CHAPTER - III

RESULTS AND DISCUSSION

3.1 GEOGRAPHICAL DISTRIBUTION OF *Eichhornia crassipes* :

Water hyacinth is distributed today throughout the world in the tropics and subtropics. It occurs in freshwater ponds, pools, tanks, lakes, streams and rivers and in irrigation channels. The history of its distribution is only about a century old. Enough evidence is now available to prove that, man has willingly or unintentionally aided in its dispersal and present distribution. Water hyacinth was recorded first in Central and South America and later on from south-east Brazil (Gopal and Sharma 1981).

Eichhornia crassipes Solms. is well established in entire Indian sub-continent. Maharashtra is one of the regions from Western ghats region of India. *E. crassipes* is a common aquatic weed in this region. At the centre of present study the weed is common in Khodshi weir on river Krishna near the campus of Yashwantrao Chavan College of Science, Karad (L 21°, 10'N, L 72°, 50'E).

3.2 GROWTH PERFORMANCE OF *Eichhornia crassipes* :

The effect of different environmental factors on growth and flowering in water hyacinth have been invesdtigated in detail by Penfound and Earle (1948), Das (1968) and Francois (1970).

TABLE - 1

Growth Performance of the *Eichhornia crassipes*

in light and shade habitat

Parameter	Obs. No.	Leaf part				Number of leaves per plant
		Lamina		Petiole		
		Length (cm)	Breadth (cm)	Length (cm)	Girth (cm)	
Light	1	4.0	6.5	9.0	7.0	6
	2	4.5	7.5	7.0	7.0	6
	3	5.0	7.5	9.5	9.0	6
Shade	1	17.0	16.0	58.0	2.5	7
	2	16.0	16.5	57.0	3.0	7
	3	15.5	15.5	44.0	3.0	6

These studiesd have shown that, the plant is heliophilous and grows best under high light intensity. They have also noticed that, the leaf form of Eichhornia crassipes is governed by light intensity.

We have studied, the growth performance of E. crassipes with reference to the morphological differences in leaf parts of the plants grown in heliophytic and sciophytic habitats. The results are illustrated with help of Table 1 and Figure 4.

It is clear that, number of leaves per plants in both ecological conditions remains almost the same. When leaf morphology was studied, it was clear that, in light conditions breadth of leaf lamina is more than the length. However, in shade condition the breadth and length of lamina is almost the same. There is remarkable difference in the morphology of petiole from light and shade habitats. The petioles of the plants from light conditions are in forms of floats and that in shade condition are very long and thin. From the data recorded in Table 1 it is clear that, the petiole length is about 5-6 times more in shade condition while the girth of petiole is about 3-4 times more in plants from the light conditions. Thus our results take the point of morphological differences in leaves of Eichhornia crassipes with reference to light conditions few steps ahead.

3.3 STOMATAL STUDY

Now-a-days stomatal behaviour has received much attention in eco-physiology of the various plants. Stomatal behaviour regulatesd the gas exchange and controls the transpiration. There is co-relation between stomatal behaviour and the path of carbon assimilation (Das and Santakumari 1977).

Stomatal frequency of both the surfaces and frequency ratio of leaves of Eichhornia crassipesis recorded in Table 2. The results show that, more stomata are present on lower leaf surface. Similar trend is observed in the plants of river and pond habitat. The value of stomatal frequency ratio is about 2.5 ± 0.6 in plants from both the environments.

Das and Santakumari (1977) have reported that, stomatal frequency ratio (Lower/upper surcace) is always high (2.2 to 4.10) in C_3 plants while it is low (0.6 to 1.60) in C_4 plants. Thus stomatal frequency can be used as a tool to predict photosynthetic nature of the plant. Our values of stomatal frequency ratio signifying the C_3 path of carbon assimilation in E. crassipes. Euphorbia geniculata; a terrestrial weed is also predicted for its C_3 path on basis of stomatal frequency ratio by Patil (1988). Our prediction of C_3 path of E. crassipes is

TABLE - 2

Stomatal frequency in the leaves of *Eichhornia crassipes* from two different water bodies

Water body	No. of stomata mm^{-2}			Stomatal frequency ratio (Lower/Upper)
	Upper epidermis	Lower epidermis	Total	
River	36	92	128	2.56
Pond	36	87	123	2.42

strengthened by our other results of chlorophylls which are discussed separately.

3.4 ORGANIC CONSTITUENTS :

Some organic constituents - moisture percentage, total solids and chlorophylls are estimated from the different parts of Eichhornia crassipes. Plants were collected from two different habitats - river and pond. The results are tabulated in Table 3 and 4.

Moisture percentage and total solids :

The values of moisture percentage and total solid percentage recorded in the table 3 indicates that, different plant parts of Eichhornia crassipes i.e. leaf lamina, petiole and root are showing appreciable quantity of moisture percentage. The table also records mean values of moisture percentage and total solid percentage of different plant parts from both the habitats - river and the pond.

The moisture percentage is 93.91%, 85.92% and 92.43% in river habitat and 90.11%, 82.54% and 87.22% in pond habitat in leaf lamina, petiole and root respectively. Similarly total solid percentage is 6.09%, 14.08%, 7.57% in river habitat and 9.89%, 17.46%, 12.78% in pond habitat in leaf lamina, petiole and root respectively. Average mean values of moisture percentage are

TABLE - 3

Moisture percentage and total solids of Eichhornia crassipes from two different water bodies

Plant part	Water body			
	River		Pond	
	Moisture %	Total solid %	Moisture %	Total solid %
Lamina	93.91	6.09	90.11	9.89
Petiole	85.92	14.08	82.54	17.46
Root	92.43	7.57	87.22	12.78
Mean	90.75	9.25	86.63	13.37

TABLE - 4

Chlorophyll content in leaves of Eichhornia crassipes .

Locality	Leaf part	Chlorophylls (mg/100 g f.wt.)			
		'a'	'b'	'a+b'	a/b
River	Lamina	113.82	65.41	179.23	1.74
	Petiole	64.14	40.42	104.56	1.59
Pond	Lamina	107.19	77.80	184.99	1.38
	Petiole	98.76	76.66	175.42	1.29

90.75% and 86.63% in river and pond water plants of Eichhornia crassipes. Corresponding total solid percentage in river water plants is 9.25% while in pond water plant it is 13.37%.

