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Valorization of a Sulphide Mine Residue for Ryegrass Production

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Abstract

The objective of this study is to examine the effect of Sphagnum peat (SP) and three composts as a source of organic phosphorus (P), on the dry biomass yield of ryegrass grown, under greenhouse conditions, in a limed sulphide mine tailing (MT). Treatments consist of two rates of SP (0 and 33.8 g/kg MT) and five rates of P (0, 114, 229, 343 and 458 mg P_2O_5/kg MT). The P sources are: peat-moss and shrimp wastes compost, sheep manure compost, peat moss and chicken manure compost, and superphosphate (inorganic P source). The treatments are arranged in a randomized complete block design with three replications. Dry matter yield of plant biomass is positively and significantly affected by peat and P treatments. In all P treatments, the higher yields are obtained with mine tailing receiving peat. In conclusion, sulphide mine-tailing amended with lime and organic fertilizer could be transformed into substrate or soil capable of producing high ryegrass biomass yield.

Keywords: Biomass; Compost; Peat; Recycling

Abbreviations: SP: Sphagnum Peat; MT: Mine Tailing; PSC: Peat and Shrimp Compost: SMC: Sheep Manure Compost; CMCPM: Chicken Manure Compost and Peat moss

Introduction

Tailings management remains a challenge for governments, the mining industry and future users of mine sites. From a sustainable development perspective, the phyto-planning of mining lands - the use of mining residues for the production of some agronomic plants, fodder and plant biomass with economic value - is an environmentally way of recycling or managing mine waste likely to generate profit. However, most mine tailings have chemical properties that are not conducive to the good growth of agronomic plants or the production of plant biomass. Indeed, these tailings are poor in organic matter and nutrients available to the plant. Major elements such as nitrogen (N), phosphorus (P) and potassium (K) are considered to be a limiting factor in achieving a high level of productivity of mineral soils [1,2].

The role of organic matter, already known at the level of agricultural soils, would be important to confer to mining residues beneficial properties giving them the same property of the agricultural soils. The addition of organic amendment would create a physico-chemical environment conducive to the installation of a vegetation cover on the tailings.

Relatively little specific work has been devoted to the study of the effect of peat on the availability of P for ryegrass used as a stabilizing plant for acidic tailings modified by composts and lime. P is an essential nutrient for cell division, plant growth, and aboveground biomass production [3]. In agriculture, a P input in the form of fertilizer is essential to obtain good yields of above-ground biomass. However, acidic culture media containing hydrated hydroxides and iron hydroxides can transform phosphate ions into a form unavailable to the plant [4].

Several studies have shown that ryegrass is a forage grass that is easy to plant in soils [5] and can tolerate and accumulate high levels of metallic trace elements in mine tailings, sediments or soils contaminated with these elements [6,7,8]. However, little is known about the effects of source and dose of P in the presence of sphagnum peat (SP) on the growth of Italian ryegrass grown in a mine residue (MR) containing pyrite previously limed to theoretical pH value of 7. The objective of this study is to examine the effect of commercial SP input together with three organic P sources in the form of composts on the yield of dry ryegrass biomass (*Lolium multiflorum Lam*) grown in a greenhouse in the MR.

Materials and Methods

Tailings (MR) samples were collected from the tailings park at the old Solbec-Cupra mine located in the Eastern Administrative Region, east of Aylmer Lake (Quebec, Canada). The situation of the Solbec-Cupra tailing sparks when taking MR samples is the same that was described by Karam and Guay (1994). Thus, oxidized and unoxidized MR samples, divided into 81 points, were collected over a depth of 0 to 20 cm in area of 2.25 ha. The MR samples were dried at room temperature and mixed to form a composite sample. The composite sample had a pH of 2.65 and contained 850 mg / kg total P, 25.6% total Fe and 10.7% total S. Mineralogical analysis revealed the presence of quartz, hematite, jaro site and pyrite.

The organic amendment used is commercial sphagnum peat (SP) which contained 65.34% organic matter (OM), 0.4% total Ca and 800 mg/kg total P. The three commercial composts used in this study are: 1) peat and shrimp compost (PSC), 2) chicken manure compost and peat moss (CMCPM) and 3) sheep manure compost (SMC). The CMCPM, SMC and PSC composts contained 40.6, 44.7 and 48.1% organic matter, respectively; 1.96, 1.12 and 1.43% of total N; 3.13, 1.71 and 0.98% of total P; 2.02, 0.82 and 0.1% of total K; 2.98, 1.7 and 2.66% of total Ca. The compost PSC was more acidic (pH 5.6) than the other two composts (pH 6.6).

