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Effect Of pH On The Nature Of Competition Between *Eichhornia Crassipes* And *Pistia Stratiotes*

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ABSTRACT

Competition for space between *Eichhornia crassipes* (Mart.) Solms. and *Pistia stratiotes* L. was studied at pH 4, 7, and 9 at constant density and by varying plant proportions as a replacement series. *Eichhornia* was found to have a clear advantage in the mixed cultures (gaining species) and *Pistia* to have a clear disadvantage (losing species). *Pistia* was sometimes completely displaced from mixed cultures by *Eichhornia*.

INTRODUCTION

There is a paucity of information pertaining to interference or competition between aquatic plant species. Since these species rarely live in isolation in nature, studies of their population dynamics become imperative, being a necessary tool for the understanding and management of aquatic vegetation.

During a symposium on the problem of *E. crassipes* (Mart.) Solms. in Africa (2), it was observed that *P. stratiotes* L. was regressing before an *Eichhornia* invasion in the Congo River. Gay (5) claimed that *P. stratiotes*, abundant in the White Nile before the advent of *E. crassipes*, had been virtually eliminated from some regions. Also, Little (9) observed that both *P. stratiotes* and *E. crassipes* were competing in Lake Apanas in Nicaragua. Tag El Seed (12) studied the effect of pH on the performance of *E. crassipes* and *P. stratiotes* in monoculture and 50/50 mixtures. It was determined that *Eichhornia* was the gaining species in the mixed cultures.

The aim of this investigation was to study further the nature of competition between the two species as a function of pH and varied plant proportions (16).

METHODS AND MATERIALS

Plants of comparable size were chosen from natural populations of both species. The experiment included five treatments: a monoculture for each of the two species and three mixed cultures. In the mixture, the proportions of the two species were varied while the overall density was kept constant. Initially four plants were placed in each container. The details of the treatments are presented in Table 1.

The experiment included three pH's: 4, 7, and 9. Each treatment had three replicates, and the experiment was conducted as a randomized block design.

The plants were grown in 3-liter plastic containers in 2% standard Long-Ashton culture solution as given by Hewitt (8). This solution was renewed twice each week, and the pH was adjusted using 5% H_2SO_4 or 10% NaOH. Appropriate amounts of Na_2SO_4 were used to compensate for the addition of sulfuric acid (sulfate ions) to the more acid media. The pH levels were adjusted daily.

TABLE 1. INITIAL POPULATIONS OF *Eichhornia* AND *Pistia* GROWN IN CULTURE SOLUTIONS TO STUDY PLANT COMPETITION.

Proportion of *Eichhornia*	Proportion of *Pistia*
X = monoculture	none (0) in mixture
3/4 of mixture	1/4 of mixture
1/2 of mixture	1/2 of mixture
1/4 of mixture	3/4 of mixture
none (0) in mixture	X = monoculture

The experiment was carried out in a 'rakoba,' an unheated, unlighted wire greenhouse, offering shelter and protection from dust and wind and overhead protection from the sun. After five months the plants were harvested. The plants were counted, dried at 80 C for 48 hr, and their dry weights determined.

RESULTS AND DISCUSSION

The results of this experiment are given in terms of dry matter production and plant numbers.

Total dry weight. The total yield per container for the *Eichhornia* and *Pistia* components of the mixture for the three pH values are represented graphically in Figures 1A, 1B, and 1C. The graphs are drawn so that the pure *Eichhornia* component is on the left and the pure *Pistia* is on the right, with the mixture in changing proportions between them.

At pH 4, the yield was proportional to the number of *Pistia* plants in the mixture. However, this was not true at pH 7 and 9 and may be partly attributed to an insect infestation of the *Pistia* plants. Dry matter production in the monoculture indicated that pH 4 was optimum for the growth of *Pistia* (3).

