Chapter - II

REVIEW
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LITERATURE
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McLean, K. (1921) considered water-hyacinth to have the distinction of being called "a Demon".

McLean, K. (1921, 1922) described it as "Bengal Terror".

Bose, P. K. (1933) regarded water-hyacinth as the "Curse of Bengal".

Matthews, L. J. (1971) described water-hyacinth as a "Million Dollar Weed".

Vietmeyer, N. D. (1975) called it a "Blue Devil".

O. P. Gupta (1973); Pieterse, A. H.; H. Sirregar and O. Soemarweto (1975); Guscio, F. J.; T. R. Bartley and A. N. Beck (1965) reported that water-hyacinth is today distributed throughout the world, in both tropics and sub-tropics in fresh-water ponds, lakes, pools, tanks, reservoirs, streams and rivers. (Smith, W. C. (1926); Penfound and Earle (1948); Backer, C. A. (1951); Gay, P. A. (1958) considered the water-hyacinth to be native of Brazil.

Bose, P. K. (1945); Shibata, M., K. Yamazaki and N. Ishikura (1965); Bailey, F. M. (1902); Standley, P. C. (1928) have designated South America to be the place of origin of water-hyacinth.
Small, J.K. (1936); Smith & Merchant (1961) reported that "it seems however appropriate that the Neotropics may be treated as the native place of water-hyacinth; without referring to a specific geographic region.

Tabita, Angello and J.W. Woods (1962) stated that the plant was naturalised in Louisiana in 1860s.

Sastroutomo, S., Ikusima and M. Numata (1978) stated that water-hyacinth spread to the old-world tropics at about the same time towards the turn of this century and was introduced into Japan in Meiji Era (1868-1912) and had soon naturalised in Southern Japan.

Kotalawala, J. (1976) stated that, water-hyacinth was introduced in Ceylon (Sri Lanka) in 1905 and it soon spread throughout the island necessitating the promulgation of "water-hyacinth ordinance, 1909" prohibiting import of the plants and making it punishable to cultivate or to fail to destroy it.

Backer, C.A. (1951) stated that water-hyacinth was first introduced in the Botanical Garden, Buitenzorg (New Bogor) in Java (Indonesia) in 1894.

McLean, K. (1921, 1922) suggested 1888 or 1889 as the possible year of entry of water-hyacinth in India.

Biswa, K. & C.C. Calder (1954) stated that the weed got established in Bengal near about 1896.
Haines, H.H. (1924) reported the presence of water-hyacinth in the river Irrawady (Burma) and other rivers in the region and only sporadic occurrence in Orissa.

Duthie, J.F. (1911) reported that water-hyacinth is not recorded in his flora of upper Gangetic-Plains and adjacent Siwalik Hills and the weed spread in Northern India much later.

Patnaik and Patnaik (1956); Majumdar, R.B. (1962); Srivastava, J.G. (1964); Mukhopadhyaya, S.K. (1968) and O.P. Gupta (1973) stated that to-day water-hyacinth occurs throughout India.

**Morphology:**

Couch, R. (1971) reported that the stem or the rhizome consists of an axis with several short internodes, the nodes bear the leaves, roots, off-shoots and inflorescence.

According to Arber, A. (1918), the morphology of the leaf has been a subject of discussion and he suggested that the blade is not true lamina but merely an extension of the petiole.

Penfound and Earle (1948) have studied the biology of water-hyacinth in detail. According to them *Eichhornia crassipes* (Mart) Solms is a perennial, mat-forming aquatic, of wide distribution in tropical and sub-tropical regions. They also reported that, from all accounts it is a native of Brazil but has spread there from to nearly all of the South American and Central American countries. The pest occurs in nearly all the countries of the world favourable
to its development such as Australia, China, India, Indo-China, Japan, Siam and South Africa. Penfound and Earle (1948) further noted that, the water-hyacinth causes damage by obstructing navigation, impending drainage, destroying wild-life reserves and constituting a hazard to life. They further reported that the morphological structure of water-hyacinth consists of roots, rhizomes, stolon, leaves, inflorescence and fruit clusters.

Olive (1894) reported that, the roots are fibrous, unbranched and with a conspicuous root cap. He further noted that the roots are purplish in exposed situations but white, when in darkness or when rooted in the soil.

Penfound and Earle (1948) reported that, the vegetative stem consists of an axis with short internodes which produces, at the numerous nodes, all the roots, leaves, off-shoots and inflorescence of the plant. This portion, they designated as rhizome. They further reported that, upon occasion, long internodes are produced which are usually nearly horizontal in open conditions but may be relatively short and nearly vertical in dense mats. In either case they produce new off-shoots at their distal ends. These elongate internodes have been designated as stolons. They further noted that, it is very difficult in dense stands of the species to differentiate between rhizomes and stolons, since, under such conditions, both are nearly vertical. However, since the two structures have quite different functions, it is likely to refer to them as rhizomes and stolons respectively.
Penfound and Earle (1948) observed that the stomata of water-hyacinth are similar in shape, number and distribution to those of the average mesophytic, monocotyledonous plant. The stomatal apparatus resembles the typical one. The average number is about 120 per square millimeter. They further reported that, the most unexpected discovery in their stomatal work was in connection with leaf size. On plants which had developed on land or in poorly oxygenated water, the leaves were small and broader than long; whereas on large plants, in flowing water, the leaves were very large and narrower than long. Despite this very great difference in size of the leaves, there were no significant differences in their stomata. Neither the number per unit area, the inter stomatal distance, the size of the guard cells, nor the size of the stomatal pore varied significantly among leaves from small, medium and large plants. This means that the greatly increased size of the leaves on the large plants is due to an increase in the number of cells and not to an augmented cell size as might have been anticipated.

Penfound and Earle (1948) also reported that, the inflorescence of water-hyacinth is an attractive, lavender spike sub stended by two bracts and surmounted on an elongate stalk (Peduncle). The individual flower consists of an hypanthium; three sepals, three petals, six stamens and a tricarpellate pistil. The pistil consists of conical ovary, a long style and a capitate stigma which is situated about half-way between two groups of anthers. They further observed that, the ovary ripens into a thin-walled capsule which is imprisoned
in the relatively thick-walled hypanthium. The ovary produces about 500 ovules but only about 50 seeds per capsule. The very small seeds are released by the splitting of the pericarp.

Weber, H. (1950) reported that the roots produce a large number of laterals of limited growth giving a fine feathery appearance.

Wakefield, J.W. & W.M. Bick. Jr. (1962) reported that the plants growing in domestic sewage were observed to be 75 cm. tall but had little roots.

In another report, Bagnall, L.O.; T. Des Furman; J.F. Hentges, W.J. Nolan and R.L. Shirley (1974) pointed out that the plants growing in nutrient rich-waters developed long petioles (upto 100 cm.) and short roots (less than 20 cm.) while in nutrient-poor-waters; petioles were less than 20 cm. long while the roots were more than 60 cm. long.

