*Effect of N application on its utilization and gaseous exchange in cat tail (*Typha elephantina*) under waterlogged condition*

S. Roy Chowdhury, P. S. Brahmanand, N. Manikandan & S. K. Ambast

Indian Journal of Plant Physiology
An International Journal of Plant Physiology

ISSN 0019-5502
Volume 22
Number 2

Ind J Plant Physiol. (2017) 22:263-266
DOI 10.1007/s40502-017-0295-y

Springer

Ind J Plant Physiol. (April–June 2017) 22(2):263–266
DOI 10.1007/s40502-017-0295-y

SHORT COMMUNICATION

Effect of N application on its utilization and gaseous exchange in cat tail (*Typha elephantina*) under waterlogged condition

S. Roy Chowdhury[1] · P. S. Brahmanand[1] · N. Manikandan[1] · S. K. Ambast[1]

Received: 23 December 2016 / Accepted: 24 May 2017 / Published online: 28 June 2017

Abstract The cat tail (*Typha elephantina*), a non-food commercial crop grows as an emergent hydrophyte in tidal waterlogged areas. Its leaves are used for preparing mats and used as roof top and wall partition. *Typha* sp. has been found to be efficient accumulator of N from sediment under waterlogged condition. The N utilization mainly through nitrate reductase (NR) activity was studied in *Typha* with four levels of N fertilizers i.e. 0, 30 and 60 and 90 kg ha^{-1} applied at three stages of plant growth i.e. basal, 3 and 6 month after planting. In general, there was reduction in NR activity under waterlogged condition in *Typha*. But application of @ 90 kg ha^{-1} maintained high NR activity when it was applied as basal stage. Basal application of N was found better than its application at 3 or 6 month stage of crop growth. The higher leaf NR activity at 60 and 90 kg ha^{-1} N application level suggested better N utilization under waterlogged environment. The photosynthesis rate showed significant increase with higher N application concomitant with greater stomatal conductance ($r = 0.84^{**}$; $n = 12$). There was significant increase in leaf yield when N was applied @ 90 kg ha^{-1} N level as basal dosage as compared to later stage (3 or 6 months) of crop growth. The highest fertilizer use efficiency (kg dry leaf kg^{-1} applied N) was also found at 90 kg N ha^{-1} as compared to 30 or 60 kg ha^{-1} N level, which corroborated superior N fertilizer utilization ability of *Typha* under waterlogged condition.

Keywords Cat tail · Nitrate reductase · Leaf yield · Waterlogged condition

India has 11.6 million ha under water logged condition (Planning Commission 2011) out of which more than 20 percent falls in eastern India. There are several non-food plants with commercial importance whose productivity is unexploited due to want of suitable package of practices (Vantomme et al. 2002; WTCER VISION 2025 2007). For better utilization of otherwise agriculturally non-productive waterlogged area, there are several such plants with economic importance like hogla (cat tails, *Typha* sp.) which is an important crop in eastern India (Ghosh 2002; Puste 2004; Datta et al. 2011). The plant is an emergent hydrophyte. The root system survives under water in marshy soil, whereas the shoot portion, mainly leaves, emerges out from standing water. *Typha* is a fast spreading species in nutrient-rich habitats. It shows high growth rates (Roy Chowdhury et al. 2014), short leaf longevity, high capacity for nutrient uptake and high leaf nutrient concentrations (Miao 2004; Das and Tanaka 2007; Li et al. 2010). Due to high nutrient uptake ability and removal rate (Das and Tanaka 2007), emergent hydrophytes like *Typha* also provide the plant an opportunity as a phytoremedial candidate as online effective interceptor of nutrients acting as deterrent to downstream eutrophication of water bodies. However, nitrogen uptake ability of such hudrophytes is strongly determined by nitrate reductase (NR) activity of the plant. As no scientific report is available on nitrogen metabolism in cat tail, present study reports dynamics of N metabolism in *Typha* vegetation assessed through changes in nitrate reduction in *Typha* leaves under waterlogged condition.

The soil in the experimental field is inceptisol derived from alluvial deposit of Rupnarayan river in Kolaghat in

✉ S. Roy Chowdhury
somnath_rc@yahoo.com

[1] ICAR-Indian Institute of Water Management, P.O. Chandrasekharpur, Near Rail Vihar, Bhubaneswar, Odisha 751 023, India

east Medinipur district. The pH of the soil is acidic ranging between 4.2 and 4.6. The pH of the surface water in experimental field ranged between 6.1 and 6.8 and the electrical conductivity of water was between 0.01 and 0.02 dS m^{-1}. As the experimental field was on the bank of river Rupnarayan, the field was under tidal waterlogged conditions with periodical partial submergence and desubmergence.

