Phosphorus Residual Effect in Andisols Cultivated with Potatoes

By Juan Córdova, Franklin Valverde and José Espinosa

Soils derived from volcanic ash (Andisols) cover an appreciable area of Central and South America. The clay fraction of Andisols is dominated by allophane and imogolite (amorphous, short range ordered minerals) which come from the weathering of pyroclastic material produced from recent volcanic depositions. Research conducted in the last 20 years has demonstrated that humus-aluminum (Al) complexes also play a significant role in Andisol chemical behavior.

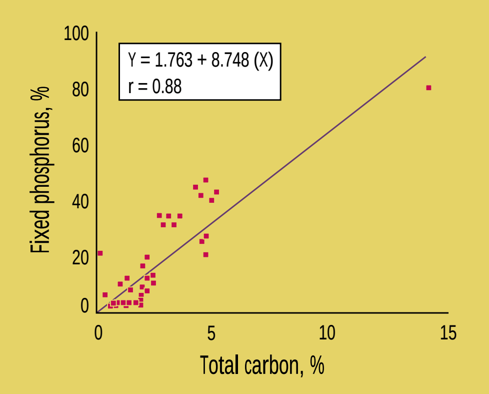
One of the most important characteristics of Andisols is their high capacity to immobilize (fix) phosphorus (P) on the surface of the amorphous minerals. This is perhaps the principal chemical constraint of Andisols. It seems that the P fixing capacity varies with the type of clay mineral, affecting the residual value of phosphate applications.

Phosphorus Fixation Mechanisms in Andisols

Initially, P fixation in Andisols was considered to occur only on the active surface of allophane and imogolite. Fixation mechanisms include chemiadsorption and displacement of structural silicon (Si). The importance of Al complexes in the P fixation processes has attracted attention. Soil humus in Andisols readily forms metal complexes with transition metals like Al. Furthermore, hydroxyl groups attached to the complexed Al enter into ligand exchange reactions with phosphates (HPO_4 and H_2PO_4).

Formation of allophane and imogolite is restricted by the accumulation of humus and the subsequent formation of humus-Al complexes. The strong complexation of Al with humus limits the possibility of coprecipitation of Al and Si released from the weathering of volcanic ash. This process is common in Andisols of high altitude. Accumulation of organic matter is higher in volcanic soils located at higher altitude (more than 2,000 m above sea level).

Figure 1. Correlation between total carbon and P fixation in Andisols of Ecuador.



Indirect evidence obtained in Andisols of Ecuador and Colombia leads to the conclusion that P fixation is strongly related to the carbon (C) content of the soil (humus-Al complexes). This would indirectly indicate the pattern of clay mineral formation in the soil and the intensity of P fixation. It seems that soils dominated by humus-Al complexes tend to fix more P. From the practical point of view, it seems that in Andisols, total C content would be a sensitive parameter to predict P fixing potential of the soil. Figure 1 illustrates the good correlation found between P fixed and total C content of 42 Andisols from Ecuador.

Residual Phosphorus in Andisols Cultivated with Potatoes

It has been reported from several parts of the world that calibration studies on Andisols to relate soil extractable P with crop yield and fertilizer requirements do not work well for all crops. This is the case of potatoes grown in soils derived from volcanic ash in the highlands of Ecuador. To test this condition, potato field experiments were conducted at two locations, El Chaupi and Santa Teresita. Soil at the test areas is Melanudand, typical of the potato country in the highlands of Ecuador.

Potato crop at flowering in the third cycle at El Chaupi site. Foreground plot received 300 kg P_2O_5/ha during the first and second cycle and none in the third. Middle plot is check plot. Back plot received 300 kg P_2O_5/ha in the third cycle.

At El Chaupi, potatoes were grown in the same plots for three consecutive growing cycles. Results of the experiment presented in Table 1 indicate that yields obtained in the check plot are low even though the P content, extracted with Olsen solution, was high at 28 parts per million (ppm). The general P critical level for this soil is 12 ppm. There was an appreciable yield response to increasing P rates in all the growing cycles, indicating that the P residual effect in this soil is low, but the soil test did not reflect this fact. The soil P test in the plot which received an application of 300 and 450 kg P_2O_5/ha in the first and second cycle increased to 38 and 59 ppm, respectively. However, potato yields in the third cycle, in the same plots but without P application, were low again. The same trend was observed with low and high application rates. The photo taken at flowering in the third cycle illustrates the differences among a plot which had 300 kg P_2O_5/ha during the first and second cycle and none in the third (foreground plot), the check plot (middle plot) and a plot with 300 kg P_2O_5/ha in the third cycle (back plot).

