Nutrient resorption efficiency of Heritiera fomes Buch. Ham and Excoecaria agallocha L

Sanjoy Saha
Khulna University
Md. Mustafizur Rahman
Khulna University
Roksana Jahan
Khulna University
Mohammad Raqibul Hasan Siddique
Khulna University
Chameli Saha
Khulna University
Mahmood Hossain
mahmoodhossain@hotmail.com

Khulna University

Research Article

Keywords: Adaptation, Excoecaria agallocha, Heritiera fomes, Nutrient, Re-translocation, Sundarbans

Posted Date: November 8th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3559996/v1

Additional Declarations: No competing interests reported.

Abstract

Nutrient resorption is a nutrient conservation approach for plants growing in nutrient-poor habitats. The nutrients (Nitrogen, Phosphorus and Potassium) resorbed from leaves of *Heritiera fomes* and *Excoecaria agallocha* in the Sundarbans, Bangladesh were examined. Mature green leaves and yellowish senescent leaves of the dominant individual of each species were picked from the selected trees during the prominent seasons. Soil samples were collected from the same sites and occasions. Comparatively ($p < 0.05$), a higher concentration of N (12.64 ± 1.05 mg/g), P (0.42 ± 0.18 mg/g) and K (10.79 ± 0.14) was observed in green mature leaves of *H. fomes* during the monsoon season. Similar ($p > 0.05$) concentration (8.33 ± 1.07 to 9.76 ± 1.40 mg/g) of N was detected for the green mature leaves of *E. agallocha* throughout the seasons. In contrast, higher concentrations of P and K were observed in the monsoon season. The highest nitrogen resorption efficiencies for *H. fomes and E. agallocha* were 76.94% and 63.33%, respectively during the pre-monsoon season followed by post-monsoon season. *Heritiera fomes* was more efficient in N and K resorption, while *E. agallocha* was more efficient in P resorption. The nutrient resorption efficiency of *H. fomes* and *E. agallocha* indicated the adaptation mechanism towards harsh environments, especially nutrient-poor conditions.

Introduction

Mangroves are ecologically and economically important coastal woody ecosystems at the tropical and sub-tropical sheltered coastline and link the terrestrial and marine ecosystems (Mahmood et al. 2008; Ribeiro et al. 2019). Mangrove plants experience regular tidal inundation at varying salinity levels (freshwater to hyper-saline conditions) (Siddique et al. 2017; Alam et al. 2018). Mangrove plants have developed unique mechanisms to adapt to tidal inundation and salinity, varying species (Alam et al. 2019; Nasrin et al. 2021). However, salinity has important control over the availability of nutrients to mangroves (Mahmood et al. 2014a; Nasrin et al. 2016).

Early season leaf and shoot development are influenced by nutrient reserves (Maillard et al. 2015). Mangroves adopt various ways to conserve and reuse nutrients for survival and growth (Nasrin et al. 2019). Nutrient resorption from senescent leaves is an important techniques for supporting plant growth in saltwater environments, which makes those elements available for other active plant tissue specially the green leaves (Reef et al. 2010; Matesanz et al. 2010). Element resorption is related to the leaf senescence and nutrient conservation, and reusing these nutrients is an important mechanism for tree survival in nutrient-poor environments (Pugnaire and Chapin 1993). At different stages of foliage development, nutrient resorption from leaves is critical for the supply of N, P, and K to the new growth in tree species (Saur et al. 2000; van Heerwaarden et al. 2003; Hu et al. 2023). Before abscission and loss, nutrient uptake and soil fertility cause nutrients to be relocated to younger leaves (Reef et al. 2010). Nutrient levels in soil and plant parts of a forest ecosystem fluctuate with plant growth form, species development capacity, and climate variabilities (Mahmood 2004; Vergutz et al. 2012).

Mangrove soil is generally nutrient-poor and saline. Excessive salt accumulation was eliminated by losing plant parts, particularly older leaves and shading of barks (Tomlinson 1986; Acosta-Motos et al. 2017). Mangrove plants have a high rate of litterfall and are mostly washed by the tidewater (Mahmood et al. 2005), which may result in poor nutrient status in mangrove soil (Mahmood 2004). The Sundarbans is the world's largest contiguous natural mangrove forest and rich in biodiversity. *Heritiera fomes* (Buch. Ham.) and *Excoecaria agallocha* L. are the dominant tree species (Mahmood 2015). The salinity of the Sundarbans' water and soil varies with the seasons and is believed to increase with time. On the other hand, the growth rate of the major tree species of the Sundarbans has been reported to have decreased since 1960 (Siddiqi 2001). The slower growth rate of major tree species may be related to the increase in salinity (Mahmood et al. 2014a, 2021). Salinity may affect the nutrient uptake capacity of mangrove plants (Reef et al. 2010; Mahmood et al. 2014a). The nutrient resorption mechanism in mangroves may be an important adaptation tool to cope with saline and nutrient-poor soil (Saenger 2002). Nutrient resorption from the foliage is influenced by plant species, interspecific competition, and element mobility (Blanco et al. 2009). The variation in nutrient resorption will help understand the nutrient conservation strategy and adaptation at the species level in a stress condition. Finally, nutrient use efficiency controls or influences mangrove growth. This study aimed to evaluate 1) the seasonal variation in nutrients (N, P and K) concentration in soil and mature and senescent leaves of *H. fomes* and *E. agallocha* 2) nutrient*s* (N, P and K) resorption efficiency for *H. fomes* and *E. agallocha.*