The crop was planted in the month of June 2011 in split-plot design with N as main plot and stage of application as sub plot. Three different levels of N fertilizers i.e. 0, 30 and 60 and 90 kg ha^{-1} were applied at three stages of plant growth i.e. basal, 3 and 6 month after planting immediately after recession of tidal water from the field. The periodical observations were taken on leaf nitrate reductase (NR) activity following Jaworski (1971) from 11th month onwards till harvest at 18th month. The number of leaves in 1 m^2 area was measured in a quadrate method following Cottam and Curtis (1956) at the end of 18th month period. The photosynthesis rate was measured with a portable photostnthesis system (CIRAS 2, M/S PP Systems, USA) with flow rate maintained at 200 ml min^{-1} (Roy Chowdhury and Varma 1998). N use efficiency was estimated as per method detailed elsewhere (Brahmananda et al. 2009).

The statistical analyses were done for separation of treatment means to determine the effect of dosage of N application as well as stages of application and interaction between them (Gomez and Gomez 1984). The relationship between net photosynthesis rate and stomatal conductance were also analysed following Gomez and Gomez (1984).

The number of leaves produced per square meter showed significant increase in response to N fertilizer application at all i.e. 30, 60 and 90 kg ha^{-1} levels. It was found maximum at 90 kg ha^{-1} level as compared to that without N or N application at 30 or 60 kg ha^{-1} level (Fig. 1). Similarly when applied as basal dosage, the effect of N fertilizer was found best in comparison to application at either 3 or 6 month after planting (MAP, Fig. 1). The higher dosage of N application consistently produced more number of leaves per unit area both at pre- (11–13 MAP) and post monsoon period (17 MAP, Fig. 1) with marginal decline at 15 MAP stage. The leaf number at 18 MAP was found highest (126.67 leaves m^{-2}) in basal N application treatment (Fig. 1). Hence maximum number of leaves per unit area was obtained when N was applied @ 90 kg ha^{-1} at basal stage of the crop planting.

At 90 kg ha^{-1} N applied as basal, highest nitrate reductase activity of 6.22 μmol NO_2 g^{-1} FW h^{-1} in pre-monsoon period was noted at 11 MAP which declined to 4.98 μmol NO_2 g^{-1} FW h^{-1} at 13 MAP stage under partial submergence. Thereafter nitrate reductase activity was maintained at minimum 5.30–5.82 μmol NO_2 g^{-1} FW h^{-1} for rest of the period till 18 MAP. In general under partial submergence during tide there was a decline in nitrate reductase activity in leaves (μ mol nitrite N produced by per g fresh weight leaf tissue per hour). The submergence induced decrease in nitrate reductase activity was more pronounced during monsoon i.e. 13–16 MAP stage (Fig. 2) due to presence of rain water in the field. However the extent of decline was lesser at higher N level i.e. at 60 or 90 kg ha^{-1} N level irrespective of stage of application. Therefore at 60 or 90 kg ha^{-1} N application, applied either as basal or 30 or 60 days after planting, the plants were able to maintain higher NR activity level in general, compared with no N fertilizer or 30 kg ha^{-1} N (Fig. 2). Higher availability of N fertilizer has been reported to promote uptake of N in both in free floating (*Salvinia cucullata* and *Ipomea aquatica*) as well as in emergent aquatic macrophytes (*Cyperus involucratus* and *Vetiveria zizanioides*), uptake being more with NH_4^+ N in comparison to NO_3^- N (Jampeetong et al. 2012). Highest NR activity was observed

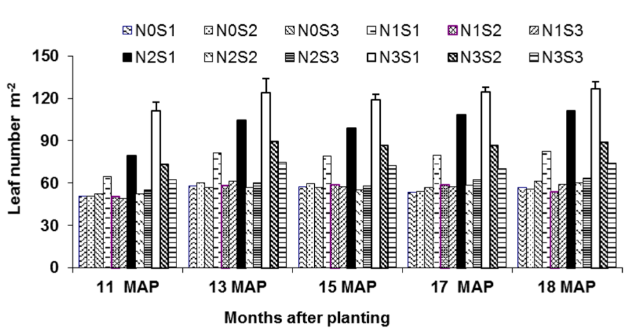

Fig. 1 The number of *Typha* leaves at different stages of crop growth under different levels of N (N0 without fertilizer, N1 30 kg, N2, 60 kg and N3 90 kg ha^{-1} N) fertilizer treatments applied at three stages (S1 basal, S2 30 DAP and S3 60 DAP). *Vertical bar* lsd at $p = 0.05$ for N

