Calculating growth rate of water hyacinth pollution wise (in relation to trophic state)

Rinku Verma, Sivappa

***Abstract*— This study was carried out with respect to calculating growth rate of water hyacinth in relation to the trophic state of the water body. 50 water hyacinth plants about 10 from each lake were taken. The concentrations of phosphorous, nitrogen, potassium and calcium were determined. Biochemical oxygen demand and dissolved oxygen were also determined. Various growth aspects like total number of leaves were counted, root and petiole length were recorded, leaf area was plotted to obtain surface area. Growth Index was calculated based on fresh weight of the plant was chosen to study the growth of water hyacinth with respect to pollution levels of the 5 lakes. Growth Index was calculated using the equation GI = (A / M) ------- where M = Mean fresh weight of 530 water hyacinth plants collected from 5 lakes. A = Mean fresh weight of 10 water hyacinth plants collected from a particular lake in a particular month. A correlation of GI to pollution status of lakes was made and a correlation of lake water constituents with growth parameters of water hyacinth was done: The fresh mean weight of water hyacinth plants collected over 12 months period was distinctly higher for polluted Lakes when compared to less polluted lakes. Mean petiole length of plants collected from Yelahanka, Nagavara and Hebbal Lakes (polluted) were greater as compared to those collected from Jakkur and Doddabommsandra Lakes (less polluted). TSI based on TP was 88.28 for Nagavara lake which was Hypereutrophic and eutrophic for Jakkur lake where TP was 69.81. GI of water hyacinth plants showed a correlation coefficient of +0.62 to TP. This study concludes that higher the pollution level of the lake, higher would be the growth rate of water hyacinth. Polluted lakes had strong and sturdy petioles and more GI compared to less polluted lakes. TP versus GI, showed a good positive person's correlation coefficient. TP the limiting nutrient has significant impact on the pollution level.**

***Index Terms*— Growth rate, Trophic state, water hyacinth, Growth Index, Fresh weight.**

I. INTRODUCTION

Effect of nitrogen and phosphorus on growth rate of water hyacinth: Demonstration of the use of water hyacinth for nutrient removal and 80% reduction in ammonia nitrogen was observed when the aerated effluent passed through a water hyacinth pond with a retention time of ten days [1]. Plants growing in nutrient rich waters have been found to possess long petioles (up to 1000 cm) and roots, which are about 60 cm long [2].

Positive correlation between the concentration of phosphorous in the medium and the concentration within the plants was observed [3]. Maximum growth of water hyacinth occurred in water with a phosphorous concentration of 20 ppm [4]. Also increased phosphorous content in nutrient rich waters promote healthy root growth [5].

Nitrogen concentration did not produce any profound effect on biomass production though nitrogen is essential to some extent for biomass production as well as plant multiplication conducted in some studies [6]. Nitrogen limitations in lakes may be attributable to high phosphate supply from the rivers and high losses of macrophyte nitrogen during floods [7]. Water hyacinth releases large quantities of juice, which have high nitrogen content, total solids and Chemical Oxygen Demand (COD) [8]. The disposal of this press liquor into water bodies would result in eutrophication.

Nitrogen along with phosphorous has been considered the primary nutrients causing excessive growth of aquatic plants. According to Hutchinson nitrogen would limit the production of aquatic plants when the Nitrogen/Phosphorous (N/P) ratio is less than 8 (by weight) whereas phosphorous may limit plant production when the ratio is high [9]. Total Nitrogen and Total Phosphorous (TN/TP) ratio > 30 were primarily phosphorus limited and lakes with TN/TP < 10 were primarily nitrogen limited found in lakes [10]. Lakes with TN/TP ratios between 10 and 30 were assumed to have a balanced nutrient status.

Water hyacinth plant contains calcium to an extent of 1.66% of its dry weight. Potassium is the most abundant metallic element in water hyacinth constituting about 3% of the dry weight of the plant [11 & 12]. Highest biomass increase was obtained at 6 mg/L potassium concentration [6]. Potassium has no effect on multiplication of water hyacinth but it does increase the biomass of individual plants [13]. Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO) on growth rate of water hyacinth showed that there was a close relationship between hydrophytes growth and nutrient removal from the effluents. A comparatively more rapid drop in BOD, as well as a fair increase in DO and biomass was observed [14].

