

**Potential contribution to the nutrient pool due to the decomposition of *Eichhornia crassipes* under different salinity in an aquatic ecosystem - A laboratory study**

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**Abstract**

The opening of Thannermukkom saltwater barriers during monsoon causes an *Eichhornia crassipes* infestation in Cochin backwater, Kerala-India; an annual occurrence. During the process, the plants are exposed to varying salinity due to tidal action. Keeping this in mind, an experiment was conducted to study the nutrient released post-decomposition to saltwater exposure. The effect of salinity on the decomposition was varied. In contrast to low nitrite concentration (ca. 6  $\mu\text{M}$ ), ammonium concentration ( $\sim 70 \mu\text{M}$ ) was very high in the whole plant decomposition. Low nitrite concentration was correlated with the increase in ammonium. Nitrate concentration was 17  $\mu\text{M}$  in 5 psu salinity. However, the increase in nitrate was negatively correlated with nitrite concentration. Phosphate concentration was  $\sim 23 \mu\text{M}$  in 25 psu salinity and silicate was in the range of  $\sim 45 \mu\text{M}$ . The decomposition of the cut pieces of *E. Crassipes* leaf and petiole under dark conditions showed very high concentration of ammonium, and low concentration of nitrite and nitrate. The concentration of phosphate and silicate was higher in leaf decomposition. The study showed that the rate of decomposition was faster in cut leaf and petiole under dark condition. This indicates that the prevailing condition could influence the degree of decomposition and the eventual release of the nutrients. The study also illustrates the complexity of *E. crassipes* plant decomposition in varying salinity which is found in the backwater system. The estimated nutrients from this study suggested that the potential contribution from the decomposition of *E. crassipes* to the nutrient pool could be considerably high. The probable role of decomposing *E. crassipes* plant in the nutrient dynamics of the Cochin backwater system has been proposed for the first time.

**Keywords**

Ammonium, Nitrite, Nitrate, Phosphate, Silicate, Practical salinity unit (psu), Dissolved oxygen, decomposition, litter chemistry, water hyacinth

## Introduction

*Eichhornia crassipes* (Mart.) Solms (common name: water hyacinth) is a highly invasive free-floating freshwater aquatic weed including the present study area. The growth of *E. crassipes* proliferates in nutrient-rich conditions. It has the highest growth rate of any saltwater, freshwater, or terrestrial vascular macrophyte (Wolverton and McDonald 1978). For example, ten individual plants can produce a population of 655,330 individuals in just eight months (Babu et al. 2003). As a result, the dense growth of this species can occupy huge areas of water bodies in a very short time. The studies showed that the dense beds of floating macrophyte, including *E. crassipes*, can negatively impact aquatic invertebrate and fish communities by reducing light penetration into the water column and inhibiting gas exchange between the water's surface and the atmosphere (Chukwuka and Uka 2007; Hill et al., 2011; Low, 2011; Smith, 2011; Wersal and Madsen, 2012; Carminani and Roy, 2017). In many ecosystems, *E. crassipes* is also considered to be an ecosystem engineer owing to its ability to cause physical modification, maintenance or creating new habitats (Villamagna and Murphy, 2010; Kriticos and Brunel, 2016).

Cochin backwater/estuary, Kerala, located on the west coast of India, is a unique ecosystem that experiences an annual phase change in its macrophyte community between monsoon (wet) and non-monsoon (dry) seasons (*Authors' observation*). Monsoon season is also marked by the freshwater influx to the backwater due to heavy precipitation from the Southwest monsoon event, coupled with high nutrient runoff (Madhu et al. 2007). *E. crassipes* thrives under high nutrient condition. However, *E. crassipes* start dying due to the influx of seawater post-monsoon and the dense mats of *E. crassipes* biomass collapse in about a two-week time (Imchen et al. 2017).

As much as nutrients are obtained through the decomposition of biomass in the terrestrial ecosystem, the decomposition of aquatic macrophytes is a critical link for nutrient cycling in an aquatic system. This helps in the return of nutrients to the system. Therefore, the decomposition of detrital matter forms an important link in the process of nutrient recycling, including the addition of organic matter to the aquatic system (Balasubramanian et al. 2012; Xie et al. 2016). *E. crassipes* can be an important component in an aquatic ecosystem and its decomposition can regulate nutrient recycling in shallow freshwater ecosystems (Battle and Mihuc 2000; Xie et al. 2004). The study showed that the detrital matter from *E. crassipes* beds is generated as a result of aging, overcrowding, pest damage, herbicide application for control of the plants and frost damage during winter (Reddy and DeBusk 1991).

In Cochin backwater due to the invasive growth of *E. crassipes* massive biomass is formed during monsoon every year. However, the biomass collapses post-monsoon due to the ingress of sea

water. In the process, it is believed that a large amount of detrital matter and nutrients are generated due to decomposition and contribute to the backwater system. But how much of these nutrients are being contributed to the system from this process is not known and no study has been conducted until now. The backwater is also exposed to varying salinity conditions due to tidal action and high precipitation during monsoon. Given this background, a laboratory experiment was designed to understand how the decomposition of *E. crassipes* plants is affected by salinity, how dark condition affect the decomposition of plant parts, and estimate of the nutrients released from a unit biomass of *E. crassipes* plant part and its potential contribution to the nutrient pool was investigated in the present study. The results, thus, obtained have been explained and discussed in the present paper.