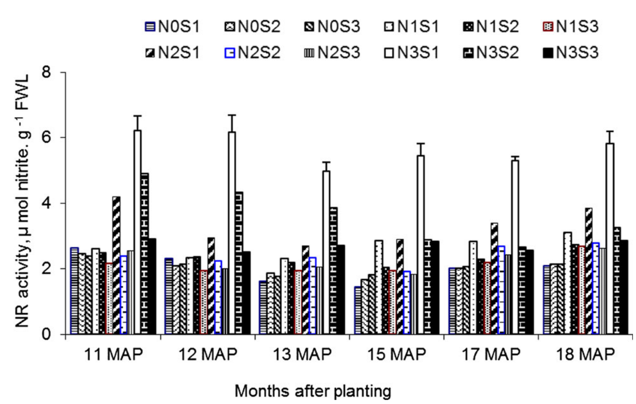

Fig. 2 Changes in nitrate reductase activity (NR activity) in *Typha* leaves at different crop growth stages under different levels of fertilizer treatments. *Vertical bars* are lsd (N) $p = 0.05$

at 90 kg ha^{-1} N level compared to 30 or 60 kg ha^{-1} N level throughout 11th to 18 MAP period. Even though NR activity in partially submerged cat tail plants showed a decline, in this study, the consistently higher NR activity at 90 kg ha^{-1} N was found. It suggested effective N uptake and metabolism in cat tail even in excess water situation during monsoon period (Fig. 2). In post submergence period after monsoon during 17–18 MAP, the NR activity in 60 and 90 kg ha^{-1} basal N treatment was found better than 0 and 30 kg ha^{-1} N, where it did not change. Without N fertilizer NR activity was found lowest (Fig. 2) and increased in post monsoon period at 18 MAP stage. Similarly, leaf NR activity showed increase with increase in leaf N in *Panicum maximum* Jacq. (Lavres et al. 2010) but in strawberry external NO_3^- concentration showed no effect on NR activity of leaves or roots. The average leaf nitrate reductase activity was 360 nmol NO_2 g^{-1} FW h^{-1} compared to 115 nmol NO_2 g^{-1} FW h^{-1} in roots. Therefore inability of strawberry to increase growth and fruit yield in response to increasing NO_3^- N concentrations was mainly due to limitations in NO_3^- reduction and/or assimilation in both roots and leaves (Darnell and Stutte 2001). In this experiment however during post submergence period, NR activity at higher N level were maintained better than without N fertilizer or 30 kg ha^{-1} N fertilizer. The removal of shoots (leaves) from standing *Typha* vegetation in summer could remove up to 29 g m^{-2} N from sediment compared to 13.9 g m^{-2} in winter (Das and Tanaka 2007). Many species of aquatic macrophytes prefers NH_4^+ N than NO_3^- N as a N-source, possibly because of the lower energy needed for its uptake and assimilation, and because of the prevalence of NH_4^+ N in water-saturated anoxic soils (Jampeetong and Brix 2009; Konnerup and Brix 2010).

At premonsoon stage 12 MAP, the net photosynthesis rate (P_n) at 90 kg basal N level was highest compared to at 60 or 30 kg ha^{-1} applied N level (Fig. 3) and was significantly higher than without N fertilizer level. Both fertilizer dosage and stage of application showed significant effect on net photosynthesis rate (at 5% level). However the interaction effect between stage of application and N level was not significant. The higher rate of application of N fertilizer at 60 or 90 kg ha $^{-1}$ significantly improved photosynthesis rate in *Typha*, more so when applied as basal dosage. The stomatal conductance (g_s) also showed a similar trend with p_n ($r = 0.84^{**}$; $n = 12$). The stomatal conductance was greater at 60 and 90 kg ha^{-1} N level in comparison to 30 kg ha^{-1} N level or treatment without N fertilizer (Fig. 3). The increased availability of soil N enhanced net photosynthesis rate in tree species *Robinia pseudoacacia* along with increase of stomatal conductance (Liu et al. 2013). In rice also higher N level significantly increased steady state photosynthesis and stomatal conductance by improving rapid response of photosynthesis under varying irradiance level (Sun et al. 2016). In our study, significant increase of net photosynthesis in association with higher stomatal conductance under higher dosage of applied N suggested non stomatal boost in photosynthesis efficiency leading to higher leaf and biomass productivity in *Typha* under non limiting water supply (waterlogged) condition.