Materials and Methods

Study area

The study site was under the Chandpai Forest Range of the Sundarbans mangrove forest of Bangladesh (22°22'06.60" N in latitude and 89°38'42.20" E in longitude) (Fig. 1). The climate is humid subtropical with 18–23°C and 27–31°C of mean temperature during the post-monsoon and pre-monsoon, respectively. The mean annual rainfall is 1980 mm, and 81% of the total rainfall is observed in the monsoon season. The soil is silty clayey and has a pH of about 7.9. Based on the salinity classification of Siddiqi (2001), the study area was situated in the less-saline area of the Sundarbans. The salinity is decreased during the monsoon season (with increased freshwater flow and precipitation), and salinity increases in the post-monsoon and pre-monsoon. The mean annual rainfall of the Sundarbans ranges from 1640–2000 mm, with a humidity range from 70 to 80% (Siddiqi, 2001). In addition, the temperature is 29, 30 and 26 20°C during pre-monsoon, monsoon and post-monsoon, respectively. Consistent monthly temperature and rainfall data were collected from a nearby meteorological station (MET Station, Khulna). The study region contains *Heritiera fomes*, *Excoecaria agallocha*, *Avicenia officinalis*, *Amoora cucullata* and *Avicennia alba* and the site was frequently submerged by tides.

Collection of leaf and soil samples

Three random sample plots (5 x 5 m) for each species were established in the study area to choose one dominant individual of each species from them. Thus, three individuals of each species (*H. fomes* and *E.*

agallocha) were selected and marked for further tasks. Green mature and yellowish senescent leaves of the selected individuals were collected during the pre-monsoon (March-May), monsoon (June-August) and post-monsoon seasons (October-November). Green mature leaves refer to third pairs of green intact leaves, while senescent leaves refer to yellowish ready to abscise when touched or when the branch is lightly shaken. Three soil samples from each plot were collected to get a homogenous sample for a sample plot using an open-face core sampler (5 cm in diameter) up to a depth of 100 cm.

Nutrients in soil and leaves samples

The collected green mature and yellowish senescent leaves were oven-dried separately according to species and collected seasons for 96 hours at 80°C. The oven-dried samples were crushed, sieved (1 mm mesh) and stored for further chemical analysis according to Allen's protocol (1989). Similar to the leaves samples, soil samples were air-dried and processed. The available form of soil N, P and K was extracted according to Allen (1989). Nitrogen and phosphorus concentrations in the sample extract were determined calorimetrically using a UV-visible Recording Spectrophotometer following Baethgen and Alley (1989) and Pote and Daniel (2000), respectively (HITACHI, U 2910, Japan). The potassium in the sample extracts was determined using a flame photometer (PFP7, Jenway LTD, England).

Nutrient resorption efficiency

Nutrient resorption was calculated according to Ricardo (1992) and Wang et al. (2003).

NRE (%) = {(Ngr-Nsen)/Ngr}*100

Where,

NRE = Nutrient resorption efficiency

Ngr = Nutrient concentration (mg/g) measured from the green leaves

Nsen = concentration (mg/g) measured from senescence leaves senescence

Statistical analysis

The nutrients (N, P and K) concentration in soil samples, mature and senescent leaves of the studied species were compared among the seasons using ANOVA followed by the Duncan Multiple Range Test (DMRT, $p < 0.05$) and unpaired ‘t’ test.

Results

Foliar nutrient concentrations

Comparatively ($p < 0.05$), a higher concentration of N (12.64 ± 1.05 mg/g), P (0.42 ± 0.18 mg/g) and K (10.79 ± 0.14) was observed in green mature leaves of *H. fomes* in monsoon. Their concentration varied significantly ($p < 0.05$) with the seasons except N in pre- and post-monsoon. The senescent leave of *H.*

fomes contained higher N (10.84 ± 0.93 mg/g) and P (0.27 ± 0.02 mg/g) during the monsoon season, while higher K (5.51 ± 0.08 mg/g) in the pre-monsoon season, but P and K concentrations did not vary significantly ($p > 0.05$) in per-monsoon and post-monsoon season. Similar ($P > 0.05$) concentration (8.33 ± 1.07 to 9.76 ± 1.40 mg/g) of N was detected for the green mature leaves of *E. agallocha* throughout the seasons. In contrast, higher contents of P and K were detected in the monsoon season. The senescent leaves of *E. agallocha* showed a higher concentration of N (6.41 ± 0.45 mg/g) in the monsoon and showed significant ($p < 0.05$) variation with seasons (Table 1).

