Habitat and Nutrition of Waterhyacinth

By KUNIKAZU UEKI

Weed Science Laboratory, Faculty of Agriculture, Kyoto University

There are no reliable estimates of the total acreage now covered by water weeds or threatened by them. Invasions of weedy aquatic plants into many water systems have created a considerable problem today as waters have been enriched with various wastes from agricultural fields, residences and from industries in recent years.

Waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) is one of the most troublesome aquatic plants and has been listed as one of the 10 most important weeds of the world. It causes a variety of problems for water management in Australia, New Zealand and the United States as well as South-east Asia and Africa. Therefore, many measures have been tried for the control of this weed. Especially in recent years, the use of biocontrol agents, such as white amur[1], insects[3] and plant pathogens[21], in aquatic weed programmes offers a new approach to the solution. Also water level manipulation[15] or laser radiation[4] have been tried for controlling this weed. On the other hand, utilization of waterhyacinth as mulching material[8], soil amendment[14], compost, source of protein[10] or energy[19], and for pollution removal[5], or feed[9] has received considerable attention. The integration of different control measures is also being investigated.

Though the plant was originally brought into Japan as ornamental in the 1890's, it was already naturalized in paddy fields or irrigation channels in the southern area of Japan in 1911[7]. Since then, it has spread rapidly. To investigate the current situation of waterhyacinth distribution and its habitat in Japan, the present author sent questionnaires to all (46) of the prefectural agriculture experiment stations[18]. Results obtained will be presented here together with results of laboratory experiments carried out by the author in relation to the growth habits.

Distribution

Waterhyacinth is distributed in the following regions: the Pacific side in south up to the Kanto area (till E 141°, N 37°), the Japan Sea side in south up to the Hokuriku area (till E 137° 8′, N 37°), but not in the Chubu area (northward from E 137° 6′, N 35° 2′).

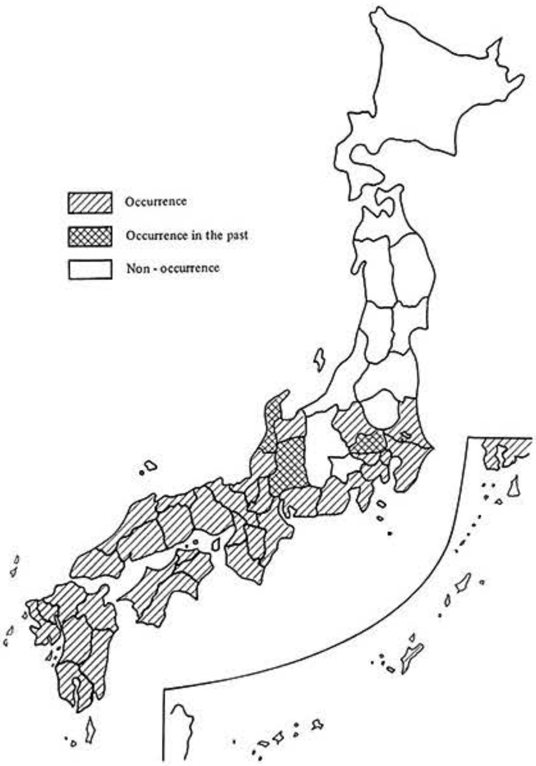

Fig. 1. Distribution of waterhyacinth in Japan

Fig. 1 indicates the above areas. At Ishikawa Prefecture (Hokuriku area), Gifu Prefecture (Chubu area) and Saitama Prefecture (Kanto area) are not known whether at present waterhyacinth occurs, but it is reported that waterhyacinth used to be found. No waterhyacinth is reported in Hokkaido, Tohoku and Chubu areas because the plant can not survive in winter thought it grows enough in summer.

Habitats

The habitats, in general, are found mostly in ponds and irrigation channels near paddy fields and residential areas (Plate 1). The presence of the weed in rivers was not much except in the southern area (Table 1). For the above habitats there is a common fact that the waters are heavily enriched by the inflows with filth of hog farms and domestic sewages. The questionnaire also revealed interesting habitats of the plant such as a dam for electricity generation, a water pool for timbers, drainage ditches of factories and fields of lotus root cultivation. Stagnation and low clarity of water appear to be also important to the habitats.

Plate 1. Irrigation pond near paddy fields entirely covered with waterhyacinth in September.