### **Materials and Methods**

A laboratory experiment was conducted to evaluate the nutrient released from *E. crassipes* plant decomposition under different salinity. A broad range of salinity levels (0, 5, 10, 15, 20, 25, 30 and 35 psu) was used in the present study to test the salinity effect on the decomposition of plant biomass. Aged seawater and freshwater (demineralized pure water-Mili Q) was used for the test. The nutrient concentration of this water was negligible or below the detection level. Freshwater was used as 0 salinity and as control without a plant in the experiment. It was also used to calibrate the different levels of salinity. Plants of similar size and age were selected for the study. Any detrital matter or sediment adhering to the plants was removed with gentle brushing under running water. A whole plant with 4-5 leaves (~75 g wet weight) was put in a 5 L vessel containing ~4 L of different salinity and allowed the decomposition of the plant to take place. The experiment was for 90 days under normal daylight conditions.  $\text{GeO}_2$  ( $\text{mg. l}^{-1}$ ) was incorporated to control the growth of diatoms (Imchen, 2012; Imchen, 2018). Water samples were collected every 15 days (ca. two weeks). The water samples were used to measure nutrients [Ammonium ( $\text{NH}_4^+$ ), Nitrite ( $\text{NO}_2^-$ ), Nitrate ( $\text{NO}_3^-$ ), Phosphate ( $\text{PO}_4^-$ ) and Silicate ( $\text{SiO}_4$ )]. The nutrients obtained from the decomposition of *E. crassipes* biomass was measured in an auto analyzer instrument (Make – Skalar, The Netherland). Dissolved oxygen (DO) was also measured at 15 days interval (ca. two weeks) by a titration method. All the analyses were done according to the Parsons standard procedure (Parsons et al. 1984). All the treatments were performed in triplicate.

Another set of experiment was performed where in leaf and petiole of *E. crassipes* were decompose separately under dark condition. During its peak growth, the invasive growth of *E. crassipes* forms a dense mat where plant parts especially drooping leaves or cut parts due to grazing and mechanical damage caused by boats/ships as it is a busy harbor remain in the dark under the thick mat of vegetation. This experiment was to understand how this condition would affect

decomposition. However, in this experiment, only four salinity (0, 15, 25, 35 psu) was used to test the effect of salinity. Approximately 2 g (wet weight.) each of the plant parts (separate cut pieces of leaf and petiole) was maintained in 1 L of water of different salinity for 90 days. The dark condition was maintained by covering the vessel with a double-layered black polythene sheet. One control (without plants) was maintained as a reference. Water samples were collected at 15 day intervals and nutrients were measured as described above in the first experiment. All the treatments were performed in triplicate.

The rate of release of dissolved inorganic nitrogen (DIN- nitrite, nitrate, and ammonium), dissolved inorganic phosphate (DIP) and silicate was determined from the decomposition of *E. crassipes* plant and its parts (leave and petioles). The release rate was calculated from 7, 45, and 90 days respectively.

The analysis of the data showed that maximum decomposition and the release of nutrients occurred within 45 days. Based on this, the results of nutrients from day 45 of leaf and petiole decomposition were used to calculate and estimate the DIN, DIP and silicate contribution from a unit of biomass. The unit of nutrients (DIN, DIP and silicate) in the experimental results have been expressed in micromoles ( $\mu\text{M}$ ). However, to estimate the potential yield from larger biomass the data in micromoles ( $\mu\text{M}$ ) was first converted to simple weight (mg - milligram) to indicate the estimated nutrients. This simple weight derived from the experimental nutrient data was used to estimate hypothetical biomass and its potential contribution to the nutrient pool. The estimated nutrient yield has been expressed in kg per unit tonne of biomass.

The effect of time and salinity on the decomposition and release of nutrients from *E. crassipes* biomass was analyzed by two-way ANOVA. One-way ANOVA was used to analyze the release rate of nutrients during *E. crassipes* decomposition. The correlation between ammonium, nitrite, and nitrate was analyzed to determine the relationship between the constituent dissolved inorganic nitrogen (DIN). All statistical analyses were performed according to Sokal (1981) using Statistica 8 software (StatSoft, Inc.).

## **Results and discussion**

The decomposition of macrophyte biomass, including *E. crassipes* plant biomass, can be important in the production processes (primary and secondary) of a water body (Barik et al. 2000). It also influences the energy flow in the aquatic ecosystem (Balasubramanian et al. 2012; Li et al. 2012).