Majid (1986) in his monograph on Aquatic weeds have compiled the moisture and total solid percentage in some local aquatic weeds. The details are as follows,

Acuatic weeds	Moisture %	Total solid %
Azolla pinnata	88-91	9-12
Eichhornia crassipes	91-95	5-9
Lemna minor	94	6
Monochoria vaginalis	93	7
Pistia stratiotes	95	5
Salvinia cuculata	97	3
S. natans	95	5
Spirodela polyrhiza	95	5
Wolffia arrhiza	91	9

Our values of moisture percentage are almost on the same line when compared to the other aquatic weeds and specially Eichhornia crassipes.

Chlorophylls :

Photosynthetic efficiency of the plant depends upon its chlorophyll content. Further the amount of chlorophylls range and their relative distribution can signifying the photosynthetic

path of the plant. With this view we have estimated chlorophylls from lamina and petiole of the leaf of Eichhornia crassipes collected from river and pond. Values of chlorophylls are shown in Table 4.

From the results it is clear that, chlorophyll content of the lamina and petiole differs considerably in river water habitat. However, in pond water plants, the chlorophyll content of lamina and petiole is almost unchanged. This seems that, in polluted environment petiole contributes the photosynthetic function of leaf lamina. This can add towards the efficiency of the plants as pollution reducer.

When relative quantities of chlorophyll 'a' and 'b' are considered the chlorophyll a/b ratio for lamina is 1.38 and 1.74 and for petiole 1.59 and 1.29 in river and pond water plants respectively from the values of chlorophyll a/b ratio we can predict about the photosynthetic path in Eichhornia crassipes. Chang and Troughton (1972) have reported the mean values of Chl.(a/b) ratios for plants with different photosynthetic CO_2 fixation cycles. According to them, the mean values of chl. (a/b) ratio for C_3 plants is 2.9 while in C_4 plants it is 3.5, with a standard deviation of 0.2 in both cases.

Holden (1973) studied the pigments in C_3 and C_4 plant species. According to him, chlorophyll a/b ratio ranges from 3.1

to 5.6 for C_4 dicotyledonous plants, while it ranges from 2.5 to 3.7 for C_3 dicotyledons. From the values of chlorophyll a/b ratio C_3 type of photosynthetic path of Eichhornia crassipes is predicted. This prediction is strengthened by the results compiled by Gopal and Sharma (1981), on the basis of CO_2 compensattion point. The value of CO_2 compensation point is 60 ppm. Our results of stomatal study have also indicated the possibility of operation of C_3 path of photosynthesis in Eichhornia crassipes.

3.5 NITROGEN METABOLISM :

Total nitrogen and proteins :

The chemical composition of Eichhornia crassipes has received considerable attention for several reasons. Some of the earliest chemical analysis were made to determine the value of Eichhornia crassipes as a source of nutrients like potassium, nitrogen and phosphorus for use in the agriculture. Later on the possibility of extraction of protein from Eichhornia crassipes was persieved by Piria (1960). Now-a-days the scope of chemical analysis of water hyacinth has been extended to include several elements which are the water pollutents and are absorbed and accumulated by water hyacinth (Howard-Williams and Jnk, 1977).

In the water bodies nitrogen and phosphorus are the primary causes of over nurishment and Eu-tropication. Sheffield

(1967) used an aquatic pond system containing water-hyacinth to remove 99% orthophosphates, 99% nitrate-N and 99% ammonia-N. Danawade (1988) in his study of aquatic plants (water hyacinth) for the utilization for the study pollution removal and energy generation and manuring has studied the nitrogen and crude protein. With this background in the present investigation an attempt is made to study the nitrogen metabolism in Eichhornia crassipes with reference to total nitrogen, crude proteins and an enzyme-nitrate reductase in different plant parts from two habitats.

Table 5 shows the nitrogen content and crude proteins from different parts of Eichhornia crassipes from two different water bodies - River and pond. The nitrogen in leaf lamina is 7.19% which is the highest value in river water plants while it is 8.91 % in pond water plants. In root and offset the values of nitrogen are 6.24%, 4.94% and 7.78% and 6.14% in river and pond water habitat plants respectively. The lowest value of nitrogen content in petiole and it is 4.08% and 5.09% in river and pond water plants respectively.

The table also records the crude protein contents from the different parts of E. crassipes from two different water bodies - river and pond. The values are 40.98% and 50.79% in leaf lamina, 35.57% and 44.35% in root, 28.16% and 35.00% in offset

TABLE - 5

Total nitrogen and proteins of Eichhornia crassipes from two different water bodies.

Plant part	Water body			
	River		Pond	
	Total nitrogen	Total proteins	Total nitrogen	Total proteins
Lamina	7.19	40.98	8.91	50.79
Petiole	4.08	23.26	5.09	29.01
Root	6.24	35.57	7.78	44.35
Offset	4.94	28.16	6.14	35.00

Total Nitrogen - g 100 g^{-1} dry wt.

Total Proteins g 100 g^{-1} dry wt.

and 23.26% and 29.01% in petiole of the plants from river and pond respectively.

Sen (1930) has reported that air dried water hyacinth has nitrogen in the range of 1.45 to 1.73%. Smith (1932-33) has recorded 0.9% of nitrogen in leaf on dry weight basis. Dymond (1947) has recorded 1.33 to 2.01% nitrogen in leaf on dry weight basis. Denton (1967) has collected water hyacinth from non-polluted and polluted sites and he has studied the chemical composition of water hyacinth for major nutrients. He has recorded 1.37% nitrogen in water hyacinth collected from non-polluted site and 2.61% nitrogen collected from polluted site. Sinha and Sinha (1969) have suggested the use of water hyacinth culture in oxidation ponds for treating different wastes. During their study they have recorded the nitrogen contents of water hyacinth and their values range from 0.97 to 2.57%. Boyd (1969) has recorded nitrogen content of three species of water weeds. He has mentioned 2.64% nitrogen in water hyacinth. Knipling et al. (1970) have reported greater than or equal to 2.67% of nitrogen on dry weight basis. Boyd and Vickers (1971) have collected water hyacinths from 17 different polluted and non polluted sites and studied these plants for their nitrogen contents. They have recorded 1.03 to 3.33% nitrogen. Parra and Horstenstine (1974) have studied the chemical composition of water hyacinth collected from various sources.