Table 1. Habitats of waterhyacinth

	Rivers	Irrigation channels	Ponds	Others*
Kind of water system	18.8%	29.2%	37.5%	14.5%
	* Others Dams for electricity generation. Water pools for timbers. Drainage ditches of factories. Fields of lotus root cultivation.			
	Area of residences	Area of factories	Area of rice paddy fields	Others*
Infested areas	39.5%	10.5%	42.1%	7.9%
	* Others River mouth Neighborhood of dam			
	Rapid	Slow		Stagnant
Water flow	3.3%	50.0%		46.7%
	High clarity			Low clarity
Clarity of water	30.8%			69.2%

Undesirable effects and control

Out of the 46 prefectural stations to which the questionnaires were sent, 70% of them reported undesirable effects: (a) choking irrigation and drainage ditches, (b) interfering with boating and fishing, (c) causing unpleasant odors, (d) causing water enriched with dead plants in the winter, and (e) reducing the water level. For the control, only the hand-weeding is employed at present, but the chemical control is under trials with 2,4-D (2,4-dichlorophenoxyacetic acid) amine, paraquat (1,1'-dimethyl-4,4'-bipyridinium dichloride), diquat (6,7-dihydrodipyrido (1,2-α:2', 1'-c) pyrazinedium ion) and endothall (7-oxabicyclo (2,2,1) heptane-2,3-dicarboxylic acid).

Growth habits

1) Life cycle

The plant starts to propagate vegetatively by stolon around May and ceases its growth in October. In summer the plant reaches 40 to 100 cm in height (Plate 2). It blooms in August to September in almost all areas.

Plate 2. Mature waterhyacinth plants reached about 60 cm in height.

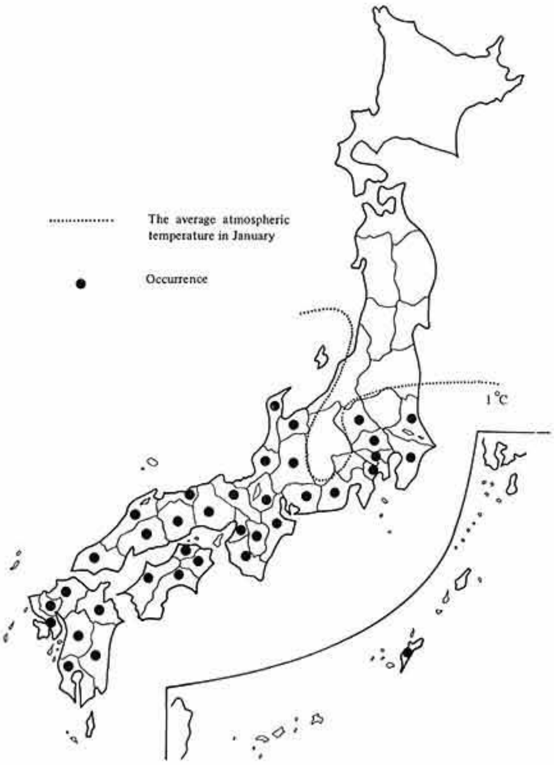

Fig. 2. Relation between distribution and average atmospheric temperature in January.

After November, foliage of the weed is gradually killed by freezing temperature in most areas, but the plant may not completely die until the rhizome is frozen. Fig. 2 indicates the relation between climatic factor and areas where the plant can spend the winter. Northern boundary of the occurrence is found in the zone with average atmospheric temperature of 1°C in January. Even in that zone, the plants do not always survive in the winter. For the survival of waterhyacinth, particular conditions are required such as stagnant and shallow water, not frozen at the surface in winter, and areas nearby other kinds of plant emerged, for an example, reed (*Phragmites communis* Trin). In April to May, regrowth from the rhizome which survived under the other plants emerged or in the peaty floating mat of decaying vegetation occurs. However, since low temperature, recently prevailed in the winter of Japan, gave severe cold damage to waterhyacinth, the plants could not survive in the winter as formerly. As a result, the seed has gradually received attention because the seeds or the seedlings are able to survive the winter in many areas (Plate 3). Concerning seedlings, many newly germinated seedlings of waterhyacinth appear in June, and the seeds are reported to be practical means of propagation of the weed in natural habitats. Therefore further experiments are required to assess the sexual reproduction or the dormancy and germination of seeds.

Plate 3. Waterhyacinth seedlings grown on the peaty floating mat of decaying vegetation.

