Phosphorus Dynamics and Bioavailability in Andosols : Estimation of Potential Bioavailable P Transport in Agricultural Runoff of Andosols

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Phosphorus Dynamics and Bioavailability in Andosols –Estimation of Potential Bioavailable P Transport in Agricultural Runoff of Andosols

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Key words : potential bioavailable P loss, surface runoff, silandic Andosols, aluandic Andosols

Abstracts

In this study, we estimated the potential bioavailable P transport in agricultural runoff of Andosols from the relations between P sorption saturation and anion exchange resin and Mehlich-3 extractable P, with special references to the difference in active Al composition. the P sorption saturation of 10 %, that is optimum P level needed for good crop yields, is critical point of inorganic P for the potential bioavailable P loss in surface runoff from agricultural Andosols with different active Al composition. However, silandic A and B soils showed lower values of Mehlich-3 P than aluandic soils when they had the same P sorption saturation. Mehlich-3 P underestimated the bioavailability of soil P in the silandic soils compared to the aluandic soils. We recommend the use of different critical values of Mehlich-3 P for assessing the upper critical limits for P in aluandic and silandic Andosols.

Introduction

Phosphorus (P) is essential element for plant and animal growth and its application has been conducted to increase crop and animal production. Phosphorus inputs can accelerate eutrophication and increase the biological productivity of surface waters. Eutrophication restricts water use for fisheries, recreation, industry and drinking due to the increase of undesirable aquatic biota, in some case toxic species of blue-green algae, and due to oxygen shortages generated by their death and decomposition. Although nitrogen and carbon are also essential to the increase of aquatic life, most concern has focused on P inputs, because of the difficulty in controlling the inputs of nitrogen and carbon and atmospheric nitrogen fixation by some blue-green algae. Therefore, P is often the limiting element for the growth of aquatic biota and its control has the greatest significance in reducing the accelerated eutrophication of fresh waters (Sharpley and Rekolainen, 1997).

The world P resources of high quality is decreasing, while agricultural lands are gathering concern as major non-point P sources for the water bodies (Sharpley et al., 1999). Therefore, there is a growing need for accurate recommendation of P fertilizer and animal manure to establish agronomically, economically and environmentally sound agricultural systems. The P input from agricultural lands to surface waters occurs in the ways of surface runoff (sediment-bound and dissolved forms) and subsurface flow. Dissolved P in surface runoff is most available for aquatic biota and also a part of soil particulate-bound P is available for fresh water algae. These bioavailable P in surface runoff is estimated by traditional soil P tests and P-sink approaches. One of the former methods is Mehlich-3 soil P test, which is adopted by several states in USA to set upper critical limits for P in soils (Sharpley et al., 1999). Pote et al (1996) found that the dissolved P concentration of surface runoff was related to Mehlich-3 extractable P content of surface soil. The P-sink approach, such as anion-exchange resin extractable P (AER-P) and P-sorption saturation (%) closely related to dissolved P concentration of surface runoff (Sibbesen and Sharpley, 1997). The P-saturation approach provides a greater degree of flexibility across soil types than soil test P in estimating the potential P loss in surface runoff because it accounts for soil properties affecting P sorption and desorption (Sibbesen and Sharpley, 1997).

Andosols are major soil type of agricultural upland in Japan and have large amounts of active aluminum (Al) and iron (Fe) derived from short-range-order minerals and show a very high P fixation. Two major types of Andosols are recognized, Silandic Andosol in which allophanic clay is predominant, and Aluandic Andosol in which Al-humus complex prevails (Driessen et al. 2001).

In this study, we focused on the estimation of potential bioavailable P transport in agricultural runoff of Andosols with special references to the difference in active Al composition.

Materials and methods

We used 4 high-humic aluandic horizon soils and 8 silandic horizon soils including 4 high-humic soils (silandic A horizon soils) and 4 low-humic soils (silandic B horizon soils). Soil P levels were varied in the range of 0.06 to 1.43 g P kg^{-1} (4 levels in each soil) by adding calcium phosphate to the uncultivated soils and keeping the treated soils for 9 months. Acid oxalate (Blakemore et al., 1981) and pyrophosphate extractable (Wada and Higashi, 1976) Al and Fe were measured and phosphate absorption coefficient was determined by adding 26.8 g P_2O_5 kg^{-1} soil. Total inorganic phosphorus contents were measured by extraction using hot conc. HCl. Soil test P values were determined by Mehlich-3 extractant (Mehlich, 1984) and strongly basic anion exchange resin (AER, Amberlite IRA-900) with resin to soil ratio of 1 : 1 and reaction time of 24h. Phosphorus sorption saturation was calculated by dividing total inorganic P in soils by P sorption capacity (phosphate absorption coefficient) and was expressed by percentage.

Results and discussion

Eight Silandic Andosols had major active aluminum (Al) of allophanic clay according to high amounts of acid oxalate extractable silicon (Sio) and low ratios of Alp (pyrophosphate extractable Al derived from Al-humus complex) to Alo (acid oxalate extractable Al). Four Aluandic Andosols showed low Sio contents and high Alp/Alo ratio, in which Al-humus complex were major active Al. Major form of soil inorganic P was Al-bound P (67-87%) in silandic and aluandic Andosols according to the results of sequential P extraction (data is not shown).