The yield of *Eichhornia* decreased with the increase of *Eichhornia* in the mixture at all pH levels, indicating that *Eichhornia* suffers more from intraspecific competition than from interspecific competition. However, by comparison of the proportional contributions of the two species to the total yield of the mixture for the three pH levels, it can be seen that the combined yields and the relative contributions of each component represented a situation in which the overall yield was almost equal to the production of the

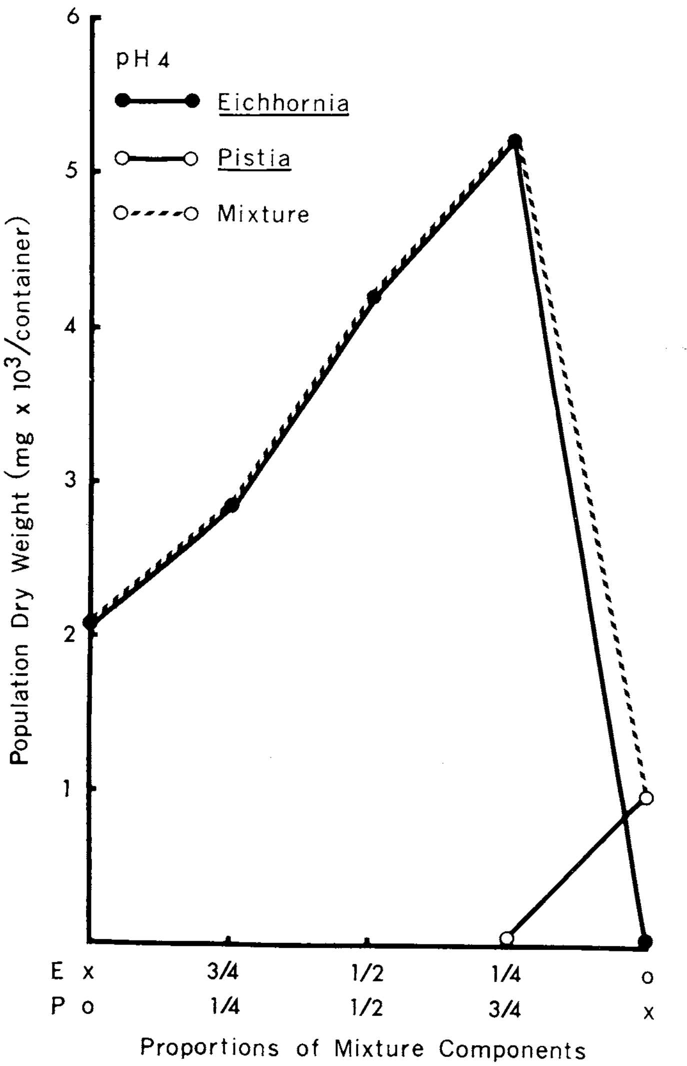

Figure 1A. Yield (dry weight) of *Eichhornia* (E) and *Pistia* (P) grown at pH 4 for five months after planting in various initial proportions.