II. MATERIALS AND METHODS

Collection of water hyacinth plants from the 5 lakes: 50 water hyacinth plants (*i.e.* 10 plants from each lake) were brought to the laboratory each month, with each plant in a separate plastic bag from July 1999 to June 2000. Water hyacinth plants were not collected from Hebbal Lake in July 1999 and from Nagavara Lake in May 2000 and June 2000. Hebbal Lake was taken up for desilting from March 2000; so plants were not collected from March 2000 to June 2000. A total of 530 plants were inspected showing maximum growth. Care was taken to collect well grown, healthy plants from different water hyacinth growing regions of the lake. In August 1999 and November 1999, 5 water samples were

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collected from each lake and concentration of phosphorus, nitrogen, potassium and calcium were determined. BOD and DO were also determined, as indicated in the previous chapter.

Measurement of growth parameters of water hyacinth: Various aspects of growth of water hyacinth plant were measured. Total number of leaves present in each plant was counted. Root length and petiole length were recorded. Every leaf in a water hyacinth plant was plotted on a graph paper and its surface area was calculated by counting the squares enclosed by the leaf surface. The surface area of each leaf in a plant was added to get the total surface area of leaves (cm^2) of a water hyacinth plant. Fresh weight of each water hyacinth plant was also recorded. Mean fresh weight, mean number of leaves, mean root length, mean petiole length and mean surface area of leaves of 10 water hyacinth plants was taken (in gm) from each of the 5 lakes (5lakes*10plants = 50 plants).

Hence Growth Index calculated based on fresh weight of the plant was chosen to study the growth of water hyacinth with respect to pollution levels of the 5 lakes.

Calculation of Growth Index (GI): GI of plants collected in a particular month from a particular lake was computed by dividing the mean fresh weight of plants collected (in that month from that lake) by the mean fresh weight of all plants collected from 5 lakes during July 1999 to June 2000. GI is calculated by the following formula:

GI = (A / M)-------- (Equation No 1.1)

Let M = Mean fresh weight of 530 water hyacinth plants collected from 5 lakes from July 1999 to Jun 2000. A = Mean fresh weight of 10 water hyacinth plants collected from a particular lake in a particular month.

In other words, the mean fresh weight of 530 water hyacinth plants was considered as standard mean fresh weight. The mean fresh weight of 10 sample plants collected from each of the five lakes once every month was compared to the standard mean fresh weight to get the GI of the water hyacinth plants collected.

Correlation of GI to pollution status of lakes: The GI and water quality parameters have been correlated using the Pearson's Correlation coefficient. The strength of the linear association between two variables is quantified by the correlation coefficient. The correlation coefficient is often more useful than a graphical depiction in determining the strength of the association between two variables.

III. RESULTS AND DISCUSSION

Studies conducted were as follows: 1) Study of growth parameters of water hyacinth plants. 2) Study of growth rate (represented by GI) of water hyacinth in relation to pollution levels (represented by trophic state) of 5 lakes under study.

Correlation of lake water constituents with growth parameters of water hyacinth: A water hyacinth plant just like any other plant has roots, petioles and leaves. In order to study the effect of lake nutrient concentration on growth of water hyacinth plants, it was important to study the growth parameters (like number of leaves, root length, etc.,) of water hyacinth plant with respect to the pollution levels. The fresh mean weight of water hyacinth plants collected over 12 months period is distinctly higher for Yelahanka, Nagavara and Hebbal Lakes when compared to Jakkur and Doddabommsandra Lakes (Table 1). Mean number of leaves in a water hyacinth plant collected varied between 10.8 for Nagavara and Doddabommsandra Lake and 12.4 for Hebbal Lake.

Table 1. Mean fresh weight and root length of water hyacinth plants collected from the 5 lakes (10 plants from each lake) from July 1999 to June 2000.