Potential bioavailable P loss in surface runoff from agricultural lands can be estimated by AER-P contents in soils. It is known that heavy P fertilizer application was practiced for newly reclaimed Andosols and the amounts of P equal to ten percent of the phosphate adsorption coefficient of soils was enough to obtain high crop yields for successive croppings in Japan(Yamamoto and Miyasato, 1972).

Table 1. Some properties of Andosols used in this study

Types of soils	Sample names	Total carbon (g/kg)	Alo*1 (g/kg)	Sio*2 (g/kg)	Alp/Alo*3	Phosphate absorption coefficient*4 ($g\ P_2O_5/kg$)
Aluandic horizon soils	Mukaiyama A1	172	15	0.9	0.99	22.6
	Mukaiyama A3	177	30	2.4	0.98	26.7
	Kawatabi A	69	16	2.7	0.72	21.3
	Hirosaki A	135	26	6.0	0.65	24.5
Silandic A horizon soils	Takizawa A1	101	44	18.6	0.25	24.1
	Takizawa A2	61	63	31.8	0.14	25.5
	Mouka A	98	51	21.7	0.26	25.7
	Nango A	47	45	19.4	0.15	20.3
Silandic B horizon soils	Takizawa B	18	64	41.9	0.07	23.3
	Mouka B	31	60	34.9	0.10	24.0
	Zao B	24	40	25.3	0.10	20.5
	Tsukuba B	44	54	26.1	0.13	22.7

Alo*1, Sio*2 ; acid oxalate extractable Al, Si
Alp/Alo*3 ; ratio of pyrophosphate extractable Al to acid oxalate extractable Al
Phosphate absorption coefficient*4; sorbed phosphate determined by addition of 26.8 g P_2O_5 kg^{-1} soil

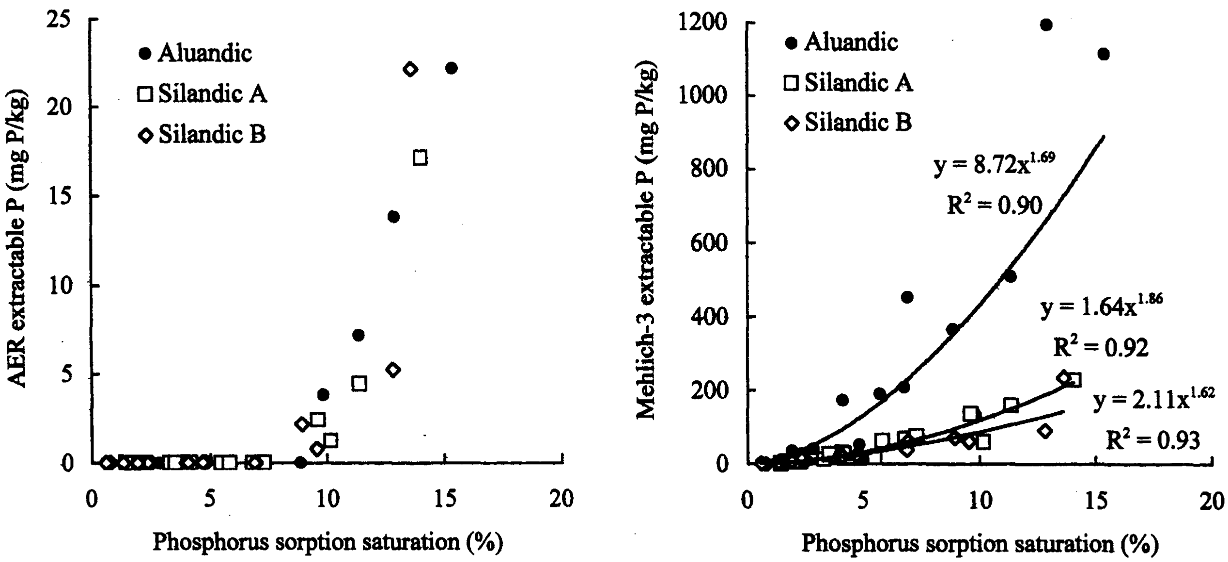

Fig. 1. Relationship between P sorption saturation and AER and Mehlich-3 extractable P contents in soils

According to Fig. 1, AER extractable P in soils showed almost zero when P sorption saturation was less than 10 % and increased sharply above 10 % of P sorption saturation. Relationship between P sorption saturation and AER-P contents can be expressed by the same curve in both of three types of Andosols including 12 soils. The result suggests that the P sorption saturation of 10 %, that is optimum P level needed for good crop yields, is critical point of inorganic P for the potential bioavailable P loss in surface runoff from agricultural Andosols with different active Al composition.

Soil P test value by Mehlich-3 method increase with increase of P sorption saturation (Fig. 1). The Mehlich-3 extractable P contents closely correlated with P sorption saturation in each type of Andosols with exponential curves. The correlations were significantly different between silandic soils and aluandic soils. Silandic A and B soils showed lower values of Mehlich-3 P than aluandic soils when they had the same P sorption saturation. Mehlich-3 P underestimated the bioavailability of soil P in the silandic soils compared to the aluandic soils. The modified Bray-2 P value decreased with the extraction time in allophanic Andosols because the net resorption was occurred during the extraction (Hylander et al., 1999). Mehlich-3 and Bray-2 extractants are strongly acidic solution. It was considered that P sorption during the extraction process happened more intensively in the silandic soils than the aluandic soils under acidic conditions (Mehlich-3 extractant) according to the results of Hylander et al. We recommend the use of different critical values of Mehlich-3 P for assessing the upper critical limits for P in aluandic and silandic Andosols.

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