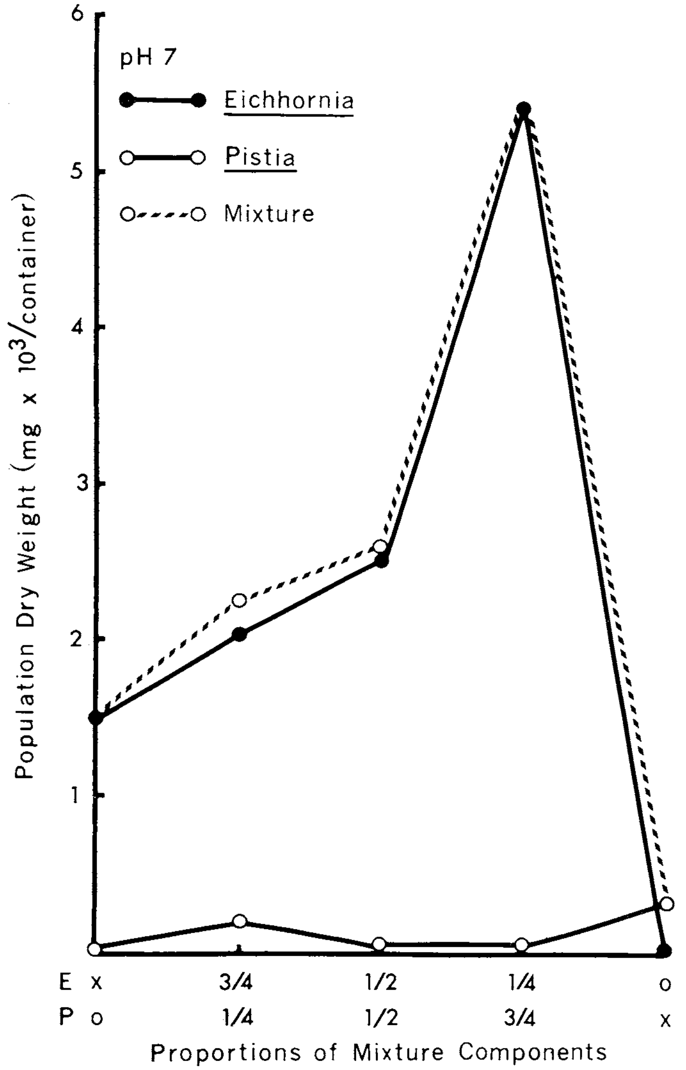

Figure 1B. Yield (dry weight) of *Eichhornia* (E) and *Pistia* (P) grown at pH 7 for five months after planting in various initial proportions.

high-yielding species (*Eichhornia*). Generally, at all pH levels studied *Eichhornia* was the gaining species and *Pistia* the losing species.

A measure of the performance of the two species in the monoculture and their competitive ability in mixtures can be obtained by assessing the performance of a component in the mixture in relation to its performance in the monoculture expressed on a per-plant basis. This value expressing "the individual crowding coefficient" was given by de Wit (16) as:

$$K = \frac{O_1 \div Z_1}{M_1 \div Zm_1}$$

where O_1 is the yield per plot of the component in the mixture, Z_1 is the number of seeds sown in the mixture, M_1 is the yield of the monoculture, and Zm_1 is the number of seeds sown for the monoculture.

However, if for any mixture the individual crowding coefficients of the two components are combined together a comparison is obtained of the relative effect of mixing on the two components. This is given by:

$$K_1/K_2 = \frac{O_1 \div Z_1}{M_1 \div Zm_1} \div \frac{O_2 \div Z_2}{M_2 \div Zm_2}$$

which is the relative crowding coefficient for species no. 1 in relation to species no. 2.

By applying these two formulae, the individual crowding coefficients for *Eichhornia* (K_e) and *Pistia* (K_p), and the relative crowding coefficients for *Eichhornia* and *Pistia* (K_{ep}) for the three pH values were calculated and are presented in Table 2.

K_e was generally greater than unity showing that *Eichhornia* benefitted from mixing. K_e increased with the decrease of the frequency of *Eichhornia* in the mixture, an indication of the high competitive ability of *Eichhornia*. For the most part, K_e was similar for similar proportions at all pH levels tried, showing little or no effect of pH on the total yield.

K_p seemed to be affected by the infestation of *Pistia* plants by insects, especially at pH values 7 and 9. K_p was generally less than unity showing that mixing was disadvantageous to *Pistia*. At pH 4, it was clearly seen that K_p