## **Dissolved inorganic nitrogen (DIN)**

Nutrients, including organic carbon, are released into the water column as a result of decomposition of floating plants and through leaching (Yule and Gomez, 2009; Imchen et al. 2017). The analysis of the results of *E. crassipes* plant biomass (whole plant, leaf, and petiole) decomposition showed that salinity had a significant effect ( $P < 0.05$ ) on the release of DIN (ammonium, nitrite, and nitrate). The concentration of ammonium (ca 70  $\mu\text{M}$ ) was highest amongst the three different constituents of DIN (ammonium, nitrite, and nitrate) in 15 psu salinity at day 15 (Figure 1.a;  $P < 0.05$ ). On the other hand, the concentration of nitrite was very low, maximum concentration was ca. 6  $\mu\text{M}$  in 35 psu salinity at day 60 ( $P < 0.05$ ). Nitrite concentration started to increase from day 30 (Figure 1.a) and peaked at day 60 in all the salinity conditions. Although the analysis showed that low nitrite was positively correlated with high ammonium concentration ( $r = 0.02$ ,  $P < 0.05$ ), the correlation was weak. The maximal nitrate concentration was ca. 17  $\mu\text{M}$  in 5 psu salinity at day 15 ( $P < 0.05$ ). However, the increase in nitrate concentration was observed at day 75 under all the salinity condition which declined subsequently. The nitrate concentration was negatively correlated to nitrite ( $r = -0.2$ ;  $P < 0.05$ ). The correlation between ammonium and nitrate concentration was not statistically significant ( $r = 0.07$ ;  $P > 0.05$ ).

The decomposition of leaf and petiole under dark conditions showed that the effect of salinity on the decomposition and concentration of nutrients was statistically significant ( $P < 0.05$ ). The results showed that ammonium concentration was considerably higher (4 – 8 times) compared to the whole plant decomposition. Ammonium concentration from leaf decomposition was in the range of 525 - 571  $\mu\text{M}$  in all the salinity conditions on day 45 (Figure 1.b). However, the opposite was true in the case of nitrite and nitrate. Nitrite was 2.2  $\mu\text{M}$  in 35 psu salinity condition at 75<sup>th</sup> day, and nitrate was 3.4  $\mu\text{M}$  in 35 psu salinity at day 60 (Figure 1.b).

Similarly, ammonium concentration from the decomposition of petiole was ~ten times of whole plant decomposition. The concentration of ammonium was ca 305  $\mu\text{M}$  in 0 psu salinity at day 45, nitrite was 0.8  $\mu\text{M}$  in 25 psu salinity after 15 days, and nitrate was ca. 3.0  $\mu\text{M}$  at 25 psu salinity on day 90 (Figure 1.c). The analysis of the results showed that nitrate and nitrite concentration was more in whole plant decomposition than leaf and petiole decomposition. However, the results indicated that the rate of decomposition occurred faster when the plant parts were into pieces compared to the whole plant. The results also indicated that certain factor/s could be promoting a rapid reduction process that resulted in high ammonium concentration. The increase in the concentration of nutrient-N due to decomposition was stated to be due to the increase in bacterial biomass or the exoenzymes secreted by the microbial consortium (Santos et al. 2009).

The results also showed that the increase and decline of nitrate concentration complemented and negatively correlated with low nitrite concentration. Similarly, in the decay study of water milfoil, the concentration of nitrite reportedly remained low which was attributed to N immobilization (Nichols and Keeney, 1973). A similar observation of high ammonium and a very low nitrite concentration was made by Habermeyer and Sanchez (2005) in their nitrification-denitrification study. The extent of nutrients released in the present study showed that the rate of decomposition was higher under dark conditions. Although there was no definite trend, the maximum concentration of DIN was mostly observed in the 25-35 psu salinity condition. The higher salinity condition is believed to have induced osmolytic stress and leached the cell content of the biomass.

### **Dissolved inorganic phosphate (DIP)**

The effect of salinity was significant ( $P < 0.05$ ) on the release of phosphate during the decomposition of *E. crassipes* biomass. The maximal concentration of phosphate in the whole plant decomposition was ca. 23  $\mu\text{M}$  in 25 psu salinity at 45 days ( $P < 0.05$ ; Figure 1.a). In the case of leaf and petiole decomposition, the concentration of phosphate increased rapidly after 15 days. The concentration of phosphate remained more or less constant after 30 days until the 75<sup>th</sup> day. Phosphate concentration in leaf and petiole decomposition was ca. 33  $\mu\text{M}$  after 75 days and ca. 27  $\mu\text{M}$  after 90 days in 25 psu salinity ( $P < 0.05$ ; Figure 1.b and c). Comparatively, the release of phosphate was higher in leaf and petiole decomposition than whole plant decomposition. The previous study showed that the degradation products of biological membranes (e.g. cuticle, middle lamella and cellular membranes) contribute to phosphate nutrient in the aquatic system (He et al. 2015; Liu et al. 2016). The concentration of DIP was also higher in leaf than in petiole decomposition. A high concentration of DIP was also reported in the decomposition of *Potamogeton crispus* and *Miriophyllum verticillatum* (Tang et al. 2013).

### **Silicate**

The effect of salinity in the release of silicate during whole plant decomposition was significant ( $P < 0.05$ ). The highest concentration of silicate was observed between 45 and 60 days in 15 psu salinity. The silicate concentration was in the range of ca. 45  $\mu\text{M}$  (Figure 1.a). However, a temporal decline in silicate concentration from the water sample was observed in the present study. This decline in the silicate concentration is reportedly due to the immobilization and biogenic silica becoming less soluble over time (Canfield et al., 2005).

