De-inking paper sludge requirement of liming high acidic potato soil

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Abstract: Biosolids from de-inking processes are increasingly being used in Quebec (Canada) to improve acid soil. The objective of this study is to determine the optimum rates of de-inking paper sludge (DPS) for attaining target soil pH values of 5.2 and 5.5 for potato grown on podzolic soil. Incubation experiment was conducted during 18 weeks with a coarse textured soil (pH 4.8) and increasing rates of $CaCO_3$ or DPS. Results indicate that the amounts of DPS required varied from 4.0 to 8.2 dry Mg DPS ha^{-1} for attaining pH 5.2 and from 7.6 to 15.2 dry Mg DPS ha^{-1} for attaining pH 5.5. The required amount of DPS is proportional to its total $CaCO_3$ equivalent.

Key words: Liming materials, Soil amendment, Soil acidity, Lime requirement.

Introduction

The most common problem associated with acid coarse-textured soils in the province of Quebec (Canada) is aluminum (Al) toxicity particularly in soils devoted to potato (*Solanum tuberosum* L.) cultivation with pH below 5.5. Potato producers often attack this problem with soil amendments or liming materials. However, liming acid soils devoted to potato cultivation above 5.2 constitute a potential risk of scab disease especially for sensitive cultivars and soils infested with *S. scabies*. Although planting scab-tolerant potato is a reasonable option for dealing with acid soils and scab disease, liming is traditionally used to enhance pH to 5.5 in order to reduce Al availability and to improve soil productivity. Soils infested with *S. scabies* may be managed by adjusting the soil pH to a point unfavorable to the scab organism (Waterer, 2010).

In Quebec, about 74 000 Mg of primary de-inking paper sludge (DPS) were used in 2010 as soil amendment in crop plants (MDDEP 2010). This DPS contains cellulose fibers, removed inks, clay fillers (Barriga et al., 2010), coatings of used paper by a de-inking process (Charest and Beauchamp, 2002) and chemical additives added during the manufacture of paper, printing, and recycling (Beauchamp et al., 2002). Due to its high content of calcium carbonate, DPS may help reduce the use of commercial lime to treat acidic coarse-textured soils. DPS has been used to reduce soil acidity and availability of toxic Al (Baziramakenga et al., 2001; Battaglia et al., 2007), to enhance biological functioning (Chantigny et al., 1999), and to improve soil fertility (Fierro et al., 1997) and physical properties of soils (Trépanier et al., 1996; Chantigny et al., 1999).

Although the optimum pH range commonly reported for potatoes is 5.5 to 7.5 (Smith 1940), a soil pH of 5.2 to 6.2 is typical for commercial potato production in Quebec (CRAAQ, 2010). Potato is an important crop in Quebec's agricultural economy. The aim of the present experiment was to determine the optimum rates of DPS for attaining target sandy loam soil pH values of 5.2 and 5.5.

Materials and Method

Three types of primary de-inking paper sludge (DPS) were collected from three Cascade factories in Canada, namely Breakey fibers (DPS1), Candiac (DPS2) and Kingsey Falls (DPS3). DPS were air-dried, mixed, homogenized and ground to pass a 2 mm sieve prior to analysis for total C, total N and total Ca. Briefly, DPS1 contained 45% organic matter (OM), 0.2% total N and 16.1% total Ca; DPS2 contained 44.0% OM, 0.14% total N and 14.1% total Ca; DPS3 contained 52.0% OM, 0.12% total N and 12.7% total Ca. The pH was 8.0, 7.8 and 8.2 for DPS1, DPS2 and DPS3, respectively. The total calcium carbonate equivalent (TCCE) (BNQ, 2005) was 45.0, 42.0 and 37.5 for DPS1, DPS2 and DPS3, respectively. All analyses were done in triplicate. The pH of DPS was measured in deionised water using 1:10 DPS to water ratio. The Morin sandy loam soil (humo-ferric podzol) used for soil-liming material mixtures was taken from Patates Dolbec inc. farm in St-Ubalde (Quebec, Canada). Selected properties of the soil were as follows: sand 72%; clay 4%, pH_{water} (1:1 soil:distilled water ratio) 4.8; buffered pH or pH_{SMP} 5.6; organic matter 4%, Mehlich-3-extractable Al 1888 mg kg^{-1}.