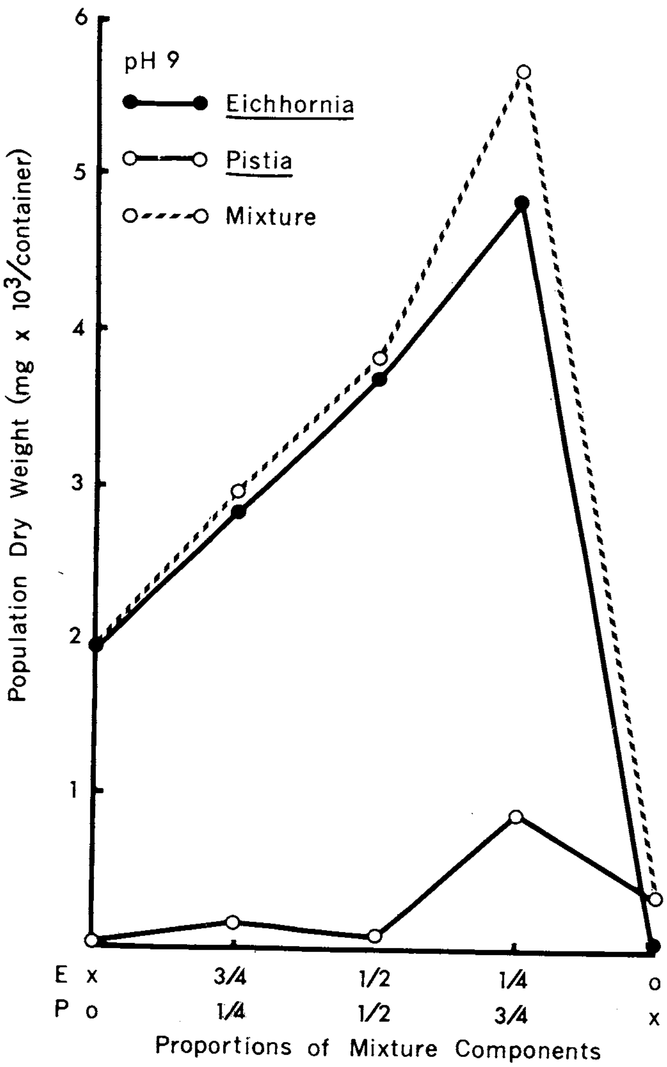

Figure 1C. Yield (dry weight) of *Eichhornia* (E) and *Pistia* (P) grown at pH 9 for five months after planting in various initial proportions.

increased with increases in the frequency of *Pistia* in the mixture. However, this was not so evident at pH values 7 and 9.

The product of K_e and K_p is another valuable and sensitive parameter related to competition. If (K_e) (K_p) is unity, the species influence each other only by crowding for the same space, and no actual competition ensues between them (14, 16). Space describes the exhaustible supply of growth factors of the environment. If the product of K values is smaller than unity, the species affect each other in some way other than crowding for the same space, and the mixture is not advantageous. K value products greater than unity mean that the space is exploited to a greater extent by the mixture than by the monoculture (16).

The products of K_e and K_p at pH 4, 7, and 9 for *Eichhornia* and *Pistia* are listed in Table 3. At pH 4, the product of K values was very low because K_p values were very small, showing the weak competitive ability of *Pistia* in mixed culture with highly competitive *Eichhornia.* At pH 7 and 9, however, the products of K values were generally greater than unity implying that mixed populations were advantageous to *Eichhornia.*

TABLE 3. THE PRODUCT OF INDIVIDUAL CROWDING COEFFICIENTS FOR *Eichhornia* (K_e) AND *Pistia* (K_p).

Initial proportions		$(K_e \times K_p)$		
Eichhornia	*Pistia*	pH 4	pH 7	pH 9
3/4	1/4	0.00	5.27	3.40
1/2	1/2	0.03	0.70	1.91
1/4	3/4	0.26	2.10	33.50

Plant numbers. The results expressed as plant numbers are included in Figure 2. The total number of *Eichhornia* plants harvested was almost constant in the mono- and mixed cultures at the three pH values, indicating that the container was probably limiting growth.

Pistia at pH 4 produced the highest number of vegetative propagules in the monoculture. In general, the number of *Pistia* plants harvested decreased as the proportion of *Eichhornia* plants in the initial mixture increased. *Pistia* was virtually eliminated from the mixture in some replicates.

