Decomposition of paper de-inking sludge during revegetation of a sandpit minesoil : a reply to the comments of Beyer and Mueller.

The objective of our study (Fierro et al., 2000) was to characterise in situ patterns of de-inking paper sludge (DPS) decomposition and of N and P accumulation and release, as affected by increasing rates of N and P. The context was to use high loads of DPS to increase the revegetation of an abandoned minesoil (sand pit). We concluded that DPS presented a particularly large recalcitrant pool decomposing slowly, the remaining mass of sludge was still 43 % of its initial amount after 27 months in the soil, and that during decomposition, sludge was a continuous source of C, N and P in the sand pit that likely contributed to the successful re-establishment of a vegetation cover.

Specific comments :

(I) We agree with Beyer and Mueller that an investigation of the remaining material and its organic matter fractions would have been useful. We discussed this point in our paper and referred to Fierro et al. (1999c) in which physical fractionation was used to characterise the remaining material. Chantigny et al. (2000) used wet chemistry (carbohydrate analysis) to study DPS decomposition in an arable soil. The time sequence of soil C : N data for the litter bag study are in Fig. 3B and those for the soil are presented in Fierro et al. (1999c).

(II) The context of our study was not agronomic and we never intended to make recommendations to farmers. The soil used is an abandoned minesoil on which we were trying to establish a perennial vegetation using a single massive application of DPS. The N rates used in this study were based on greenhouse preliminary trials (Fierro et al., 1997) and are needed to ensure adequate vegetation growth in a minesoil amended with this large dose of DPS. Other experimental studies on wood residue decomposition in revegetated minesoil used up to 1000 kg N ha^{-1} (e.g. Schuman and Belder, 1991). When considering large scale DPS incorporation for revegetation of a degraded soil, one could obviously consider using a mixture of adapted plant species where legumes would constitute a large proportion of the species. Little to N additions would then be required

(Fierro et al., 1997). In the latter study, we found that Melilotus officinalis and Galega orientalis would constitute excellent choices under the climatic conditions of Eastern Canada. In the study reported by Fierro et al. (2000), we voluntarily used a grass species in order to asses N dynamics without interference from fixed atmospheric N and without the use of isotopic tracers.

The issue of high nitrate leaching potential using such N rates is addressed in our paper, and we referred the reader to Fierro et al. (1999a), in which the mean nitrate concentrations of soil solution were presented. The spring following sludge and fertiliser incorporation, we also measured nitrate concentrations in the rivulet flowing along the sandpit. From months 12 to 26, nitrate concentrations were below hazardous limits (10 mg l^{-1}).

(III) The characterisation of the DPS has been published in a monograph (CRH, 1998) and a summary was presented in Trépanier et al. (1998). We followed the National Standards of Canada regarding heavy metals carried by organic amendments (BNQ, 1997) as well as the Québec Guidelines for using organic amendments (Gouvernement du Québec, 1997). We obtained agreement from the Ministère de l'Environnement et de la Faune du Québec for performing this experiment.

The impact of high pH following DPS incorporation was addressed in Fierro et al (1999b) and we suggested that this had a positive effect on availability of nutrients such as P, Ca, Mo and K in this acidic minesoil.

(IV) The issue of C : N ratio is discussed in the third paragraph of section 3.2 (Fierro et al. (2000)). As we mention, the initial C : N ratios (61, 41 and 31) were calculated using both the N content of the sludge and the amounts of added N. For example, for the lowest DPS rate, the values would be : N in DPS (3.3 mg/g dry DPS), added N (3 mg/g dry DPS) for a total amount of N of 6.3 mg N/g dry DPS. The C content of DPS is 382 mg C/g dry DPS, so the calculated initial C : N ratio for the lowest DPS rate is 382/6.3 = 60.6 which is the value presented in our paper (61). We believe that the calculated values presented by Beyer and Mueller (2000) (127, 64, 42) did not take into account the N present in the DPS. In the third paragraph of Section 3.2, we also mention that these calculated values are lower that the measured values presented in Fig. 3b.