On the other hand, 26  $\mu\text{M}$  in 25 psu salinity at day 60 ( $P < 0.05$ ; Figure 1.b) and 9.8  $\mu\text{M}$  in 35 psu salinity ( $P < 0.05$ ; Figure 1.c) at 90<sup>th</sup> day were the maximal silicate concentration from leaf and

petiole decomposition respectively. Silicate concentration was more in whole plant decomposition compared to leaf and petiole. Conversely, leaf decomposition showed higher concentration than petiole. The difference in silicate concentration is probably due to the difference in the level of tissue content. However, a previous study reported that young petioles of *E. crassipes* contain more silica than leaves (Nguyen, 2001).

Silicate is an important nutrient for the growth of diatoms (Shanti et al. 2014), and silicate-rich water promotes phytoplankton biomass, particularly diatoms (Sumper et al. 2005; Madhu et al. 2007; Javaheri et al. 2015; De Sanctis et al. 2016). A report of a recent study found high silicate concentration (range of 8-94  $\mu\text{M}$ ) in the Cochin backwater/estuary (Rajaneesh et al. 2015). The study period coincided with the *E. crassipes* plant decomposition in the Cochin backwater/estuary. Based on this report and from our study, it is suggested that silicate released from the decomposition of *E. crassipes* may have contributed to the nutrient pool in the backwater system.

### **Release rate of nutrients**

The results of the release rate of inorganic nutrient-N from the decomposition of the whole plant, leaf, and petiole showed a considerable difference in the present study (Table 1 & 2). The decomposition process is said to be greatly affected by the quality, chemical constituent, of plant part (Chen and Wang, 2019). The analysis showed that the interactive effect of time and salinity was significant in the release rate of DIN from leaf and whole plant decomposition ( $P < 0.05$ ), unlike, from petiole decomposition ( $P > 0.05$ ). Similarly, the interactive effect of time and salinity was also significant in the release rate of DIP during the decomposition of the whole plant, leaf and petiole ( $P < 0.05$ ). The results showed that the release rate was higher during the initial stage of whole plant decomposition especially in the case of DIN and DIP (Table 1). Subsequently, the rate of release declined over time. On the other hand, an increased rate of release of silicate was observed on day 45 in most of the salinity levels which declined at a later stage.

Similar to the whole plant decomposition, the release rate of DIP including silicate was higher during the initial stage of decomposition of leaf and petiole parts (Table 2). Conversely, the release rate of DIN in leaf decomposition increased gradually and peaked on day 45 in all the salinity conditions. The release rate of DIN from petiole decomposition was quite rapid in the initial stage which was similar to whole plant decomposition.

The salinity did not show a definite trend in the release of DIN during the process of decomposition of the whole plant, leaf, and petiole. The salinity level like 0, 15, and 25 psu showed the optimal rate of release. The rate of release under these salinities was 2.5, 5.3 and 6.63  $\mu\text{M} \cdot \text{d}^{-1}$

respectively (Table 1 & 2). The effect of salinity on the rate of release of DIP was also similar to DIN release. In the decomposition of the whole plant, the release rate of DIP per day was  $1.3 \mu\text{M} \cdot \text{d}^{-1}$  in 35 psu salinity,  $1.7 \mu\text{M} \cdot \text{d}^{-1}$  in 15 psu salinity from leaf decomposition and  $1.3 \mu\text{M} \cdot \text{d}^{-1}$  in 25 psu from petiole decomposition (Table 1 & 2). However, the effect of salinity on the release of silicate was more consistent. All the plant parts decomposition like whole plant, leaf, and petiole showed an optimal rate of release in 15 psu salinity. The rate of release under this salinity was  $2.2 \mu\text{M} \cdot \text{d}^{-1}$ ,  $2 \mu\text{M} \cdot \text{d}^{-1}$  and  $0.6 \mu\text{M} \cdot \text{d}^{-1}$  respectively (Table 1 & 2). In agreement with our observation, the initial rate of release was reported to be quite rapid in water milfoil decomposition which declined in the later stage (Nichols and Keeney, 1973). The present study showed that the rate of release was comparatively higher in DIN than DIP and silicate.

### **Estimate of nutrient output from the decomposition of a unit biomass**

In the present study, an attempt was made to give an estimate of potential yield of nutrients from a unit of the biomass of *E. crassipes*. The estimation was made by using the experimental results (data) obtained from the present study and extrapolating to larger biomass. For calculation of the estimate, the mean yield of DIN, DIP and silicate obtained from the decomposition of leaf and petiole was used (Table 3). The results showed that the estimate of potential DIN, DIP, and silicate expected to release from the decomposition of a tonne of *E. crassipes* leaf could be ca. 3.9 kg, 1.4 kg and 0.39 kg after 45 days (Table 4). Similarly, the estimated potential yield of ca. 1.5 kg, ca 1.2 kg and ca. 0.2 kg of DIN, DIP, and silicate respectively could be obtained from a tonne of *E. crassipes* petiole after 45 days (Table 4). The nutrients of the estimated potential yield from this study suggested that the potential contribution from the decomposition of *E. crassipes* to the nutrient pool could be considerably high. This indicates that it can have a significant implication on the nutrient dynamics of the system.