Das, R.R. (1968) opined that, there is a strong correlation between root length and leaf length.

Tagelseed, M. and M. Obeid (1975) pointed out that, each spike has 4-26 flowers though the number is sometimes as high as 35. They further observed that 8-15 flowers per inflorescence are more common.

According to Sharma (1967), the pollen grains are monocoplate, sometimes 2-coplate, ellipsoidal or spindle-shaped; planoconvex

Along with floral trimorphism; pollen trimorphism is also observed in water-hyacinth although Bock, J.H. (1966) reported only monomorphic authors.

According to J.C. Haigh (1936) the seeds of water-hyacinth are brown, 1.5 mm x 0.3 mm; narrow-shaped; pointed at one end and truncate at the other, with about 12 longitudinal ridges of a darker-brown colour. He further reported that, they were very uniform in size, varying from 1.2 - 1.6 mm in length and 0.6-0.9 mm in width.

Pariija, P. (1934) suggested that, the hardnes of the seedcoat of water-hyacinth is responsible for its delayed germination. He further stated that, the germination can be induced by rupturing the seedcoat or by bubbling oxygen through the water in which the seeds are kept. It is suggested either that the oxygen, by virtue of its greater concentration, penetrates the seed coat in sufficient quantity to induce germination of the embryo or that it may so act on the seed coat as to increase it permeability.

Phenology:

Das, R.R. (1968) has shown that, in Northern India there are two distinct flowering seasons of water-hyacinth, i.e. pre-rainy
period (April-June) and Post-Rainy period (August-December). He also further pointed out that the plants collected from the upper-Gangetic-plains (Jammu to Calcutta) and grown at Varanasi did not flower during July and early August.

Penfound and Earle (1948) also reported two flowering peaks in Southern United States; one in June and the other in September.

Bock, J.H. (1966) observed flowering in Berkley (California 35°N) from mid July to November.

Tackholm, V. and M. Drar (1950) observed flowering of water-hyacinth from May to September in Egypt (25-30°N).

Agharkar, S.P. and I. Banerjee (1930) noted two periods of flowering of water-hyacinth, i.e., from April to mid-May and from July to mid-December, also at Calcutta.

But Dekimpe, P. (1957) reported flowering throughout the year in Congo (5°N-10°S). The same observation has also been made by Parija, P. (1934) in Orissa.

As mentioned earlier, the number of flowers per inflorescence is quite variable and the time taken for all flowers to open also varies from 02-15 days. But as reported by S.C.H. Barett (1977), majority of the flowers in an inflorescence open on the first day.

Agharkar, S.P. and I. Banerjee (1930) reported that, the flowers open in the morning soon after sunrise but on cloudy and humid days late-opening has been recorded.
Vegetative Propagation:

Parija, P. (1934) observed seven-fold increase in water-hyacinth spread in fifty days.

Perfound and Earle (1948) reported that, the edge of water-hyacinth mat was extended by 60 cm. every month.

Polling, J. and J. Barr (1965) reported that two plants of water-hyacinth could multiply to 1200 in 120 days.

Holm, L.G., L.W. Weldon and R.D. Blackburn (1969) observed 30 off-springs from two parent plants in 23 days.

In another study in Egyptian Nile, Batanouny, K.H. and A.M. El.Fiky (1975) reported that a plant with 450 cm² basal area; 40 gm. fresh weight and 7.4 leaves, was observed to grow within 50 days, to plants with 43 off-shoots, 1,0827 m² area; 1.244 kg. fresh weight and 208 leaves. In 200 days it had grown to 3418800 plants spread over 14928 m².

Bock, J.H. (1969) suggested that the rate of mean daily increment by vegetative means can be calculated by the equation:

$$\text{No} \times X^t = \text{Nt}$$

where, \(\text{No}\) = Number of plants growing at a certain time

\(X\) = Geometric rate of daily increment

\(t\) = time (Number of days)

\(\text{Nt}\) = Number of plants after time 't'
Different workers have observed the rate of mean daily increment to range from 1.012 to 1.077.

In another study, the growth rate has been expressed in terms of Relative Growth Rate (RGR) and Doubling Time (DT) following the formula noted below as per De Kimpe, P. 1958 and Mitchell, D.S. (1974).

\[
\begin{align*}
\text{RGR} & = \frac{\ln X_1 - \ln X_0}{t} \\
\text{DT} & = \frac{\ln^2 X_0}{RGR} \\
X_0 & = \text{Initial weight} \\
x_0 & = \text{Weight after time 't'}
\end{align*}
\]

In terms of weight, 50 per cent increase has been reported in 13 days by Bock, J.H. (1969) and same 50 per cent has been reported by Knipling, E.B.; S.H. West and W.T. Haller (1970).

Sastroutomo, Soetikno; Ikusima Isao and Numata Makoto (1978) had an ecological study of water-hyacinth with special emphasis on their growth. They found out that the relative growth rate (RGR) and the doubling time (DT) of water-hyacinth in summer were five times higher and four times shorter than those in winter respectively, and with addition of fertilizer (10 kg NPK/ha) were eight times higher and five times shorter respectively. Besides temperature, the nutrient status of the water was also an important factor for the growth of water-hyacinth. They further noted that, during winter
period with average air temperatures of 10-15°C, the exposed portions of the leaves were destroyed by low temperatures as indicated by blackening and yellowing of the blades and the upper part of the petioles. Experiment on the resprouting ability in different temperatures of rhizome showed that after two weeks at 20°C the rhizome could sprout 100% while at 15°C and 25°C gave results of 60% and 80% respectively.

Experiment on the RGR of water-hyacinth during winter period showed that the winter growth of water-hyacinth was very low, in comparison to summer-growth.

**Sex Reproduction:**

Redley, H.N. (1930) observed that the plant reproduces only vegetatively in its adventive range.

Bock, J.H. (1966) also reported the absence of sexual reproduction in California.

Penfound and Earle (1948) observed mature fruits from May to December.

Haigh, J.C. (1936) suspected seed production in the tropics and said that the seeds may be an important factor in spread of the weed in Sri Lanka.

Sastroutomo, S., I. Ikusima and M. Numata (1978) reported that in Japan also, seedlings have been observed in Summer and Autumn season after the plants died in previous winters.
However, Mitchell, D.S. and P.A. Thomas (1972) did not find seeds or mature fruits in the area of South America.

Bruhl, P. and J. Sengupta (1927) obtained seeds by artificial pollination.

Agharkar, S.P. and I. Banerjee (1930) observed that only about 35% of the flowers are pollinated under natural conditions.

Subramanyam, K. (1922) reported that seed formation takes place only in the submerged inflorescence.

Das, R.R. (1968) reported that submergence was not necessary. He observed an average of 15 seeds per fruit in submerged inflorescence while 41 seeds per fruit were recorded in non-submerged fruits.

