Extended abstract No. 105

THE EFFECT OF USING DIFFERENT QUALITY AND QUANTITY OF CARBON COMPONENT ON THE ACID PHOSPHATASE ENZYME ACTIVITY IN PEAT

Mohd F. A. Ramli, David Johnson
Institute of Biological and Environmental Sciences, (BIS),
University of Aberdeen, AB24 2TZ, UK.
e-mail: r03mfa8@abdn.ac.uk.

SUMMARY

We know little about P turnover in peatlands particularly how the phosphatase enzyme activity (PME) by microorganisms could be affected by supplying exudates with different C quality and quantity. We describe an experiment using a synthetic model root exudates with different quality/quantity and C/N ratio using glucose, citric acid and arginine. The results revealed that under aerobic conditions PME was higher and significantly different (P<0.05) from anaerobic conditions. Arginine accelerated more the activity phosphatase enzyme than citric acid and glucose. This result suggests that N-rich amino acids may be a main root exudates component that stimulates the production of phosphatase enzyme.

KEYWORDS: peatlands; microbial activity; phosphatase enzyme; quality; quantity

INTRODUCTION

In ombrotrophic peat systems the water-level is close to the peat surface and sometimes above the surface throughout the year. This creates sub-oxic conditions and depresses microbial activity which may have important effects on P-cycling. The microbial activity is stimulated directly or indirectly by photosynthetically derived rhizosphere carbon (mainly found as root exudates). Even though plants can supply C sources to rhizosphere microbe, they also could affect the microbe on producing phosphatase enzyme. The situation becomes complicated by the fact that plants also produce phosphatase enzyme in their root exudates compound. Many studies have also shown that a large proportion of phosphatase may derive from plant root (Asmar, 1997) and plants also known to differ in the amounts of the phosphatase that they produce (Johnson et al., 1999; Phoenix et al., 2004). For that reason, we create synthetic root exudates that contains three main soil microbial C sources which are glucose, organic acid and amino acid in different quality, quantity and C:N ratio. Moreover, only a few studies aimed at directly involvement of exudates in soil microbial activity (Baudoin et al., 2003).

The hypothesis tested here is that the addition of different quality and quantity of carbon (artificial root exudates) will result in changes in the performance of

phosphatase enzyme activity due to a different of O_2 availability. These changes will have relevance to P-cycling in peat systems and therefore plant productivity.

MATERIALS AND METHODS

Peat bulk surface soil (0-20cm) from Red Moss National Nature Reserve, Aberdeenshire (57.23ºN, -2.13ºW) was used in the experiments. The collected peat, then air dried about 70% water holding capacity (WHC). The peat was ground to pass a 2 mm sieve and used immediately or after storage at 5ºC for maximum of 1 month.

10 treatments (Table 1) with control treatment (dd H_2O) were used to mimic root exudates (simple sugar (glucose), organic acid (citric acid) and amino acid (arginine)) of different quality and quantity. To reduce the acidic effect from citric acid to the soil microbial activity, we prepared the mixture of citric acid and citrate in the ratio of 1:10. After 48 hours incubation, soil samples were removed from core area for phosphatase enzyme activity determination.

Table 1: Treatment for quality and quantity of carbon (synthetic model root exudates).

Treatment	Substrate	C concentration (mM)
Quality of C	Glucose	204
	Citric acid	204
	Arginine	204
Quantity of C	Glucose, Citric acid & Arginine	204
	Glucose, Citric acid & Arginine	20.4
	Glucose, Citric acid & Arginine	2.04
C/N ratio	Glucose & Citric acid	204 (C without N)
	Glucose, Citric acid & Arginine	204 (10:1)
	Glucose, Citric acid & Arginine	204 (20:1)
	Glucose, Citric acid & Arginine	204 (40:1)

