Linking the Lab Experience with Everyday Life: An Analytical Chemistry Experiment for Agronomy Students

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Analytical chemistry with theoretical and practical classes is part of the curriculum of several areas of study, among them agronomy. But students generally lack interest in the subject matter. A teaching strategy that links the laboratory experiences to the daily expectations of the students increases their interest in the discipline. Chemical equilibrium, hydrolysis, pH calculation, common-ion effect, buffer solutions, solubility product, identification reactions, and ion separation processes are introduced to students in the first stage. In the second stage, gravimetry, volumetric titrimetry with redox, complexation, precipitation reactions, and potentiometric and spectrophotometric analyses are studied.

During practical classes samples are usually obtained by dilution of commercial solutions. Such procedures are indispensable for the student's learning. However, use of samples related to agronomy makes the study and consequently the learning of chemistry more attractive. The principles involved in the second stage can be applied to quantitative analysis of several parameters. This work shows that application of chemical principles to study of soil–plant interactions stimulates students' interest in chemistry by showing the importance of chemistry for agronomy.

Experimental Procedure

Soil was prepared and divided into five lots of 1 m^2 each. The first lot was maintained as a control, the second was treated with 1 L of molasses residue, the third with 1 kg of lime, the fourth with 1 kg of organic matter (chicken manure), and the fifth with 1 kg of humus. One week later, each planter was seeded with 0.6 g of zinnia seed (*Zinnia* sp.), a plant resistant to bad weather that germinates in little time and presents good growth in the time period of the experiment, about ten weeks. After this period the soil was sampled and analyzed for pH, organic matter, calcium, magnesium, phosphorus, and aluminum. These parameters were correlated to plant height (ph) and flower diameter (fd) ten weeks after planting. The soil samples were dried, homogenized, sifted, and stored for later analysis for pH, K, Ca, Mg, P, and Al in the laboratory classes (*1*). To analyze Ca, Mg, and Al, 5.0 g of soil and 50.0 cm^3 of 1.0 M KCl extractor were used. For phosphorus analyses the Mehlich (HCl + H_2SO_4) extractor was used. The organic matter was oxidized with potassium dichromate (*2*). The chronology of activities is found in the Table 1. The methodology was based on titrimetric analyses (*3–5*) (Ca, Mg, exchangeable Al, total acidity, organic matter), spectrophotometry (P), and flame photometry (Na, K). The results were evaluated by analysis of principal components (*6–8*).

Results and Discussion

The data obtained in 1996 are presented in the Table 2. Figure 1 shows the dispersion of the samples in principal components 1 and 2, as functions of the different treatments. The soil treated with lime is separated from the others in the second component owing to larger concentrations of calcium, magnesium, and hydrogen ions. The plants' average growth was greater than that of the control. The difference observed

Table 1. Chronology for Activities and Field Experiment

Week	Parallel Activities	Topics Studied in the Second Stage
1	Soil preparation	Laboratory techniques
2	Planting of the *Zinnia*	Neutralization volumetry
3	Development of the plants	Titration of diluted hydrochloric acid
4	Development of the plants	Titration of nitric (3%) and hydrochloric (37%) acids
5	Development of the plants	Titration of potassium hydroxide
6	Development of the plants	Potentiometric titration of strong and weak acids
7	Development of the plants	Redox volumetry: titration of oxygenated water
8	Development of the plants	Titration of iron(II) sulfate solution
9	Development of the plants	Complexometry: determination of calcium and magnesium in potable water
10	Soil and plants collected	Spectrophotometry: determination of iron(III) with phenanthroline
11	Preparation of soil samples[a]	Analysis of water content (plants and soils), gravimetry
12		Analysis of total soil acidity (neutralization volumetry)
13		Analysis of calcium and magnesium in soil (complexation volumetry)
14		Determination of organic matter in soil (redox volumetry)
15		Analysis of phosphorus in soil (spectrophotometry)
16		Potentiometric analysis: soil pH
17		Determination of sodium and potassium in soil (flame photometry)

[a]Soil samples collected in this phase are used for the determinations during the remainder of the course.

