in lake water supplemented with varying levels of the heavy metal. It was evident that the concentration of Hg in submerged tissues was consistently much higher compared with that of emergent tissues during the experimental period. As the level of the heavy metal introduced into the culture solution increased, there was a corresponding rise in the Hg content of both submerged and emergent tissues. Plants exposed to 50 ppm Hg contained about 32 times as much as the heavy metal than those of the control group and the emergent or aerial tissues about I7 times as much. An examination of the ratio of the Hg concentration between submerged and emer-

gent tissues indicates an almost two-fold increase in plants grown in lake water supplemented with up to 10 and 20 ppm Hg and a five-fold increase with 50 ppm Hg (Table 1a). In the control plants, the ratio was only about 1.5.

The experimental plants after one week are shown in Fig. 4, after two weeks in Fig. 5, after three weeks in Fig. 6 and after four weeks in Fig. 7. The effect of Hg concentration in the culture solution on the fresh weight of the whole E. crassipes plants is shown in Table 2. It is quite apparent that the addition of Hg at higher concentrations into the culture medium correspondingly decreased plant fresh weight. This was especially noted in plants exposed to 1.0 and 2.0 ppm Hg additions. The weekly changes in fresh weight is presented in Table 2a. The bulk of the gain in weight was evident during the first two **weeks** of the experimental period. At 1.0 and 2.0 ppm Hg, a decline in fresh Weight was noted after the third and fourth weeks. When the total gain in fresh weight after four weeks was considered, great reductions in fresh weight increase were noted in plants exposed to 1.0 and 2.0 ppm Hg additions. The gain in fresh weight of plants grown at lower concentrations was only slightly less than that of the control.

Root elongation was inhibited by the exogenous addition of Hg into the culture solution (Table 3). This reduction was quite evident at concentrations of 1.0 and 2.0 ppm during the four-week observation period. But when root growth was analyzed in terms of total increase in length and percent increase over initial length, it appear that the addition of 0.005 and 0.01 ppm Hg into the culture medium only caused about 20% reduction in root elongation when compared with the control (fable 3a). Greater reductions in root elongation were noted at higher Hg levels, especially at 2.0 ppm.

The addition of varying concentrations of Hg into the culture medium did not seem to adversely affect leaf growth or elongation (Table 4). The increase in length after two weeks did not vary much among treatments (Table 4a). The observation period was only two weeks since no further increases in all treatment groups were noted during the third week.

The effect of different levels of Hg in the culture solution on the expansion of the leaf surface area of E. crassipes plants during the three-week observation period is presented in Table 5. Apparently, low concentrations of added Hg at 0.005 to 0.05 enhanced leaf expansion when compared with the control as shown in percentage increases over the initial leaf size or area (Table 5a). At higher levels of 1.0 and 2.0 ppm Hg slightly inhibited leaf enlargement.

The introduction of Hg into the culture solution decreased the chlorophyll content of mature leaves of E. crassipcs after three weeks (Table 6). This reduction in pigment concentration was evident even only after two weeks in the case of 0.01 and 0.05 ppm. Compared with the control plants, the chlorophyll content of those grown at 0.01 to 2.0 ppm Hg was reduced from about 15 to 44% of the initial levels of the pigment in mature leaves (Table 6a). The greatest decrease was noted in the leaves of plants grown at 1.0 and 2.0 ppm Hg.

The formation of new rarnets, as indicated by the emergence of young expanded leaves, was also inhibited by the addition of 0.05 to 2.0 ppm Hg into the lake water after four weeks (Table 7). This inhibition was, however, not evident during the initial three weeks of the culture period.

The influence of Hg on visible leaf injury in terms of dried and curly tips and the appearance of necrotic spots on the whole plant surface is presented in Table 8. In both parameters, the degree or extent of injury apparently increase with higher levels of Hg in the culture solution.

DISCUSSION

The persistence and rapid proliferation of the water hyacinth in polluted freshwater habitats are indicative of its capacity to tolerate toxic elements, notably the heavy metal species. The data obtained from the present study strongly suggest the high potential of the plant to absorb a toxic heavy metal like mercury. The studies of Haider et al. (1984) and Buddhari et al. (1984) showed that the plant can accumulate heavy metals such as copper (Cu^{++}), iron ($Fe^{+?}$) and zinc (Zn^{++}) at concentrations considered toxic in other higher plant species. Apparently, the heavy metals in the cells and tissues of the water hyacinth plant are easily bound in a chelate form with amino acids, carboxylic and hydroxyl group in the cell sap (Haider et al., 1984c). The presence of large vacuoles in the tissues of the plant (Haider et al., 1984 b) may also have contributed to its high capacity for the absorption of mercury.

The non-toxic effect of 2.0 ppm Hg in the nutrient medium strongly suggests a high tolerance level of the water hyacinth plant. Buddhari et al. (1984) reported that the plant can tolerate up to 100 ppm of lead in the nutrient medium. Although reductions in plant fresh weight, root growth, as well as ramet production were noted with the addition of 1.0 and 2.0 ppm in the lake water, the plants still survived. Such a higher survival potential may be due to the observation that even at 1.0 and 2.0 ppm Hg the growth and expansion of the leaves and the photosynthetic organs of the plant, were not adversely affected. In fact, plants exposed to 0.005, 0.01 and 0.05 ppm Hg even had leaf areas slightly greater than the control. This enhancement of leaf expansion further reflects the high tolerance of the water hyacinth plant to the heavy metal. It was also reported by Wolverton (1978) that water hyacinth plants can accumulate high levels of cadmium, another toxic heavy metal. The high reduction in chlorophyll content of the leaves of plants grown at 1.0 and 2.0 ppm Hg may also reflect the inhibition of the enzymes involved in the synthesis of the pigment (Falchuk et al., 1977).

The reduction in plant fresh weight, root growth and ramet formation with increasing levels of Hg in the medium reflects the inhibitory effects of mercuric ions on enzymatic activities in living cells (Falchuk et al., 1977). Reproduction is inhibited when mercuric ions replace the metal component or co-factor of metalloenzymes. This heavy metal may also replace the zinc of the protease enzyme carboxypeptidase to promote the degradation of proteins in living cells. Reduction in the supply of energy and metabolites with the inhibition of respiration and the enhancement of protein degradation may account for the observed decreases in fresh weight, root elongation and formation of ramets, especially at higher levels of Hg in the growth medium. Whatever mercuric ions entering the plant that cannot be complexed or chelated will eventually interfere with the activities of metallienzymes in the roots and leaves of the plant.