Table 1: Seasonal variation in nutrient concentration (mg/g) in green (GL) and senescent (SL) leaves of *Heritiera fomes* and *Excoecaria agallocha* of the Sundarbans.

Season	Species	N (mg/g)±SD		P (mg/g)±SD		K (mg/g)±SD	
		GL	SL	GL	SL	GL	SL
Pre-Monsoon	*H. fomes*	8.50 ± 0.76	2.00 ± 0.58	0.30 ± 0.00	0.17 ± 0.03	8.46 ± 0.09	5.51 ± 0.08
	E. agallocha	8.33 ± 1.67	3.00 ± 0.58	0.31 ± 0.00	0.23 ± 0.03	10.89 ± 0.09	7.52 ± 0.03
Monsoon	*H. fomes*	12.64 ± 1.05	10.84 ± 0.93	0.42 ± 0.18	0.27 ± 0.02	10.79 ± 0.14	3.45 ± 0.14
	E. agallocha	9.76 ± 1.40	6.41 ± 0.45	0.38 ± 0.01	0.21 ± 0.01	12.02 ± 0.07	4.33 ± 0.03
Post-Monsoon	*H. fomes*	8.67 ± 0.67	4.00 ± 0.58	0.33 ± 0.00	0.17 ± 0.03	7.05 ± 0.11	5.07 ± 0.05
	E. agallocha	9.00 ± 0.00	4.67 ± 0.67	0.32 ± 0.00	0.23 ± 0.03	10.62 ± 0.06	5.11 ± 0.18

Nutrients (N, P and K) in soil

The highest concentration of nitrogen (0.075 mg/g), phosphorous (0.047 mg/g) and potassium (0.10 mg/g) concentration was observed during post-monsoon season, while it was the lowest for N (0.067 mg/g) and K (0.085 mg/g) during pre-monsoon and P (0.031 mg/g) in monsoon season. No significant ($p > 0.05$) seasonal variation was observed for the N concentration in the soil. A similar ($p > 0.05$) concentration of P and K was detected between monsoon and post-monsoon seasons (Fig. 2).

Nutrient resorption efficiency

Both the species showed the highest nitrogen resorption efficiency in the pre-monsoon (76.94% and 63.33% for *H. fomes and E. agallocha*, respectively) followed by post-monsoon and monsoon season. Regarding phosphorous resorption efficiency, *H. fomes* showed a higher resorption efficiency in post-monsoon time (44.44%), while the highest (53.33%) was for *E. agallocha* in the pre-monsoon season. An opposite relation was observed for potassium resorption efficiency. The studied species *H. fomes* and *E. agallocha* showed the highest resorption efficiency in the monsoon season, 68.02% and 63.96%, respectively. Collectively, both species showed significant ($p < 0.05$) differences in nutrient resorption efficiency among the seasons except the phosphorous for *H. fomes* (Fig. 3).

Discussion

Mangrove soils have a deficient nutrient concentration (Lovelock et al. 2005), and the concentration varies among mangroves of the world and the dominant types (Feller et al. 2003; Hossain and Nuruddin, 2016). The nutrient availability in mangroves is controlled by different factors such as salinity, soil type, tidal inundation, elevation in the tidal frame, etc. (Reef et al. 2010). In comprising of other studies (e.g. Mahmood 2004 and Hossain and Nuruddin 2016), the present study site contained relatively lower N and higher P in soil. The variation in soil nutrients among the mangroves and seasons is highly related to the natural process of weathering, environmental conditions, and nutrient flux in the mangroves (Feller et al. 2003; Mahmood 2004). In monsoon time, nutrients become more available in the soil because of the influence of the nutrient input and output sources (Alongi et al. 1992; Mahmood 2004) and lower soil salinity due to higher flow of freshwater flow (Mahmood 2004). Therefore, plants do not need more nutrients to reabsorb with more nutrients in the soil (Feller et al. 1999). After the onset of the monsoon period, the leaching and decomposition afterward help to build up the soil nutrient reserves (Mahmood et al. 2014b). Soil nutrient status during the growth phases supports our findings, as nutrient concentrations remain high during the post-monsoon season, indicating that nutrients have been taken up by the plants, resulting in nutrient deficiency. Drought and increased evaporation (Naskar and Bakshi 1987) combined with reduces flow of freshwater (Siddiqi 2001) influence the saline intrusion (Basar 2012). This situation results in increased soil salinity during the pre-monsoon season, which reduces the availability of nutrients (Saenger 2002; Singh et al. 2005; Alam et al. 2018).