In another study Jilghman, N.J. (1963) reported that the fruit formation and seed development are unaffected by submergence or water level, though the calcium content appeared to affect seed production.

Barett, S.C.H. (1980) reported that seed production is affected by environmental conditions and he concluded that more seeds have been found to be produced in water-hyacinth grown in tropics than in temperature regions.

Muller, F. (1883) observed more than 260 seeds per capsule while Tagelseed, M. and M. Obeid (1975) and Talatala, R.L. and
A. Djalil (1974) recorded the number varying between 5 and 542 (Average 99 ± 80.3).

Pollination:

The pollination in water-hyacinth has received considerable attention from many workers.

According to Penfound and Earle (1948) the question of the method of pollination has intrigued research workers for years. Despite the excellent adaptions of the flowers for cross-pollination by insects, no pollinators had been observed. They further pointed out that very rarely the honeybees visit the flowers. It is doubtful whether much pollination is effected by the insects.

According to Penfound and Earle (1948) self-pollination is the natural process in water-hyacinth. They carried out hundreds of self-pollination by hand and obtained ripe capsules in nearly every case.

David L. Mulcahy (1975) reported that Eichhornia crassipes (Mart) Solms exhibits two floral forms: the long and midstyled forms of a tristylos system. An investigation of these floral forms revealed the correlation between pollen size and stamen length, frequently found in heterostylosous taxa and possible indications of a weak self-incompatibility system, supporting earlier suggestions that, reproduction in this species is wholly asexual.

M. Tagelseed and M. Obeid (1975) reported in a study of some of the factors that are believed to affect fruit-setting in Eichhornia crassipes under sudan conditions, the average number of flowers
per inflorescence was twelve (range 4-26) while the number of capsules per inflorescence was 1.5 (range 0-16). The problem of low fruit-setting was suggested to be basically due to the ecological factor of high temperature and low relative humidity.

Djalil, A. (1973) and Barret, S. CH. (1977, 1980), reported that 4 groups of bees were observed to visit flowers of water-hyacinth under natural conditions.

Seed Germination:

It has been reported that, the fruits get detached from the inflorescence axis, dehisce longitudinally and the seeds are released. The seeds sink down to the bottom of the mud, where they remain, until suitable conditions are met with for their germination.

Muller, F. (1883) considered that desiccation was essential for germination of water-hyacinth seed in Brazil.

Crocker, N. (1907) reported germination within seven days in seeds kept constantly in water though he has also noted that in water plants, drying helps in cracking of the seed coat, thereby facilitating germination.

Parija, P. (1934) reported that, the seed coat was a barrier for germination and its removal favoured 100% germination. He also found oxygen, bubbled into water, to help seed germination.

Halgh, J. C. (1940) observed that the germination in the seeds of water-hyacinth took place seven days after collection and did
not find drying or dry storage necessary for germination. He further observed that, seeds remain viable longer, when stored in water.

Barton, L.V. and J.E. Hotchkiss (1951) observed that water storage for 17 months at 20-30°C decreases seed dormancy.

Hitchcock et al. (1959) reported that, dry-stored seeds take twice longer time for germination than wet-stored seeds.

Matthews, L.J. (1967) reported that, the seeds remain viable for several years.

Obeid, M. & M. Tagel-Seed (1976) also conducted a similar experiment and observed 78% viability after two years.

Barton, L.V. & J.E. Hotchkiss (1951) reported that, the seeds can tolerate near-freezing temperature of 4°C and fluctuating temperature up to 40°C, in a greenhouse. He further noted that, maximum germination takes place under conditions of large diurnal temperature fluctuation, i.e. 5-23 - 59°C.

Pettet, A. (1964) reported seed germination in nature, after the water-hyacinth mat had been killed by 2,4-D spray. This provided ideal conditions (light, O₂, Temp. - fluctuation) for seed germination. In another experiment he further reported that, no germination was observed in clear water or on pure sand.

Francois, J. (1970) studied the effect of light and temperature on seed germination and he concluded that both these factors have profound influence on germination. He observed that, high light
intensity and alternating high and low temperature favour germination. He further concluded that 30-40°C temperature during the light phase and 20°C during the dark phase are required for germination.

Tagel Seed, M. (1972, 1975) in an experimental study found that, seed germination was not affected by 2,4-D.

Obeid, M. & M. Tagel-Seed (1976) reported that, the seed germination has been found to be favoured by 2.5-3cm. deep water layer, clayey soil, rich in organic matter. They also reported that, burial of seeds in soil also prevents germination.

Although many workers have concluded that, vegetative propagation is the most important type of reproduction in water-hyacinth, some efforts have also been made to study in relation to seedling development. Subramanyam, K. (1922) reported that in the early stages of seed germination, the cotyledon emerges first through the micropyle as a knob-like protuberance. The first leaf grows out when the radicle is fixed in the soil.

Tomihisa, Y. (1975) also reported that, the young seedlings grow anchored on a loose substratum of clay or peat and usually in 10-15 cm. deep water. Later they become free-floating after 10-12 leaf stages.

Cytology:

A little work has been done on the cytological investigations of water-hyacinth. Krishnappa, D. G. (1971) reported that, the
chromosome number in *E. crassipes* is $2N = 32$. He further showed that the chromosomes can be grouped into three sizes. There are four pairs of long chromosomes, two with nearly median centromere and two with sub-median centromeres. Eight pairs of median sized chromosomes comprise of two pairs with median and six pairs with sub-median centromeres. The remaining four pairs of short chromosomes possess sub-median centromeres. The somatic nuclei do not show the occurrence of SAT-chromosomes.

Sharma, A.K. & C. Talukdar (1961) confirmed $2N = 32$ and reported that six chromosomes also possessed secondary constriction.

**Ecology:**

Water-hyacinth multiplies so rapidly that it forms dense monospecific mat covering the entire body. This mat helps in the elimination of most of the submerged aquatics as light does not reach under water. It is commonly seen, when the density of water-hyacinth is low there is regrowth of many submerged plants and other free-floating plants like *Azolla*, *Pistia*, *Salvinia* occur in the area. Therefore the study of the ecology of water-hyacinth has gained immense importance by various workers.

Gay, P.A. (1960) reported occurrence of *Vossia cuspidata* and *Cyperus papyrus* among the mats of water-hyacinth on the white Nile.

Little, A.C.S. (1966) observed that in *Apanas* Lake (Nicaragua) the water-hyacinth competes with *Pistia* and Tagel-Seed, M. (1972)
on further investigation reported that Pistia is shown to be replaced by water-hyacinth in mixed culture and this is largely due to the fact that the larger leaf Canopy enables water-hyacinth to occupy the surface and thereby shading smaller Pistia plants. Tagel Seed, M. (1975, 1978) further observed that the pH of the habitat also appeared to favour water-hyacinth in competition with Pistia.