The visible injury on leaf surfaces such as drying and curling of tips and the presence of necrotic spots are also reflections of the toxic effects of Hg on tissue metabolism. When the level of free mercuric ions is high, this may lead to death of cells and tissues (Falchuk et al., 1977). Hence the accumulation of unbound mercuric ions in certain parts of the leaf surface, especially the tips, may lead to the death of the cells and tissues in such portions of a water hyacinth leaf. Recently, it has also been demonstrated that heavy metals like copper, zinc and cadmium at high levels can cause tissue damage through the destruction of the vascular bundles of root and leaf tissues (Jamil et al., 1984). As a heavy metal, Hg could also bring about histopathological damage or injury in leaf tissues. The injury, as expected, would be greater in the presence of higher levels of mercury in the growth medium.

CONCLUSIONS, AND RECOMMENDATIONS

1. The water hyacinth plant has a high capacity to absorb mercury in the growth medium. The submerged tissues of the plant can accumulate higher levels of the heavy metal than the aerial tissues. The higher the level of mercury in the growth medium, the greater was the accumulation rate. Thus, this remarkable ability of the water hyacinth plant to absorb mercury makes it a potential agent for the biological control of heavy metal pollution in rivers and lakes.

2. Water hyacinth plants managed to survive even when rather high levels of Hg were present in the medium. Only at 1.0 and 2.0 ppm did Hg cause great reductions in plant fresh weight, root growth and ramet production. This high tolerance level would therefore make the plant an efficient heavy metal pollution remover in fresh water ecosystems.

3. The enhancement of leaf expansion when 0.005 to 0.05 ppm Hg was added to the growth medium and the only slight decrease in leaf area noted at 1.0 and 2.0 ppm may account for its high survival rate. This response would, thus, ensure its persistence in heavy polluted fresh water habitats because photosynthesis would not be adversely affected. This enhancement of leaf enlargement may also deserve further investigations.

4. Although mercury did not cause leaf death, a decrease in chlorophyll content. of mature leaves, necrotic spots and the dying of tips were noted in plants exposcd to high levels of the heavy metal. Further studies on the anatomical and biochemical aspects of leaf injury due to mercury in the water hyacinth plant are needed for a better understanding of the action mechanism of this heavy metal.

5.Based on its high potential uptake of and tolerance level to mercury and other heavy metals as shown in other studies, the water hyacinth would be a cheap and effective biological control of heavy metal pollution in Philippine fresh water ecosystems. Other aquatic macrophytes may also be considered in further studies on controlling heavy metal pollution in lakewatcrs.

*Table 1, **Influence of varying concentrations of exogenously added mercury in lake water on the mercury content of emergent (E) and submerged (S) tissues of Eichhornla crassipes,***

	Mean Hg Content (ug/g tresh weight) After Day					
	2		4		6	
Hg Level (ppm)	E	S	E	S	E	S
0 (control)	24.5	38.7	24.5	38.7	31.9	45.9
1.0	52.8	95.2	109.2	207.8	144.9	258.
10.0	52.8	179.5	179.5	348.8	215.6	399.4
20.0	151.4	433.1	193.8	433.2	286.3	696.4
50.0	151.7	898.0	306.5	1545.8	555.0	1587

Table 1a. The ratio of Hg concentration between submerged and emergent tissues of crassipes exposed to varying levels of Hg in the culture solution.

	Ratio of Hg Content Between Submerged and Emergent Tissues (S/E) After Day		
Hg Level (ppm)	2	4	6
0 (control)	1.58	1.58	1.44
1.0	1.80	1.90	1.78
10.0	3.40	1.94	1.85
20.0	2.86	2.24	2.43
50.0	5.69	5.04	2.86

Table 2. Influence of varying levels of mercury on the fresh weight of whole E crass[pea plants.

Hg Level (ppm)	0 (Initial)	Mean Fresh Weight (g) After Week 1	2	3	4
0 (control)	14.442.5	22.742.7	30.9±3.4	33.8±5.0	37.844.8
0.005	13.540.8	20.4±1.8	26.1±2.2	30.8±2.9	32.4±2.8
0.01	13.240.9	20.5±1.4	26.9±2.2	29.0±3.0	31.4±2.8
0.05	13.4±1.0	20.8±1.3	29.5±2.0	29.72.5	29.8£2.2
1.0	15.6±1.1	19.8±1.6	28.1±2.1	27.732.4	27.5±2.8
2.0	16.342.5	19.122.3	27.8±3.0	25.0±2.5	28.5±3.1

Table 2a. Weekly changes In fresh weight of whole E. crassipes plant as influenced by varying levels of mercury In lake water.

Hg Level (ppm)	Mean Increase (+)/Decrease (·) In Plant Fresh Weight (g) Week 1	Week 2	Week 3	Week 4	Total
0 (control)	+8.3	+8.2	+2.9	4.0	23.4
0.005	+6.9	+5.7	+4.7	+1.6	+18.9
0.01	+7.3	+6.4	+2.1	+2.4	+18.2
0.05	47.4	+8.7	+0.2	+0.1	+16.4
1.0	+4.2	+8.3	O.4	-0.2	+11.9
20	±2.8	48.7	:2.8	43.5	+12.2

Table 3. Influence of varying levels of mercury on root length of E crass/pas plants.

Hg Level (ppm)	0 (Initial)	Mean Root Length (cm) After Week 1	2	3	4
0 (control)	6.1±1.2	7.4±1.2	10.6±1.5	12.9±1.6	13.1±1.5
0.005	6.640.7	8.30.9	10.2±1.1	12.840,9	13.0±1.0
0.01	7.2±1.0	9.3±1.4	11.4±2.1	13.0±1.8	14.0±1.7
0.05	6.7±1.2	8.9+1.2	10.8±1.9	11.4±2.0	11.5±1.7
1.0	5.7±0.9	6.7±1.4	8.O0.9	8.6±1.0	9.4±1.0
2.0	6.240.9	6.940.6	7.6±0.9	8.4±1.3	9.4±1.4

Table 3a. Increase in root length of E. crass/pea plants after four weeks under varying levels of mercury

Hg Level (ppm)	Mean Increase In Root Length	
	Total (cm)	Percent of Initial
0 (control)	7.0	215
0.005	6.4	197
0.01	6.8	194
0.05	4.8	172
1.0	3.7	165
2.0	3.2	152