2) Requirement of some essential elements

A laboratory study was carried out to determine the deficiency of which one or ones of essential elements (N, P, K, Ca, Mg and Fe)

Table 2. Composition of culture solution

Source	Concentration	Element*	
$Na_2HPO_4 \cdot 12H_2O$	63.1 mg/l	P_2O_5	12.5 mg/l
KCl	39.9	K_2O	25.2
$MgSO_4 \cdot 7H_2O$	123.0	MgO	20.0
$CaCl_2 \cdot 2H_2O$	57.7	CaO	22.2
EDTA-Na-Fe salt	20.6	Fe_2O_3	4.3

* Nitrogen was supplied as ammonium-N at 20 ppm, except in the experiment on the effect of pH, where two levels of nitrogen, 20 and 160 ppm, were used.

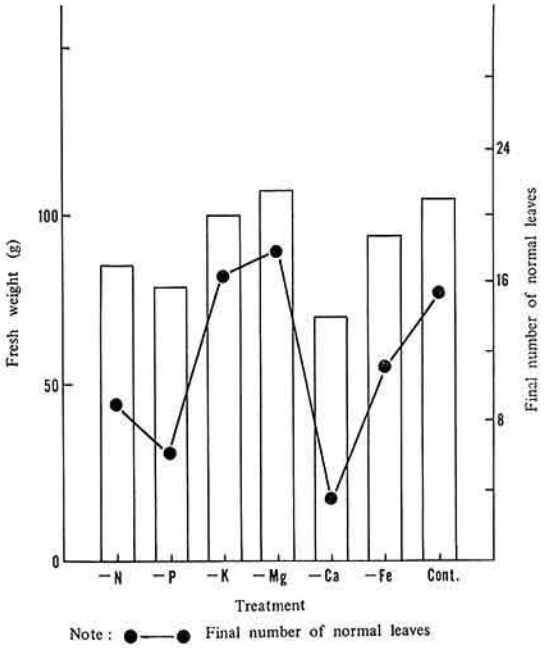

Fig. 3. Effect of mineral deficiency in nutrient solution on fresh weight and number of normal leaves.

might inhibit vigorous growth of this plant. The uniform-sized plants were grown in nutrient solutions (Table 2) with or without each of the essential elements. After 4 weeks, plants were harvested. The result in Fig. 3 demonstrates that plants grown in solutions deficient of N, P, or Ca were very poor in fresh weight and in the number of normal leaves. The number of new plants was also depressed in the above three treatments. Especially with the lack of Ca, the development of new roots and new leaves was depressed and root rot was increased. The deficiency of P exhibited a typical chlorotic mottling of leaves, while N deficiency induced some retardation of growth, but only root growth was extremely promoted and the root exhibited the purple coloration. Chemical analysis revealed that P contents of the aerial parts were low at the above three treatments. Thus, it was recognized that waterhyacinth is susceptible to N, P and Ca deficiency.

3) *Effects of pH*

Hydrogen ion concentration influences the metabolism of plants. Especially the growth of waterhyacinth was thought to be affected by pH because it has the habitats in water. Massive infestations of waterhyacinth are found in water with a pH range of 6.2 to 7.6[2]. Then laboratory experiment was designed to determine the effects of pH on growth and reproduction of this plant. Both mature and immature plants were selected for the experiment. The uniform-sized plants were grown in nutrient solutions (Table 2) with two levels

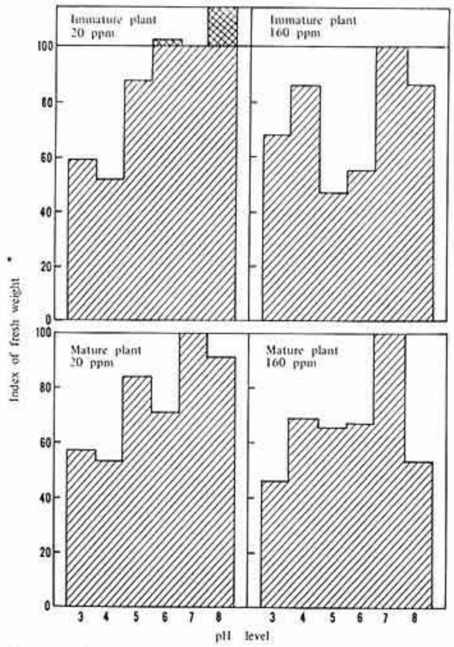

Fig. 4. Growth of waterhyacinth plants grown in nutrient solutions with different pH levels.