They have recorded 1.61% nitrogen in dry matter of water hyacinth. Abdel Haffez (1975) has recorded 1.03% nitrogen in water hyacinth. Boyd (1976) has grown water hyacinth in nutrient medium and studied the nitrogen content. He found 1.25 to 2.28 % nitrogen. Knopf and Habeck (1976) have reported 1.75% of nitrogen in water hyacinth. Nag (1976) has studied the destruction of water hyacinth by its utilization. During his study he has recorded 4.0% nitrogen. Wolverton and McDonald (1976) have reported that the values of nitrogen contents of water hyacinth ranged from 2.8 to 3.5%. Baruah (1979) has reported that the nitrogen content of water hyacinth ranges from 1.5 to 2.0%. Yaduraju and Mani (1979) have reported 1.61% nitrogen on dry weight basis.

Musil and Breen (1977) from Soiuth Africa have studied the nitrogen content of water hyacinth collected from Umlass river and they have recorded 2.96% nitrogen on dry weight basis. They have analysed various parts of the E. crassipes and reported maximum value of 4.9% nitrogen in leaf lamina, 2.17% in petioles and a lowest value of 1.79% nitrogen in roots.

Danawade (1988) have recorded nitrogen content and crude protein values from different parts of water hyacinth. The values are 5.63, 6.25, 4.22, 3.44, 6.56 and 4.23 percent in root, rhizome, stolon, petiole, lamina and entire plant respectively.

The values of crude proteins ranges from highest 41% in lamina and lowest 21.5% in petiole.

Our results of nitrogen and crude proteins are in the range of previous observations. We have recorded highest value of nitrogen and crude protein in leaf lamina. This is possibly because the lamina is the centre of active metabilism. The highest value of nitrogen and protein in leaf lamina may be due to its role in synthesis of proteins associated with activities of enzymes. The lowest values of nitrogen and crude protein is recorded in the petiole. This can be attributed to the main function of the petiole - the buyoncy, as it contains the aerenchyma.

Considering the protein values of E. crassipes it can be used as fodder. Majid (1986) have reported that, the digestability trials indicated that water hyacinth could only be fed to the animals as a supplementary feed. The E. crassipes in food form has two aspects - feeding the sheep with water hyacinth alone caused heavy water loss, diarrhoea and death of the animals and when water hyacinth was fed in combination with feed concentrate the sheep showed increase in weight. Recently Poddar et al. (1990) have studied the effect of feeding different forms of water hyacinth on pelatability in growing calves. This shows

that, the attempts in utilization of E. crassipes as a fooder due to rich nitrogen and protein content are in progress.

The values of nitrogen from different plant parts of Eichhornia crassipes from two different habitats when compared, shows that, plants from polluted water body (pond) show more nitrogen and protein content than the plants from non-polluted water body (river). This change in the values of nitrogen can be attributed to the fact that, water hyacinth removes several elements from the polluted water body (Gupta 1980; Trivedy and Goel 1985).

Nitrate reductase :

Nitrate reductase activity in leaves, root and offset (stem) of Eichhornia crassipes is depicted in Table 6. NR activity from different reference plants is also recorded in the table for ready reference. It is evident from the table that the values are in range when compared with one another. There is little variation in the activity of nitrate reductase activity in leaf, root and offset of Eichhornia crassipes. The values are 39.09, 20.0 and 25.91 μ mol of NO_2 $h^{-1}g^{-1}$ f.wt. respectively.

From the results it is evident that the activity of enzyme nitrate reductase is maximum in leaves followed by stem offset (stem) and least is found in root. The trend of enzyme activities in co-ordination with the amount of total nitrogen and

TABLE - 6

Activity of Nitrate reductase in Eichhornia crassipes

Plant	Plant part	NR-Activity [μ moles of $NO_2 h^{-1} g^{-1}$ fr.wt.]	Reference
Eichhornia crassipes	L	39.09	Present investigation
	R	20.00	
	O	25.91	
REFERENCE PLANTS			
Euphorbia geniculata	L	97.99	Patil and Waghmode(1989)
	S	8.82	
	R	6.82	
Pennisetum purpureum	L	55.34	Upadhye (1986)
Trianthema monogyna	L	75.32	

L = leaves, S = stem, O = offset, R = root

total proteins. The maximum values are recorded in leaves, minimum in root while in stem the values are intermediate. Thus the enzyme activities and amount of total nitrogen are proportionate to each other. Water potential of the tissue plays a vital role in the activity of nitrate reductase (Morilla et al. 1973, Plaut 1973, Rhodes and Matsuda 1976, Shinde 1981). Considering the values of moisture percentage (Table 3) of leaf stem and root, they can be easily corelated with the activities of nitrate reductase which are proportionate to the total nitrogen.

The values of the activity of nitrate reductase are comparable with other plants. Euphoria geniculata a terrestrial nitrophilous weed and petroplant is worked out by Patil and Waghmode (1989). The values are 97.99, 8.82 and 6.82 in leaf, stem and root respectively. Upadhye (1986) have worked out the enzyme activity of nitrate reductase from the terristrial weeds namely Pennisetum purpureum and Trianthema monogyna. The estimate of enzyme activity of NR from leaves are 55.34 and 75.32 μ moles NO_2^{-1} g^{-1} f.wt. respectively. Considering these values we can say our results are in range of values of other weeds which are cited for reference.

The trend of enzyme activity i.e. maximum in leaves, followed by stem and root is attributed to the proportion of

total nitrogen content and moisture percentage in early paragraph of discussion. Maximum enzyme activity of leaf can also be justified. Since the leaves are the major contributors to the biomass of the plant, the enzyme activity in these organs can have a lion's share in the nitrate reduction process of the entire plant. Further the higher level of enzyme in this plant part correlates well with the fact that the nitrate reduction process depends on a constant supply of reductants which are produced during the process of photosynthesis. Our observations agree with the findings of Srivastava (1965) in case of bean. He found that leaves always had higher level of enzyme activity than the root or stem. Chavan (1987) has also shown the similar trend of enzyme activity in groundnut. In a wetland plant, Typha sps. the decreasding order of activity of NR from leaf to stem to root is shown by Waghmode and Patil (1988).

It is evident from table 6 that the offset also has appreciable nitrate reductase activity. These observations support the work of Andrews et al. (1984) which indicated that stem tissue can contribute significantly to over all nitrate metabolism. These workers observed that more than 20% of total plant nitrate reductase activity can occur in the stem of legminous plant like Pisum sativum. Our observations also indicate more or less similar trend because in stem tissue

appreciable nitrate reductase activity as well as total nitrogen and proteins are detected.