Table4. *Influence of varying levels of mercury on leaf length in E. crass/peg*

HgLevel (ppm)	Mean Leaf Length (cm) After Week		
	0 (Inilial)	1	2
0 (control)	8.740.5	9.940.6	10.640.8
0.005	7.640.5	8.840.5	9.740.8
0.01	8.140.9	9.50.8	10.240.6
0.05	7.70.6	9.0±0.4	10.040.6
1.0	7.540.7	8.640.6	9.4±0.7
2.0	8.1±1.0	9.540.8	10.041.1

Table 4a. ***Increase*** *in leaf length after two weeks under varying levels of mercury in* ***E.*** *crass[pea*

Hg Level (ppm)	Mean Increase in Leaf Length	
	Total (cm)	Percent of Initial
0 (control)	1.9	122
0.005	2.1	128
0.01	2.1	126
0.05	2.3	130
1.0	1.9	125
2.0	1.9	123

Table 5. Influence of varying levels of mercury on leaf area in E. crassipes

Hg Level (ppm)	Mean Leaf Area (cm2) After Week 0 (Initial)	1	2	3
0 (control)	25.9±2.3	26.6±2.2	28.3±2.0	29.1±1.8
0.005	23.5±1.7	24.0±1.1	26.5±1.8	30.0±1.7
0.01	26.7±2.7	27.1±2.1	29.8±2.0	30.3±1.9
0.05	24.4±1.8	25.6±1.9	27.7±1.7	29.2±1.8
1.0	23.3±2.6	24.032.0	24.2±2.0	24.5±2.0
2.0	25.3±2.2	26.5±2.1	26.9±2.0	27.1±1.8

Table 5a. Mean Increase In Leaf area In E. crssIpes after three weeks.

Hg Level (ppm)	Mean Increase in Leaf Area Total (cm)	Percent of Initial
0 (control	3.2	112
0.005	6.5	128
0.01	3.6	113
0.05	4.8	120
1.0	1.2	105
2.0	1.8	107

Table 6. Influence of varying levels of mercury on the chlorophyll content of the leaf of E. crassipes

Hg Level (ppm)	Mean Chlorophyll Content (mg/g Fresh Weight) After Week 0 (Initial)	1	2	9
0 (control)	0.7140.03	0.6940.02	0.70±0.04	0.6840.03
0.005	0.6840.02	0.6930.02	0.7140.06	0.6640.04
0.01	0.7040.03	0.6840.03	0.6540.03	0.6040.04
0.05	0.7140.03	0.7140.04	0.5440.03	0.5040.03
1.0	0.6940.02	0.55±0.05	0.4440.02	0.4040.4
2.0	0.7140.03	0.5740.03	0.4140.05	0.4040.5

Table 6a. Increase/decrease and percentage change in the chlorophyll content of the leaf of E. crass/peg after three weeks.

Hg Level (ppm)	Decrease from Initial (mg)	Percent of Initial
0 (control)	0.03	95.8
0.005	0.02	97.0
0.01	0,10	85.7
0.05	0.21	70.4
1.0	0.29	60.0
2.0	0.31	56.3

Table 7. Influence of varying levels of mercury on the formation of new ramets in E. crassipes .

Hg Level (ppm)	Mean Number pt Ramets Formed per Plant After Week			
	1	2	3	4
0 (control)	1.6	3.6	5.6	7.8
0.005	1.6	3.6	5.6	7.5
0.01	1.7	3.7	5.6	7.5
0.05	1.4	3.4	5.2	6.1
1.0	1.5	3.4	5.3	6.3
2.0	1.6	3.4	5.4	6.3

Table 8. *Influence of varying levels of mercury on visible leaf injury in E. crassipes after four weeks*

Hg Lvel (ppm)	**Mean** Number of Leaves per Plant Showing Dried and Curly Tips	Necrotic Spots
0 (control)	None	None
0.005	1.0	0.3
0.01	1.8	1.3
0.05	1.3	1.3
1.0	2.3	2.0
2.0	2.9	3.0

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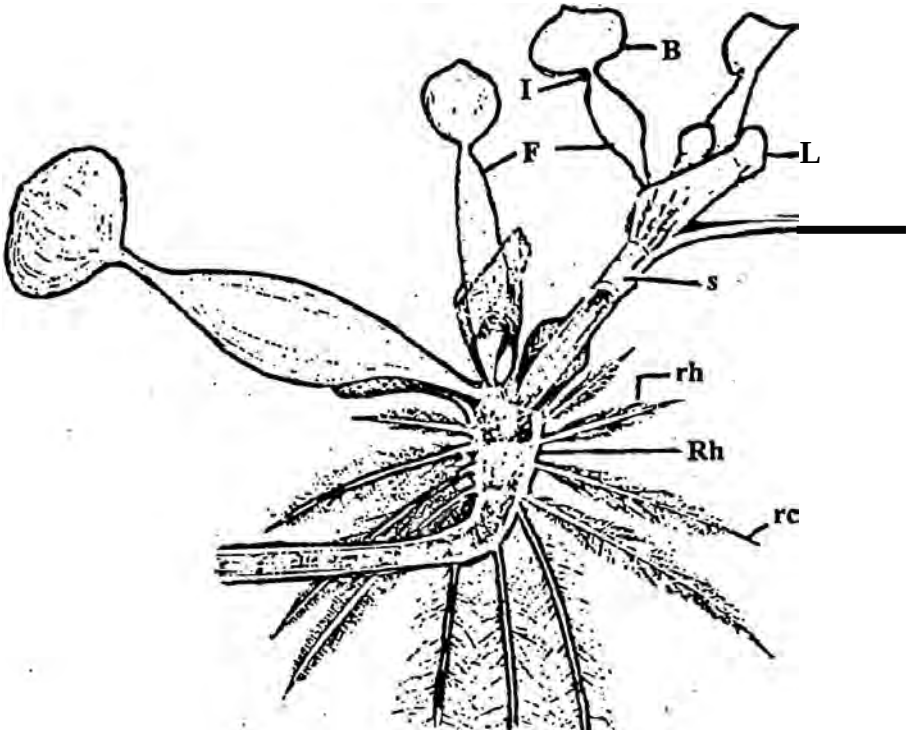

Figure 1. *A portion of the plant showing sympodial branching.*

B - Leaf blade	F - Float
I - Isthmus	L - Ligule
Rh - Rhizome	rh - Root hairs
re • Root cap	s - Stolon