Table 2. Data Obtained during the Activities

Lot	Variable[a]								
	pH	fd/ cm	ph/ cm	Ca/ g kg^{-1}	OM/ g kg^{-1}	Al/ mg kg^{-1}	Mg/ mg kg^{-1}	K/ mg kg^{-1}	P/ mg kg^{-1}
Control	5.03 (0.07)	3.17 (0.24)	35.6 (3.0)	524 (25)	17.6 (0.3)	15.8 (0.8)	70.3 (7.1)	17.9 (0.7)	3.23 (0.40)
Lime	6.55 (0.06)	3.89 (0.18)	42.0 (3.3)	654 (30)	17.5 (0.2)	0.04 (0.02)	196 (9)	11.9 (0.6)	1.71 (0.23)
Molasses residue	5.59 (0.04)	5.27 (0.22)	46.8 (3.1)	372 (22)	16.3 (0.9)	13.6 (0.5)	107 (6)	18.5 (0.5)	2.54 (0.23)
Chicken manure	5.56 (0.06)	8.10 (0.38)	83.5 (4.58)	554 (18)	19.9 (0.6)	5.3 (0.5)	119 (4)	30.1 (2.1)	92.9 (2.4)
Humus	5.46 (0.03)	7.19 (0.34)	78.0 (5.3)	527 (23)	22.6 (0.7)	10.9 (0.3)	142 (8)	17.6 (0.1)	18.8 (1.0)

[a] Mean (standard deviation).

in the lot with added lime can be attributed to the calcium and magnesium ions. The lime addition reduces the acidity of the soil to pH 6.55, moving the acid–base equilibrium and decreasing the activity of the aluminum ion (*9*). In agreement with Schlesinger (*10*), at pH values above 4.7 the aluminum ion activity decreases and at pH values above 5.7 the aluminum ion is present as the insoluble hydroxide [$Al(OH)_3$] and cannot be determined by sodium hydroxide titration.

The organic matter, in larger concentration in the soil treated with manure and humus, separates these two groups of samples along the diagonal, showing the influence of phosphorus and potassium. The height of the plants and diameter of the flowers were greater in comparison to the others. The good development of the plants when organic matter is added is related to the effect of microbiological activity on the availability of nutrients. The organic matter preserves the remaining elements of the biota as carbon, oxygen, nitrogen, and phosphorus, including them in the cycles of organic matter (*10*). The control was only slightly separated from the plots treated with molasses residue, probably owing to the slightly lower pH, which favors a larger concentration of aluminum ion. The acidity of the soil promotes solubilization of the aluminum ion, which has unfavorable effects on plant development (*11*).

In Figure 2, the analysis of groups shows the effects at the origin of the calcium and magnesium in the added lime (dolomitic), and the similarity among the other parameters (flower diameter, plant height, organic matter, pH, aluminum, phosphorus, and potassium). The association of the organic matter with phosphorus and potassium provided the best development of plants. Except in the treatment with lime, the pH values were quite similar. The results highlighted the treatment with manure, which offered the largest amount of organic matter, as more efficient in terms of plant growth. Thus, the student can easily understand the correlations through the evaluation of the presented illustrations.

This experiment should stimulate other teachers to develop experiments related to other disciplines and motivate students to understand associated chemical principles. The development of the activities in agronomy reduced the number of students dropping out and produced the largest index of approvals, when compared on average with the 2 years previous. This experiment has been used for 3 years. In agreement with the data of this university, the smallest dropout index appears directly associated to the student's interest (Table 3).

Table 3. Student Approval Rating

Approved, by Year (%)[a]				
1992	1993	1994	1995	1996
47.6	64.5	63.5	67.1	74.3

[a]The shaded area indicates data for years in which the experiment was conducted.

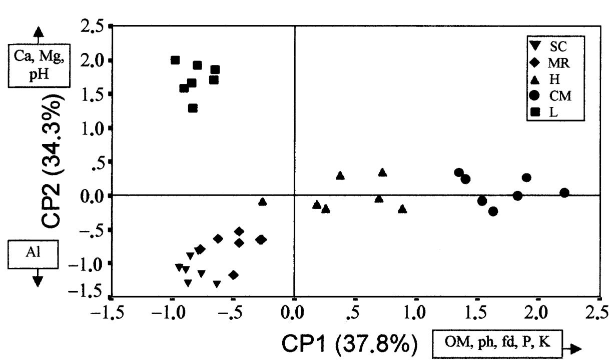

Figure 1. Sample dispersion in principal components 1 and 2 (CP1 and CP2), with varimax rotation.

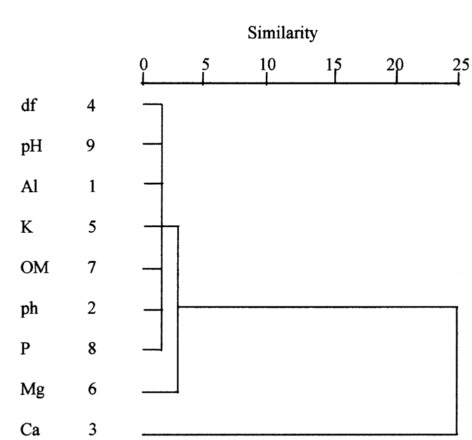

Figure 2. Similarity between the analyzed parameters.

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