Besides stem tissue, the roots also show enzyme activity but activity of nitrate reductase is about two fold less in root than the leaf. (Table-6). Bowerman and Goodman (1971) in case of Lolium perenne, have shown that the shoot material has ten fold more nitrate reductase activity than root material. Hatam (1978) found that in case of soybean the root tissue had lower nitrate reductase activity as compared to leaf tissue. Our results can be well explained in light of these results.

Distribution of nitrate reductase activity in different parts of Eichhornia crassipes from two different localities is shown in Table 7. The results show that NR activity in the plants collected from river are 39.09, 36.36, 20 and 25.91 μ molesd NO_2 $h^{-1}g^{-1}$ f.wt. in lamina, petiole, root and offset respectively. In pond water plants which are considered to be from polluted environment. The values are 18.18, 16.36, 9.69 and 11.36 in lamina, petiole, root and offset respectively. It is evident that NR activity in plants from polluted environment is comparatively less than the river water plants. This trend of enzyme activity seems to be difficult for interpretation. In earlier discussion we have correlated the nitrogen, protein, moisture content and activity of nitrate reductase. The present

TABLE - 7

Distribution of Nitrate reductase enzyme activity in different parts of Eichhornia crassipes at two different localities.

Plant part	Locality	
	River NR activity	Pond NR activity
Lamina	39.09	18.18
Petiole	36.36	16.36
Root	20.00	9.09
Offset	25.91	11.36

NR activity = μ moles NO_2 $h^{-1}g^{-1}$ fresh wt.

result cannot be interpreted the basis of these aspects. If the values of chlorophylls from the plants form two different habitates (river and pond) are considered (Table 4) it is clear that, in polluted environment the plant has more chlorophylls. Chlorophylls are contributing towards the photosynthetic efficiency. The interrelationship between the photosynthesis and nitrogen metabolism is well known (Boner and Vener, 1965). Here, in plants from polluted (pond) environment nitrogen content, total proteins and chlorophylls are more than the plants from river water. However, the nitrate reductase activity is about 50% less in plants from polluted environment. E. crassipes removes the nitrogen from polluted water (Gupta 1982). For the high nitrogen content inspite of low nitrate reductase activity there can be some another route, may be from photosynthetic carbon reduction cycle or other which directly contributes to the total nitrogen. Further probe of study of effect of pollutants on NR activity, photosynthesis and total nitrogen can make the picture more clear.

Behaviour of Enzyme Nitrate Reductase :

Nitrate reductase a key enzyme of nitrogen metabolism is worked out in different plants. Desai (1986) has worked out nitrate reductase in sunhemp [Crotolaria juncea] in detail. Nitrate reductase of two groundnut varities is worked out by

TABLE - 8

Effect of substrate concentration on activity of Nitrate reductase in different parts of *Eichhornia crassipes* collected from two localities.

Substrate (KNO_3) concentration [mM]	NR activity [μ moles NO_2^{-} h^{-1} g^{-1} fresh wt.]							
	Lamina		Petiole		Root		Offset	
	River	Pond	River	Pond	River	Pond	River	Pond
10	29.55	11.82	25.00	9.09	9.09	0.91	15.91	4.55
20	39.09	18.18	36.36	16.36	20.00	9.09	25.91	11.36
30	31.36	11.82	26.36	9.09	14.55	3.64	14.09	5.45
40	31.82	8.18	23.64	6.82	14.55	1.36	11.36	4.55
50	26.82	8.18	23.64	6.36	14.55	1.18	11.82	4.09

Localities : River (Non polluted); Pond (Polluted)

Chavan (1988). These workers have studied NR activity with reference to various endogenous and environmental factors. Study of nitrogen metabolism of E. crassipes was found interesting during present investigation because it was found that plant respond to changed environment - endogenous and environment differently. With this view an attempt was made to study the behaviour of NR activity. NR activity is studied with different aspects.

Effect of substrate (KNO_3) concentration on NR activity :

It can be seen from the Table-8 that nitrate reductase responds well to the substrate concentration in the incubation medium. It can be seen that, as the nitrate concentration increases from 10 mM to 20 mM there is increase in enzyme activity. However, above 20 mM and upto 50 mM concentration the enzyme activity shows decline. Similar trend is recorded in different plant parts of the plants from two different waterbodies. It is very well realized that the regulation of nitrate reductase is a very complex process and it is mediated through either induction, deprepression or direct activation or inactivation of the enzyme. Hewitt et al. (1979) have divided mechanisms of nitrate reductase regulation into three classes namely; i) regulation by amount of enzyme, ii) by its activity and iii) by the control of substrate access. The third factor is

mainly regulated by the pools of nitrate invarious compartments of the plant cell. It is difficult to correlate the enzyme activity with the level of endogenous nitrate, probably due to existence of large storage pool compared to the metabolic one. Heimer and Filner (1971) have postulated that nitrate in the storage pool is inaccessible to the enzyme and hence does not function as an inducer. Ferrari and Warner (1960) have shown in cultured cells of tobacco that the size of the nitrate metabolic pool varied with the age of the cells. It is reported in several experiments with the algae, fungi and several higher plants that nitrate reductase activity appears in response to nitrate addition and declines on its removal. Andrews et al. (1984) recently noticed that in temperate legumes namely Lupinus angustifolius L., Pisum sativum L. and Vicia faba L. increase in nitrate reductase activity occurred in the shoot as the nitrate concentration increased. On the contrary, in the tropical legume namely Cajanus cajan (L.) Wilisp.; Glycine max (L.) Merr. and Phaseolus vulgaris L., the proportion of total plant nitrate reductase activity in root and shoot was relatively constant, regardless of nitrate concentration.

Several mechanisms have been proposed to explain the effect of nitrate on nitrate reductase activity. It is speculated that the induction of nitrate reductase in plants by nitrate is a protein synthesis dependent response (Afridi and Hewitt, 1965).

In the experiments of Buczek (1985), the loss of *in vivo* nitrate reductase activity in second leaf and excised roots of cucumber measured in the absence of substrate (NO_3^-) in the leaf discs and excised roots of cucumber plants growing in the absence of NO_3^- uptake, to a rapid degradation or inactivation of nitrate reductase caused by a low availability of nitrate stored in the tissues. Aryan *et al.* (1983) observed that nitrate reductase enzyme in wheat leaves was converted to a reduced inactive state especially in plants grown on limited nitrate supply. The fact that enzyme is substrate inducible, is also evident from our studies with *in vivo* system, since lowest enzyme activity is noticed in the leaves floating in a medium containing 5 mM nitrate. The behaviour of nitrate reductase of groundnut seems to be similar to the one reported for legumes like winged bean and soybean where 20 to 25 mM nitrate concentration was found optimum for *in vivo* nitrate reductase activity (Munjal *et al.* 1983, Nicholas *et al.* 1976). This response however, seems different from the monocot triticale where upto 300 mM nitrate concentration was found optimum for the enzyme (Lin and Kao, 1980).