Growth Parameters	Names of Lakes				
Name of lakes/month	Yelaha nka	Nagav ara	Heb bal	Jak kur	Doddabomms andra
mean fresh weight of 10 plants (in gm)	152.68	178.5 3	182.7 2	73.8	87.74
mean root length of 10 plants (in cms)	14.15	6.5	7.9	11.8	12.2

No significant difference in number of leaves was observed in plants collected from all the 5 lakes. From Table 1, the mean root length of 12 monthly samples of water hyacinth was high in Yelahanka (14.15 cm) followed by Doddabommsandra (12.2 cm), Jakkur (11.8 cm), Hebbal (7.9 cm) and Nagavara (6.5 cm) Lakes. In July, August, September 1999, February, March, May and June 2000, Yelahanka Lake had higher mean root length. Doddabommsandra Lake had higher mean root length in December 1999 and January 2000. In October, November 1999 and April 2000, water hyacinth plants from Jakkur Lake had longer mean root length than other lakes. In case of lower concentration or no nutrients present in the lakes, the water hyacinth roots grow deeper in search of nutrients required for their growth. This leads to longer root lengths in less polluted lakes. While, in more polluted water bodies, the roots are shorter as nutrients are readily available. Petiole lengths were seen to be greater in polluted lakes. It was observed that the colour of the root varied from the young to matured water hyacinth plants; the young roots were purple and became darker as they matured.

Mean petiole length of plants collected from Yelahanka, Nagavara and Hebbal Lakes were greater as compared to those collected from Jakkur and Doddabommsandra Lakes. The petioles in water hyacinth plants collected from Yelahanka, Nagavara and Hebbal Lakes were strong and sturdy as compared to petioles seen in plants collected from Jakkur and Doddabommsandra Lakes. Total leaf surface area was seen to be more in plants collected from Yelahanka, Nagavara and Hebbal Lakes when compared to plants collected from Jakkur and Doddabommsandra Lakes. Mean leaf surface area was seen to be more in plants collected from Yelahanka, Nagavara and Hebbal Lakes when compared to plants collected from Jakkur and Doddabommsandra Lakes. After analyzing various growth parameters of water hyacinth plants, fresh weight, petiole length and leaf surface area of water hyacinth were found to be the major distinguishing growth parameters.

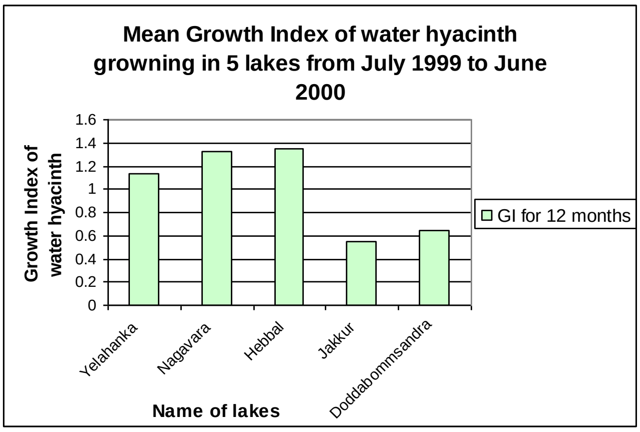
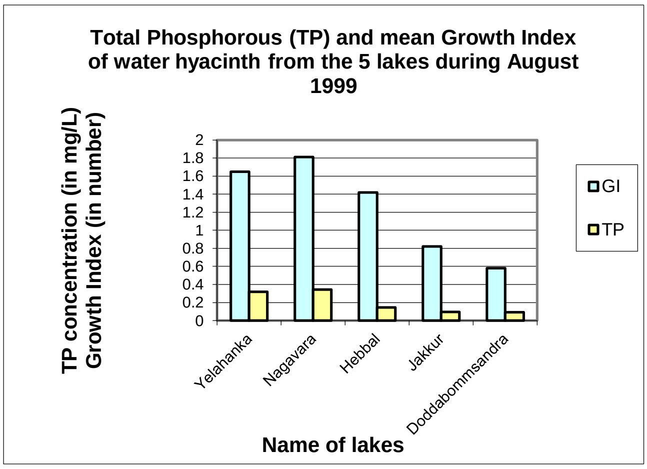


Figure 1. Mean GI of water hyacinth plants in the 5 lakes during July 1999 to June 2000.