RESULTS

After the addition of various C concentration (quantity) and types/C:N ratio (quality), phosphatase enzyme activity of soil microbial depended strongly on oxygen availability and ranged from 41.1 to 62.9 nmol pNP g^{-1} s^{-1} for quality treatments, 41.1 to 49.9 nmol pNP g^{-1} s^{-1} for quantity treatments and 41.1 to 59.9 nmol pNP g^{-1} s^{-1} for C:N ratio treatments (Fig. 1). The presence of O_2 encouraged significantly the production of phosphatase enzyme eventhough we used different quality (P<0.001), quantity (P=0.006) and C:N ratio (P<0.001) of carbon components. Fig. 1 presents data on the phosphatase enzyme activity that stimulated by free living microorganisms and used various components of artificial root exudates as additional C sources. These mimic root exudates components consist glucose, citric acid and arginine with different quality, quantity and C:N ratio. The addition of glucose and citric acid (Fig. 1(a)) did not encouraged the microbial activity on producing phosphatase enzyme and they not significantly (P<0.05) different with the control

treatment. Addition of arginine (204mM C) elicited a significantly (P<0.05) higher enzyme activity compared to glucose. Arginine addition also showed the strongest phosphatase enzyme activity than other C quality treatments with 63 nmol pNP g^{-1} s^{-1} in aerobic condition and 56 nmol pNP g^{-1} s^{-1} without O_2 treated (anaerobic). The production of phosphatase enzyme did not response to the quantity treatment (Fig. 1(b)) eventhough a range of C components from 2.04mM to 204mM C added into the soil. Phosphatase enzyme activities were ranged from 41.1 to 60 nmol pNP g^{-1} s^{-1} (Fig. 1(c)) after the addition of glucose, citric acid and arginine with different C:N ratio but in the same C concentration with 204mM C. As shown in Fig. 1 (c), phosphatase activity was higher in the treatment with high N content; 10:1 ratio compared to treatments with high C:N ratio; 40:1 (low N) and these differed significantly (P<0.05).

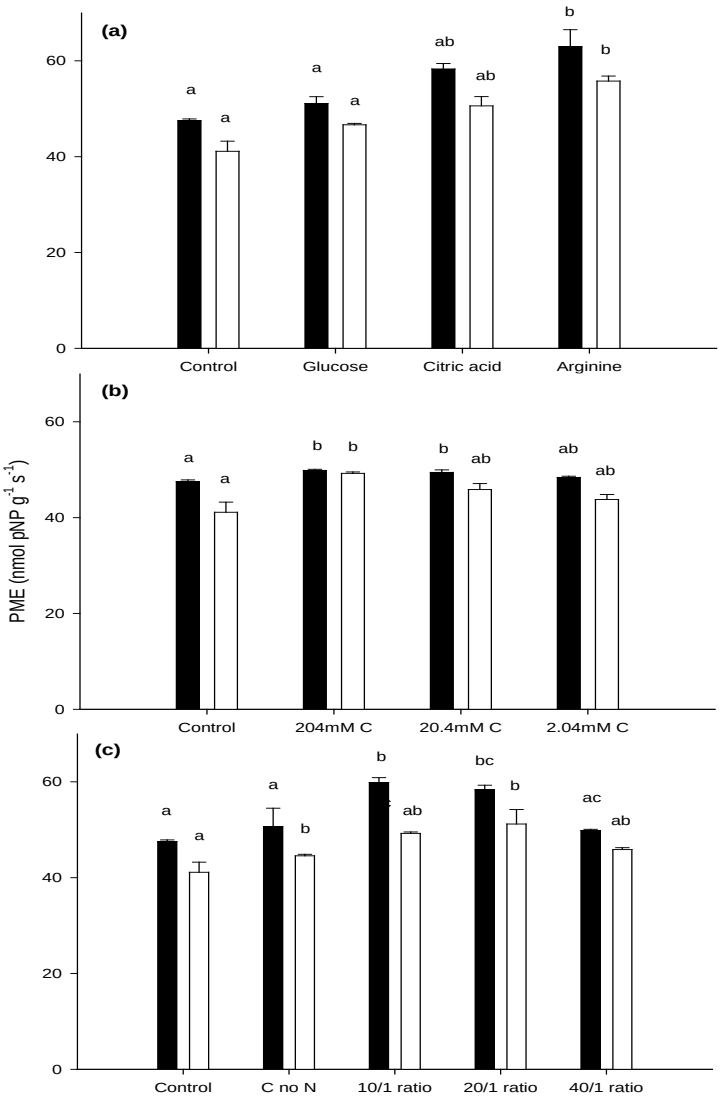

Fig. 1. PME activity (nmol pNP g^{-1} s^{-1}) from soil microorganisms activity with different C quality and quantity treatment. Bars sharing a letter are not significantly different (P>0.05). Aerobic (black bar) and anaerobic (white bar) treatments were differentiate separately.