It was evident that mixing was clearly advantageous to *Eichhornia* and disadvantageous to *Pistia,* but the total plant number in the mixture was greater than either of the monocultures. This finding is similar to the model of de Wit (16), in which one species gains more than its share (environment/total number of plants) of the environment, i.e. one plant is the more aggressive species.

Considering both the total dry matter production per container and the plant numbers, *Eichhornia* was always at a clear advantage in the mixed cultures and *Pistia* was at a clear disadvantage. *Eichhornia* is endowed with a larger leaf canopy which enables it to occupy the water surface, encroaching upon the relatively smaller *Pistia* plants and shading some of the light from them. The root system of *Eichhornia* is also very well developed (1), which enables it to exploit the environment efficiently. Indeed, Clatworthy and Harper (4) wrote, "Morphological characteristics . . .

TABLE 2. INDIVIDUAL (K_e AND K_p) AND RELATIVE (K_{ep}) CROWDING COEFFICIENTS CALCULATED FROM DRY WEIGHT DATA OF *Eichhornia* AND *Pistia* GROWING IN MIXED POPULATIONS AT pH 4, 7, AND 9.

Initial proportions		K_e			K_p			K_{ep}		
Eichhornia	*Pistia*	4	7	9	4	7	9	4	7	9
3/4	1/4	1.86	1.81	1.94	0.00	2.92	1.75	∞[1]	0.6	1.1
1/2	1/2	4.03	3.37	3.86	0.01	0.21	0.49	403.0	16.0	7.9
1/4	3/4	10.25	14.27	10.03	0.03	0.14	3.34	341.6	101.9	3.0

[1] Number divided by zero (0) was infinitely large.