Study of growth of water hyacinth plants in relation to pollution level of the lakes:

Comparison of GI of water hyacinth plants and nutrients in lake water: Discharge of sewage is the prime source of phosphorous in the water of all the 5 lakes taken up for study. The prime reason for the growth of water hyacinth weed in all these 5 lakes causing hyper-eutrophic condition is pollution. The discharge of untreated sewage results in high concentration of phosphorous and nitrogen in lake water and accumulation of phosphorous and nitrogen in lake sediment bed by sedimentation of organic solids. Besides, the dead water hyacinth plants and dead algae also contribute to the accumulation of organic nutrients in the lakebed. The accumulated nutrients in the lakebed get released back into the lake water due to temperature changes causing thermal inversion and mixing of lake water [15]. Water hyacinth collected from Yelahanka, Nagavara and Hebbal Lakes showed higher GI as compared to water hyacinth collected from Jakkur and Doddabommsandra Lakes in August 1999 and November 1999 (Table 2 & Figure 1). It was observed that more the concentration of TP in the lake water, higher was the GI of water hyacinth. This was confirmed in the correlation chart of TP vs. GI of water hyacinth plants (in Figure 2).

Higher the nitrogen concentration in lake water, higher was the GI of water hyacinth plants. The extent of correlation between Total Nitrogen (TN) and the GI was also determined by a linear plot.



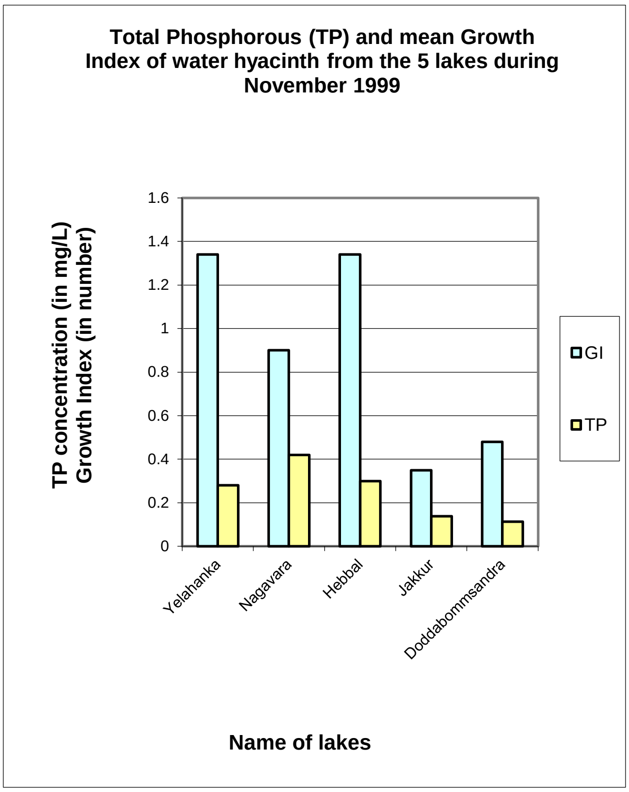


Figure 2. Histogram showing TP concentration and monthly mean GI of water hyacinth collected from 5 lakes during August 1999 and Nov 1999.

Comparison of Total leaf surface area of water hyacinth plant with TP in lake water: TSI based on TP and Total leaf surface area of water hyacinth plants for the month of August 1999 and November 1999 showed Yelahanka,

Nagavara and Hebbal lakes had higher TP concentration and higher surface area of leaf of water hyacinth plant when compared to Jakkur and Doddabommsandra Lakes. The number of leaves of water hyacinth plants, in more polluted and less polluted lakes did not vary much (Figure 3) indicating that the number of leaves of water hyacinth cannot be used to study the effect of pollution. Yelahanka, Nagavara water had higher TP concentration and higher surface area of leaf of water hyacinth plant when compared to Jakkur and Doddabommsandra Lakes. Water hyacinth collected from Yelahanka and Doddabommsandra Lakes showed that mean number of leaf in more polluted (Yelahanka) Lake and less polluted (Doddabommsandra) Lake are not much differing. The water hyacinth plants collected from highly polluted Nagavara Lake, with high nutrient levels had longer petioles in comparison to plants collected from lesser polluted Jakkur Lake with low nutrient levels. Water hyacinth plants collected from Jakkur Lake had smaller petioles which were usually bulbous. Yelahanka was more polluted in comparison to Jakkur.