Effect of phosphate application on potato plant growth at the Santa Teresita site.

Data presented in Table 2

Table 1. Residual P effect on potato yield and its relation to soil test at El Chaupi site.

Cycle 1 P_2O_5 kg/ha	Cycle 1 Yield t/ha	Cycle 2 P_2O_5 kg/ha	Cycle 2 Yield t/ha	Cycle 3 P_2O_5 kg/ha	Cycle 3 Yield t/ha	Soil P test[1] ppm
		0	6.04	0	6.37	28
0	3.09	0	5.09	300	32.39	41
		300	39.34	300	31.19	46
		0	9.90	0	8.33	28
150	18.46	150	32.65	0	11.32	32
		150	35.44	150	30.45	40
		0	17.72	0	7.90	27
300	27.60	300	36.54	0	12.44	38
		300	39.86	300	32.63	64
		0	18.84	0	13.21	34
450	27.74	450	42.55	0	24.09	59
		450	45.12	450	28.28	89

[1]*Soil P test after the third cycle; P extracted with $NaHCO_3$ + NH_4F + EDTA (Olsen)*

Table 2. Potato yield in the third cycle related to previous phosphate applications at El Chaupi site.

Cycle 1	Cycle 2	Cycle 3	Total P_2O_5 applied	Yield, t/ha
P_2O_5 rate, kg/ha				
0	0	300	300	32.39
150	150	0	300	11.32
300	0	0	300	7.90
150	150	150	450	30.45
450	0	0	450	13.21
0	300	300	600	31.20
300	300	0	600	13.43
300	300	300	900	32.63
450	450	0	900	24.08

Table 3. Effect of phosphate application on potato yield at the Santa Teresita site.

P_2O_5 rate, kg/ha	Yield, t/ha
0	5.52
150	30.61
300	33.57
450	35.50

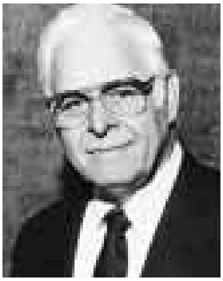
suggest that even at very high rates of phosphate application, the fixing capacity of the soils is not satisfied, and the residual benefit is low. To obtain an adequate potato yield, P application is needed every cycle. The data reported from the Santa Teresita site cover only the first cycle but illustrate equally the high fixing capacity of these soils (Table 3 and photos).

Conclusion

Phosphate fixation potential of Andisols appears to be related to the presence of different materials in the clay fraction as a result of different weathering conditions of volcanic ash. Soil dominated by humus-Al complexes seem to have higher P fixing potential, which is apparently difficult to satisfy. Nutrition management of potato in these type of soils requires a high P application every cycle due to the low P residual effect. BCI

Mr. Córdova and Mr. Valverde are with the Ecuadorian Agronomic Research Institute, Santa Catalina Experiment Station, Casilla 340. Quito, Ecuador. Dr. Espinosa is Director, PPI Northern Latin America Program (INPOFOS), Quito, Ecuador.

Robert E. Wagner Award Nominations Due



The Robert E. Wagner Award was established in 1988 by the PPI Board of Directors to recognize distinguished contributions to advanced crop yields through maximum yield research (MYR) and maximum economic yield (MEY) management. The MEY concept, also known as most efficient yield, can provide a solid foundation for better meeting world food needs.

The Award honors Dr. Wagner, retired President of PPI, for his many contributions to agriculture. He is widely recognized for originating the MEY management concept...for more profitable, efficient agriculture.

Last year's recipient in the senior scientist category was Dr. L.D. Bailey of Agriculture and Agri-Food Canada's Brandon Research Centre and in the young scientist division Mr. David Quipeng Zeng, Soil and Fertilizer Institute of the Guangdong Academy of Agricultural Sciences, People's Republic of China. The recipient in each category receives a $5,000 monetary award.

The format for preparation of nominations for this Award can be obtained by contacting the Potash & Phosphate Institute, 655 Engineering Drive, Suite 110, Norcross, Georgia 30092-2837; phone (770) 447-0335, ext. 203, fax (770) 448-0439. Private or public sector agronomists, crop scientists and soil scientists from all countries are eligible. Nominations must be received by December 31, 1996. BCI