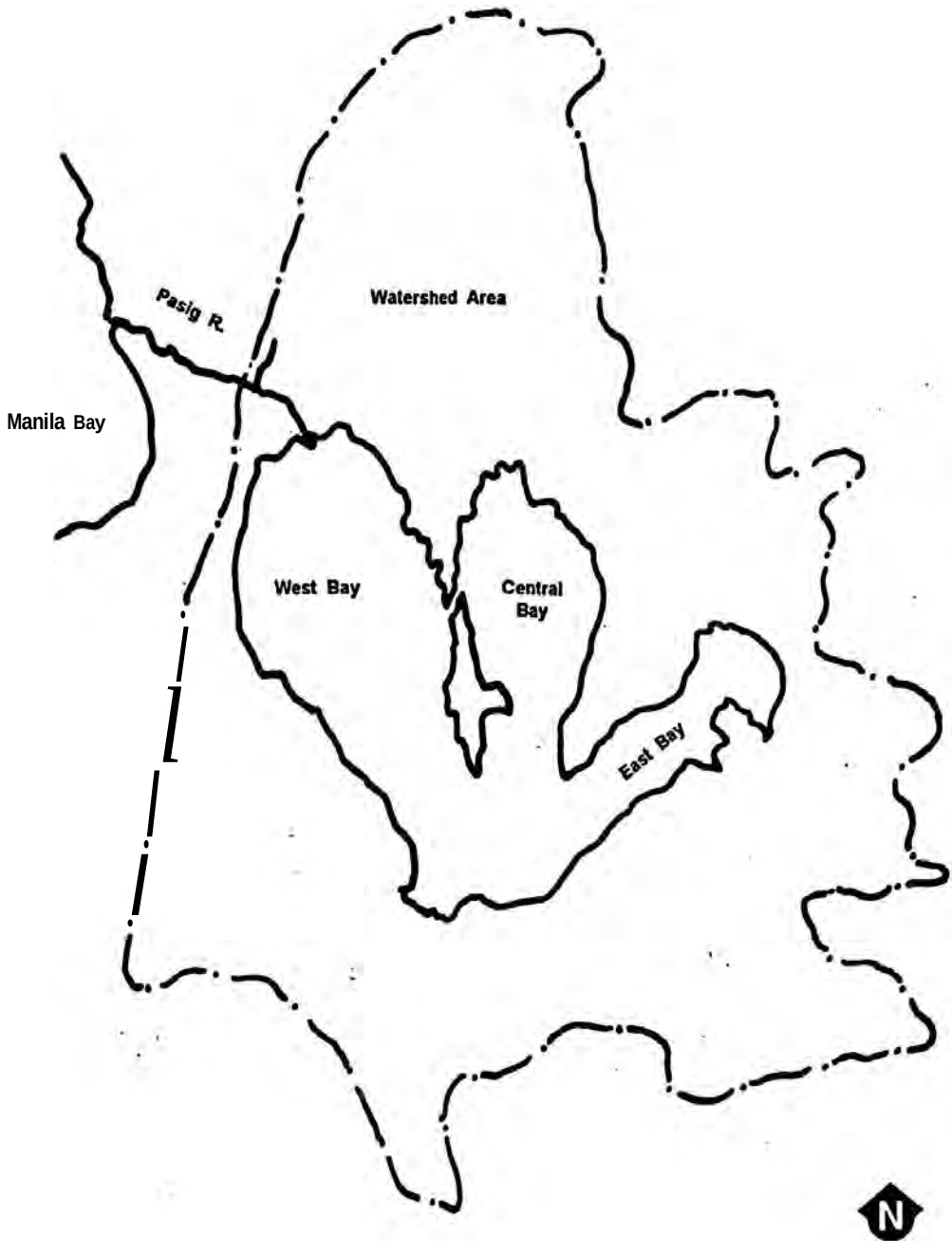

Figure 2. *Laguna de Bay and its watershed.*

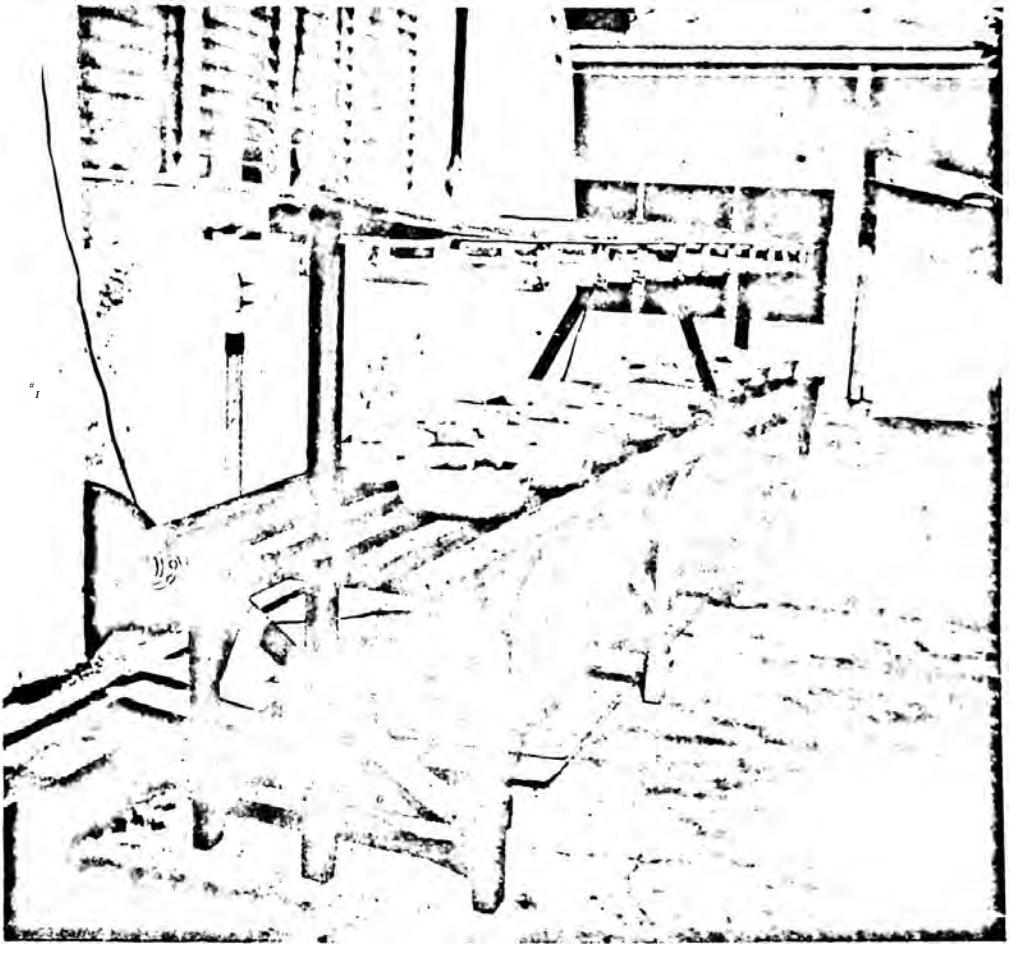

Figure 3. *The experimental set-up at the Binangonan Freshwater Station in Tapao Point, Binangonan, Rizal.*