### **Dissolved oxygen (DO)**

The availability of dissolved oxygen is vital in the function of the aquatic ecosystem (Mehring et al. 2014; Gomes et al. 2018). It plays a big role in the decomposition of organic materials in an aquatic system because the decomposition of litter is faster under high dissolved oxygen condition (Tonin and Hepp, 2011). Dissolved oxygen decline or its consumption was at a maximum during the early stage of leaf litter decomposition and increased gradually at the end of the experiment (Santos et al., 2009; Wang et al., 2018). Similarly in the present study, the level of dissolved oxygen (DO) declined initially until day 15 (Figure 2) during the whole decomposition in 10, 15, 20, 25 and 30 psu salinities. However, it remained more or less the same in the later stage which agrees with the



previous study. Conversely in hypo (0 and 5 psu) and hypersaline (35 psu) condition, very little change occurred in the DO. The concentration of DO ranged from 7 – 9 mg. l<sup>-1</sup> throughout the study period. The high DO concentration and less variability could be due to the equilibrium of both consumption and diffusion, a process of oxygen exchange between air-water interphase as stated by Schladow et al. 2002 and Molder et al. 2005. In a similar decomposition study of water milfoil, DO concentration remained near saturation levels ca. 8 mg l<sup>-1</sup> (Nichols and Keeney, 1973) which concurred with the result of the present study. Nichols and Keeney (1973) further stated that DO remain near saturation when diffusion of O<sub>2</sub> exceeds the O<sub>2</sub> demand.

On the other hand, the DO level showed a marginal increase from the initial concentration in the decomposition of leaf and petiole in higher salinity. It gradually declined which indicated its utilisation by the decomposers. Conversely, the rapid decline of DO was observed in 0 psu salinity of both leaf and petiole decomposition from the initial stage of decomposition. This indicated that 0 psu salinity offers an ideal condition to the decomposers. The temporal variability and decline of DO were also similar between leaf and petiole decomposition (Figure 2). However, DO level was negligible and insignificant on day 90 in leaf decomposition. The study of the pattern of oxygen consumption between whole plant decomposition with leaf and petiole decomposition showed that oxygen consumption was more in the case of leaf and petiole decomposition which were incubated under dark conditions. It could also be true that the loss of DO could not be replenished under dark conditions through the diffusion process as it was covered. However, the previous study also showed that oxygen consumption were lower in light condition compared to dark incubation (Dunn et al., 2013).

Litter decomposition is a complex process with a marked difference in the release rate of nutrients (Goya et al. 2008). However, the nutrients present in the system are assumed to be readily available for assimilation by neighboring plants or other primary producers. Therefore, the study suggested that the decomposition of *E. crassipes* plants may have implications for the phytoplankton community. On this premise, a separate study on the post-decomposition effect of *E. crassipes* on marine phytoplankton was conducted, and the nutrient water obtained through *E. crassipes* plant decomposition showed that it has the potential to affect the growth of phytoplankton productivity (Imchen et al. 2018). As observed in the present study, the release of the high amount of ammonium may promote group-specific phytoplankton growth especially Cyanobacteria which assimilate ammonium as a nitrogen source, but it may also negatively affect the nutrient-N utilization because high ammonium concentration inhibits the nitrate assimilation.

The present study showed that salinity has a varying effect on the decomposition of *E. crassipes* plant. This illustrates the complexity involved in the decomposition of *E. crassipes* plant in different salinity condition which is found in the Cochin backwater system. The study also showed that the rate of decomposition was more rapid in dark conditions. This indicates that the prevailing condition could determine the degree of decomposition and the eventual release of the nutrients from the decomposition of biomass. Also, the accelerated decomposition of the cut leaf and petiole indicated that grazing activity in the natural environment may facilitate faster decomposition. The estimated nutrients from this study suggested that the potential contribution from the decomposition of *E. crassipes* to the nutrient pool could be considerably high. The probable role of decomposing *E. crassipes* plant in the nutrient dynamics of the Cochin backwater system has been proposed for the first time.

### **Acknowledgement**

Authors are thankful to the Director, CSIR-National Institute of Oceanography, Dona Paula, Goa for the support and encouragement. This is NIO contribution no #####