It has been reported by Monakev, A.V. (1969) that, water-hyacinth is also associated with a specific animal community in its natural habitat. He listed 11 crustaceans and several rotifers in addition to aquatic insects and their larvae. He also reported that zooplanktons increased in white Nile after the invasion of water-hyacinth.

The rapid growth and development of water-hyacinth plant has drawn attention of many workers. According to Iswaran, V.; A. Sen and R. Apte (1973), Azotobacter chroococcum is present in the leaf surface of water-hyacinth growing in a pond near Lipa (Phillipines). Later it was reported by Iswaran, V. (1976) that the bacterium favoured the growth of leaves, stem and roots and the germination of seeds of Secale Cereal (Rye), possibly due to the presence of growth substances like gibberelins, thymine or riboflavin. Similar bacteria have been reported on the roots of water-hyacinth by Dunigan, E.P. (1974).

Nayak, D.N.; A. Swain and and V. Raja Rammohan Rao (1979) reported Azospirillum lipoforum from the roots and phyllosphere of water-hyacinth.
The study of Das, R.R. (1968) and Francois, J. (1970) reveals that the plant is heliophilous and can grow best under high light intensity and high temperature. He further reported that the plant can also grow under a wide range of light intensities (24,000–2,40,000 lux hours), and photoperiods ranging from 6-16 hours. The plants are day neutral with respect to flowering. Francois (1970) also reported that minimum light intensity of 5380 lux is required for float formation. He further emphasized that, the leaf form is governed by light intensity, i.e. it is with floats in high light intensity and with long petioles in shade or crowded condition. Boresch, K. (1912) also reported that, along with low light intensity, high temperature promotes elongation of petiole.

Francois (1970), and Knipling et al. (1970) studied the temperature requirement of the plant and reported that the temperature requirement of the plant is 27-30°C and they further noted that the plant ceases to grow when water temperature is below 10°C or above 40°C. The plants do not withstand higher temperatures. Francois (1970) was of the opinion that, the plant can tolerate frost except that the terminal bud is found to be killed. He also determined that, the plants die within 48 hours at 45°C. Anderson, R.G. (1977) in another study reported that, low temperature has been shown to result in more stolons per unit area and reduced leaf size.

Kirkland, D.L. (1977) demonstrated that, the temperature affects nutrient uptake and transpiration. Soekisman, T. (1977) reported a direct correlation between stolon number and light intensity.
Hitchcock et al. (1959) and Francois, J. (1970) reported that, the flowering is affected by temperature during day and night but is not influenced by light period. Francois (1970) further noted that a minimum of 20°C or 21°C temperature during night and about 35-40°C during the day is required to induce flowering. Hitchcock et al. (1959) were of the opinion that no flowering occurs if the temperature falls below 16°C.

As water-hyacinth is free-floating fresh water aquatic many workers have been interested to study the effect of fluctuation in water level on the growth of this plant (In the present investigation biochemical studies are made in water-hyacinth plants with different water level). Freidel, J. (1976); Hestand et al. (1973); Widyanto, L.S. (1976); Hestand and Carter (1974, 1975) reported that, the fluctuations in the water level and desiccation do not affect growth of water-hyacinth plants. Haigh, J.C. (1930) observed better growth in 15 cm. deep water with the plant roots anchored in the mud.

As the plants grow directly on water, the level of nutrients in water has drawn attention of several workers. Hitchcock et al. (1959) observed optimum growth with the addition of 100-150 g compost soil per litre of water.

Chadwick, M.J. & M.Obeid (1966) observed optimum growth of water-hyacinth with 25 ppm nitrogen or 100 ppm nitrogen. Haller, W.T. & D.L.Sutton (1973), with 20 ppm phosphorous while, Haller, Kipling, and West (1970) reported that, the critical level of phosphorous for growth is 0.1 ppm, though luxury consumption occurs at higher concentrations (at 40 ppm phosphorous level in water, plants accumulated 9.1 mg per gr.dry et.). They also reported that excess nutrients, absorbed from the medium are usually leached out of the stem and roots within six days.

Centre, T.D. & J.Balciunas (1976); Das, R.R. (1968); Penfound & Earle (1948) reported that, the plants grow only in fresh water and do not tolerate salinity but Haller et al. (1974) in a study observed that the plants tolerated salinity up to 0.25 per cent though the growth was adversely affected.

As water-hyacinth is a fresh water plant the pH condition of water and effect of pH on growth has been studied by several workers.

Parija, P. (1934) observed that the optimum growth occurs at pH 6 to 8, and plants growing in more acidic or alkaline waters, tend to change the pH within this range. Haller & Sutton (1973) observed maximum growth at pH 4.0 (which changed to 4.6 after four weeks) and more or less the same growth up to pH 8.0 (which changed to 7.3 after 4 weeks). Chadwick, M.J. & M.Obeid (1966, 1964); Salamet, S. & S.Sukowati (1975); Santiago, C. (1973); Soekisman, T.
(1977) observed optimum growth at pH 7.0. Bery, A. (1959-61) in an extensive survey in the Congo basin for water-hyacinth in relation to pH of water revealed that the pH from 3.5 to 4.2 is highly toxic; 4.2 to 4.3 is inhibitory; possibly inhibitory in the range 4.3-4.5 and non-inhibitory in the range 4.5-5.2. In another study he pointed out that pH 4.0 is toxic and satisfactory growth occurs at pH 5.0 to 7.0.

Mohamed (1975) worked on the ecology of water-hyacinth in the white Nile, Sudan. He opined that, infestation of the white Nile system by water-hyacinth (Eichhornia crassipes (Mart) Solms) can be classified into three major consecutive phases of a cyclical nature. These phases are related to seasonal changes in certain environmental factors, results in an annual cycle. He showed that the periodic rise and fall of infestation is based on the responses of water-hyacinth to the optimum conditions of high flood season and adversities of low flood respectively. He further explained that, the annual cycle is affected by (a) the direction and extent of water-hyacinth drift and (b) vegetative vigour as indicated by the rates of vegetative multiplication and seed regeneration.

P.A. Gay (1960) conducted ecological studies of Eichhornia crassipes in Sudan. In this study he recorded details concerning its spread, to analyse the probable causes of its variable rate of dispersion and to forecast probable further development, if it is not controlled. He reported that the determination of growth rate gives an approximate value of 10-15% increase in fresh weight.
per day. He further noted that the roots of *E. crassipes* hang into the water to a depth of 80 cm or more providing a friction surface upon which current can act.

J.S. Singh and K.P. Singh (1967) worked on ecological studies of ten Noxious Weeds including *Eichornia crassipes* to explain the mechanism of acclimatisation and speciation in the concerned weeds.

R. Sahai and A.B. Sinha (1969) studied on the contribution to the ecology of Indian Aquatics. Here they investigated the seasonal changes in biomass of water-hyacinth. Their studies revealed that macrophytic communities were more productive per unit area than phytoplankton. They reported that the values of biomass were minimum during September and maximum during January for dry and organic matters and during February for fresh matter.