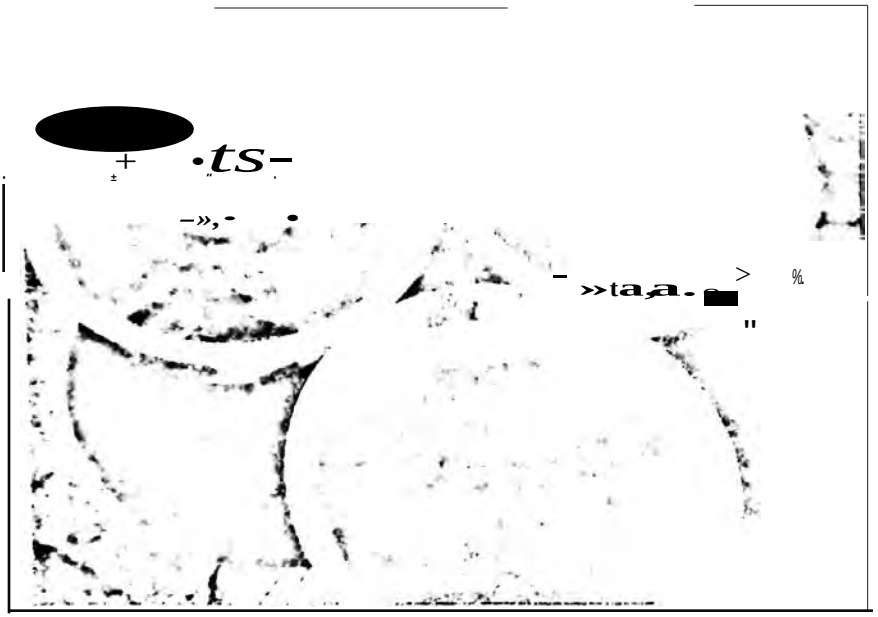

Figure 4a. *The control plants after one week*

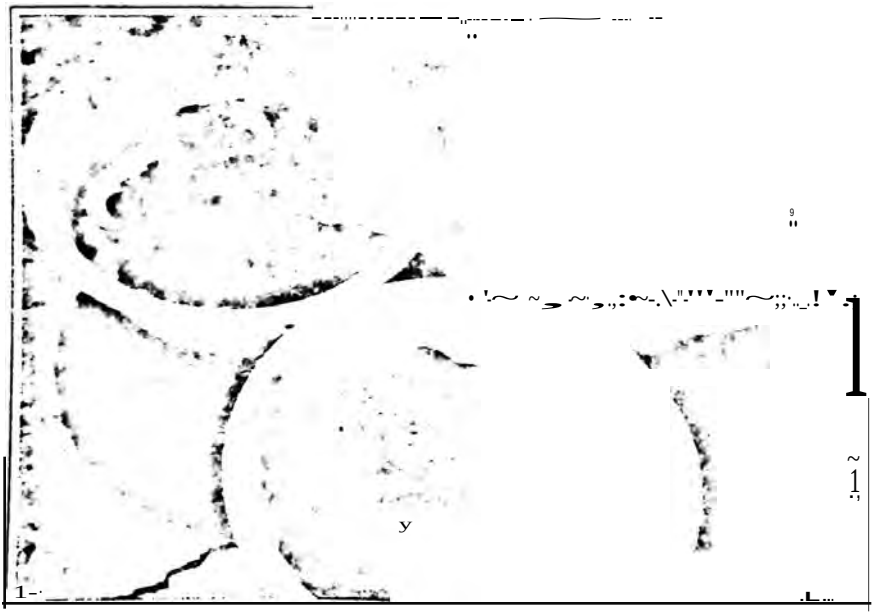

Figure 4b. *Plants grown in the culture solution with 0.005 ppm Hg after one week,*

Figure 4c. *Plants grown in the culture solution with 0.01 ppm Hg after one week*

Figure 4d. *Plants grown in the culture solution with 0.05 ppm Hg after one week.*

Figure 4e. *Plants grown in the culture solution with 1.0 ppm Hg after one week.*