Several portions of MR samples (1 kg) were treated with calcium carbonate to obtain a theoretical pH value of 7.0 mixed with two doses of SP (0 and 3.8%). MR samples received five doses of P in the form of composts and single superphosphate (0-20-0). The doses of compounds and superphosphate were equivalent to 0, 1x, 2x, 3x and 4x, where x was 114.5 mg P_2O_5/pot. The substrates were placed in plastic pots of 15 cm of diameter at the neck level and 12 cm for height. Each pot received a dose of N (ammonium nitrate of formulation 27.5-0-0) and another of K (potassium chloride of formulation 0-0-60) to obtain a constant concentration of N of K in each pot according to the fertilization grid [9]. The peat dose treatments were divided into three replicates, according to a completely random block device.

Five days after the peat, compost and fertilizer applications, each pot received 15 seeds of Italian ryegrass (*Lolium multiflorum Lam*) from 'Maris Ledger'. The temperature of the greenhouse was set at 24 °C during the day and 18 °C at night. Sixteen hours of light was maintained during the growth period using sodium lamps when weather conditions did not allow natural lighting. The plants were watered with distilled water 1 to 2 times a day. The cuts (3) were made after 8, 10 and 12 weeks of growth respectively.

The aerial parts were harvested 1 cm above the level of the growth substrate. In addition, the MR grown from each pot was recovered. The plant material collected in each pot after each cut was dried at 70 °C for 48 h and weighed to determine the dry matter yield of the aerial part, plant growth index. Statistical analyzes were performed using the SAS software package [10]. The yields values of the indicator plants were subjected to a variance analysis. A variance homogeneity test (Bartlett test) was performed on the yield parameters. However, the homogeneity of variance test was satisfied.

Results and Discussion

Increasing of P dose resulted in a significant increase in dry aerial ryegrass biomass. Ryegrass, which has a root mass: high air mass ratio, responds favorably to phosphorus fertilization [11,12,13], resulting in an increase in aboveground biomass. The statistical results in Table 1 indicate a simple effect of the source and dose of P highly significant on the dry matter yield of ryegrass in the absence and in the presence of 3.8% of commercial sphagnum peat. Similar results have been reported for ryegrass grown in soils initially poor in P [12,14-16]. These results show the beneficial effect of phosphate fertilization on aerial biomass production.

The dose and source of P also significantly interact with the dry matter yield of the first two cuts (Table 1). Except the sheep manure compost, which gave yields comparable to those obtained with simple superphosphate, the two organic sources of P, namely CMCPM and PSC, performed better than the mineral source (Figure 1). Thus, the comparison between the different sources of P shows the superiority of the composts or the organic source of P. These results corroborate those obtained by Hountin et al. [17] who found that organic manure gave the best yield, compared to mineral fertilizer, of barley grown in sandy soil low in organic matter.

Dry aerial biomass yield					
Variation source	**d.l.**	**Cut 1**	**Cut 2**	**Cut 3**	**Total**
Model 1		7.7***	24.4***	2.2*	11.4***
Source of P (sp)	3	17.6***	53.9***	6.1***	26.5***
Doses of P (dp)	4	8.1***	24.5***	NS	11.7***
SP x DP	12	3.2***	11.4***	NS	4.6***
Model 2		7.5***	14.7***	NS	11.8***
Source of P (sp)	3	18.8***	50.1***	2.9**	32.8***
Doses of P (dp)	4	8.6***	9.4***	NS	11.8***
spxdp	12	2.9**	4.0**	NS	4.2***

Table 1: Results of variance analysis (F value) of source and dose effects of P on dry matter yield of ryegrass grown on mining residue in the absence (model 1) and in the presence (model 2) of sphagnum peat.
*, **, ***Significant at the level of 0.05, 0.01 and 0.001 respectively; NS: no significant.