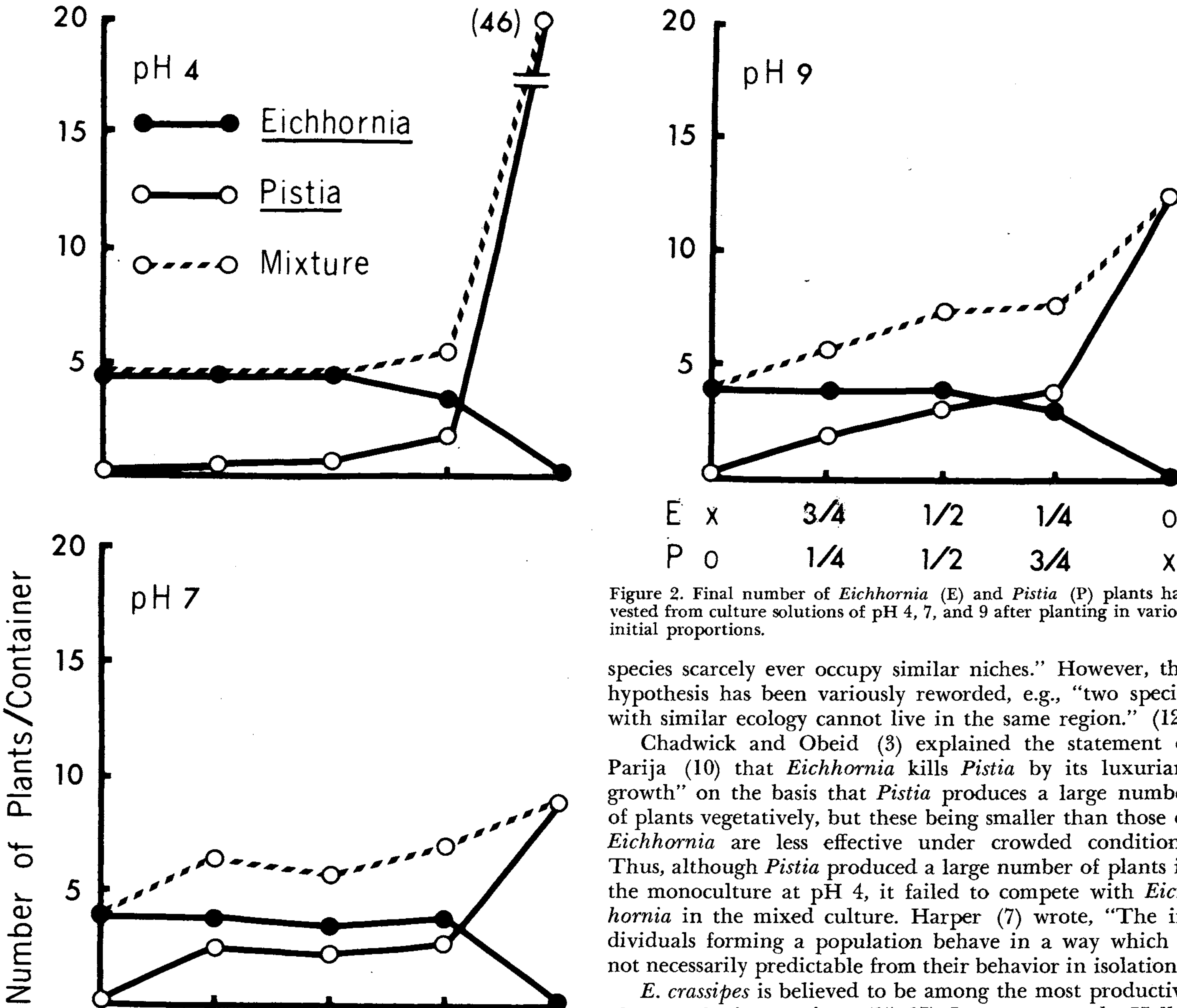

Figure 2. Final number of *Eichhornia* (E) and *Pistia* (P) plants harvested from culture solutions of pH 4, 7, and 9 after planting in various initial proportions.

clearly determine the outcome of a struggle for existence in which a successful species is that one which comes to occupy the surface of the layers of a mat of fronds."

The fact that *Pistia* was sometimes eliminated from mixed cultures by *Eichhornia* at pH 4, which is optimum for *Pistia's* growth (3) was interesting. Clatworthy and Harper (4) studied interference within some reduced free-floating species and concluded that ecologically similar species making demands on the same controlling factor of the environment (surface area or light) are unable to persist together indefinitely. The elimination of *Pistia* at pH 4 lends support to the possibility that both species were in fact competing in a 'de Wit sense' for the same space, which was light. Sculthorpe (11) wrote, "Antagonism is likely to be evident in communities of floating-leaved or free-floating species for which optimal exposure to light or occupation of the maximum surface area is the critical element of competition." Gause (12) wrote, "Two similar species scarcely ever occupy similar niches." However, this hypothesis has been variously reworded, e.g., "two species with similar ecology cannot live in the same region." (12).

Chadwick and Obeid (3) explained the statement of Parija (10) that *Eichhornia* kills *Pistia* by its luxuriant growth" on the basis that *Pistia* produces a large number of plants vegetatively, but these being smaller than those of *Eichhornia* are less effective under crowded conditions. Thus, although *Pistia* produced a large number of plants in the monoculture at pH 4, it failed to compete with *Eichhornia* in the mixed culture. Harper (7) wrote, "The individuals forming a population behave in a way which is not necessarily predictable from their behavior in isolation."