Figure 4f. *Plants grow in the culture solution with 2.0 ppm Hg after one week.*

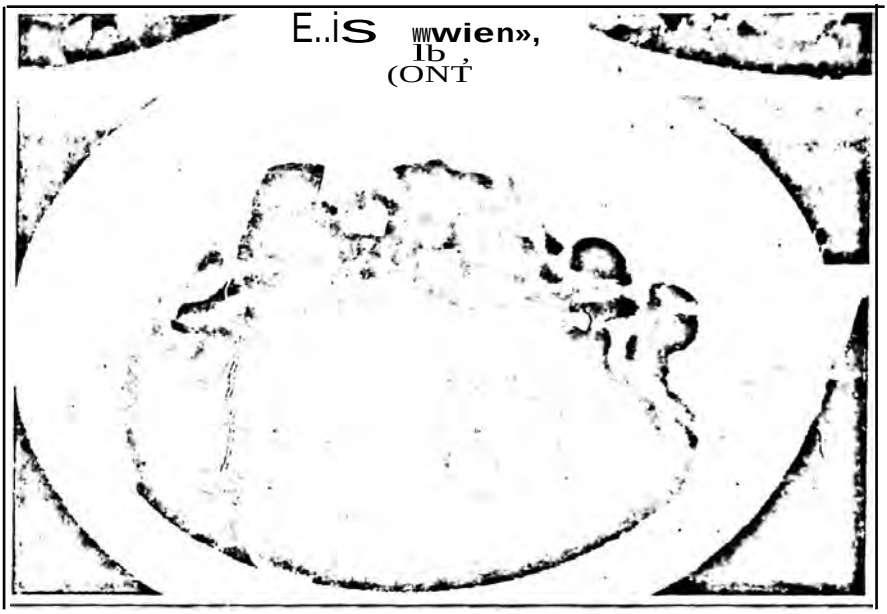

Figure 5a. *The control plants after two weeks.*

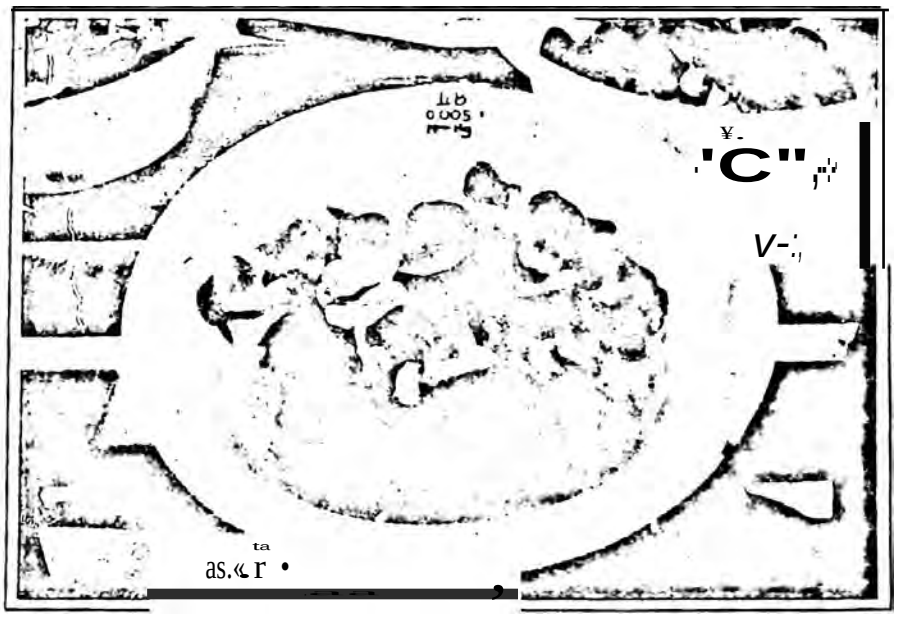

Figure 5b. *Plants grown in the culture solution with 0.005 ppm Hg after two weeks.*

Figure 5c. *Plants grown in the culture solution with 0.01 ppm Hg after two weeks.*

Figure 5d. *Plants grown in the culture solution with 0.05 ppm Hg after two weeks.*

Figure 5e. *Plants grown in the culture solution with I.0 ppm Hg after two weeks.*

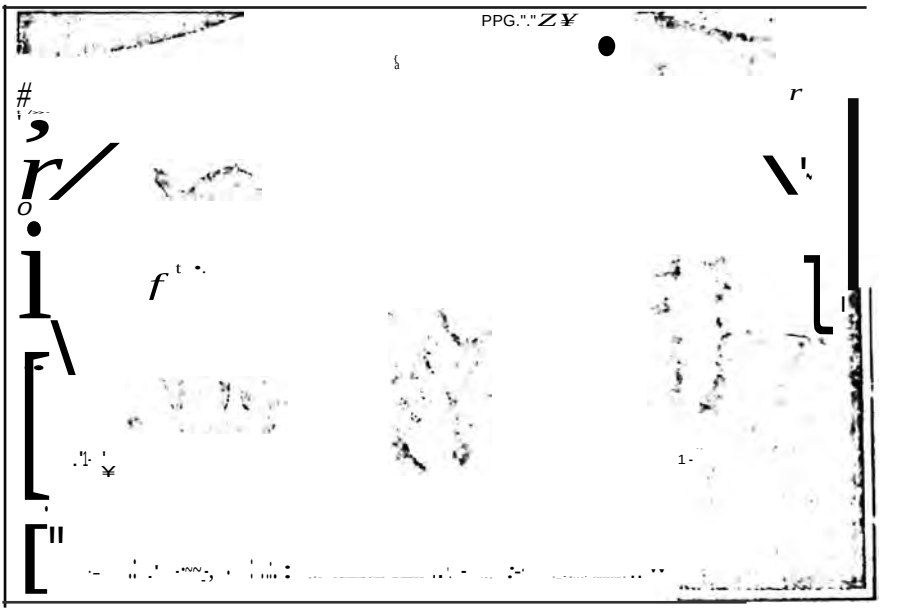

Figure Sf. *Plants grown in the culture solution with 2.0 ppm Hg after two weeks.*