The efficiency of nutrient uptake and utilization varies between species and stages of life form due to nutrient availability, leaf longevity, leaf type, and the nature of nutrient pools (Lovelock and Feller 2003; Mahmood 2004). This could be the reason for observing variation in leaf nutrient composition and nutrient *resorption efficiency* among the studied species and seasons of the present study. Generally, plants resorb about 50% of N and 52% of P (Aerts and Chapin 2000). Our current study found resorption efficiency of N (76.94–14.15% and 63.33–31.76%) and P (44.44–34.33% and 53.33–16.24%) for *H. fomes* and *E. agallocha*, respectively. McKee and Faulkner (2000) claimed that mangroves resorb between 20% and 60% of N and 30–70% of P, that depends on the nutrients availability in soil. Wang et al. (2003) also found comparatively higher resorption efficiency (72.22 and 57.53%, respectively, for N and P) for *Kandellia candel*. It indicates that many N and P were retranslocated out of the senescing leaves for reuse, though mangrove plants exchange leaves frequently to eliminate excess salt accumulation in their bodies.

In the case of P resorption efficiency, the studied species were comparatively lower efficiency than the study of Aerts and Chapin (2000). Comparatively higher P concentration in the soil of the study area with similar concentration throughout the seasons may influence the lower resorption efficiency for *H. fomes* and *E. agallocha*. The resorption efficiency in K may be overestimated, as it is a readily leachable element. Alam et al. (2018) and Noor et al. (2015) observed a higher resorption efficiency of K for *Avicennia officinalis* and *Rhizophora* spp. Higher K resorption efficiency was observed during the monsoon than in other seasons. The readily leaching nature of K from the leaf litter (Mahmood et al. 2014b) may influence the higher resorption during the monsoon season. Resorption has been considered the most important nutrient conservation strategy for plants in nutrient-poor or stressed sites or environments (Hörtensteiner and Feller 2002). However, environmental factors have resulted in similar adaptations among mangrove species in various habitats, such as water relations (Macinnis-Ng et al. 2004) and architecture, which may explain why the species have varying levels of nutrient resorption efficiency. Additionally, the capacity for salt tolerance varies among the studied species. The different nutrient resorption efficiency between species may be due to species convergence, which is unique to each species.

Conclusion

Heritiera fomes and *E. agallocha* are the two important species of the Sundarbans. The variation of the resorption efficiency for the species depends on the seasons, species, nutrient concentration in soil and specific nature of the nutrients. *Heritiera fomes* was more efficient in N and K resorption, while *E. agallocha* was more efficient in P resorption during the pre-monsoon. The nutrient resorption efficiency of the studied species indicated the adaptation mechanism towards harsh environments, especially nutrient-poor conditions.

Declarations

Acknowledgement

Authors acknowledge the Nutrient Dynamics Laboratory, Khulna University and Bangladesh Forest Department for their laboratory and logistic supports.

Conflict of interest

No conflict of interest

References

1. Acosta-Motos JR, Ortuño MF, Bernal-Vicente A, Diaz-Vivancos P, Sanchez-Blanco MJ, Hernandez JA (2017) Plant Responses to Salt Stress: Adaptive Mechanisms. *Agronomy 7:* 18. https://doi.org/10.3390/agronomy7010018.
2. Aerts R, Chapin III FS (2000) The mineral nutrition of wild plants revisited. A re-evaluation of processes and patterns. Adv Ecol Res 30: 1-67. https://doi:10.1016/S0065-2504(08)60016-1.
3. Alam MR, Mahmood H, Biswas T, Rahman MM (2019) Physiologically adaptive plasticity in nutrient resorption efficiency of *Avicennia officinalis* L. under fluctuating saline environments in the

Sundarbans of Bangladesh. Hydrobiologia 828 (1): 41-56. https://doi: 10.1007/s10750-018-3795-5.