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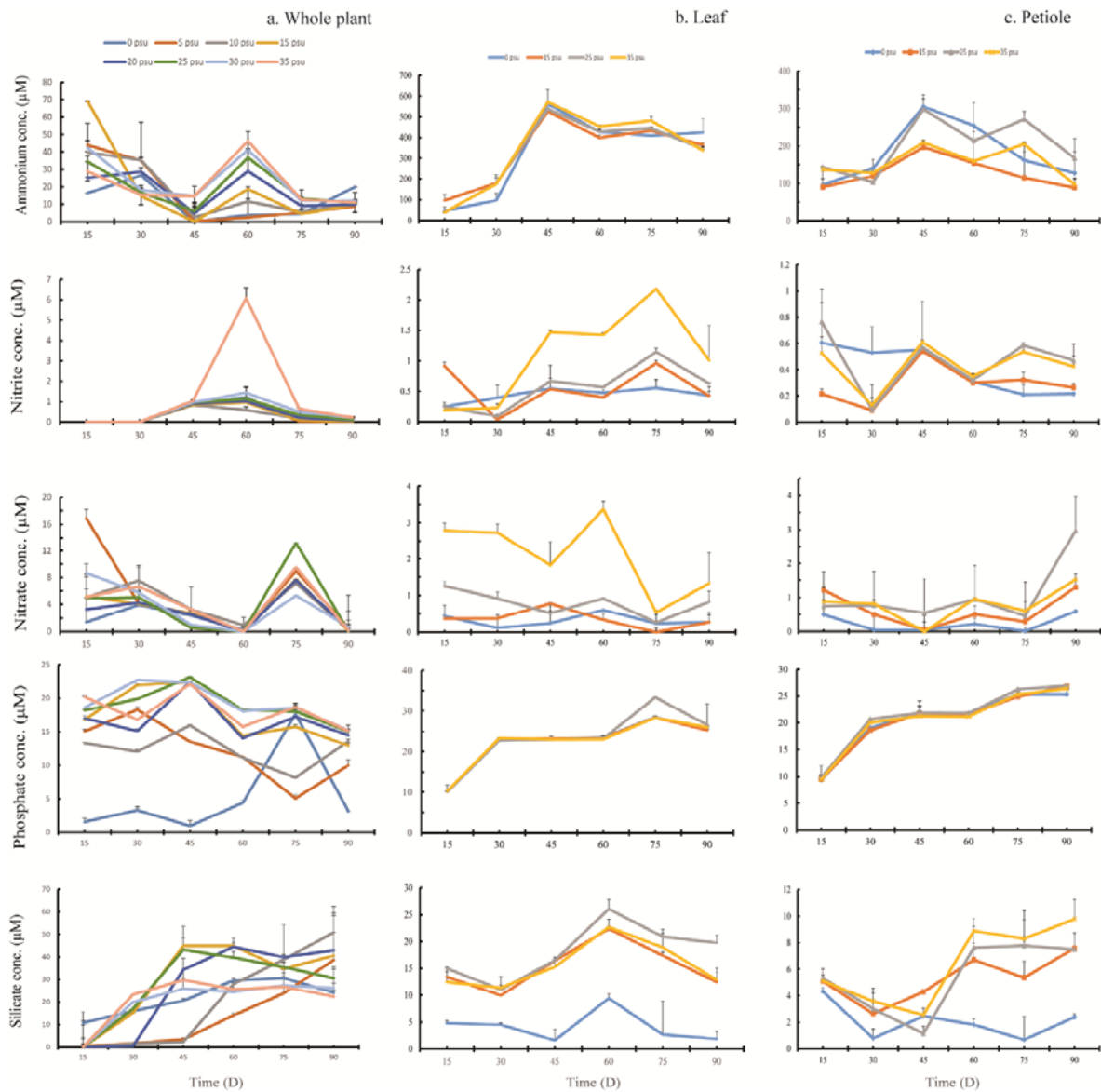
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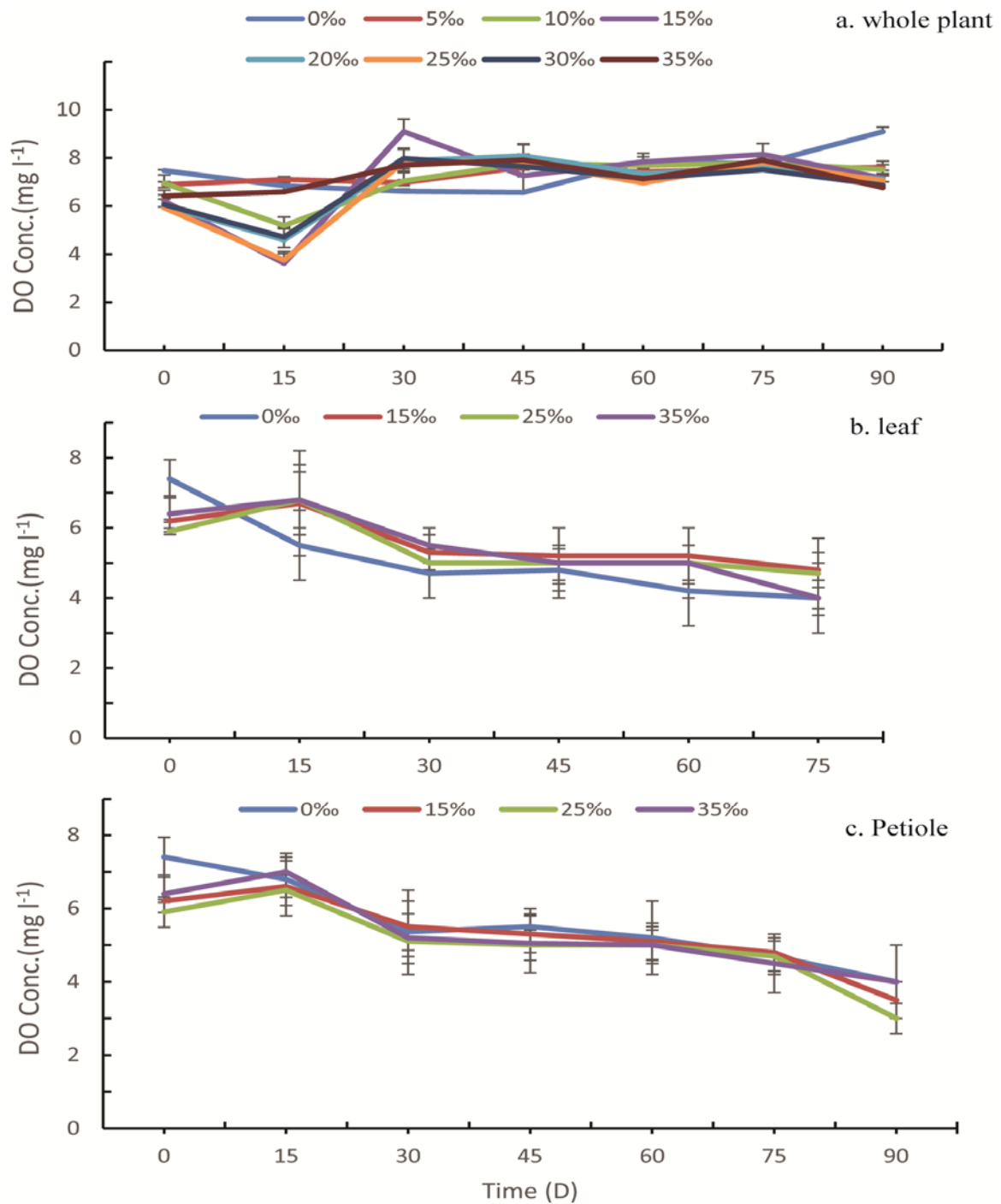
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**Figure 1:** Variation in the mean concentrations of ammonium, nitrite, nitrate, phosphate, and silicate from the decomposition of *E. crassipes* plant. a. Whole plant decomposition under normal day-night cycle, b. Leaf and c. Petiole decomposition under dark condition.