Comparison of growth of water hyacinth in more polluted lakes and less polluted lakes: Lake qualities indicated by trophic status. Mean petiole length in water hyacinth plant was more in polluted Yelahanka Lake when compared to less polluted Jakkur Lake.

Table 2. Growth Index (GI) of water hyacinth plants collected from 5 lakes from July 1999 – June 2000

Name of lakes	Monthly mean Growth Index (GI) of plants collected from July 1999 to June 2000													No. of months	Annual Mean Growth Index
	Jul-99	Aug-99	Sep-99	Oct-99	Nov-99	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Total Growth Index -GI		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Y	1.65	1.65	1.33	1.02	1.34	1.01	1.42	1.08	0.64	0.83	0.8	0.79	13.56	12	**1.13**
N	2.25	1.81	1.72	1.4	0.9	1.59	1.17	1.45	0.74	0.18	*	*	13.22	110	**1.32**
H	*	1.42	1.67	1.35	1.34	2.27	0.42	0.99	*	*	*	*	9.47	7	**1.35**
J	1.49	0.82	0.58	0.56	0.35	0.48	0.23	0.22	0.45	0.32	0.56	0.5	6.55	12	**0.55**
D	1.21	0.58	1.14	0.4	0.48	0.84	0.55	0.56	0.62	0.41	0.45	0.56	7.79	12	**0.65**
Total	**6.6**	**6.28**	**6.44**	**4.73**	**4.41**	**6.19**	**3.79**	**4.3**	**2.45**	**1.74**	**1.81**	**1.85**			

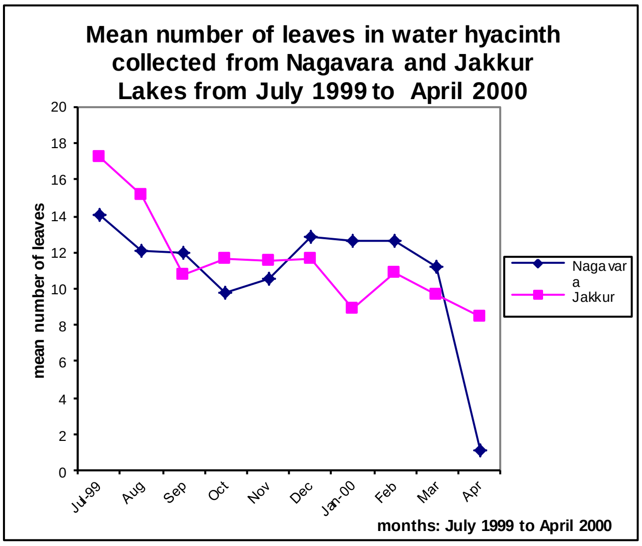
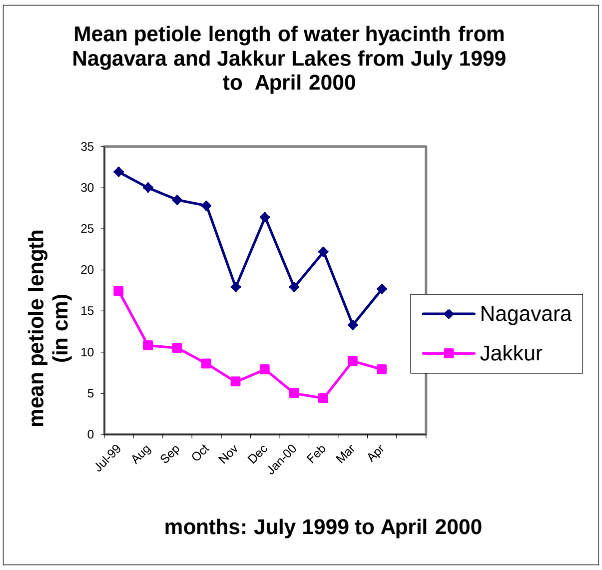


Figure 3. Time series chart showing mean number of leaves of water hyacinth plant in more polluted Nagavara Lake and less polluted Jakkur Lake from July 1999 to April 2000.