4. Alam MR, Mahmood H, Khushi MLR, Rahman MM (2018) Adaptive phenotypic plasticity of *Avicennia officinalis* L. across the salinity gradient in the Sundarbans of Bangladesh. Hydrobiologia. 808(1): 63-174. https://doi:10.1007/s10750-017-3420-z.
5. Allen SE (1989) Chemical analysis of ecological materials. Blackwell Scientific Publications, Oxford.
6. Alongi DM, Boto KG, Robertson AI (1992) Nitrogen and phosphorus cycles. in: Robertson, A.I., Alongi, D.M. (Eds.). Tropical Mangrove Ecosystem, Coastal and Estuarine Studies 41, Washington, DC. Amirican Geographical Union, pp 251-292
7. Baethgen WE, Alley MM (1989) A manual colorimetric procedure for measuring ammonium nitrogen in soil and plant Kjeldahl digests. Commun. Soil Sci Plant Anal 20(9 & 10): 961-969.
8. Basar A (2012) Water security in coastal region of Bangladesh: would desalination be a solution to the vulnerable communities of the Sundarbans? Bangladesh e-J Socio, 9 (2): 31.
9. Blanco JA, Imbert JB, Castillo FJ (2009) Thinning affects nutrient resorption and nutrient-use efficiency in two *Pinus sylvestris* stands in the Pyrenees. Ecol App 19(3): 682-698.
10. Feller IC, Whigham DF, McKee KL, Lovelock CE (2003) Nitrogen limitation of growth and nutrient dynamics in a disturbed mangrove forest, Indian River Lagoon, Florida. Oecologia 134(3): 405-414
11. Feller IC, Whigham DF, O'Neill JP, McKee KL (1999) Effects of nutrient enrichment on within-stand cycling in a mangrove forest. Ecol 80(7): 2193-2205
12. Hörtensteiner S, Feller U (2002) Nitrogen metabolism and remobilization during senescence. J Exp Bot 53(370): 927-937
13. Hossain MD, Nuruddin AA (2016) Soil and mangrove: A Review. J Environ Sci Technol 9: 198-207.
14. Hu R, Liu T, Zhang Y, Zheng R, Guo J (2023) Leaf nutrient resorption of two life-form tree species in urban gardens and their response to soil nutrient availability. PeerJ 19: 11:e15738. https://doi: 10.7717/peerj.15738. PMID: 37483974; PMCID: PMC10362843.
15. Lovelock CE, Feller IC (2003) Photosynthetic performance and resource utilization of two mangrove species coexisting in a hypersaline scrub forest. Oecologia 134(4): 455-462
16. Lovelock CE, Feller IC, McKee KL, Thompson RC (2005) Variation in mangrove forest structure and sediment characteristics in Bocas del Toro, Panama. Caribbean J Sci 41(3): 456-464.
17. Macinnis-Ng C, McClenahan K, Eamus D (2004) Convergence in hydraulic architecture, water relations and primary productivity amongst habitats and across seasons in Sydney. Funct Plant Biol 31(5): 429-439.
18. Mahmood H (2004) Biomass, Litter Production and Selected Nutrients in *Bruguiera parviflora* (Roxb.) Wight & Arn. Dominated Mangrove Forest Ecosystem at Kuala Selangor, Malaysia. PhD thesis, Universiti Putra Malaysia.
19. Mahmood H (2015) Handbook of selected plant species of the Sundarbans and the embankment ecosystem, SustainableDevelopment and Biodiversity Conservation in Coastal protection Forests,

Bangladesh, GIZ GmbH, German Federal Ministry for Economic Cooperation and Development (BMZ).

20. Mahmood H, Ahmed M, Islam T, Uddin MZ, Saha C (2021) Paradigm shift in the management of the Sundarbans mangrove forest of Bangladesh: issues and challenges. Trees For People 5: 2021, 100094 https://doi.org/10.1016/j.tfp.2021.100094
21. Mahmood H, Saberi O, Japar Sidik B, Misri K (2005) Litter flux in Kuala Selangor Nature Park mangrove forest, Malaysia. *Indian J For* 28(3): 233-238.
22. Mahmood H, Sanjoy S, Siddique MRH, Hasan NM (2014a) Salinity Stress on Growth, Nutrients and Carbon Distribution in Seedlings Parts of *Heritiera fomes.* Inter J Env Eng 4: 71-77.
23. Mahmood H, Siddique MRH, Abdullah SMR, Saha S, Ghosh DD, Rahman MS, Limon SH (2014b) Nutrient dynamics associated with leaching and microbial decomposition of four abundant mangrove species leaf litter of the Sundarbans, Bangladesh. Wetlands 34 (3): 439-448. https://doi.org/10.1007/s13157-013-05
24. Mahmood H, Saberi O, Japar Sidik B, Misri K (2008) Net primary productivity of *Bruguiera parviflora* (Wight & Arn.) dominated mangrove forest at Kuala Selangor, Malaysia. For Ecol Manag 255: 179-182.
25. Maillard A, Diquélou S, Billard V, Laîné P, Garnica M, Prudent M, Garcia-Mina J-M, Yvin J-C, Ourry A (2015) Leaf mineral nutrient remobilization during leaf senescence and modulation by nutrient deficiency. Front Plant Sci 6: 317. https://doi.org/doi: 10.3389/fpls.2015.00317
26. Matesanz S, Gianoli E, Valladares F (2010) Global change and the evolution of phenotypic plasticity in plants. Ann N Y Acad Sci 1206(1): 35-55.
27. McKee KL, Faulkner PL (2000) Restoration of biogeochemical function in mangrove forests. Restor Ecol 8(3): 247-259.
28. Naskar K, Guha Bakshi DN (1987) Mangrove swamps of the Sundarbans. Naya Prokash.
29. Nasrin S, Mahmood H, Rahman MM (2019) Adaptive responses to salinity: nutrient resorption efficiency of *Sonneratia apetala* (Buch.-Ham.) along the salinity gradient in the Sundarbans of Bangladesh. Wetl Ecol Manag 27(2): 343-351.
30. Nasrin S, Mahmood H, Rahman MM (2021) Salt adaptive divergence of *Sonneratia apetala* (Buch.-Ham.) seedlings along the salinity gradient in the Sundarbans of Bangladesh. Environ Challen 4: 100121. https://doi: 10.1016/j.envc.2021.100121
31. Nasrin S, Mahmood H, Abdullah SMR, Alam MR, Saha S, Siddique MRH (2016) Salinity influence on survival, growth and nutrient distribution in different parts of *Millettia pinnata* (L.) Panigrahi seedlings. Agri For 62 (4): 161-173. http://DOI: 10.17707/Agricult Forest.62.4.19.
32. Noor T, Batool N, Mazhar R, Ilyas N (2015) Effects of siltation, temperature and salinity on mangrove plants. Eur Acad Res 2(11): 14172-14179.
33. Pote DH, Daniel TC (2000) Analyzing for total phosphorus and total dissolved phosphorus in water samples. Methods of Phosphorus Analysis for Soils, Sediments, Residuals, and Water, 94-97.