**Figure 2:** Variation in dissolved oxygen (DO) concentration under different salinity conditions during the decomposition of whole *E. crassipes* plant and its parts.



**Table 1:** Rate of release of nutrient per day under different salinity during the decomposition of *E. crassipes* whole plant

Nutrients	Days	Rate of release of nutrients ( $\mu\text{M. d}^{-1}$ )							
		0 psu	5 psu	10 psu	15 psu	20 psu	25 psu	30 psu	35 psu
DIN	7	0.6 ( $\pm$ .4)	2 ( $\pm$ .8)	1.5 ( $\pm$ 1)	2.5 ( $\pm$ 2)	0.9 ( $\pm$ .7)	1.3 ( $\pm$ .9)	1.7 ( $\pm$ 1)	1 ( $\pm$ .7)
	45	0.5 ( $\pm$ .06)	0.06 ( $\pm$ .06)	0.1 ( $\pm$ .06)	0.5 ( $\pm$ .06)	0.1 ( $\pm$ .09)	0.1 ( $\pm$ .02)	0.3 ( $\pm$ .04)	0.3 ( $\pm$ .03)
	90	0.2 ( $\pm$ 0.1)	0.07 ( $\pm$ .02)	0.07 ( $\pm$ .02)	0.07 ( $\pm$ .02)	0.07 ( $\pm$ .01)	0.08 ( $\pm$ .01)	0.09 ( $\pm$ .02)	0.08 ( $\pm$ .03)
DIP	7	0.1 ( $\pm$ .02)	1 ( $\pm$ .5)	0.9 ( $\pm$ .04)	1 ( $\pm$ .5)	1 ( $\pm$ .5)	1.2 ( $\pm$ .5)	1.2 ( $\pm$ .5)	1.3 ( $\pm$ .6)
	45	0.05 ( $\pm$ .02)	0.6 ( $\pm$ .04)	0.8 ( $\pm$ .5)	1 ( $\pm$ .5)	1 ( $\pm$ .5)	1.2 ( $\pm$ .6)	1 ( $\pm$ .5)	1 ( $\pm$ .5)
	90	0.07 ( $\pm$ .03)	0.2 ( $\pm$ .02)	0.3 ( $\pm$ .04)	0.3 ( $\pm$ .02)	0.3 ( $\pm$ .04)	0.3 ( $\pm$ .04)	0.3 ( $\pm$ .04)	0.3 ( $\pm$ .03)
Silicate	7	0.7 ( $\pm$ .3)	0.02 ( $\pm$ .001)	0	0	0	0	0	0
	45	1 ( $\pm$ .5)	0.2 ( $\pm$ .04)	0.1 ( $\pm$ .05)	2.2 ( $\pm$ 1)	1.7 ( $\pm$ .7)	2 ( $\pm$ 1)	1.3 ( $\pm$ .6)	1.5 ( $\pm$ .5)
	90	0.5 ( $\pm$ .3)	0.9 ( $\pm$ .1)	1 ( $\pm$ .1)	0.9 ( $\pm$ .1)	0.9 ( $\pm$ .1)	0.7 ( $\pm$ .1)	0.6 ( $\pm$ .1)	0.5 ( $\pm$ .1)

**Table 2:** The rate of release nutrient per day from a unit biomass of the decomposed parts of *E. crassipes* leaf and petiole.