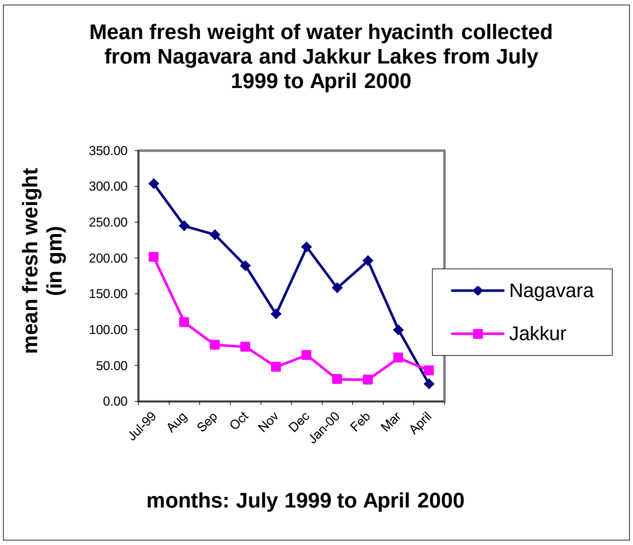


Figure 4a. Time series chart showing mean petiole length of water hyacinth plant in more polluted Nagavara Lake and less polluted Jakkur Lake. Figure 4b. Time series chart showing mean fresh weight of water hyacinth plant in more polluted Nagavara Lake and less polluted Jakkur Lake (from July 1999 to April 2000).

The mean petiole length of a water hyacinth plant was more in more polluted Nagavara Lake when compared to less polluted Jakkur Lake (Figure 4a). In all the months, Nagavara showed higher fresh weight except in the month of April 2000 (Figure 4b). Petiole length seems to be an indicator of pollution level in water hyacinth i.e. higher the pollution level longer is the petiole.

Mean fresh weight of a water hyacinth plant collected from Yelahanka Lake (polluted lake) was more when compared to that from Doddabommsandra Lake (less polluted lake). Mean total surface area of all leaves of water hyacinth plants was higher in the more polluted Nagavara Lake than in the less polluted Jakkur Lake. This indicates that, water hyacinth plants collected from polluted, Yelahanka Lake had more leaf surface area when compared to those collected from the less polluted Doddabommsandra Lake. Larger leaf surface area was prevalent in water hyacinth plants in more polluted water than in less polluted water.

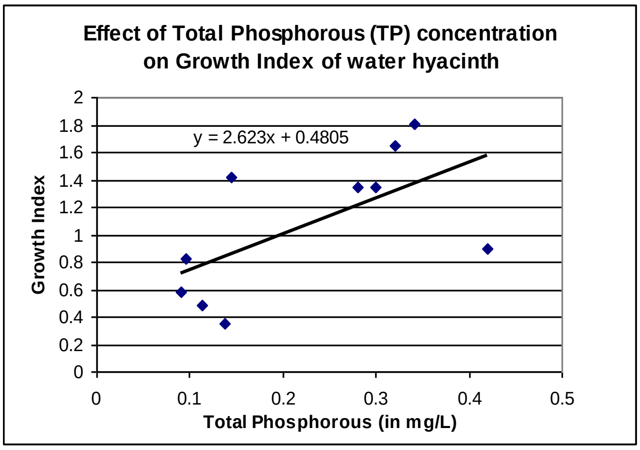
Correlation of lake water constituents to various aspects of growth of water hyacinth: The growth of the individual plant in relation to the concentration of essential nutrients nitrogen and phosphorous were studied with respect to water hyacinth plants collected from each lake. The correlation of TP concentration in lake water with growth parameters showed that the rate of growth of water hyacinth plant had a linear positive relationship to the TP concentration in the water of 5 lakes. The values of TP concentration in the 5 lakes is plotted in the graph (Figures 2) and the fresh weight of water hyacinth is given in Table 1. The Pearson's Correlation coefficient for TP versus GI was found to be +0.62, indicating a good correlation, (the correlation coefficient is nearing to 1) Figure 5.The growth rate of water hyacinth tends to increase as the pollution (TP concentration) level of the lake increases. The graphical plot for TP concentration in lake water vs. mean number of leaf shows the Pearson's Correlation coefficient obtained was only 0.11, showing that the pollution level of lake had no significant impact on the number of leaf of water hyacinth plants. The correlation coefficient was 0.11was less than 0.5 indicating a poor correlation between the pollution level of lakes and number of leaves of water hyacinth.