Nambiar *et al.* (1986) examined the relationship between leaf nitrate content and leaf nitrate reductase activity in groundnut genotypes Robut 33-1, J-11 and non-nodulated genotype. These workers observed that both groundnut genotypes showed low

leaf nitrate reductase activity even at very high levels of nitrate content in leaves in contrast to sorghum genotypes which showed higher levels of nitrate reductase activity at low levels of leaf nitrate. According to them probably higher nitrate concentration is required to induce nitrate reductase in groundnut than in sorghum. These workers have employed in vivo method of Jaworski (1971) where 20 mM KNO_3 was used in the medium. However, they have not studied the effect of varying nitrate concentrations in the medium on the enzyme activity. Our observations indicate that 20 mM nitrate in the incubation medium is probably the proper concentration for enzyme activity under in vivo conditions and higher concentration of nitrate do not cause any noticeiable stimulation of the enzyme.

Effect of tissue weight on Nitrate Reductase activity :

Table-9 records the effect of tissue weight on in vivo activity of nitrate reductase in leaf lamina, petiole root and offset of the Eichhornia crassipes, collected from river and pond. It can be seen from the table that maximum enzyme activity is noticed in the incubation medium containing 500 mg leaf discs while the minimum enzyme activity is recorded in the medium containing 100 mg of the leaf discs. Although this is the case, the relationship between the tissue weight and enzyme activity does not seem linear. This is naturally because of the fact that

TABLE - 9

Effect of tissue weight on activity of Nitrate reductase in different parts of *Eichhornia crassipes* collected from two localities.

Tissue weight (mg)	NR activity [μ moles NO_2 h^{-1} g^{-1} fresh wt.]							
	Lamina		Petiole		Root		Offset	
	River	Pond	River	Pond	River	Pond	River	Pond
100	9.09	6.36	9.09	4.55	0.91	0.45	4.55	3.18
200	20.91	7.27	20.45	4.55	3.64	2.27	11.82	3.64
300	23.64	13.18	20.91	9.09	11.82	4.55	13.64	7.27
400	29.09	15.45	27.27	15.45	17.27	7.27	19.09	11.36
500	39.09	18.18	36.36	16.36	20.00	9.09	25.91	11.36

Localities : River (Non polluted); Pond (Polluted)

there are several factors other than the tissue weight which can interact and affect the enzyme activity. Our results recall the work of Lin and Kao (1980) and Munjal et al. (1983) who noticed increase in enzyme activity alongwith increase in tissue weight in the medium and it is obvious that this is directly related to the enzyme protein yield from the tissue.

Nitrate reductase from two varieties of groundnut is worked out in detail by Chavan (1987). He has studied the effect of tissue weight on nitrate reductase activity in two groundnut cultivers JL-24 and TMV-10. He has found that enzyme activity is directly proportional to the tissue weight. Our results also show the same trend.

Effect of pH on nitrate reductase activity :

In order to find out optimum pH of buffer required for nitrate reductase activity in water hyacinth different assays with different pH of buffer (viz. pH - 5.8, 6.2, 6.6, 7.0, 7.4 and 7.8) were performed. The study was done in different plant parts of E. crassipes (viz. leaf lamina, petiole, root and offset) collected from river and pond. It is evident from Table-10 that there is maximum in vivo nitrate reductase activity at pH 6.2. The activity shows a marked drop at pH above 7.0 in case of all plant parts from two habitats.

TABLE - 10

Effect of Buffer pH on activity of Nitrate reductase

in different parts of *Eichhornia crassipes* collected from two localities.

Buffer (pH)	NR activity [μ moles NO_2 h^{-1} g^{-1} fresh wt.]							
	Lamina		Petiole		Root		Offset	
	River	Pond	River	Pond	River	Pond	River	Pond
5.8	37.14	16.22	34.30	14.17	17.85	7.10	24.00	9.33
6.2	39.09	18.18	36.36	16.16	20.00	9.09	25.90	11.36
6.6	39.00	17.33	35.66	15.34	19.20	7.97	24.82	10.43
7.0	37.63	16.77	34.86	14.68	18.57	7.69	24.44	9.92
7.4	37.37	16.47	34.60	14.39	18.28	7.27	24.58	9.63
7.8	37.29	16.35	34.55	14.36	18.17	7.26	24.11	9.53

(Plant material from two water bodies - River (non-polluted) and Pond (polluted)

During the study of any enzyme system the selection of optimum pH is of great significance. This is because the changes in pH profoundly affect ionic characters of the amino and carboxylic groups of the enzyme proteins. The change in ionic state induced by high or low pH may affect binding of enzyme substrate complex or conversion of enzyme substrate complex to the product. There are several reports of effects of pH on activity of various enzymes under *in vitro* system, although the information about *in vivo* system is rather limited.

According to Srinivasan and Naik (1982), during *in vivo* assay of nitrate reductase in wheat leaf discs, the amount of nitrite released in the medium was grately influenced by the pH of the medium, although it had no effect on total nitrite formed in the leaf tissue. In an acidic medium nitrite excreted out was negligible, while it increase considerably at alkaline pH values. At either very high or very low pH, enzyme itself may undergo irreversible structural changes and this may result in complete loss of activity. In case of *in vivo* nitrate reductase study for soybean leaves the optimum pH was found to be 7.5 with a broad peak between 7.00 and 8.00 (Nicholas *et al.*, 1976). While in cotton, maximum enzyme activity was evident at 7.00 pH of the phosphate buffer and there was marked decline in the pH range 5.5 to 6.00 (Bate *et al.* 1978). According to Streeter and Bosler (1972), the pH value of the external medium during infiltration

and incubation does not have any marked effect on the in vivo nitrate reductase assay. As per their opinion cytoplasmic pH value is little influenced by the changes in extracellular pH value. The observations recorded for E. crassipes agree with the findings of Lin and Kao (1980) where the optimum pH for in vivo nitrate reductase activity in triticale was noticed to be 6.00. The enzyme activity in E. crassipes seems to be more susceptible to the alkaline range than the acidic range of the medium.