Jean W. Wooten & John D. Dodd (1976) studied on the growth of water-hyacinth in treated sewage effluent. According to them two thousand plants of water-hyacinth were introduced on April, 1971 into a series of five ponds, each 5000 sq.ft. in area and 2.6 feet deep. Treated waste water effluent from the Ames Sewage treatment plant filled the ponds and was added to pond - 1 at 127 gallons per minute. By growth and vegetative reproduction, these plants increased to more than 5,00,000 and all five ponds were covered completely by July. On that date the extrapolated estimate of total wet weight was 287 U.S. tons/acre (645 metric tons/hectare; 2970 g/m²). They further reported that ammonia and
nitrate disappeared rapidly from the pond water and phosphate concentrations were lowered appreciably. Evapotranspiration and seepage accounted for water losses of more than 0.5 inches per day. They observed that, the data for *E.crassipes* growing in water, enriched with effluent from a secondary sewage treatment plant indicate much higher growth rates attained than when plants grown in natural habitat.

A very unusual feature of the root of *E.crassipes* is the place of origin of the lateral rootlets in natural ecological habitat. The primordia of the lateral rootlets of this plant do not arise from mature and completely differentiated tissue, as in most plants. Chester, A. Arnold (1940) studied on the origin of the lateral rootlets of *Eichhornia crassipes* and concluded that the lateral rootlets make their first appearance in the immature pericycle only a short distance from the promeristem, and not, as in most plants, in mature or nearly mature tissue. He further concluded that, they first show as a series of closely spaced cell enlargements which become more distantly spaced as the tissue matures and the root elongates.

Maxine A. Watson & Craig S. Cook (1982) studied the development of spatial pattern in clones of the aquatic plant, *Eichhornia crassipes*, Solms, and noted that the spatial geometry of clonal growth of *Eichhornia crassipes*, a plant which increases in number by the vegetative production of stolon off-shoots (or Ramets), was assessed by the the use of a vector analysis. They further pointed out that growth of water-hyacinth clones was found to be assymetric;
assymetry increasing with time. The direction of assymetry was independent of either population density or the position of nearest neighbours. According to them the analysis revealed the importance of geometric relationship within the parental growth axis for determining patterns of clonal spread. Meristem growth and differentiation appear to be controlled so as to maximize clonal growth rate. This contrasts with the pattern observed in rhizomatous terrestrial species in which the control of meristem growth and differentiation appears to result in efficient use of space at the expense of greater increase in clonal size.

Lusianty S.Widyanto (1975) conducted autecological study of water-hyacinth. Quadrats of one square meter were made in a pond at the Bogor Botanic Garden with various depth (21-46 cm), pH (7.1-7.7), K (3.4-3.8 PPM) and Ca(8.5-11 PPM). Bulbous form plants (6 leaves of 20 g) were planted and SGR, fresh and dry weight were measured. The important factors affecting the growth of water-hyacinth were water depth (the lower the better) and P contact (the higher the better for the growth of water-hyacinth). The number of leaves was doubled every 7-10 days and the mass production was 106 tons/ha/year, which absorbed 313.0 kg N and 95.8 kg P/ha/year.

Slamet,S. and S.Sukowati (1975) in a study on the effect of light intensity and levels of nutrients on the growth of water-hyacinth, pointed out that interaction was found only between
different levels of P and light intensity as observed on the growth of water-hyacinth (the summed growth ratio, number of leaves fresh and dry weight). They further reported that water-hyacinth grows better in a medium with a pH of 7.0 than with a pH of 5.5 or 4.0. An interaction was found between the effects of different levels of pH and levels of P (but not with levels of N and K). The uptake of P was more intensive at pH 4.0 while that of N and K was more intensive at pH 7.0.

Development of axillary buds is an important factor in the vegetative growth of water-hyacinth. In a study, Jennifer H. Richards (1982) reported that, buds axillary to foliage leaves of water-hyacinth can elongate either as vegetative stolons or as renewal shoots produced in association with the terminal inflorescence. He further pointed out that, stolons differ from renewal shoots in position within the shoot system; morphology and function. Renewal shoot buds always expand, whereas stolon buds may or may not. A stolon bud develops in conjunction with the subtending leaf: as that leaf matures, the stolon bud reaches a critical period in development. At this point, the bud either continues to expand producing a stolon, or it stops growth and matures. Maturation is not irreversible, but the probability of a bud-expanding decreases as bud-age increases. In the field, buds on plants at the water-hyacinth mat edge frequently produce stolons, whereas buds on plants inside the mat rarely do so. Leaf morphology also varies between plants in these two regions of the mat. The particular association of leaf and branch
type found in the field, however, can be reversed experimentally indicating that although leaf and bud development are coordinated, the particular course of each is independent.

Sastroutomo Soetikno, S.; Ikusima Isao and Numata Makoto (1978) conducted ecological studies of water-hyacinth (Eichhornia crassipes (Mart) Solms with special emphasis on their growth. The study was conducted in the laboratory as well as in the field. They reported that, the productivity at the Hanami river, Chiba, was decreased in winter in term of fresh weight and dry weight. Some of the rhizomes still had a good growing ability if placed in a high temperature (25°C). Therefore it is possible that they can survive the winter in the field of Central Japan. The relative growth rate (RGR) and doubling time (DT) of water-hyacinth in summer were 5 times higher and 4 times shorter than those in winter respectively, and with addition of fertilizer (10 kg NPK/ha) were 8 times higher and 5 times shorter respectively. Besides temperature, the nutrient status of the water was also an important factor for the growth of water-hyacinth. A little detail of this has been described in respect of growth.

Physiology:

As reported earlier water-hyacinth has been able to resist a considerable drought and survives even when the water content of the soil falls as low as 5.7 per cent of the saturation value. Apart from that water-hyacinth has served test material for several
physiological studies. Its rapid vegetative multiplication has baffled the domain of scientific workers and the reappearance of water-hyacinth in carefully cleared tanks has puzzled the scientific community. Therefore many workers have thought it necessary to have a physiological investigation of the plant, hoping that some indication may be obtained as to the mode of eradication.

Cholonky, B. J. (1952) used epidermal cells of *E. crassipes* to study the permeability of NaCl and KNO₃ and concluded that, the resistance of passage of alkali like NaOH and KOH indicates the protein structure of plasmalemma instead of a lipoidal nature.

Gagetti, A. (1947) pointed out that, in aquatic plants like *E. crassipes*, the epidermis alone and not the mesophyll have protoplasm capable of regulating the intensity of transpiration.

Water-hyacinth is well-known for its great ability to lose water rapidly through transpiration by leaves. From this property probably the name of the plant has been given as "Samudra Sokh". Brenzy et al. (1970) reported 26 per cent more water loss through Eichhornia cover while Das (1968) reported the water loss to be 5.78-9.84 (average 7.76 ± 1.36) times higher in different seasons.