DISCUSSION

In this study the phosphatase enzyme activity has been observed under aerobic and anaerobic condition with the addition of different quality and quantity of C component. The evidence comes from previous work demonstrating significant increases of microbial activity on degrading hydrocarbon with the presence of O_2 (Gallizia et al., 2004). We confirmed that the aeration factor gave a positive responsive to the phosphatase enzyme activity for all treatments. The findings clearly support our hypothesis.

Total maximum concentration of C added in this study was 2448 µg C g^{-1} larger than general C concentration in root exudates in soil. For example, about 100 µg C g^{-1} soil was released by oat growing tip in 24 h (Trofymow et al., 1987). But according to the author experiments, the enzyme activity not responded to carbon concentration (quantity treatment) where no significance different (P>0.05) between 2448, 244 and 24.4 µg C g^{-1} treatments. As mentioned by Baudoin et al. (2003), rhizosphere root carbon input was varying depending on the environmental and biological factors. These factors could be affecting the high C concentration needed during this study. In addition, 500-1500 µg C g^{-1} have been measured by Cheng et al. (1996) in rhizosphere, even though the daily input could have been less than this.

Artificial root exudates with different quality C component (type and C:N ratio) have been found significantly increased the microbial activity and density (Baudoin et al., 2003). In the present study addition of arginine increased the rate of phosphatase enzyme activity and significantly higher than glucose and citric acid. The addition of organic acid seem not encouraged the microbial activity on producing phosphatase enzyme. The same finding also found by Teng et al. (2010) but they used succinic acid as an organic acid source. Arginine, N-rich amino acid can be directly and easier degraded by soil microorganisms as a C and energy source compared to glucose and organic acid. Moreover nitrogen is an importance element for cellular growth and as an alternative electron acceptor (Teng et al., 2010). The effectiveness of phosphatase enzyme activity in carbon quality treatments adjusted with different C:N ratio revealed that 10:1 was tremendously superior than C:N 20:1 and C:N 40:1. Our findings are agreed with previous reports by Thomspon et al. (2008) reported that C:N 36:1 totally not encouraged the soil organic degradation.

ACKNOWLEDGEMENTS

This study was funded by Ministry of Higher Education, Malaysia and University of Putra Malaysia. The authors wish many thanks to Dr. David Johnson for great support and supervision. Also thank to Janis Brodie, Norman Little, Janet Woo, Bruce Gordon and David Hay for technical support.

REFERENCES

Asmar, F. (1997). Variation in activity of root extracellular phytase between genotypes of barley. Plant and Soil 195,61-64.

Johnson, D., Leake, J.R. and Lee, J.A. (1999). The effects of quantity and duration of simulated pollutant nitrogen deposition on root-surface phosphatase activities in calcareous and acid grasslands: a bioassay approach. New Phytologist 141,433-442.

Phoenix, G.K., Booth, R.E., Leake, J.R., Read, D.J., Grime, J.P. and Lee, J.A. (2004). Simulated pollutant nitrogen deposition increases P demand and enhances root-surface phosphatase activities three plant functional types in a calcareous grassland. New Phytologist 161 (1),279-289.

Baudoin, E., Benizri, E. and Guckert, A. (2003). Impact of artificial root exudates on the bacterial community structure in bulk soil and maize rhizosphere. Soil Biology and Biochemistry 35,1183-1192.

Trofymow, J.A., Coleman, D.C. and Cambardella, C. (1987). Rates of rhizodeposition and ammonium depletion in the rhizosphere of axenic oats roots. Plant and Soil 97,333-344.

Gallizia, I., Vezzulli, L. and Fabiano, M. (2004). Oxygen supply for biostimulation of enzymatic activity in organic-rich marine ecosystems. Soil Biology and Biochemistry 36,1645-1652.

Cheng, W., Zhang, Q., Coleman, D.C., Carroll, C.R. and Hoffman, C.A. (1996). Is available carbon limiting microbial growth in the rhizosphere? Soil Biology and Biochemistry 28,1283-1288.

Teng, Y., Luo, Y., Ping, L., Zou, D., Li, Z. and Christie, P. (2010). Effects of soil amendment with different carbon sources and other factors on the bioremediation of an aged PAH-contaminated soil. Biodegradation 21,167-178.

Thomspon, O.A., Wolf, D.C., Mattice, J.D. and Thoma, G.J. (2008). Influence of nitrogen addition and plant root parameters on phytoremediation of pyrene-contaminated soil. Water Air Soil Pollution 189,37-47.