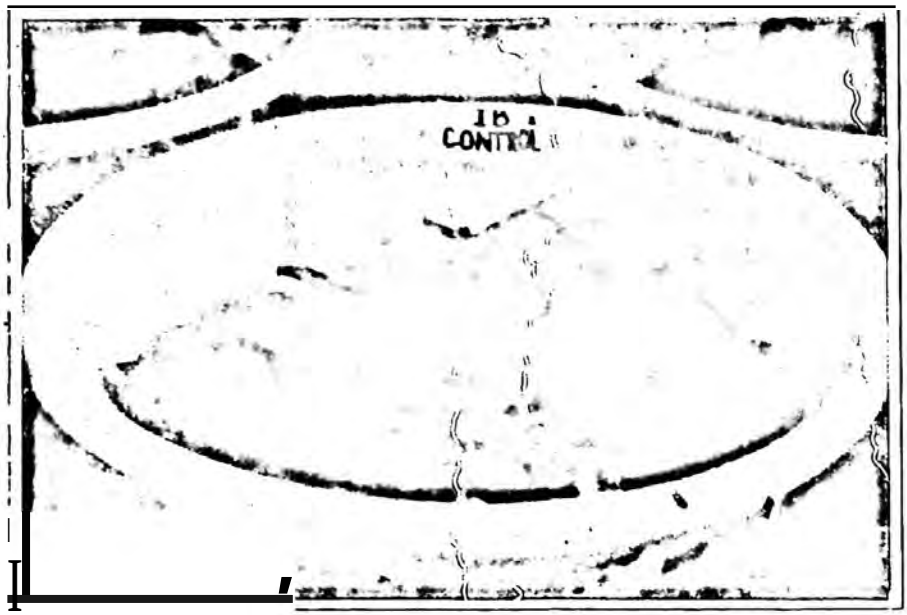

Figure 6a. *The control plants after three weeks.*

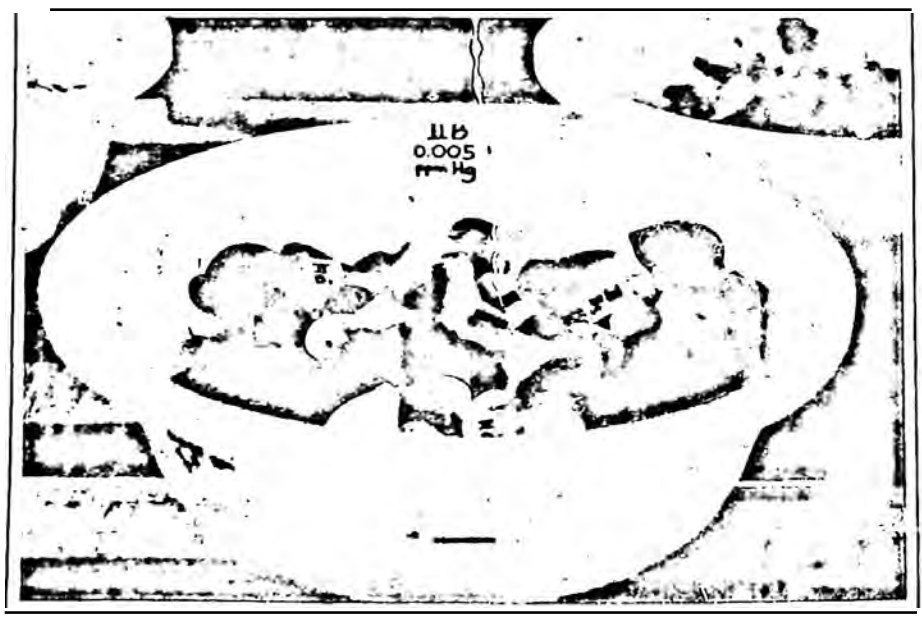

Figure 6b. *Plants grown in the culture solution with o.005 ppm Hg after three weeks.*

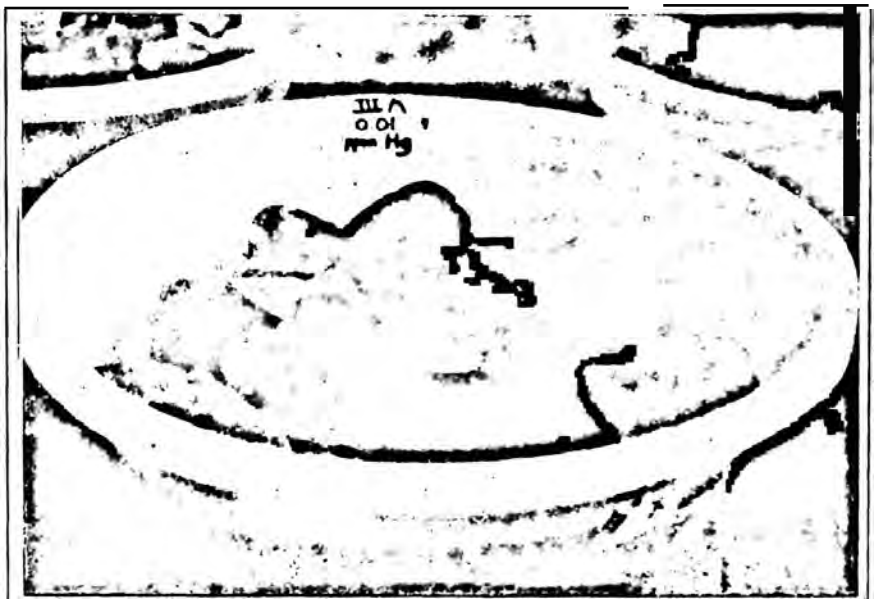

Figure 6c. *Plants grown in the culture solution with 0.01 ppm Hg after three weeks.*

Figure 6d. *Plants grown in the culture solution with 0.05 ppm Hg after three weeks.*

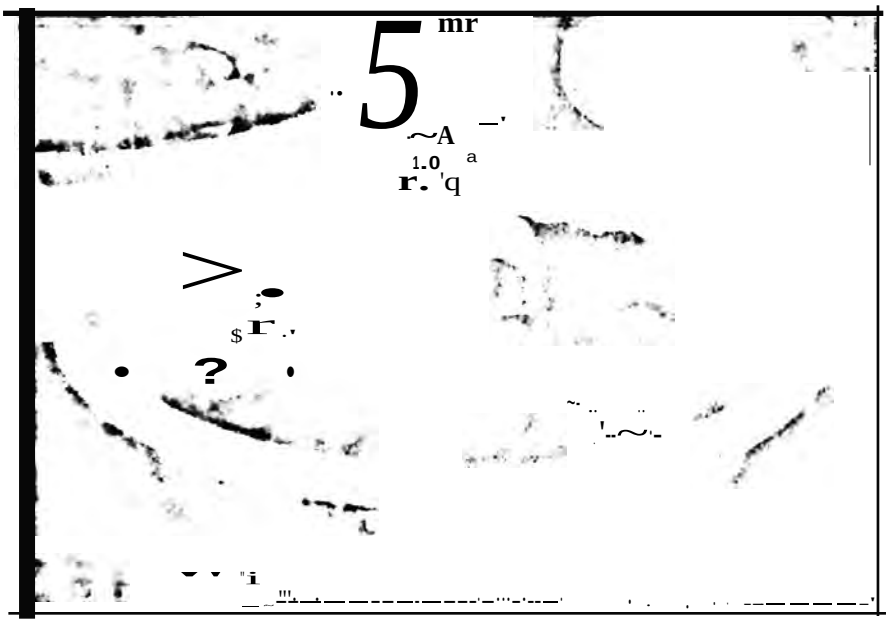

Figure 6e. *Plants grown in the culture solution with 1.0 ppm Hg after three weeks.*

Figure 6f. *Plants grown in the culture solution with 2.0 ppm Hg after three weeks.*

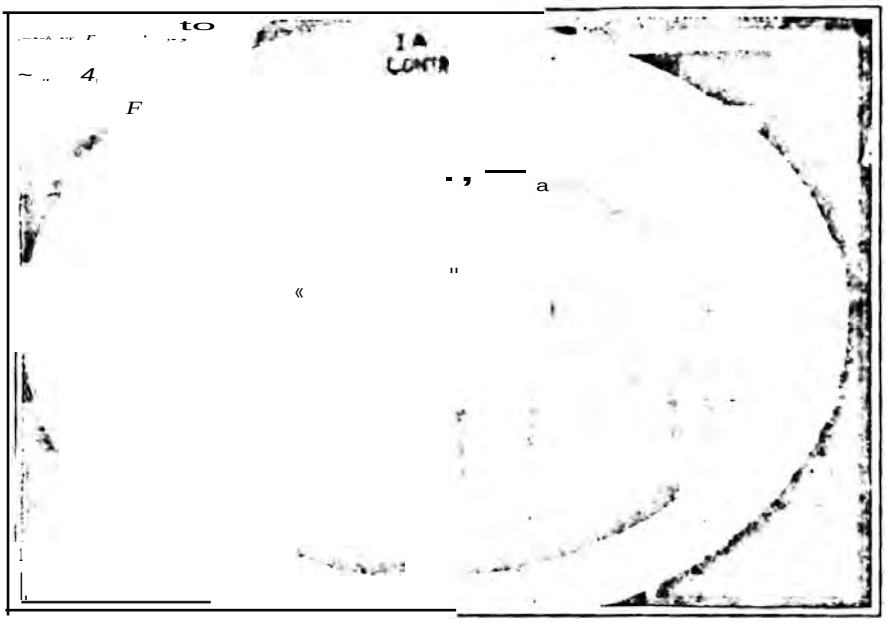

Figure 7a. *The control plants after four weeks.*

Figure 7b. *Plants grown in the culture solution with 0.005 ppm Hg after four weeks.*