Nitrogen use efficiency (NUE)

The increase in supply of nitrogen from 30 to 90 kg ha^{-1} resulted in enhancement in nitrogen use efficiency (agronomic efficiency) considerably (Fig. 4). The higher growth rate in terms of leaf yield per unit area per unit time at higher nitrogen levels might have contributed for the significant increase in NUE. The result suggested that there is scope for investigation enhancing nitrogen application rate beyond 90 kg ha^{-1} in *Typha* sp. to obtain higher leaf yield in *Typha*.

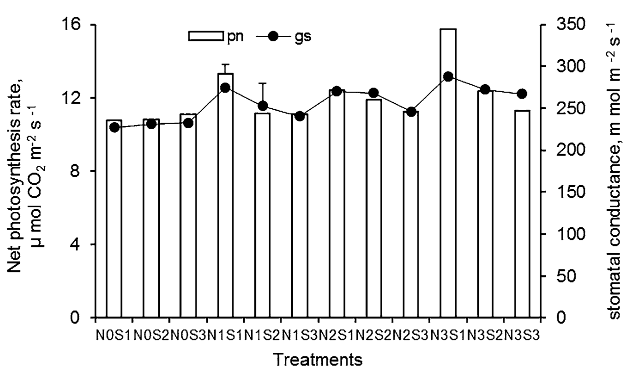

Fig. 3 Changes in stomatal conductance (g_s) and net photosynthesis rate (p_n) in *Typha* leaves at 12 MAP under different levels of fertilizer treatments. *Vertical bars* are lsd (N) $p = 0.05$

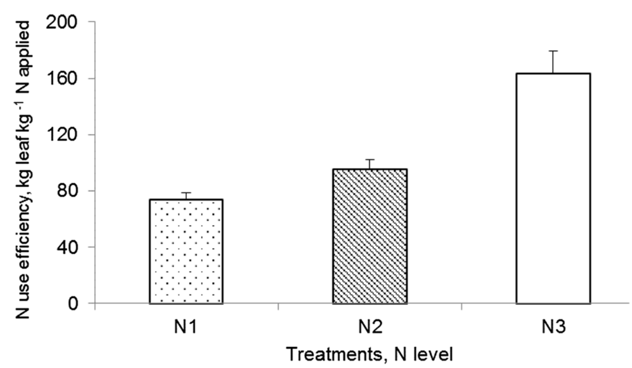

Fig. 4 Nitrogen use efficiency (kg dry leaf yield kg^{-1} N applied) of *Typha* sp. Under different levels of N fertilizer treatments viz. N1 30 kg, N2 60 kg and N390 kg ha^{-1} applied N fertilizer. *Vertical bars* are ±SE of treatments means

References

Brahmananda, P. S., Ghosh, S., Chandra, D., Singhandhupe, R. B., Roy Chowdhury, S., Reddy, G. P., et al. (2009). Studies on performance of rice as influenced by drainage in eastern India. *Archives of Agronomy and Soil Science, 55,* 295–300.

Commission, Planning. (2011). *Mid-term appraisal of eleventh five year plan 2007–2012* (p. 500p). New Delhi: Oxford University Press.

Cottam, G., & Curtis, J. T. (1956). Use of distance measures in phytosociological sampling. *Ecology, 37,* 451–460.

Darnell, R. L., & Stutte, G. W. (2001). Nitrate concentration effects on NO_3-N uptake and reduction, growth, and fruit yield in strawberry. *Journal of the American Society for Horticultural Science, 126,* 560–563.

Das, S., & Tanaka, N. (2007). Estimating nitrogen budgets of *Typha angustifolia* by considering the regrowth shoot productivity and nitrogen content after harvesting aerial organs in different growing seasons. *Landscape and Ecological Engineering, 3,* 99–108.

Datta, D., Chattopadhyay, R. N., & Deb, S. (2011). Prospective livelihood opportunities from the mangroves of the Sunderbans, India. *Research Journal of Environmental Sciences, 5*, 536–543. doi:10.3923/rjes.2011.536.543. Accessed 26 August 2015.