34. Pugnaire FI, Chapin IIIFS (1993) Controls over nutrient resorption from leaves of evergreen Mediterranean species. Ecol 74(1): 24-129.
35. Reef R, Feller IC, Lovelock CE (2010) Nutrition of mangroves. Tree Physiol 30(9): 148-1160.
36. Ribeiro RDA, Rovai AS, Twilley RR, Casta~neda-Moya E (2019) Spatial variability of mangrove primary productivity in the neotropics. Ecosphere 10(8): e02841. 10.1002/ecs2.284
37. Ricardo S (1992) Nutrient concentration and retranslocation in coastal vegetation and mangroves from the Pacific coast of Costa Rica. Brenesia 37: 33-50.
38. Saenger P (2002) Mangrove ecology, silviculture and conservation. Springer Science & Business Media.
39. Saur E, Nambiar EKS, Fife DN (2000) Foliar nutrient retranslocation in Eucalyptus globulus. Tree Physiol 20(16): 1105-1112.
40. Siddiqi NA (2001) Mangrove Forestry in Bangladesh. Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong.
41. Siddique MRH, Saha S, Salekin S, Mahmood H (2017) Salinity strongly drives the survival, growth, leaf demography, and nutrient partitioning in seedlings of *Xylocarpus granatum* J. König. iForest 10(5): 851.
42. Singh SP, Bargali K, Joshi A, Chaudhry S (2005) Nitrogen resorption in leaves of tree and shrub seedlings in response to increasing soil fertility. Curr Sci 89(2): 389-396.
43. Tomlinson PB (1986) The botany of mangroves. Cambridge University Press, Cambridge.
44. Van Heerwaarden LM, Toet S, Aerts R (2003) Current measures of nutrient resorption efficiency lead to a substantial underestimation of real resorption efficiency: facts and solutions. Oikos 101(3): 664-669.
45. Vergutz L, Manzoni S, Porporato A, Novais RF, Jackson RB (2012) Global resorption efficiencies and concentrations of carbon and nutrients in leaves of terrestrial plants. Ecol Mono 82(2): 205-220.
46. Wang WQ, Wang M, Lin P (2003) Seasonal changes in element contents in mangrove element retranslocation during leaf senescence. Plant Soil 252(2): 187-193.