(V) As reported by Chantigny et al. (1999) and Fierro et al. (1999), the carbonate content of the de-inking paper sludge was less than 3%.

(VI) We agree with Beyer and Mueller that the litter bag method has limitations but it is still a useful tool to study residue decomposition in soil. It has been used to study the decomposition of wood-derived residues in revegetated mine soils (e.g. Schuman and Belder, 1991). We would also like to point out that we have investigated the decomposition of the sludge using other tools (Fierro et al., 1999c; Chantigny et al., 1999). Chemical and physical fractionation methods as well as litter bag studies are complementary approaches to the study of organic residue decomposition. The problems associated with the physical isolation of the material in a litter bag was addressed in our paper. We hypothesised that the the organic material was stabilized by the clay already present in the sludge and not so much from that coming from the soil which had a sand content of 94 % sand). In fact, soil infiltration ranged from only 1 to 8% on a weight basis (see Material and Methods).

In our conclusions (see above), we did not intend to provide any recommendation for purposes of cultivation. If ever this may have appeared unclear or ambiguous to the reader, we thank Beyer and Mueller for mentioning it and to allow us to re-emphasise that our objective was to study the decomposition of DPS at large loading rates in the context of revegetating an abandoned minesoil (sandpit).

References

Bureau de normalisation du Québec (BNQ). 1997. Organic Amendments - Composts. National standard of Canada CAN/BNQ 0413-200. 25 p. ISBN 2-551- 17138 - 5.

Chantigny, M.H., Angers, D.A. and Beauchamp, C. J. (1999) Aggregation and organic matter decomposition in soils amended with de-inking paper sludge. Soil Science Society of America Journal 63, 1214-1221.

Chantigny, M. H., Angers, D.A. and Beauchamp, C.J. (2000) Decomposition of de-inking paper sludge in agricultural soils as characterized by carbohydrate analysis. Soil Biology and Biochemistry (in press)

CRH (Centre de Recherche en Horticulture). 1998. La valorisation agricole des résidus papetiers. Le cas de Daishowa, inc. Document de synthèse (1992-1998). Centre de Recherche en Horticulture, Université Laval. 20 pp. ISBN 2-9806202-0-3.

Fierro, A., Norrie, J., Gosselin, A., and Beauchamp, C.J. (1997) Deinking sludge influences biomass, nitrogen and phosphorus status of several grass and legume species. Canadian Journal of Soil Science 77, 693-702.

Fierro A., Angers, D. A. and Beauchamp, C. J. (1999a) Paper mill sludge as a revegetation tool in an abandoned sandpit: project outline and preliminary results. In *Remediation and management of degraded lands*, eds. M.H. Wong, J.W.C. Wong and A.J.M. Baker. pp 89-95. Lewis Publishers, Boca Raton.

Fierro, A., Angers, D.A. and Beauchamp, C.J. (1999b) Restoration of ecosystem function in an abadoned sandpit: plant and soil responses to de-inking paper sludge. Journal of Applied Ecology 36, 244-253.

Fierro, A., Angers, D. A. and Beauchamp, C. J. (1999c) Dynamics of physical organic matter fractions during de-inking sludge decomposition. Soil Science Society of America Journal 63, 1013-1018.

Fierro, A.,. Angers, D.A and Beauchamp, C.J. (2000) Decomposition of paper de-inking sludge in a sandpit minesoil during its revegetation. Soil Biology and Biochemistry 32, 143-150.

Schuman, G.E. and Belder, S.E. Decomposition of wood-residue amendments in revegetated bentonite mine spoils. Soil Science Society of America Journal 55, 76-80.

Gouvernement du Québec. 1997. Critères provisoires pour la valorisation des matières résiduelles fertilisantes (Épandage, entreposage temporaire, compostage, fabrication et utilisation de terreaux). Ministère de l'Environnement et de la Faune. Service de l'assainissement agricole et des activités de compostage.

Trépanier, L., Gallichand, J. Caron, J. and Thériault, G. 1998. Environmental effects of deinking sludge application on soil and soil water quality. Transactions of the American Society of Agricultural Engineers. 41, 1279-1287.

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