The Pearson's Correlation coefficient obtained for TP versus root length of water hyacinth was only - 0.17, indicating the pollution level of lake had no significant impact on the root length of water hyacinth plants. The correlation coefficient of 0.17 close to zero indicated no correlation between pollution level of lake water and root length of the water hyacinth plants.

The graphical plot for TP concentration in lake water vs. mean petiole length of water hyacinth plants showed the Pearson's Correlation coefficient to be +0.64 indicating the pollution level of lake had significant impact on the petiole length in water hyacinth plants. The correlation coefficient of +0.64 was near to 1 showing good correlation of pollution level of lake water and petiole length of the water hyacinth plants. The graphical plot for TP concentration in lake water vs. mean total leaf surface area of water hyacinth plants from 5 lakes showed the Pearson's Correlation coefficient to be +0.56, showing the pollution level of lake had significant impact on the leaf surface area of water hyacinth. The correlation coefficient of +0.56 was near to 1 showing a good correlation between pollution level of lake water and mean leaf surface area of the water hyacinth plants.

Correlation of water quality parameters to GI of water hyacinth plant: It is observed that the rate of growth of water hyacinth had a linear positive relationship to the TP concentration in the water of 5 lakes (Figure 5).The line of best fit for the graphical plot of phosphorous concentration in the lake water vs. overall GI of water hyacinth is shown in Figure 5.

The line of best fit showed the correlation of GI to concentration of phosphorous in lake water having Pearson's Correlation coefficient of +0.62 indicating a strong correlation. Lower the concentration of phosphorous in the lake water, lower was the GI of water hyacinth; and as the phosphorous concentration in the lake water increased the overall GI of water hyacinth also increased.



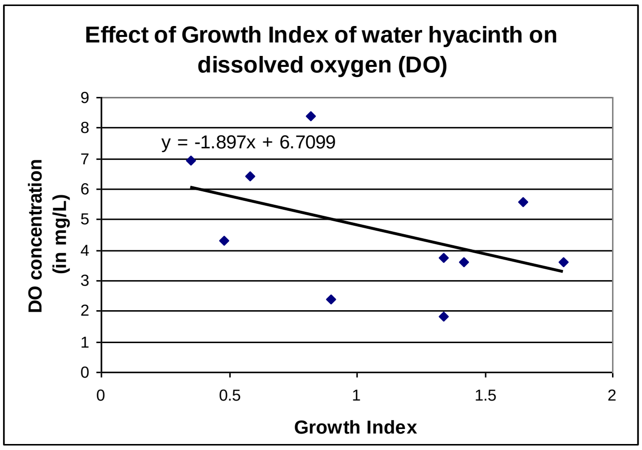


Figure 5. Graphical plot of Total Phosphorous (TP) concentration in lake water versus Growth Index of water hyacinth. Figure 6. Graphical plot of Growth Index of water hyacinth plants to DO level in lake water.