Figures

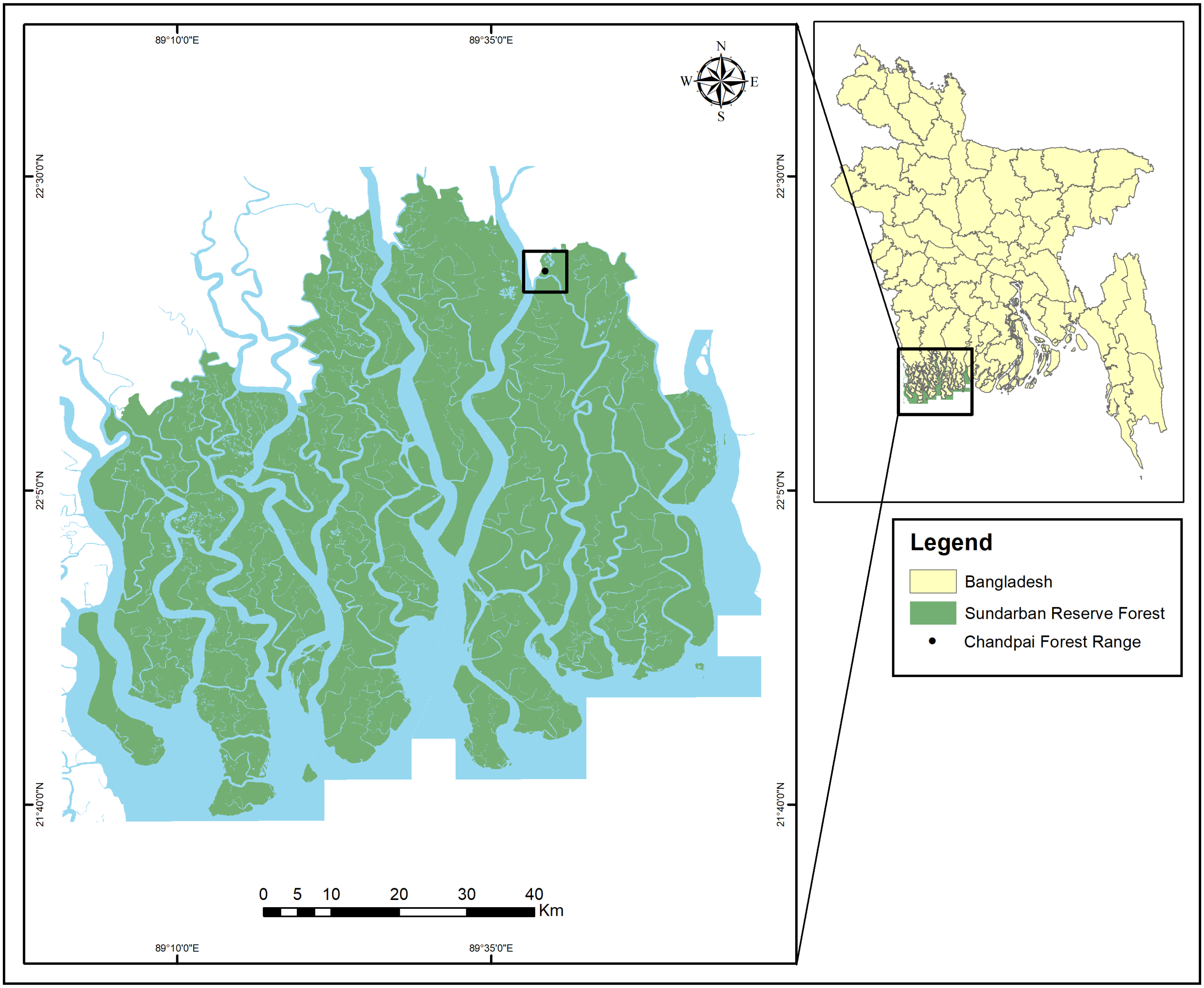

Figure 1

Location map of the study area

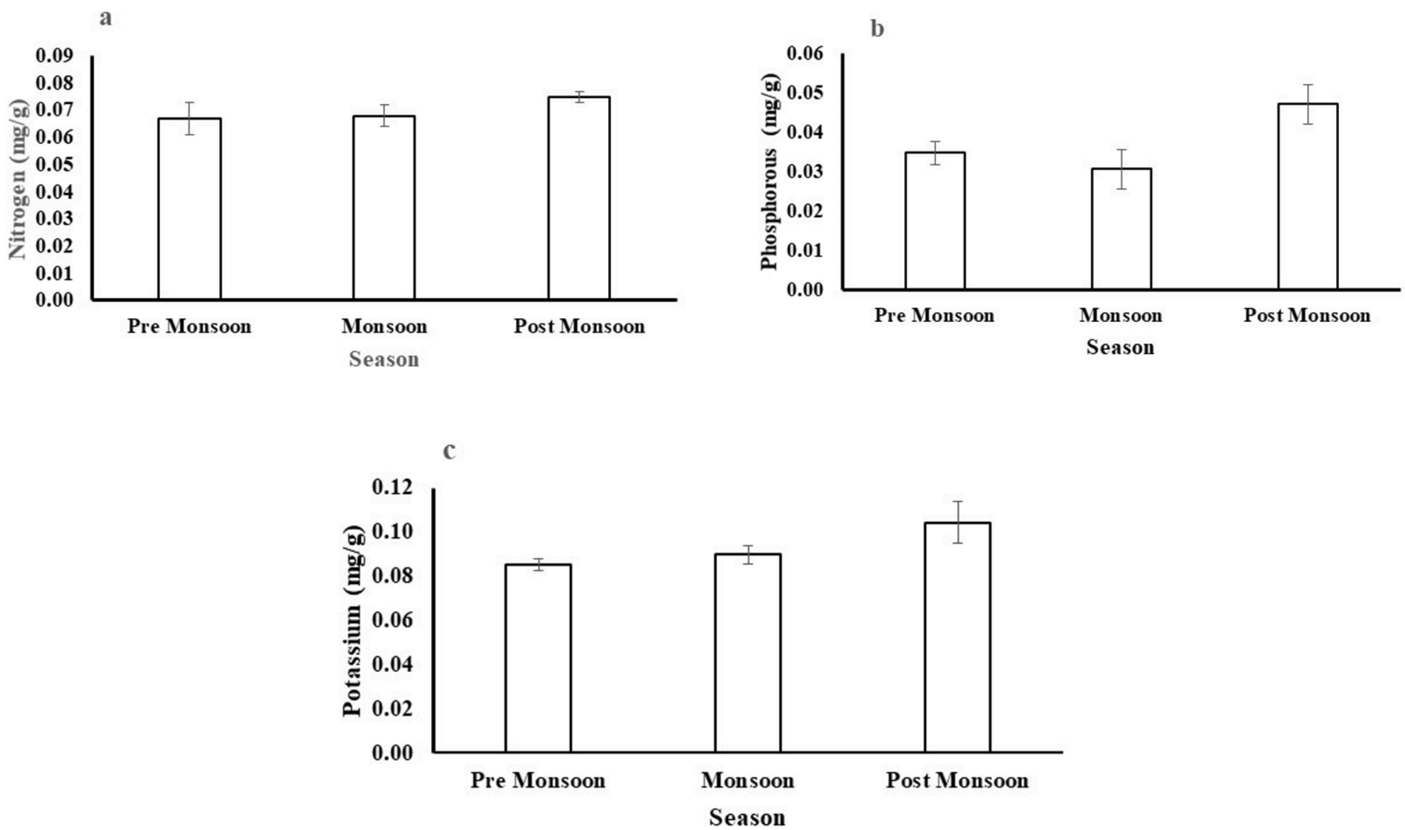

Figure 2

Soil available nutrient status in different seasons of the study site