Parts	Nutrients	Time (D)	0 SA	15 SA	25 SA	35 SA
Leaf	DIN	7	0.55 ( $\pm$ .2)	0.87 ( $\pm$ .25)	1.1 ( $\pm$ .4)	1.5 ( $\pm$ .5)
		45	5.3( $\pm$ 1)	4.9 ( $\pm$ 1)	4.9 ( $\pm$ 1)	5.2 ( $\pm$ 1)
		90	0.93 ( $\pm$ .4)	1.4 ( $\pm$ .8)	1.6 ( $\pm$ .5)	1.8 ( $\pm$ .8)
	DIP	7	1.2 ( $\pm$ .5)	1.7( $\pm$ .8)	1.4 ( $\pm$ .8)	1.5 ( $\pm$ .6)
		45	0.4 ( $\pm$ .02)	0.4 ( $\pm$ .02)	0.4 ( $\pm$ .05)	0.4 ( $\pm$ .05)
		90	0.05 ( $\pm$ .03)	0.04 ( $\pm$ .02)	0.07 ( $\pm$ .03)	0.06 ( $\pm$ .02)
	Silicate	7	0.32 ( $\pm$ .1)	2 ( $\pm$ .5)	2( $\pm$ .5)	1.8 ( $\pm$ .5)
		45	.02 ( $\pm$ .002)	0.04 ( $\pm$ .004)	0.05 ( $\pm$ .01)	0.08 ( $\pm$ .02)
		90	0.005	0.081	0.07	0.05
Petiole	DIN	7	4.43 ( $\pm$ 1)	4.68 ( $\pm$ 1)	6.63( $\pm$ 2)	5.68 ( $\pm$ 1.5)
		45	2 ( $\pm$ .5)	0.9 ( $\pm$ .3)	1.5 ( $\pm$ .5)	0.9 ( $\pm$ .3)
		90	1.2 ( $\pm$ .5)	0.7 ( $\pm$ .4)	0.9 ( $\pm$ .5)	0.8 ( $\pm$ .3)
	DIP	7	0.6( $\pm$ .2)	0.9 ( $\pm$ .4)	1.3( $\pm$ .9)	1.2 ( $\pm$ .5)
		45	0.5( $\pm$ .2)	0.5( $\pm$ .2)	0.4 ( $\pm$ .2)	0.4 ( $\pm$ .4)
		90	0.07( $\pm$ .3)	0.1( $\pm$ .004)	0.1( $\pm$ .004)	0.1( $\pm$ .004)
	Silicate	7	0.18( $\pm$ .02)	0.6 ( $\pm$ .05)	0.6( $\pm$ .2)	0.5 ( $\pm$ .2)
		45	0.03( $\pm$ .02)	0.009	0.09 ( $\pm$ .04)	0.06 ( $\pm$ .03)
		90	0.001	0.07( $\pm$ .03)	0.1 ( $\pm$ .05)	0.1( $\pm$ .05)

**Table 3:** The mean yield of dissolved inorganic nitrogen (DIN - ammonium, nitrite, and nitrate), dissolved inorganic phosphate (DIP), and silicate from a unit biomass of the decomposed parts of *Eichhornia* plant

Parts	Days	Mean DIN ( $\mu\text{M}$ )	Mean DIP ( $\mu\text{M}$ )	Mean silicate ( $\mu\text{M}$ )
Whole plant	7	117 ( $\pm 70$ )	15 ( $\pm 6$ )	1.4 ( $\pm 0.8$ )
	45	23 ( $\pm 18$ )	18 ( $\pm 7$ )	26 ( $\pm 16$ )
	90	32 ( $\pm 20$ )	12 ( $\pm 4$ )	35 ( $\pm 10$ )
Leaf	7	21 ( $\pm 11$ )	10 ( $\pm 0.8$ )	11 ( $\pm 5$ )
	45	551 ( $\pm 317$ )	23 ( $\pm 0.07$ )	0.8 ( $\pm 0.4$ )
	90	369 ( $\pm 212$ )	26 ( $\pm 0.2$ )	12 ( $\pm 7$ )
Petiole	7	113 ( $\pm 64$ )	7 ( $\pm 1$ )	3.5 ( $\pm 1.4$ )
	45	210 ( $\pm 1.3$ )	26 ( $\pm 3$ )	5.3 ( $\pm 3$ )
	90	122 ( $\pm 69$ )	26 ( $\pm 1$ )	7 ( $\pm 3$ )

**Table 4:** Estimated dissolved inorganic nitrogen (DIN), dissolved inorganic phosphate (DIP) and silicate expected to release by a tonne of biomass as a result of the decomposition of *E. crassipes* plant parts after 45 days

Parts	Estimated DIN (kg/tonne)	Estimated DIP (kg/tonne)	Estimated silicate (kg/tonne)
Leaf	3.86	1.14	0.39
Petiole	1.47	1.23	0.17
Estimated total (kg)	5.33	2.37	0.56

#The experimental results of nutrients are expressed in  $\mu\text{M}$  and it was converted to simple weight to calculate and estimate the potential nutrients contribution from a unit biomass. The unit of estimated nutrients are expressed in kg/tonne.