Incubation test

The incubation experiment was planned using randomized block design containing three replicates for each test (chemically pure $CaCO_3$ ground to pass a 400 mesh sieve, DPS) and control treatment (without $CaCO_3$ or DPS). The treatments consisted of six $CaCO_3$ rates (1.1, 2.2, 3.4, 4.5, 6.7, and 9.0 Mg $CaCO_3$ ha^{-1}) and three rates of DPS: Breaky fibers (0.0, 10.0, and 20.0 Mg ha^{-1}, dry basis), Candiac (10.5 and 21.0 Mg ha^{-1}, dry basis) and Kingsey Falls (12.0, and 24.0 Mg ha^{-1}, dry basis). One kg of air-dried soil samples were placed into 1.5 L polypropylene recipients with drainage holes. A filter paper was deposited in the bottom of each recipient to prevent nutrient leaching. The soil was thoroughly mixed with reagent-grade $CaCO_3$ or DPS. Soil samples were moistened until water flows through the drainage holes. The moisture was adjusted every week by adding de-ionized water. All treatments were incubated in triplicate at 23 ± 2°C for 18 weeks.

Results

Increasing $CaCO_3$ or DPS rates significantly raised the soil pH after 18 weeks of incubation (Fig. 1). The pH of soil amended with $CaCO_3$ or DPS varied from 4.8 to 6.6. Soil samples amended with liming materials ($CaCO_3$ or DPS) exhibited the same pH response pattern. The four curves shown in Figure 1 are the best-fit asymptotic regression curves describing the relationship between $CaCO_3$ or DPS rates and pH of incubated soil samples. These relationships were significantly described ($P < 0.05$) by means of quadratic model: $pH = aX^2+bX+C$ (R^2: 0.91-0.99), where X is the rate of $CaCO_3$ or DPS rate and a, b and c are constants. Soil pH increased with the rate of DPS in the following order: Breakey fibers > Candiac > Kingsey falls. The first target pH of 5.2 is attained by adding 4.0, 5.3 and 8.2 Mg ha^{-1} of Breakey fibers, Candiac and Kingsey falls, respectively. The second target pH of 5.5 is attained by adding 7.6, 10.3 and 15.2 Mg ha^{-1} of Breakey fibers, Candiac and Kingsey falls, respectively. For calcitic limestone, soil pH values of 5.2 and 5.5 were attained by adding 2.6 and 4.6 Mg $CaCO_3$ ha^{-1}, respectively. The effectiveness of DPS in neutralizing soil acidity is negatively proportional to their TCCE value (Fig. 2).

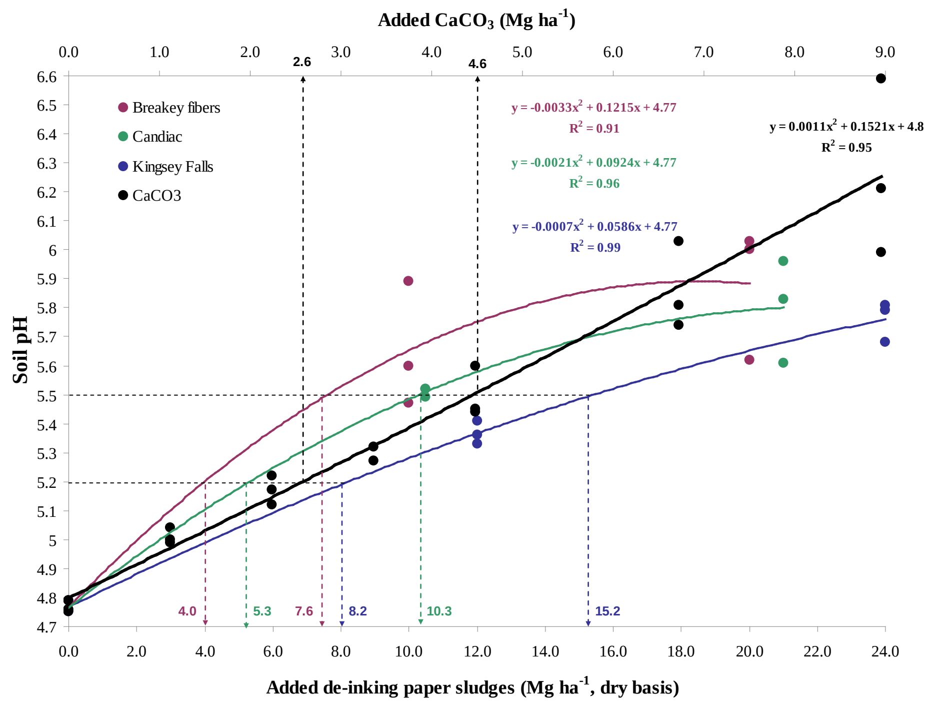

Figure 1: Graphic method for determining the amount of $CaCO_3$ and de-inking paper sludge (Breakey fibers, Candiac and Kingsey Falls) needed to reach soil pH values of 5.2 and 5.5.