Wooten, J. W. & J. D. Dodd (1976) observed that a water-hyacinth mat over a pond measuring 100 x 50 x 2.5 feet results in lowering of water level by 1.3 inch (3.3 cm) per day while Miner et al. (1971) would amount to only 0.6 inch (1.5 cm) per
day water loss. In view of the high rates of evapo-transpiration it has been suggested by Stephens, E.L. (1972) and Stephens, J.C. V.L. Guzman and C.C. Seale (1955) that the plants can be used in reclaiming marshes and water-logged soils.

Growth of the plants is associated with the rate of photosynthesis. Due to rapid vegetative growth of water-hyacinth plant several workers have been interested in its photosynthetic ability. Soekisman, T. (1977) studied growth in terms of carbon dioxide assimilation and pointed out that, the water-hyacinth appears to follow the C₃ pathway but differs from other C₃ plants in the fact that the photosynthetic mechanism does not exhibit light saturation at 30 Klx or more. The theoretical net primary production from the CO₂ assimilation rate comes to 18.6 t/ha/yr.

Ultsch, G.R. & D.S. Anthony (1973) demonstrated that, water-hyacinth can also utilise dissolved CO₂ through roots for photosynthesis.

In another study, David, T. Patterson & Stephen O. Duke (1979) conducted an experiment on the effect of growth-irradiance on the maximum photosynthetic capacity of water-hyacinth (Eichhornia crassipes (Mart) Solms). They grew water-hyacinth for 60 days in a greenhouse under natural light and in a controlled environment room at 31/25°C day/night temperatures and 90,320 and 750 \text{ E m}^{-2} \text{ sec}^{-1}. They then determined maximum photosynthetic rates in 21% and 1% oxygen, stomatal diffusion resistances, contents of chlorophyll and soluble protein, and the size and density of the photosynthetic
units (PSU) in representative leaves from the four treatments. In air containing 21% oxygen, maximum photosynthetic rates were 14.27 and 29 mg CO$_2$ dm$^{-2}$ hr$^{-1}$ for plants grown in artificial light at 90,320 and 750 μ Em$^{-2}$ sec$^{-1}$, respectively. Plants grown in natural light (maximum of 2000 μ Em$^{-2}$ sec$^{-1}$) had maximum photosynthetic rates of 34 mg CO$_2$ dm$^{-2}$ hr$^{-1}$. In all treatments, photosynthetic rates in 1% oxygen were about 50% greater than rates in normal air, indicating the presence of photorespiration in water-hyacinth. There was no apparent relationship between maximum photosynthetic rate per unit leaf area and stomatal conductance, chlorophyll content per unit area or PSU density per unit area. However, the higher maximum photosynthetic rates were associated with greater mesophyll conductances, specific leaf weights and protein contents per unit area. When plants grown at 90 μ Em$^{-2}$ sec$^{-1}$ for 120 days were transferred to 750 μ Em$^{-2}$ sec$^{-1}$ for 5 days, only young leaves that were just beginning to expand at the time of transfer exhibited adaptation to the higher irradiance. The 40% increase in light-saturated photosynthetic rate in these young leaves was associated with increases in mesophyll conductance, soluble protein content per unit area and specific leaf weight.

There has been considerable work on the presence of growth regulating substances in the extracts of root and other parts of water-hyacinth plant, possibly anticipating that, these might be responsible for the rapid vegetative growth and multiplication of the plant. The studies in this regard were primarily made by
S.M. Sircar and his students at Calcutta University. Sircar, S.M. and M. Kundu (1960) for the first time reported the presence of growth regulating substances in water-hyacinth roots. The root extract promoted shoot growth but inhibited root growth in rice plant. It also helped in early emergence of ear (inflorescence). Further they found out that, the extracts accelerated the growth of shoots of rice, oat, wheat, maize, chickpea and peanut. They suspected the substance, to be different GA & IAA because of a difference in plant responses to the extract.

In other study, Sircar, S.M. and Rothin Chakrabarty (1962) reported that there was increase in height of rice (cv Chinsurah boro I) and gram (NP 50), increased tillering in rice and more lateral branching in gram. They further observed that the growth promoting substances in root extract of water-hyacinth were similar to gibberellins. Sircar and Chakrabarty (1961) in another study pointed out that, the height of the jute plant increased after treatment with the root extract of water-hyacinth. The basal circumference of the stem was also markedly increased. The total number of leaves and nodes on the main stem also showed an increase over the control.

Sircar, S.M. and Arati Ray (1961) revealed through chromatographic study of the plant extract of water-hyacinth, the presence of growth substances in addition to GA and indole compounds.
In another study, R.K. Mukherjee, Arati Bhanja, P. Roy Burman and S.M. Sircar (1964) pointed out the presence of bound auxin in the roots of water-hyacinth (*Eichhornia crassipes*).

An experiment on cell growth and metabolism of pea (*Pisum sativum* L.) internodes as affected by the growth substances from the root of water-hyacinth was conducted by Susama Ganguly and S.M. Sircar (1964). They found out that the cell number at the shoot tip and the frequency of division are significantly increased by the treatment. The diameter of the vessels was found to have considerably increased in the treated internodes but the forms of the vessels remained unchanged. It was interesting to note that nitrogen and carbohydrate metabolism was influenced by the application of the extract. The percentage of sugar in different treated internodes was greater than the control. The total and reducing sugar markedly increased in the fourth internode.

Arati Bhanja and S.M. Sircar (1966) extracted gibberellins from the roots of water-hyacinth and later Sircar et al. (1973) isolated four gibberellin like factors $A_1, A_2, A_3$ and $A_4$.

Further investigations have shown that the growth and leaf form in water-hyacinth are influenced by gibberellin concentration. Pieterse et al. (1976) found that the leaves had longer petiole with smaller diameter, with increasing concentration of $GA_3$. The float formation was totally suppressed at a low concentration i.e. 0.03 PPM. At 0.1 PPM, the floats were small as compared to those in control (without GA). They suggested that external factors (light
and temperature) affecting float formation, act through endogenous gibberellins perhaps cytokinins. They also reported that benzyl-adenine induces thicker floats and counteracts the inhibitory effects of gibberellin on float formation. Compounds like 2-chloroethyl, 1-trimethyl ammonium chloride (CCC), IBA, abscissic acid and ethylene releasing compounds have no effect on float formation.

Widyanto, L.S. (1978) also observed that gibberellic acid at a concentration up to 0.02 PPM results in improved growth but higher concentration results in loss of weight and in supression of float formation. The supression of float formation by gibberellic acid reduces buancy and makes plants unstable. The plants sink partially below water surface. GA also reduces vegetative growth and induces profuse flowering.