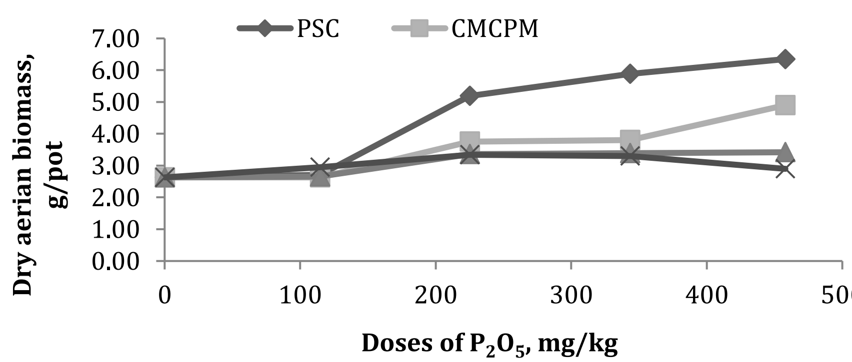

Figure 1: Variation of dry biomass yield average of first cut of ryegrass versus P_2O_5 added to mine residue in the absence of *sphagnum peat.*

With: PSC= peat and shrimp compost; CMCPM= chicken manure compost and peat moss; SMC= sheep manure compost

For the same amount of P_2O_5 added, composts brought more organic matter and nutrients to MR than mineral fertilizer. The results can also be explained by the fact that the plant can absorb inorganic P and soluble organic P. In addition, the phosphorus of the inorganic fertilizer being totally soluble is easily adsorbed on the surfaces of the free oxides and hydroxides of Fe, Al and Mn present in the growth area and therefore no longer be (or be less available) for the plant. Unlike synthetic chemical fertilizers, the organic amendment would gradually release the P, which is favorable to a continuous phosphate feeding of the plant. In addition, some composted materials can retain the moisture of the area growth, a capacity that is not available to mineral fertilizers.

As shown in Figure 2, average dry matter yields of ryegrass, with increasing doses of P (organic sources combined), are higher in the presence than in the absence of SP. These results are agree with the observations of Cyr and Karam [18] who found that sphagnum peat intake to an alkaline mineral residue fertilized with commercial manure compost had a favorable effect on growth ryegrass. Several studies have reported that peat increases the nutrient content of the plant [13]. Peat contributes to the growth of the plant due to the formation of new stimulating compounds [19], to improve the water conditions of the growth substrate [20] and to chelate the toxic metals.

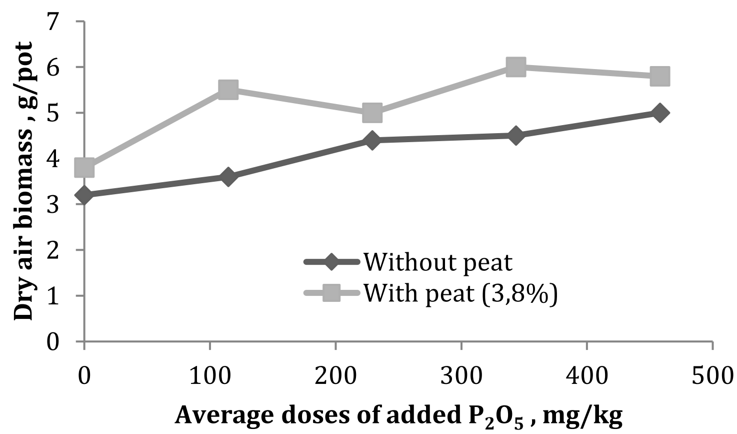

Figure 2: Variation in the total dry-matter yield of ryegrass in terms of average P_2O_5 doses (organic sources combined) added to the mine residue in the presence and absence of sphagnum peat.

Although the addition of composts improved the yield of ryegrass biomass for the first cut, a significant reduction in yield was observed for the 2nd cut. It is likely that the amounts of available nutrients after the first harvest were not sufficient to obtain high yields. McNeilly and Johnson [21] also observed a decrease in yield at the 2nd cut, for *Agrostis tenuis* Sibth grown in a mineral residue that received mineral fertilization only at the beginning of the crop trial. They attributed this to the nutrients lack due, on the one hand, to their absorption during the 1st growth period, and on the other hand, to leaching losses. As a result, ryegrass was reported to be deficient in nutrients during the second 7-week growing season, resulting in reduced yield. It is known that compost alone cannot meet all the nutrient requirements of the plant [11]. It would be important to provide supplemental mineral fertilization after each cut in order to stimulate the subsequent growth of ryegrass.

Conclusion

Whether with or without the addition of organic matter, the source and dose of P influenced the growth of ryegrass grown in a previously limed sulfurous mine residue. Organic matter plays an important role in the phosphate nutrition of the plant. In this sense, the performance of organic sources of P over simple superphosphate is demonstrated. The cultivation of mine tailings containing oxidized pyrite is an option that allows to value of organic amendments and sulphide mine tailings for growing ryegrass in a mining area.

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