Effect of Triton X-100 on nitrate reductase activity :

In order to see whether the addition of surfactant Triton X-100 is really essential, Triton X-100 was omitted from the incubation medium and the enzyme activity was determined. Simultaneously the assy with triton X-100 was also performed. The results are shown in Table-11. It was observed that in different plant parts of Eichhornia crassipes from river and pond there was marked decline in the enzyme activity in the absence of Triton X-100. These observations indicate that, addition of Triton X-100 is quite beneficial for better study of the enzyme nitrate reductase.

Jones and Sheard (1977) found that 0.1% Triton X-100 gave a 20% stimulation of nitrate reductase for maize leaf strips but was either without affect or inhibitory for several other species. Lawrence and Herrick (1982) noticed that in Chenopodium

TABLE - 11

Effect of Triton X-100 (surfactant) on activity of Nitrate reductase in *Eichhornia crassipes*

Plant part	NR-activity [μ moles NO_2 h^{-1} g^{-1} fresh wt.]			
	River		Pond	
	A	B	A	B
Lamina	39.09	9.09	18.18	3.64
Petiole	36.36	8.18	16.36	2.73
Root	20.00	4.09	9.09	1.36
Offset	25.91	5.00	11.36	1.82

A = with Triton X - 100

B = without Triton X - 100

album leaves, the addition of 0.015% Triton X-100 caused a marked increase in enzyme activity. According to them most likely explanation for this effect is the release of nitrate from a storage pool. Nitrate reductase activity of groundnut cultivers also prefers the presence of Triton X-100 in the incubation medium. In absence of Triton X-100 there was about three to nine fold decrease in enzyme activity as reported by Chavan (1987). Our results show that, in Eichhornia crassipes collected from river, there is about 4 to 5 times decrease in the enzyme activity. However, in the plant collected from pond (polluted environment) the decrease in the enzyme activity was about 6 to 9 folds. This indicates that, NR in the plants from polluted environment prefers the surfactant, Triton X-100 in the incubation medium.

Effect of Temperature on Nitrate Reductase Activity :

Enzymes are proteins and they are thermolabile. Shrivastava (1984). Balasooriya et al. (1983), have shown that, luxurient growth of the water hyacinth occurs when temperature ranges between 26-36°C. In nature Eichhornia crassipes thrives well in all seasons of the year. It was thought that, to cope-up with the seasonal environment the plant may modify its enzyme machinery accordingly. With this view, the effect of temperature on in vivo activity of nitrate reductase in different plant parts

TABLE - 12

Effect of Temperature on activity of Nitrate reductase

in different parts of *Eichhornia crassipes* collected from two localities.

Temperature (°C)	NR activity [μ moles NO_2^{-} h^{-1} g^{-1} fresh wt.]							
	Lamina		Petiole		Root		Offset	
	River	Pond	River	Pond	River	Pond	River	Pond
22	33.63	13.64	31.81	12.72	15.91	5.45	23.64	11.36
27	35.45	13.64	32.27	13.64	17.27	6.36	22.72	10.00
32	39.09	18.18	36.36	16.36	20.00	9.09	25.91	11.36
37	10.00	4.55	7.27	3.66	5.00	2.73	6.36	3.66
42	8.18	3.64	5.45	2.73	2.73	0.91	3.18	1.36

Localities : River (Non polluted), Pond (polluted)

of Eichhornia crassipes, collected from river and pond was studied. The results are recorded in Table-12.

Temperature range studied is 22°, 27°, 32°, 37° and 42°C. The selected temperature range covers the normal extremes of the different seasons of the year. From the results it is clear that, normal minimum temperature i.e. 22°C when goes upto 32°C; the enzyme activity is least affected. When temperature goes above 32°C i.e. 37°C and 42°C the enzyme activity is adversely affected. From the results it is clear that, in both river and pond water plants of Eichhornia crassipes about 4 to 10 fold decrease in the enzyme activity is recorded. From this it is easy to predict that, temperature variation in normal range has no effect on enzyme machinery of E. crassipes while at higher temperature the enzyme become physiologically inactive.

3.6 INORGANIC CONSTITUENTS

Mineral elements play a vital role in plant metabolism. These are absorbed at different rates and are accumulated in different concentrations according to the requirement of plants. To understand ther requirement and pattern of accumulation, the entire plant as well as different parts of Eichhornia crassipes are analysed for various mineral contents and the results are presented in Table-13.

Sodium :

Sodium is the dominant cation in saline soils and hence plays an important role in physiology of saline plants. It is also present in all glycophytes. However, it has not been accepted as an essential element for plant nutrition. In plants it is beneficial in micro quantity.

Denton (1967) has studied the water hyacinth plants from non-polluted and polluted sites for their sodium contents. He found 0.5% sodium in plants grown at non-polluted site and 0.1% sodium in plants growth at polluted site. Boyd (1969) has mentioned 0.34% sodium in water hyacinth ondry weight basis. Boyd and Vicker (1971) recorded the sodium value between the range of 0.17 and 0.25% in water hyacinth collected from 17 different polluted and non-polluted sites. Stephens et al. (1973) and Susiawaningrini et al. (1979) have recorded 0.5% and 0.61% of sodium in dry matter of water hyacinth respectively. Parra and Horstenstine (1974) have reported that water hyacinth powder on dry weight basis contains 0.56% of sodium. A study of Musil and Breen (1977) in SDouth Africa reveals that the sodium content of water hyacinth plants collected from different sites showed considerable difference. A highest value of 0.395% sodium has been recorded in plants collected from Ispingo Canal, 0.189% in plants from Umlass river and 0.259% in plants from Enselani

TABLE - 13

Inorganic constituents in different parts of *Eichhornia crassipes* and surrounding water

Parameter	Leaf lamina		Petiole		Root		Offset		River water	Pond water
	A	B	A	B	A	B	A	B		
Sodium	0.06	0.26	0.20	0.30	0.22	0.34	0.80	1.50	0.06	10.77
Potassium	0.84	1.34	1.04	4.05	1.32	3.15	1.5	4.58	0.83	10.65
Glacium	0.77	1.49	1.18	3.05	0.76	2.41	1.41	3.81	0.13	10.65
Manganese	0.02	0.01	0.04	0.01	0.11	0.01	0.01	0.14	ND	ND
Iron	0.03	0.04	0.05	0.04	0.29	0.09	0.05	0.03	ND	ND

Values are expressed as g per 100 g dry matter

A - Plants from river water

B - Plants from pond water

ND - Not determined

river. Trivedy (1983) has studied the chemical composition of water hyacinth grown in tap water and in sewage water. As sewage contains more nutrients the percentage of various nutrients in plants grown in sewage water was also high. Particularly the sodium content of water hyacinth showed maximum concentration of 0.42% of sodium when grown in sewage while a minimum value of 0.26% of sodium in water hyacinth grown in tap water.