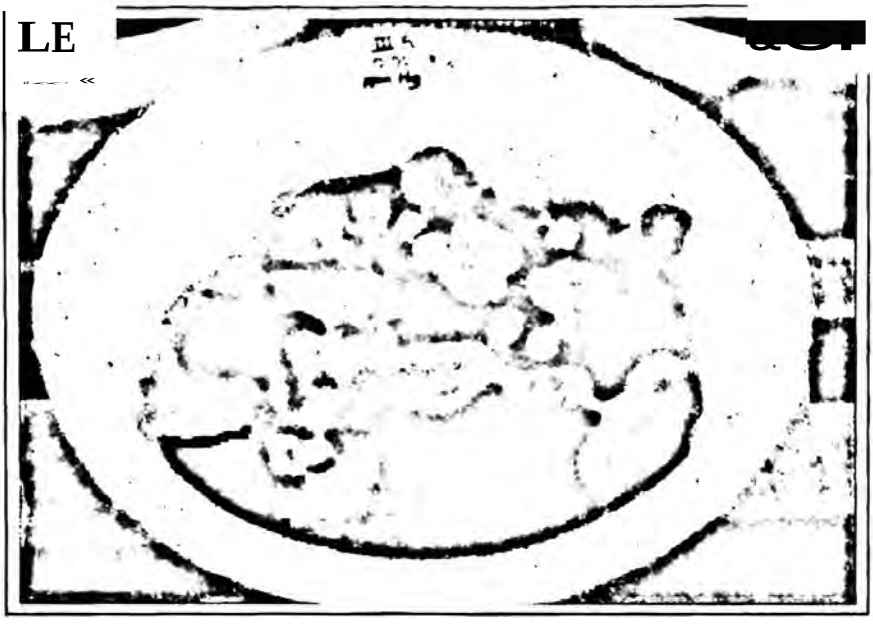

Figure Tc. *Plants grown in the culture solution with 0.01 ppm Hg after four weeks.*

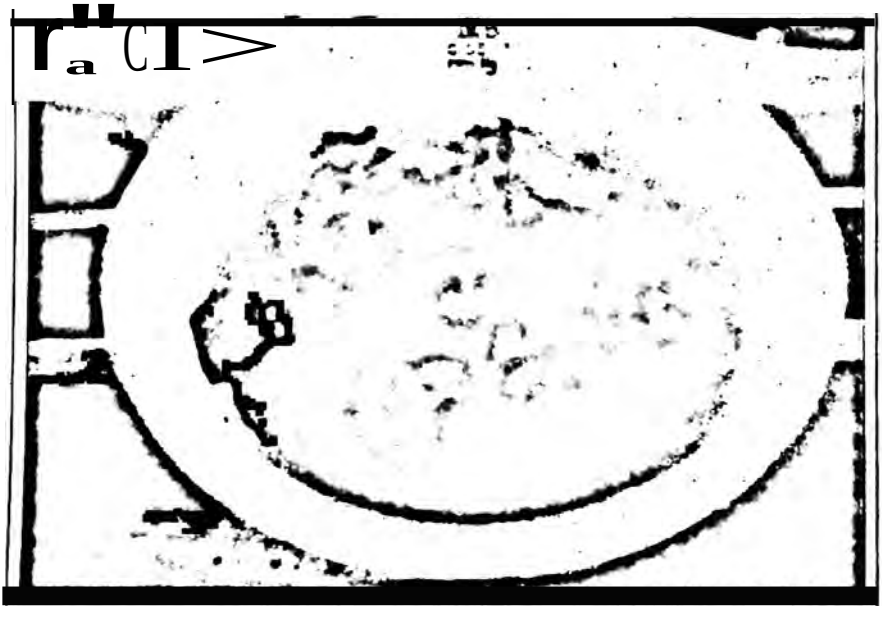

Figure 7d. *Plants grown* in *tke culture solution with 0.05 ppm Hg after four week.*

Figure Te. *Plants grown in the culture solution with 1.0 ppm Hg after four weeks.*

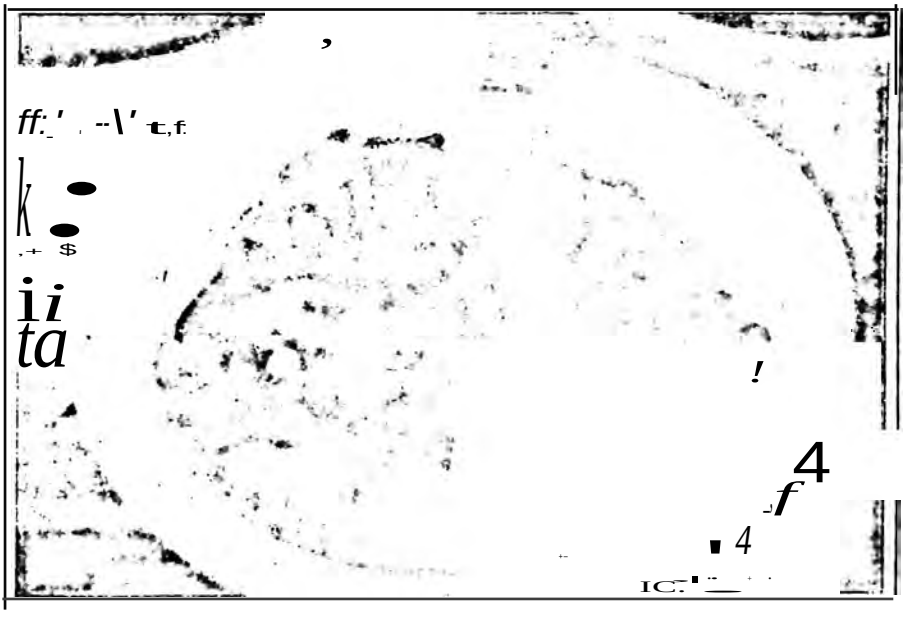

Figure 7f. *Plants grown in the culture solution with 2.0 ppm Hg after four weeks.*