Several other physiological aspects of water-hyacinth were studied by different workers. M.Obeid & M.Tagel-Seed (1976) studied the factors affecting dormancy and germination of seeds of *Eichhornia crassipes* (Mart) Solms from Nile. They concluded that, the best laboratory germination was in clay soil, rich in organic matter, under less than 3 cm. depth of water, in light. They further noted that, there were interactions with water depths, soil types, organic deposits, light and temperature. Storage conditions of seeds before germination affected the result. Wetting, drying and re-wetting gave quickest and complete germination.
L.A. Desougi and M. Obeid (1978) worked on some aspects of the evapotranspiration of *Eichhornia crassipes* and some other water weeds and pointed out that water loss through evapotranspiration caused by water-hyacinth was found to be greater than that caused by either of the aquatic weeds: water lettuce (*Pistia stratioties*), hornwort (*Ceratophyllum demersum*); Canadian Pond Weed (*Elodea canadensis*) on a free water surface and wet soil.

D.R. Gossett and W.E. Norris, Jr. (1971) studied on the relationship between nutrient availability and content of nitrogen and phosphorous in tissues of the aquatic macrophyte, *Eichhornia crassipes* (Mart) Solms., and concluded that the nitrogen and phosphorous content of the blades, floats and roots showed a positive correlation with the nitrogen and phosphorous content of the environment. Both the nitrogen and phosphorous content of the blades, roots and floats increased as the nitrogen and phosphorous content of the culture medium was increased.

Thomas N. Cooley & Dean F. Martin and Willey C. Durden Jr. & B. David Perkins (1978) conducted an experiment on preliminary study of metal distribution in three water-hyacinth biotypes and analyzed for chlorophyll content and metal distribution (Potassium, calcium, magnesium, cobalt, copper, manganese and iron) in roots, leaves and stems. Two biotypes were distinguished by size (medium or "stunted" and large or "super") and by whether they were or were not eaten ("stunted" and "super" respectively) by the water-
hyacinth weevil, *Neochetina eichhornae* Warner. Results were compared with a third biotype (small or normal"), i.e. plants from the Hillsborough and Peace rivers where the Weevils had not been released. The data indicated abnormal concentration of cobalt and iron in the leaves of the "super" plants relative to the third biotype. Fractions of calcium, magnesium, manganese, iron, and copper in roots showed a significant, negative linear correlation coefficient, $r$, with solubility product constant (log KSP) for metal carbonates of the small and medium biotypes.

Craig S. Tucker (1981) pointed out that, the average daily dry matter yield, percentage nitrogen and chlorophyll. Content of water-hyacinths were found to differ significantly when cultured in nutrient solution containing either $NH_4^+\text{-N}$ or $NO_3^-\text{-N}$. Average daily ash-free dry matter yield, cell-wall fraction and non-structural carbohydrate content were not significantly affected by the ionic form in which nitrogen was supplied. Varying the amount of nitrogen supplied to the water hyacinth, resulted in significant differences in yield and composition. Low supplies of nitrogen resulted in decreased yields and fibrous plants with lower nitrogen and higher non-structural carbohydrate content. They concluded that increased nitrogen supplies not only increase the yield of water-hyacinths but also produce plants of greater nutritive value. They further concluded that, as nitrogen availability increased, synthesized carbohydrates are more rapidly converted to proteins and less carbohydrate is available for deposition as cell-wall material.
Control Aspect:

Water-hyacinth; like some other aquatic weeds creates a large number of problems, particularly related to the use and management of water resources, i.e. dense growth of the plants obstructing water-flow in irrigation channels, interfering with navigation and hydroelectric power generation. Therefore several workers have tried to control or destroy the water-hyacinth plants. During the last 75 years or so, a large number of chemicals have been tried in different concentrations and formulations to control the plant along with some mechanical means.

Hildebrand, E.M. (1946) first reported the effect of 2,4-D on water-hyacinth. Subsequently several workers like Penfound and Earle (1947); Verginia Maynard (1947); Barton & Hotchkiss (1951); Padwick, G.W. (1948); Srinivasan & Chacko (1952); Thomas & Srinivasan (1947); Wanderlich, W.E. (1962); J.W. Woods (1963); M.T. Phillipose (1963); Saha et al. (1958); A.C. Sen (1957); Braddock, W.B. (1966); Roger & Dotty (1966); Little, E.C.S. (1969); K. George (1971); Brown, C.A. (1974); Singh & Muller (1979) used several formulations of 2,4-D like sodium salt, esters and amines in different concentrations. It has been reported that 15-30 mg of 2,4-D per kg water-hyacinth are effective for sinking the water-hyacinth mat.

Different chemicals like ammonia, formaline, barium-chloride, sodium chloride, sulphuric acid, arsenic oxide and copper sulphate etc. have been used.
Sutton, D.L. and R.D. Blackburn (1971) reported that more than 3.5 PPM copper sulphate inhibits growth of water-hyacinth. They further pointed out that water-hyacinth absorbs and accumulates large quantities of copper in its tissue, so copper is to be applied in larger doses.

Koegel et al. (1973) reported that high temperature increases the effect of 2,4-D.

Penfound, W.T. & Virginia Maynard (1947) reported that the effect of 2,4-D in causing greater injury is more in shade than in full sun and it may be applied with advantage in evening than in morning.

White, A.C. (1965) used diquat and Singh & Muller (1979) used paraquat for the control of water-hyacinth. Corner et al. (1964) suggested Amitrol-T to have certain merits over 2,4-D although it was slower in action than 2,4-D.

Bajpai & Chauhan (1973); Joshi, N.C. (1969); Koegel et al. (1973); Naidu, Murty and Rao (1965) reported that 2,4-D amine salt and diamquat are most effective in controlling water-hyacinth. But Faust, S.D. & O.M. Aly (1962); Samuel, D.F. & M.A. Osman (1962) reported that these chemicals are not safe for other forms of life and water quality for most human uses is adversely affected.

Choudhury, H.C. (1956) applied Mercene special for the control of water-hyacinth and reported that the plant was successfully
killed in 14 days with solutions of Mercene special. Mishra & Das (1960); Mishra & Tripathy (1975) suggested that 2,4-D at 1000 PPM daily spray is effective in killing water-hyacinth plant. They further reported that 2,4,5-T was more effective than 2,4-D.

Harris et al. (1975) conducted greenhouse and field experiments and suggested that, various herbicides showed a satisfactory effect against *Eichhornia crassipes*. They further reported that, in the growth chamber, the action of 2,4-D proved better at higher temperature and relative humidity levels than at the corresponding lower levels with temperature being more important than relative humidity. Low spray volumes brought no noticeable change in the effectiveness of 2,4-D and diquat compared with high volume rates, but herbicide reliability was somewhat reduced at the lower rates.

Experiments conducted by Singh & Muller (1979) in the greenhouse with water-hyacinth plants revealed that three hours after spraying with paraquat or 2,4-D at recommended herbicidal rates, 43-53% of the herbicide was found in the plants and the rest was present in the water culture. Absorption of 2,4-D from the culture solution by the roots and floats of the water-hyacinth was evident. Translocation of root-absorbed 2,4-D into the meristematic foliar parts was demonstrated.