E. crassipes is believed to be among the most productive photosynthetic organisms (15, 17). In a recent study, Haller and Knipling (unpublished) reported that *Eichhornia* and *Pistia* are C_3 plants. The maximum photosynthetic rate of *Eichhornia* was found to be about 40 mg CO_2 dm^{-2} hr^{-1}, and the plant appears to become light-saturated at approximately full sunlight. On the other hand, the maximum photosynthetic rate of *Pistia* was much lower (about 5 mg CO_2 dm^{-2} hr^{-1}) and light-saturation occurred at 20-25% of full sunlight. These authors believe that this low photosynthetic rate could be attributed to the low amount of chlorophyll present in the *Pistia* plants. The total chlorophyll content of *Pistia* leaves was only 0.3 mg dm^{-2}, compared to 3.4 mg dm^{-2} in *Eichhornia* leaves. According to Ultsch and Anthony (13), the high productivity of *E. crassipes* could also result from the ability of the plant to utilize carbon from the root zone where respiration of decomposing organic matter and associated faunal communities is high.

In this investigation, *Pistia* generally reacted to mixing with *Eichhornia* by a plastic reduction in size and number and in some cases it was virtually eliminated from the plant community.

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LITERATURE CITED

1. Arnold, C. A. 1940. A note on the origin of the lateral roots of *E. crassipes* (Mart.) Solms. Amer. J. Bot. 27:728-730.
2. C.C.T.A./C.S.A. 1957. (Commission for Technical Cooperation in Africa South of the Sahara/Scientific Council for Africa South of the Sahara) Report of the symposium on *Eichhornia crassipes,* Leopoldville. C.C.T.A./C.S.A. Publs. 27:1-31.
3. Chadwick, M. J. and M. Obeid. 1966. A comparative study of the growth of *E. crassipes* Solms. and *Pistia stratiotes* L. in water culture. J. Ecol. 54:563-575.
4. Clatworthy, J. N. and J. L. Harper. 1962. The comparative biology of closely related species living in the same area. V. Inter- and intraspecific interference within cultures of *Lemna* spp. and *Salvinia natans.* J. Exp. Bot. 13:307-324.
5. Gay, P. A. 1958. *Eichhornia crassipes* in the Nile of the Sudan. Nature (London) 182:538-539.
6. Haller, W. T. and E. B. Knipling. Light saturation and photosynthesis of six emergent aquatic plants. Unpublished manuscript.
7. Harper, J. L. 1964. The individual in the population. British Ecol. Soc. Jubilee Symp. A supplement to the J. Ecol. 52:149-158.
8. Hewitt, E. J. 1952. Sand and water culture methods used in the study of plant nutrition. Commonwealth Agricultural Bureau, Reading.
9. Little, E.C.S. 1966. The invasion of man-made lakes by plants. *In*: R. H. Lowe McConnell, ed. Man-Made Lakes. Symposium Inst. Biol. 15:75-86. Inst. Biol. and Academic Press, London.
10. Parija, P. 1934. Physiological investigations on waterhyacinth (*Eichhornia crassipes*) in Orissa with notes on some other aquatic plants. Indian J. Agr. Sci. 4:399-429.
11. Sculthorpe, C. D. 1967. The biology of aquatic vascular plants. Edward Arnold Ltd., London. 610 pp.
12. Tag El Seed, M. 1972. Some aspects of the biology and control of *Eichhornia crassipes* (Mart.) Solms. Ph.D. Thesis. University of Khartoum.
13. Ultsch, G. R. and D. S. Anthony. 1973. The role of aquatic exchange of carbon dioxide in the ecology of the waterhyacinth (*Eichhornia crassipes*). Florida Sci. 36(1):16-22.
14. Van Den Bergh, J. P. and W. T. Elberse. 1962. Competition between *Lolium perenne* L. and *Anthoxanthum odoratum* L. at two levels of phosphate and potash. J. Ecol. 50:87-95.
15. Westlake, D. F. 1963. Comparison of plant productivity. Biol. Rev. 38:385-425.
16. Wit, C. T. de. 1960. On competition. Versl. Landb. Onderz. Ned. 66.8:1-82.
17. Yount, J. L. 1964. Aquatic nutrient reduction-potential and possible methods. Rep. 35th Ann. Meeting, Florida Antimosquito Assoc. pp. 83-85.

J. Aquat. Plant Manage. 16: 57-59