Yaduraju and Mani (1979) have recorded 0.6% of sodium in water hyacinth on dry weight basis. Wolverton and McDonald (1979) have reported 1.5 to 2.5% sodium in oven dried material. Danwade (1988) has found that, among the different plant parts the maximum value of 2.56% sodium has been recorded in rhizome. This is followed by 1.44% sodium in stolon, 1.36% in leaf petiole and 0.88% in root and the lowest value of 0.24% of sodium in leaf lamina.

A study of Musil and breen (1977) in South Africa reveals that water hyacinth plant parts exhibit variations in their sodium contents. They have reported the values of sodium in roots, petioles and pseudolaminae as 0.178%, 0.479% and 0.178% respectively.

Our results of sodium content of different parts of E. crassipes show that maximum sodium content (1.5%) is observed in offset while minimum (0.06%) in leaf lamina.

From these values it appears that water hyacinth is a sodium absorbing plant. However, its accumulation is very well regulated. Rhizome has maximum value of 2.56% sodium. This part is metabilically less active and obviously the high values of sodium may not interfere with physiological processes. Possibly this part serves as sodium accumulating organ. As the absorbed sodium is stored here in large quantities in rhizome its harmful effect on other plant parts could be avoided.

Potassium :

Potassium is one of the essential elements in the nutrients of plants. Even though it appears to have no structural role in plants, it is indispensible for growth.

Potassium contents in the different parts of E. crassipes are depicted in Table 13. The results show that, the value of potassium in different parts of the Eichhornia plants from river and pond habitat ranges between from 0.84% to 4.58%. Maximum (4.58%) potassium content of offset is followed by petiole and root and minimum (1.34%) in leaflamina of the plants from pond. If we compared the values of potassium in river and pond environment we can find that, potassium content of the pond environment plant is about 2-4 times greater.

Boyd and Vickers (1971) studied the variations in elemental contents of water hyacinth collected from 17 different

polluted and non polluted localities. They found that the potassium contents in water hyacinth range from 1.6 to 6.7%. Knipling et al. (1970) have reported 2.28% potassium in dried water hyacinth.

Denton (1967) studied the water hyacinth collected from the nonpolluted and polluted sites and recorded 2.08% and 4.16% K in dried water hyacinths respectively. Boyd (1969) has recorded the nutritive values of three species of water weeds. He has reported 4.25% potassium in water hyacinth. Abdel Hafeez (1975) has recorded 1.81% K in dried water hyacinths. Knopf and Habeck (1976) have recorded 3.07% potassium in dried water hyacinth. While Baruah (1979) has reported 4 to 5% potassium in dried water hyacinths. Yaduraju and Mani (1979) have reported 3.8% of K in water hyacinth. Wolverton and McDonald (1976) have recorded 2 to 3.5% potassium in dried water hyacinth. A study by Musil and Breen (1977) from South Africa reveals that the potsssium contents of water hyacinth collected at Ispingo canal, Umlass river and Enseleni river were 3.633%, 2.86% and 2.81% respectively.

Smith (1932-33) has recorded 6.02% K_2O in water hyacinth on dry weight basis. Dymond (1947) studied water hyacinth ash and recorded 4.8 to 11.2% K_2O. Finlow and McLean

(1917) have mentioned 6.95% K_2O in water hyacinth on dry weight basis. Sen et al. (1929) have recorded 5.25% K_2O in dried water hyacinths while Boyd (1972) has stated 5.30% K_2O in dried water hyacinth powder.

Stephans et al. (1973) have recorded 0.2% K in dried water hyacinth. Nag (1976) and Susiawaningrini et al. (1979) have recorded 4.2% and 4.04% potassium in dry water hyacinth.

A study by Musil and Breen (1977) from South Africa reports that the potassium content in plant parts exhibits differences. They have found that the potassium contents were lowest in roots 1.417% followed by 2.817% in pseudolaminae and the highest value of 5.072% in petioles. Danwade (1988) has recorded the K content of different parts of water hyacinth. The highest value of 8.80% has been recorded in stolon. It is followed by 7.04% in leaf petiole, 4% in leaf lamina, 3.12% in rhizome and 2.24% in root.

These studiesd indicate that K accumulation is different in various parts of water hyacinth. We have recorded highest K content in offset. Offset (Stolon) is mainly responsible for vegetative propagation for which K is needed in large quantities. It is interesting to record high K contents in petiole which is metabolically not so significant.

Calcium :

Calcium is metabolically an important cation. Calcium pectate is a constituent of middle lamellae and hence large amount of calcium is needed to ensure a good plant growth.

Boyd (1969) observed 1% of calcium in water hyacinth. Denton (1967) studied the water hyacinth from non-polluted and polluted sites and observed 1.94% and 1.99% of calcium at two different sites respectively. Boyd and Vikers (1971) recorded the calcium values of water hyacinth growing in 17 different sitesd including polluted and nonpolluted environments. The calcium content ranged from 0.66 - 2.11%. Stephens et al. (1973) have mentioned 2.2% calcium in water hyacinth. Parra and Horstenstine (1974) have recorded 1.66% of calcium in water hyacinth on dry weight basis. Shirley et al. (1976) have reported that the calcium values of water hyacinth range from 0.45 to 2.51%. Wolverton and McDonald (1976) have reported that the calcium content of water hyacinth ranges between 0.6 and 1.3%. Knopf and Habeck (1976) reported 1.06% calcium in water hyacinth. Yaduraju and Mani (1979) have mentioned 1.7% of caclium in water hyacinth. Trivedy and Brij Gopal (1981) have recorded 1.42 to 2.6% of calcium in water hyacinth grown at polluted sites. Finlow and McLean (1917) have mentioned 3.10% CaO in water hyacinth powder. Sen et al. have recorded 1.85% CaO in water hyacinth dry

powder. Boyd (1972) has reported 1.4% CaO in water hyacinth while 7.56% of CaO has been recorded by Sarma and Rao (1983). Danwade (1988) has recorded 1.02% of calcium in entire plant E. crassipes.