Discussion

Strongly acidic soils and soils with a high buffering capacity often require a large quantity of lime. The amount of lime required to raise soil pH to 5.5, noted $LR_{5.5}$, is usually estimated in Quebec (Canada) by the recommendation system using pH_{SMP} as the diagnostic index of lime requirement (Table 1). According to this system, the amount of liming material that must be applied to the coarse-textured soil with a pH_{SMP} of 5.6 in order to reach soil pH_{water} of 5.5 was 7.1 meq per 100g (Tran and van Lierop, 1982) or 7.8 Mg $CaCO_3$ ha^{-1} (CRAAQ, 2010), substantially larger than the value of 4.6 Mg $CaCO_3$ ha^{-1} derived from soil-$CaCO_3$-moist incubation LR method (Fig. 1). This amount is somewhat close to 3.8 and 5.3 Mg ha^{-1} predicted respectively from Webber et al. (1977) and Soon and Bates (1986) equations (Table 1).

Table 1: Lime recommendation equations for Canadian mineral soils based on SMP soil-buffer pH.

References	Number of samples	Provenance	Soil type	Equilibrium period	Equations of lime requirement	r^2
Tran and van Lierop (1982)	37	Quebec soils	Coarse-textured soils	3 months	LR(5.5)* = 4.0 (pH_{SMP})2 -54.7 (pH_{SMP}) + 188	0.894
Soon and Bates (1986)	24	Ontarian soils	Loamy sand to clay	72 hours	LR(5.5)* = 3.66 (pH_{SMP})2 -48.98 (pH_{SMP}) + 164.3	0.828
Webber et al. (1977)	39	Candaian soils	Loamy sand to clay	30 days	LR(5.5)# = 3.4 (pH_{SMP}) + 23.3	0.740

* LR(5.5) in meq $CaCO_3$ per 100 g soil

\# LR(5.5) in t $CaCO_3$ per acre

This result indicates that the current recommendation system (Table 1) overestimates the lime requirement of the sandy loam soil by 3.2 (7.8-4.6) Mg $CaCO_3$ ha^{-1}. Excess amount of lime can be expected to increase soil pH to 6.0 rather than target pH value of 5.5 (Fig. 1) which would constitute a potential risk of scab disease especially for sensitive cultivars.

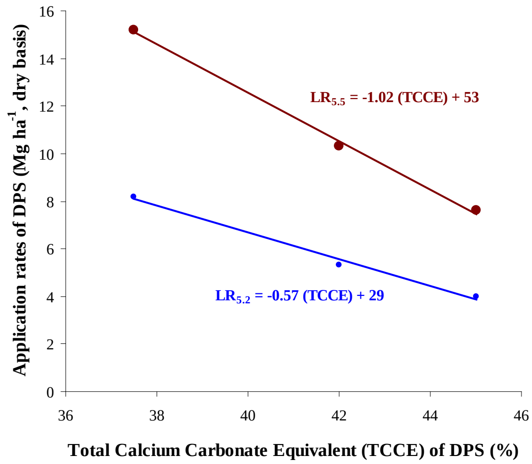

Figure 2: Application rates of DPS relative to their total calcium carbonate (TCCE) and target soil pH for potato crop.

As would be expected, Breakey fibers with the highest TCCE (45.0%) had greater effectiveness to attain the optimum pH range for potato plant than Candiac with TCCE of 42.0% and Kingsey Falls with TCCE of 37.5%. A one percent change in the TCCE of DPS could vary $LR_{5.5}$ and $LR_{5.2}$ by one and one half Mg DPS ha^{-1} (Fig. 2). TCCE values are probably related to the origin of recycled paper. Therefore, the amount of DPS required varies, depending on liming value of DPS and target pH value for potato crop.

Conclusions

The results indicated that the current Quebec recommendation system overestimate the lime requirement of coarse-textured soil.

The amounts (Mg ha^{-1}, dry basis) of DPS that must be applied to the coarse-textured soil with a pH_{water} of 4.8 in order to reach soil pH_{water} of 5.2 and 5.5 were respectively in the following range: 4.0-8.2 and 7.6-15.2. The amounts of DPS were negatively proportional to their TCCE value. Results also revealed that DPS were as efficient as $CaCO_3$ to neutralize soil acidity.

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