Delineating Management Zones for Optimizing Soil Phosphorus Recommendations Under a No Till Field in Eastern Canada

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Abstract.

Corn (Zea mays L.) and soybean (Glycine max L.) represent the most common crop rotation in Eastern Canada. These crops are cultivated using no-tillage (NT) practice for agroecosystem sustainability. However, NT practice can cause several agri-environmental issues related to phosphorus (P) stratification leading to P eutrophication in waters. Another major challenge is the expensive costs of extensive soil sampling and laboratory tests needed for accurate mapping of soil P to implement site-specific P management under no-tilled soils. There is a need to investigate spatial variability of P under no-tilled soils to improve P fertilization programs, while preventing P stratification and losses. There was limited information on controlling field-scale P spatial variability under no-tilled soils using management zone (MZs) approach. To date, no studies were performed on delineating MZs using the soil apparent electrical conductivity (ECa)–P relationship to characterize spatial variability of soil P for optimizing P recommendations under NT systems in Eastern Canada. This study aimed to delineate MZs in a corn–soybean rotation field (9.5 ha) under NT for 20 years, using the relationship between ECa and P to reduce soil sampling and soil P spatial variability to optimize P recommendations in Eastern Canada. To achieve this, an intensive grid sampling of 35 m by 35 m (total: 134 soil samples) was conducted in fall 2014. Soil was classified as Humaquept and attributed to Kierskoski soil series in the Canadian Soil Classification. The soil surface texture was a clay loam. The soil ECa data were collected in two depths (0–30 cm and 0–100 cm; ECa_{30} and ECa_{100}, respectively) using a Veris system. Phosphorus fertilizer was applied to the field following local recommendations for corn and soybean productions. Mehlich-3 extractable P and aluminum (Al) were measured in the top soil layer (0–5 cm). The $(P/Al)_{M3}$ agri-environmental index was then calculated. The MZs were delineated using ISODATA method following three different delineation strategies: $(P/Al)_{M3}$, ECa, and combined $(P/Al)_{M3}$+ECa measurements. The mean $(P/Al)_{M3}$ value was 7.9% in the field. Variability of $(P/Al)_{M3}$ was moderate (32%), meaning that P uniform fertilizer recommendation was not suitable across the field. ECa_{30} and ECa_{100} mean values were 15.8 and 32.6 mS m^{-1}, respectively. A weak but significant correlation ($r = 0.23$) between ECa_{30} and soil P was observed. Delineating into two to three MZs using $(P/Al)_{M3}$ measurements represented the most effective agronomy strategy owing to the highest P reductions (40–74 kg P_2O_5). This study showed the potential for using MZ delineation strategy to reduce spatial variability of soil P, while preventing P losses in the NT field. 426 words.

Keywords.

soil apparent electrical conductivity, ISODATA method, Veris, spatial variability, $(P/Al)_{M3}$, variance reduction, site-specific management, precision agriculture.

Introduction

Corn (Zea mays L.) and soybean (Glycine max L.) represent the most common crop rotation in Eastern Canada. These crops are cultivated using no-tillage (NT) practice to enhance agroecosystem sustainability. However, NT practice can cause several agri-environmental issues related to phosphorus (P) stratification, movement and runoff leading to P eutrophication in waters. Another major challenge is the expensive costs of extensive soil sampling and laboratory tests needed for accurate mapping of soil P to implement site-specific P management under no-tilled soils (Peralta and Costa 2013; Lawrence et al. 2020). Consequently, spatial variability of soil P under NT management should be taken into account for developing P fertilization programs, while avoiding P losses and stratification. Little is known on controlling field-scale P spatial variability using management zones (MZs), particularly under no-tilled soils. Thus, the general objective of this study was to delineate MZs in a corn–soybean rotation in a cropland (9.5 ha) under NT for 20 years, exploring the soil apparent electrical conductivity (ECa)–P relationship to reduce soil P spatial variability for site-specific P fertilizer recommendations in Eastern Canada.

Materials and methods

The study was conducted in the Monteregie region, Quebec, Canada. A crop field (9.5 ha) under NT for 20 years NT field under corn–soybean rotation was selected. An intensive grid sampling of 35 m by 35 m (total: 134 soil samples) was conducted in fall 2014. Soil was classified as Humaquept and attributed to Kierskoski soil series in the Canadian Soil Classification. The soil surface texture was a clay loam. The soil ECa data were collected in two depths (0–30 cm and 0–100 cm; ECa_{30} and ECa_{100}, respectively) using a Veris system. Phosphorus fertilizer was applied to the field following local recommendations for corn and soybean productions. Mehlich-3 extractable P and aluminum (Al) were measured in the top soil layer (0–5 cm). The $(P/Al)_{M3}$ agri-environmental index was calculated. The MZs were delineated using ISODATA method following three different delineation strategies: $(P/Al)_{M3}$, ECa, and combined $(P/Al)_{M3}$+ECa measurements. Lastly, accurate P fertilizer recommendations were developed in the commercial field for corn and soybean in each MZ using these three strategies. The results were compared to the local uniform P fertilizer recommendations (based on $[P/Al]_{M3}$ mean values) established for Eastern Canada (CRAAQ 2010) to estimate field-scale P_2O_5 profits and losses.

Results and discussion

Variability of $(P/Al)_{M3}$ was moderate (32%), meaning that P uniform fertilizer recommendation was not suitable across the field. ECa_{30} and ECa_{100} mean values were 15.8 and 32.6 mS m^{-1}, respectively. A weak but significant correlation (r = 0.23) between ECa_{30} and soil P was observed. Delineating into two to three MZs using $(P/Al)_{M3}$ measurements represented the most effective agronomy strategy compared to the other agronomy strategies, including the current method (conventional agriculture). This was due to the highest P reductions (40–74 kg P_2O_5). (Table 1).

Table 1. Agri-environmental P gain (kg P_2O_5) calculated for a corn–soybean rotation based on $(P/Al)_{M3}$ value from each MZ delineation strategy compared to the mean value $(P/Al)_{M3}$ from the current method under the no-tillage field.

	Current method	strategy 1 $(P/Al)_{M3}$ measurements		strategy 2 ECa_{30} measurements		strategy 3 $(P/Al)_{M3}+ECa_{30}$	
Management Zone (MZ)	1MZ	2MZs (MZ_1, MZ_2)	3MZs (MZ_1, MZ_2, MZ_3)	2MZs (MZ_1, MZ_2)	3MZs (MZ_1,MZ_2, MZ_3)	2MZs (MZ_1, MZ_2)	3MZs (MZ_1,MZ_2, MZ_3)
P recommendations for[3] corn from each MZ (kg P_2O_5)	380	231 75	170 132 39	240 140	144 146 90	234 146	148 143 89
Total P recommendations for corn (kg P_2O_5)	**380**	**306**	**341**	**380**	**380**	**380**	**380**

Conclusions

Delineating into two to three MZs using $(P/Al)_{M3}$ measurements represented the most effective agronomy strategy owing to the highest P reductions (40–74 kg P_2O_5). This study showed the potential for using MZ delineation strategy to reduce spatial variability of soil P, while preventing P losses in the NT field.

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