According to Musil and Breen (1977) water hyacinth plant parts exhibit differences in their calcium contents. They found lowest value of 0.767% calcium in roots. These are followed by 1.149% in pseudolaminae and 1.36% in petioles. Wolverton and McDonald (1978) have recorded partitioning of calcium in water hyacinths collected from two locations, lueedale and Orange Groove at Mississippi (USA). Goel et al. (1985) have reported that, calcium accumulates more in the rhizome. Calcium content of different parts of E. crassipes are reported by Danwade (1988) and the values range between 0.024% and 1.32%.

These studies indicate that, the calcium content vary considerably according to environmental conditions. We have recorded calcium content of the plant parts of E. crassipes from river and pond habitats. Maximum calcium content is observed in offset (stem) in plants of river and pond environment. Minimum calcium level was recorded in root. The calcium content in different plant parts of E. crassipes from river and pond habitat ranges between 0.76% and 3.81%. These values are within the range of those recorded by other investigators.

Manganese :

Manganese participates in many physiological reactions in cells. The manganese contents vary greatly according to the availability of manganese. It is relatively immobile element. The manganese contents in water hyacinth and its various organs are presented in Table 13. The manganese content ranged from 0.01 to 0.14%.

Boyd (1970) has studied the manganese contents in dried sample of water hyacinth. He has recorded 3.940 ppm of manganese. Yaduraju and Mani (1979) have reported trace quantities of manganese in water hyacinth. Danawade (1988) has investigated 'Mn' content of different parts of E. crassipes. He has recorded highest 'Mn' value in root which is 0.13% and it is followed by 0.06% in leaf petiole, 0.08% each in leaf lamina and rhizome, and 0.02% in stolons, which is the lowest value.

We have recorded highest Mn content in offset. The Mn content in petiole is more than in lamina and this may have some physiological significance.

Iron :

Iron is an important micronutrient and plays a vital role in plant metabolism. It is one of the immobile elements in

plant and little redistribution occurs from one tissue to another.

Iron contents in water hyacinths and its various organs are presented in Table-13. The values reveal that the iron content values range from 0.03% to 0.29% on dry wt. basis.

Dymond (1947) hasd recorded 17 to 19.3% iron in 100 g ash of water hyacinth on ash weight basis. Boyd (1970) has mentioned the mean iron content of 250 ppm in dried sample of water hyacinth. Parra and Horstenstine (1974) have recorded 2772 ppm of iron in water hyacinth on dry weight basis. The values of iron in root, rhizome, stolon, leaf petiole and leaf lamina are 1.41, 0.06, 0.12, 0.15 and 0.09 percent respectively on dry weight basis (Danwade 1988).

Our results show that in water hyacinth most of the iron remains accumulated in root and then in leaf petiole, and the least in leaf lamina. Probably iron absorbed by the roots of water hyacinth is not translocated rapidly to shoots indicating its immobility. More iron in petiole and less in lamina also suggest that iron from petiole is not translocated to leaf lamina.

Dissolved Oxygen [DO] :

The Krishna river is one of the important rivers of Maharashtra. The rivr is immortalized for its holiness, beauty and majesty and people of the adjoining areas are emotionally attached with it.

The present study was confined to Karad and Sangli area only. The water samples were tested for its quality by measuring the dissolved oxygen [DO] from the places where Eichhornia crassipes was found. Similarly water samples from the pond habitat were tested for the same aspect where E. crassipes grow luxurently.

Table 14 records dissolved oxygen [DO] and pH range of the water around Eichhornia crassipes at different localities. The 'DO' is 1.26 ml of O_2/lit at NTP and 1.0 ml of O_2/lit at NTP in the tank from Botanical garden of our college and river water near Khodshi dam respectively and the pH range was 7.0 to 7.5. The values of 'DO' are quite similar from the pond at Sanjaynagar, Sangli and Krishna river near Ganesh temple, Sangli, with slight fluctuations in the pH range. The flowing waste water, near railway station, Sangli, shows 'DO' 0.77 ml of O_2/lit at N.T.P. and pH range 7.0 to 7.5. Thus in pond due to so called water pollution the magnitude of 'DO' is reduced while the pH range of the water around E. crassipes remains the same. Parija

TABLE - 14

Dissolved Oxygen [DO] and pH range of the water around *Eichhornia crassipes* at different localities.

Sr.No.	Locality	DO [ml of O_2/lit at NTP]	pH range
1.	I	1.26	7.0 to 7.5
2.	II	0.84	7.0 to 7.5
3.	III	0.77	7.0 to 7.5
4.	IV	1.00	7.0 to 7.5
5.	V	0.85	6.5 to 7.0

I - Tank from Botanical Garden at Y.C.College Science, Karad.

II - Pond at Sanjaynagar, Sangli.

III - Flowing waste water near railway station, Sangli.

IV - Khodshi dam - Krishna river, Karad.

V - Krishna river near Ganesh temple, Sangli.

(1934) has observed that, optimum growth of E. crassipes occurs at pH 6 to 8 and plants growing in more acidic or alkaline water tend to change the ph within this range. The pH values recorded by us are in the same range.

It is rather difficult to make a conclusion about the water quality with respect to pollution by considering only the dissolved oxygen. Number of parameters like B.O.D., concentration of various elements, suspeneded solids, conductivity etc. when studied simultaneously will speak more correct about the pollution aspect.

Currently Eichhornia crassipes is worked out for different aspects.

- In waste water and industry effluent treatments [Basseres and Pietrasanta, 1991; De-casabianca et al. 1991; Haung et al. 1992, Lenko et al. 1992].

- As fodder [Poddar et al. 1990; Laal, 1991; Petrell and Bagnail, 1991; Singal et al. 1992].

- Photosynthetic study [Fabreguettes et al. 1992; Peter et al. 1991].

- Pathological studies [Ganga-Vislakshy and Jaynath, 1991; Grodowitz et al. 1991; Hussain and Jamil, 1992; Hagg and Douclas, 1991].

- Pollination in Eichhornia [Husband and Barrett, 1992].
- Methane generation [Delgado et al. 1992].
- Medicinal value [Della, greeca et al. 1991, 1992].

Current trend of work and references on Eichhornia are cited above only for reference. To the possible extent we have discussed the output of our present work in light of available literature.

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