Note: Fresh weight of plant grown in the pH 7.0 solution = 100 of ammonium nitrogen (20 ppm and 160 ppm) and with six different pH (3, 4, 5, 6, 7 and 8). After 4 weeks the plants were harvested and the fresh weight and the number of normal leaves were measured.

Fig. 4 indicates that maximum growth of mature plants occurred in the pH 7.0 solution, and that mature plants grew well over a pH range of 5.0 to 8.0 in solutions with 20 ppm of ammonium-N, while only at pH 7.0 in solutions with 160 ppm. Chadwick & Obeid (1966)[2] and Santiago (1973)[17] also reported that waterhyacinth yielded best at pH 7.0. In general, the results of our experiment showed that the damage caused by pH was more obvious when grown in a medium of 160 ppm of ammonium-N than in 20 ppm, and also with immature plants than with mature plants. Normal leaves were few at pH 3.0 and 4.0 and new white roots were not found at those pH values. This result was supported by the result of Minshall & Scarth (1952)[11] that the roots of waterhyacinth, grown in water culture, exhibited a decrease in cell division and cell elongation at pH below 4.0.

Final pH values of the nutrient solutions showed the influence of the plants on pH of water. Haller (1973)[6] reported, based on measuring initial and final pH, that this plant growing in either acidic or alkaline water had a tendency to change the pH towards neutrality. Similar result was found in our experiment with immature plants.

4) Effects of different levels and forms of nitrogen

Waterhyacinth can undertake rapid growth and multiplication and absorbs large quantities of nitrogen. Obeid (1964)[12] indicated that an increased supply of nitrogen increased the total dry weight yield and plant number. Sakai (1974)[16] reported that a good growth was obtained in a water culture with 190 ppm of ammonium-N. Therefore, the experiment was carried out at various levels of ammonium-N. Both mature and immature plants were grown in nutrient solutions (Table 2) with six levels of ammonium-N (0, 10, 20, 40, 80 and 160 ppm).

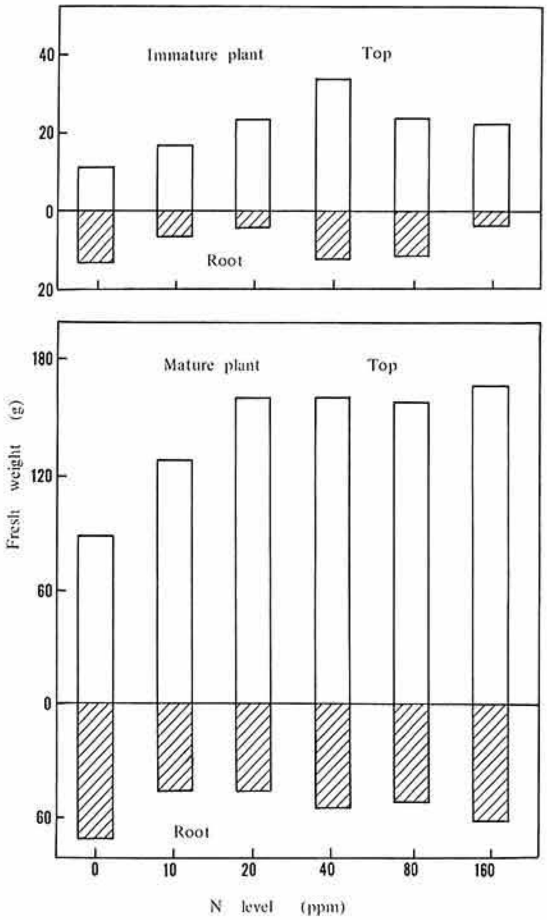

Fig. 5. Effect of level of nitrogen on growth of waterhyacinth.

After 4 weeks the plants were harvested, and the fresh weight and the number of new plants were measured.

As the ammonium-N level was increased from 0 to 160 ppm, growth of mature plants, as determined by fresh weight, increased. However, with immature plants the maximum growth was found at 40 ppm of ammonium-N, with less growth at the concentrations above and below this value (Fig. 5). Also, the plant produced a greater number of new plants at 40 ppm and their growth was maximum at this value. This result indicates that the plant differs considerably in the nitrogen requirements for the optimum growth and for optimuch reproduction as well as with plant age.