Ghosh, S. K. (2002). Wetland ecosystem. In *West Bengal state biodiversity strategy and action plan: Prepared under the national biodiversity strategic action plan (NBSAP)*. The Department of Environment, Government of West Bengal and Ramkrishna Mission-Narendrapur, West Bengal, India, pp. 86–105. Executed by Ministry of Environment and Forest, Government of India, Technical implementation by Kalpavriksh and Administrative Coordination by Biotech Consortium, India Ltd., Funded by Global Environmental facility through UNDP.

Gomez, K., & Gomez, A. A. (1984). *Statistical procedures for agricultural research* (p. 679). New York: Wiley.

Jampeetong, A., & Brix, H. (2009). Nitrogen nutrition of *Salvinia natans* effect of inorganic nitrogen form on growth, morphology, nitrate reductase activity and uptake kinetics of ammonium and nitrate. *Aquatic Botany, 90,* 67–73.

Jampeetong, A., Brix, H. & Kantawanichkul, S. (2012). Effects of inorganic nitrogen forms on growth, morphology, nitrogen uptake capacity and nutrient allocation of four tropical aquatic macrophytes, *Salvinia culcullata*, *Ipomoea aquatica*, *Cyperus involucratus* and *Vetiveria zizaniodes*. *Aquatic Botany*, *97*, 10–16.

Jaworski, E. G. (1971). Nitrate reductase assay in intact plant tissues. *Biochemical and Biophysical Research Communications, 43,* 1274–1279.

Konnerup, D., & Brix, H. (2010). Nitrogen nutrition of *Canna indica*: Effects of ammonium versus nitrate on growth, biomass allocation, photosynthesis, nitrate reductase activity and N uptake rates. *Aquatic Botany, 92,* 142–148.

Lavres, J., Jr., Monteiro, F. A., & Santos, J. G., Jr. (2010). Nitrate reductase activity and spad readings in leaf tissues of guinea grass submitted to nitrogen and potassium rates. *Revista Brasileira de Ciências Agrárias*. doi:10.1590/S0100-06832010000300022.

Li, S. W., Lissner, J., Mendelssohn, I. A., Brix, H., Lorenzen, B., McKee, K. L., et al. (2010). Nutrient and growth responses of cat tail (*Typha domingensis*) to redox intensity and phosphate availability. *Annals of Botany, 105,* 175–184.

Liu, X., Fan, Y., Long, J., Wei, R., Kjelgren, R., Gong, C., et al. (2013). Effects of soil water and nitrogen availability on photosynthesis and water use efficiency of *Robinia pseudoacacia* seedlings. *Journal of Environmental Sciences (China), 25,* 585–595.

Miao, S. (2004). Rhizome growth and nutrient resorption: Mechanisms underlying the replacement of two clonal species in Florida Everglades. *Aquatic Botany, 78,* 55–66.

Puste, A. M. (2004). *Agronomic management of wetland crops*. Ludhiana: Kalyani Publishers. ISBN: 81-272-1334-9.

Roy Chowdhury, S., Brahmanand, P. S., & Kumar, A. (2014). Production physiology of cat tail (*Typha* sp.) and leaf quality at different N level under waterlogged condition. In *Abstract proceedings in national conference of plant physiology on "Frontiers of Plant Physiology Research; Food security and environmental challanges"*. NCPP-2014, organized by ISPP, New Delhi, OUAT, Bhubaneswar, 23th–25th November, 2014.

Roy Chowdhury, S., & Varma, S. P. (1998). Diurnal changes in photosynthetic behavior in sweet potato under different irrigation regimes. *Indian Journal of Plant Physiology, 2,* 86–88.

Sun, J., Ye, M., Peng, S., & Li, Y. (2016). Nitrogen can improve the rapid response of photosynthesis to changing irradiance in rice (*Oryza sativa* L.) plants. *Nature*. doi:10.1038/srep31305. Accessed 28 November 2016.

Vantomme, P., Markkula, A., & Leslie, R. N. (2002). *Non-wood forest products of 15 countries of tropical Asia: An overview*. Information and analysis for sustainable forest management: Linking national and international efforts in South and Southeast Asia. EC-FAO Partnership Programme (2000–2002) Bankok, Thailand.

WTCER. (2007). *Perspective plan. Vision 2025*. Bhubaneswar: Water Technology Center for Eastern Region, ICAR.