a) Nitrogen, b) Phosphorous, an c) Potassium

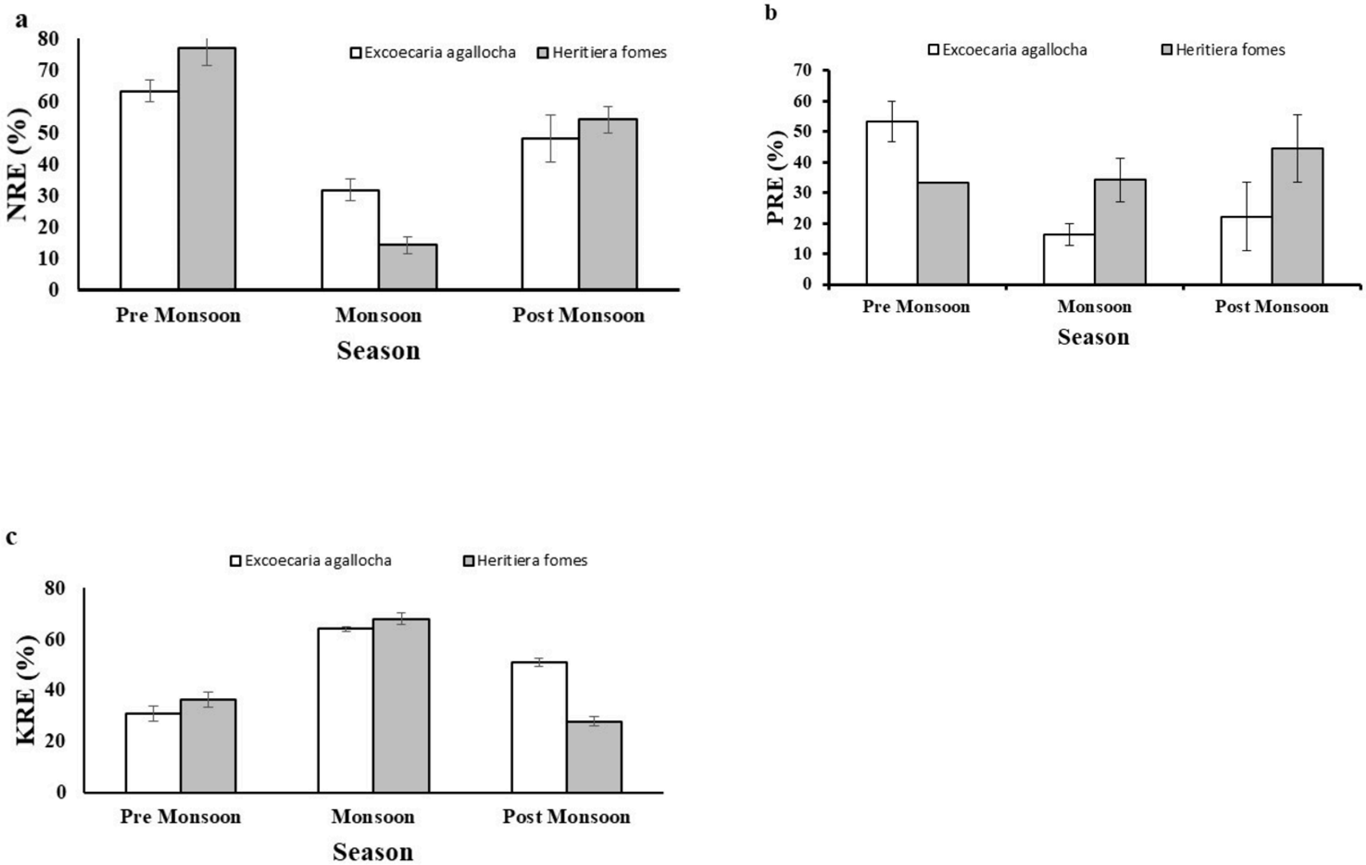

Figure 3

Nutrient re-translocation of *Excoecaria agallocha* and *Heritiera fomes* leaves a) Nitrogen, b) Phosphorous, and c) Potassium