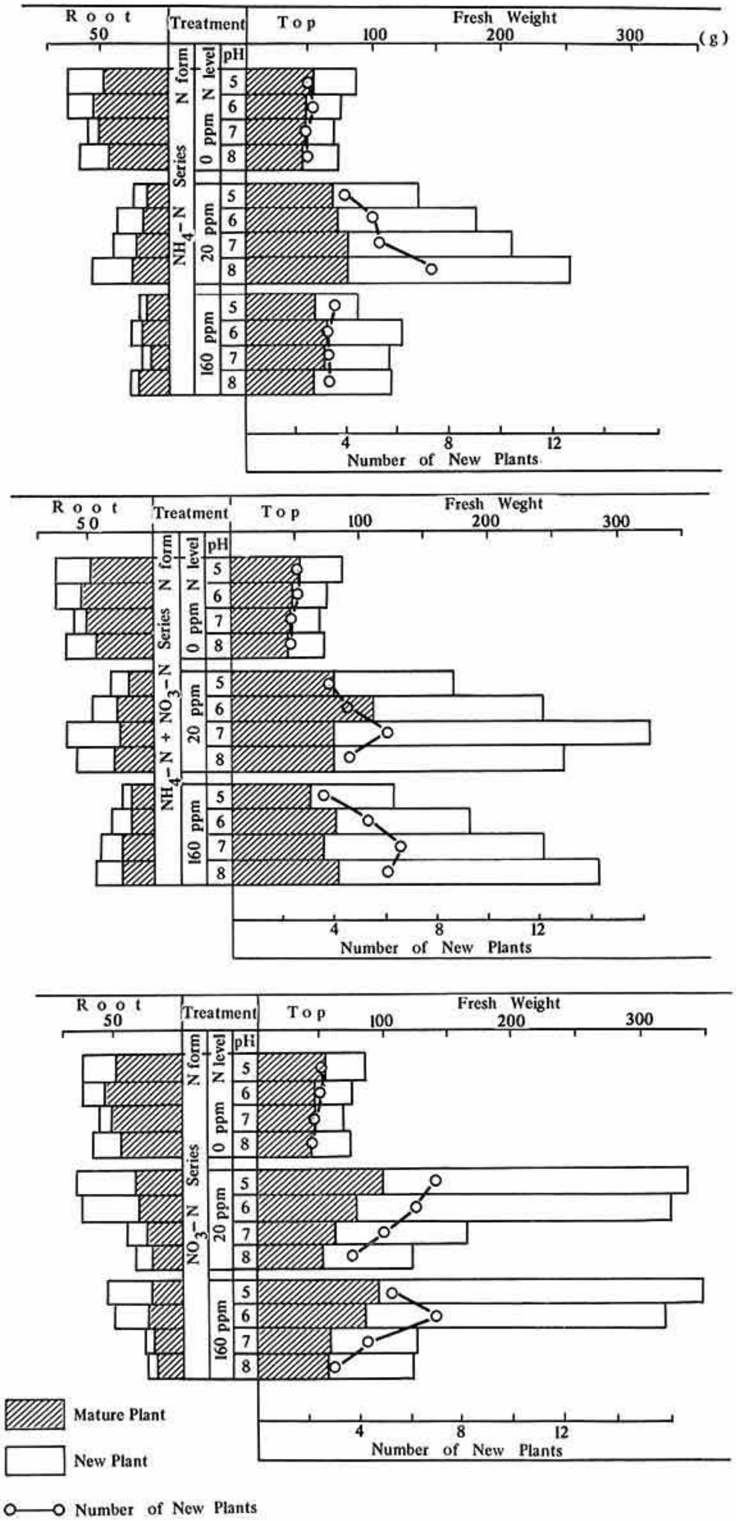

Fig. 6. Influence of nitrogen form and pH on fresh weight and number of new plants.

In the present study, the aerial parts of mature plants grown in a solution with 160 ppm ammonium-N contained total nitrogen at 8.23% on dry weight basis, while those of immature plants contained at 7.43%. Those values indicated that total nitrogen content of the plant was relatively high.

As Ogaki (1974)[13] reported that nitrate was superior to ammonium as a source of N for the growth of this plant, an experiment was done to study the influence of nitrogen forms on growth. The nitrogen forms were NO_3-N, NO_3-N + NH_4-N (5:5), and NH_4-N. Uniform-sized mature plants were grown in nutrient solutions (Table 2) with each form of nitrogen at 0, 20, and 160 ppm and at four different pH levels (5.0, 6.0, 7.0 and 8.0). After 4 weeks, the plants were harvested.