Correlation of TN to mean GI of water hyacinth plants from 5 lakes: The Pearson's Correlation coefficient obtained was +0.43, TP in lake water showed a correlation coefficient of +0.62 to the GI indicating GI was strongly correlated to the TP when compared to TN. The limiting nutrient phosphorous, had significant impact on the pollution level of lake water and also to the growth of water hyacinth, indicating higher the pollution level of the lake, higher would be the growth of water hyacinth. Correlation of Ca concentration in lake water to GI showed a positive correlation of +0.28 indicating a poor positive correlation between the calcium present in the lake water to the growth of water hyacinth plants. The correlation of potassium concentration in lake water to GI showed a positive correlation of +0.37 indicating a poor positive correlation between the potassium present in the lake water and the growth of water hyacinth plants. The correlation of BOD concentration in lake water to GI indicated poor correlation coefficient of 0.37. The correlation of DO concentration in lake water to GI showed a correlation coefficient of - 0.46 (Figure 6). The profuse growth of water hyacinth plants shuts down wind induced natural aeration and penetration of sunlight into the lake water. This results in reduced algal growth, which eliminates the contribution of DO to the lake water. Anaerobic digestion of organic sludge deposits further contributes to the depletion of DO in the water hyacinth covered areas. Thus explaining, the negative correlation of DO content in the water to the growth of water hyacinth plants on the lake water (Figure 6). The GI of water hyacinth plants and corresponding DO concentration in lake water had a correlation coefficient of -0.46 (showing no correlation) and the line of best fit equation y = -1.1897x + 67099.

Table 3. Summary of Correlation coefficients.

Parameters	Pearson's Correlation coefficient	Type of correlation
TP vs. GI	0.62	Positive correlation
TN vs. GI	0.43	Positive correlation
Ca vs. GI	0.28	Low Positive correlation
K vs. GI	0.37	Positive correlation
BOD vs. GI	0.37	Positive correlation
GI vs. DO	-0.46	Negative correlation

Table 3 shows the Pearson's Correlation coefficient for the various parameters to the GI of water hyacinth. GI of water hyacinth plants exhibited strong positive correlation to TP concentration of lake water (Figure 2).

The studies made on various growth aspects of water hyacinth like mean petiole length, mean fresh weight of the plants, mean leaf surface area have shown that lakes which are highly polluted had given rise to higher growth rate of water hyacinth. The mean petiole length in Nagavara Lake was higher than that of Jakkur Lake during the period July 1999 to June 2000. Mean fresh weight of water hyacinth grown in Nagavara Lake was higher than that in Jakkur Lake during the period July 1999 to June 2000. Mean leaf surface area of water hyacinth grown in Nagavara Lake was higher than that in Jakkur Lake during the period July 1999 to June 2000. TSI based on TP was 88.28 for Nagavara lake which was Hypereutrophic and eutrophic for Jakkur Lake where TP was 69.81. Hence Nagavara Lake was highly polluted as compared to Jakkur Lake. Nitrogen concentration vs. mean GI of water hyacinth was plotted and a straight line linear plot satisfying the equation Y = 0.0446X + 0.7757 was obtained. The Pearson's Correlation coefficient obtained in this case was +0.43 whereas, GI of water hyacinth plants showed a correlation coefficient of +0.62 to TP. In other words, Growth of water hyacinth was strongly correlated to TP (correlation coefficient >0.5) as compared to TN (correlation coefficient <0.5). Hence TP which was the limiting nutrient had significant impact on the pollution level of lake water and the growth of water hyacinth. This indicates that higher the pollution level of the lake, higher would be the growth rate of water hyacinth. Calcium present in the lake water to the GI of water hyacinth plants in the lakes shows a positive correlation of +0.28. This indicates a poor positive correlation between the calcium present in the lake water and the GI (or growth rate) of water hyacinth plants. The graphical plot of potassium present in the lake water to the GI of water hyacinth plants in the lakes showed a positive correlation of +0.37. This indicates a poor positive correlation between the potassium present in the lake water and the GI of water hyacinth plants. Correlation plot of BOD to the growth of water hyacinth plants showed a positive correlation coefficient of 0.37. This indicates poor correlation between the BOD in the lake water and the GI of water hyacinth plants. DO showed a negative correlation to the GI of water hyacinth (correlation coefficient -0.46). This indicates that more the area covered by water hyacinth, lesser would be the DO concentration in the lake water.

As the phosphorous concentration in the lake water increased the overall GI of water hyacinth also increased. TP the limiting nutrient has significant impact on the pollution level then higher would be the growth rate of water hyacinth. TP versus GI, showed a good positive person's correlation coefficient. Pearson's Correlation coefficient of TP, TN, and the GI of water hyacinth indicated good correlation. Highly polluted lakes gave rise to higher growth rate of water hyacinth. Polluted lakes had strong and sturdy petioles and more GI compared to less polluted lakes.

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