C.F. Musil and C.M. Breen (1977) conducted experiments on application of growth kinetics to the control of *Eichhornia crassipes* (Mart) Solms., through nutrient removal by mechanical
harvesting, and pointed out that, the growth of *Eichhornia crassipes* under nitrate-nitrogen limiting conditions can be explained by Monod rectangular model. The kinetic constants, maximum specific growth rate, half saturation constant and yield coefficient were determined under nitrate-nitrogen limiting conditions in nutrient culture at an air temperature of 35°C. The practical application of these constants for the possible control of water-hyacinth through nutrient limitation was illustrated.

**Utilisation:**

Though several efforts have been made to control the water-hyacinth plant, no man had 100% success in controlling or destroying it. Therefore some workers thought of aspects of some utilisation of this plant.

Finlow, R.S. & K. McLean (1917) recommended it for fertilizer. It was reported by Day, F.W. (1918) that water-hyacinth is a valuable source of potash.

Hentges et al. (1972) described processing of water-hyacinth by dehydration, grinding and pelleting and mixing with ingredients for better consumption. Their experiments with cattle, mice and rats showed no toxicity or other bad effects on these animals, though in one of the studies; rats fed on 30% water-hyacinth-diet showed weight-loss.

As reported by several workers, water-hyacinth has, more often been used as a pig feed. Thohari, Hartiyanto and Pangesti
(1977) reported that 5-15% of fresh chopped water-hyacinth in pig diets had no adverse effects, while in broilers, the weight decreased.

Ghosh, J.J. (1967) has reported possibility of extracting protein from water-hyacinth and its use in combating protein deficiency in human beings. The water-hyacinth has also been recommended for compost and soil amendment as suggested by Wolverton & McDonald, (1976).

Sen and Chatterjee (1931) were first to demonstrate the possibility of using water-hyacinth for generation of power alcohol and fuel gas.

**Miscellaneous:**

Recent studies on water-hyacinth have focussed some light on its status of infestation and management, utilisation, controlling measure, mineral uptake, absorption of heavy metals environmental management etc. Imaoka, T. & Teranishi, S.(1988), conducting an experiment on the rates of nutrient uptake and growth of water-hyacinth, pointed out that, the specific growth rate of water-hyacinth was dependent on the air temperature, plant density and N content, N-uptake rate was correlated with N-concentration.

In this study he discussed the significance of the finding in terms of (i) knowledge of the plant canopy (LAI) which would allow the transformation of $r_aC$ to $rC$, the total canopy diffusive resistance and (ii) proper accounting for different trace gas diffusivities, which would allow the transformation of $rC$ for water vapour to the variety of $rC$ values required to interfere the gaseous deposition of important pollutant gasses at leaf surfaces.

Rao, A.S. and Subramanyam, K. (1987) studied on the chemical control of water-hyacinth and reported that, 2,4-D amine at 5.4 kg/ha and 2,4-D ester at 3.6 kg + paraquat at 0.25 kg. provided the highest mortality of water-hyacinth up to 30 days after spraying.

Dai, Q.Y. and Zhang, Y.S. (1988), working on absorption of heavy metals by the water-hyacinth and second accumulation in fishes after fed on the water-hyacinth reported that, the presence of water-hyacinth (*E. crassipes*) in river water in the eastern suburbs of Suzhou City reduced the concentration of phenols from 0.005-0.023 mg/litre to trace amounts; Total N from 5.33 to 2.33 mg; total phosphates from 0.84 to 0.183 mg; Cu from 0.57 to 0.32 PPb; Pb from 0.14 to 0.006 PPb; Zn from 65.6 to 25.6 PPb and Cd from 0.14 to 0.003 PPb. They also reported that no secondary accumulation of heavy metals was evident in fish when fed in this plant material.

Nor, Y.M. & Cheng, H.H. (1988) worked on the chemical speciation and bio-availability of copper-uptake and accumulation by *Eichhornia* and pointed out that, the uptake of copper by *Eichhornia*
crassipes was studied using solution culture techniques in the green uptake of copper was a direct function of its speciation, e.g., only free Cu^{2+} was absorbed by the plant in the presence of strong ligands such as EDTA and humic acid.

Raju, R.A. and Reddy, M.N. (1988) reported that, mixture of 4 kg 2,4-D/ha + 1 kg paraquat, has been excellent control measure within two weeks. Cost of treatment was Rs.460.00/ha and it was 61% lower than that for manual weeding.

Narasaiah, J.; Prasad, A.R.; Jamil, K. and Sattur, P.B. (1989) reported that several newly synthesized triazole-thiadiazoles showed varying degrees of toxicity when sprayed on to E. crassipes, plants. Of these 2-(2,4-dichlorophenoxy-methyl) 5-(3,4-methylene-dioxy phenyl)-5-triazole [3,4-6]-1,3,4-thiadiazole gave 100% control.

Abdullah, M.Y. (1990) reported that, in Malaysia, water-hyacinth (Eichhornia crassipes) commonly proliferates in irrigation canals, stagnant ponds, disused mining pools, water-ways and semi-wet areas. Methods used to manage E. crassipes and the cost of control programmes are considered. Their results indicated that E. crassipes can be used to economically, and effectively, treat palm oil meal and rubber factory effluents.

Baruah, J.N. (1990), working on an environmentally sound scheme for management of water-hyacinth through utilisation suggested paper manufacture from the petioles, bio-fertiliser production from the roots and bio-gas production from the remaining plant material.
The present investigation aims at eco-physiological study of water-hyacinth in respect of seed germination, especially with the effect of pH and herbicides; association of plants with water-hyacinth in its ecological habitat, morphological changes with change in habitat; study of water-quality; effect of pH on growth; biochemical and enzymological changes in relation to its ecology, effect of water and NaCl stress; effect of herbicide on the biochemical and enzymological status of the plant. Almost no work has been done in relation to its biochemical and enzymological setup of this plant. Therefore in the present investigation stress is given on those aspects as well as the biochemical and enzymological changes of the water-hyacinth plant in relation to age of the leaf and with manipulation of water level. Because the leaf of water-hyacinth has been discussed by several authors as a very specific and interesting structure. Also many workers have reported existence of water-hyacinth plant in the environment with low water content. Therefore, the present study has also aimed at the biochemical and enzymological changes, if any, with manipulation of water level, so that some indicative clue might be suggested for the control of this plant. Apart from this, biochemical study has also been made with NaCl stress applied to the plant with a view to find out some biochemical and enzymological changes of the plant because several authors have suggested that the plants do not grow in the saline habitat. Therefore this study is an attempt to present some important data on all the above aspects of water-hyacinth which has long been regarded as one of the most problematic aquatic weeds.