Fig. 6 presents that with NH_4-N and NH_4-N + NO_3-N the maximum growth occurred in neutral or slightly basic water, while with NO_3-N growth was better in acidic water than in neutral or slightly basic water. In general, a high pH favors uptake of ammonium-N and a low pH that of nitrate. The result of the above experiment showed such a trend.

Total nitrogen contents of plants grown with NH_4-N were higher than those with NO_3-N.

References

1) Baker, G. E., Sutton, D. L. & Blackburn, R. D.: Feeding habits of the white amur on waterhyacinth. *Hyacinth Control J.*, 12, 58–62 (1974).
2) Chadwick, M. J. & Obeid M.: Comparative study of the growth of *Eichhornia crassipes* Solms. and *Pistia stratiotes* L. in water-culture. *J. Ecology*, 54, 563–575 (1966).
3) Cordo, H. A. & Deloach, C. J.: Biology of the water hyacinth mite in Argentina. *Weed Science*, 24(3), 245–249 (1976).
4) Couch, R. & Gangstad, E. O.: Response of waterhyacinth to laser radiation. *Weed Science*, 22(5), 450–453 (1974).
5) Dunigan, E. D., Phelan, R. A. & Shamsuddn, Z. H.: Use of waterhyacinth to remove nitrogen and phosphorus from eutrophic waters. *Hyacinth Control J.*, 13, 59–61 (1975).
6) Haller, W. T. & Sutton, D. L.: Effect of pH and high phosphorus concentrations on growth of waterhyacinth. *Hyacinth Control J.*, 11, 59–61 (1973).
7) Hanzawa, Z.: Zassogaku, 114p, Rokumeikan 1911) [In Japanese].
8) Kamal, I. A. & Little, E. C. S.: The potential utilization of waterhyacinth for horticulture in the Sudan. *PANS*, 16(3), 488–496 (1970).
9) Kiflewahid, B.: Nutrient composition and digestibility of waterhyacinth by cattle. *Dissertational*, B. 36(12), 5878–5879 (1975).
10) Matai, S.: Protein from water weeds. In Aquatic weeds in S.E. Asia Proc. of a Regional Seminar on Noxious Aquatic Vegetation, New Delhi, (1976).
11) Minshall, W. K. & Scarth, G. W.: Effects of growth in acid media on the morphology, hydrogen-ion concentration, viscosity and permeability of waterhyacinth and forbit root cells. *Canad. J. Bot.*, 32, 188–208 (1952).
12) Obeid, M. & Chadwick, M. J.: Some factors affecting the growth of two aquatic weed species of the Nile-waterhyacinth and water lettuce. *Proc. 7th. Br. Weed Control Conf.*, 14(508) (1964).
13) Ogaki, K.: Studies on the mechanism of waterhyacinth and its growth habit. (1974) [In Japanese].
14) Parra, J. V.: The use of water hyacinth as a soil amendment and source of plant nutrients. Dissertation Abstracts International, B., 36, (1975).
15) Richarson, L. V.: Water level manipulation: a tool for aquatic weed control. *Hyacinth Control J.*, 13, 8–11 (1975).
16) Sakai, E.: Nutrient removal from effluent with of hog farms by waterhyacinth. *Animal Husbandry*, 27(4), 533–538 (1973) [In Japanese].
17) Santiago, C. M. Jr.: Proc. 2nd Indon. Weed Sci. Conf., Yogyakarta (1973) [In Press].
18) Ueki, K., Ito, M. & Oki, Y.: Waterhyacinth and its habitats in Japan. Proc. of the 5th Asian-Pacific Weed Sci. Soc. Conf. Tokyo, Japan. 424–428 (1975).
19) Wolverton, B. C. et al.: Bioconversion of water hyacinth into metane gas. NASA Technical Memorandum. TM-X-72725, (1975).
20) Zeiger, C. F. & McGehee, J. T.: Waterhyacinth control plan for the St. Johns River. *J. Aquatic Plant Management*, 15, 10–12 (1977).
21) Zettler, F. W., Freeman, T. E. & Charudattan, R.: Biological control of water weeds with plant pathogens. In Annual Research Report of the Institute of Food and Agricultural Sciences, University of Florida, 167 (1975).