Corporación Colombiana de Investigación Agropecuaria (CORPOICA), Colombia

Leyla Amparo Rojas Coordinator of the project
Gabriel Roveda
José Eurípides Baquero
Margarita Ramirez
Fernando Rodriguez

1. Objective

The Eastern plains (Llanos Orientales) of Colombia have an area of about 26 million hectares. The big agronomic potential of the region has an area of about 4.6 million hectares with a physiographic landscape of terraces and high planes (altillanura). Oxisols and Ultisols are the main soil Orders of this region whose principal soil characteristics are a clay fraction of low cation exchange capacity, with an advance state of weathering, high acidity and aluminum (Al) content and poor fertility due to the low organic matter content and low availability of nutrients for the plants, specially phosphorus (P) (Mejia, 1996). Maize crop has been a good option, for the farmers of this region because it can be used by humans and animals with no or very low mechanization and industrial processing, being a very good crop, for big and small farmers who live very far away (Valencia,1996). However, the high acid characteristics due to the Al saturation (more than 80%) and the low fertility have been the most important restrictions for this crop. The necessity of applying lime and fertilizers has increased the cost of growing maize in that region.

A Program of plant breeding has been carried out by CIMMYT-ICA and CIMMYT-CORPOICA during the last two decades, in order to select maize varieties with characteristics of tolerance to Al toxicity and ability to take up nutrients, especially P. The development of some hybrids and varieties like ICA-Sikuani V-110 (Sikuani), which may grow on soils with Al saturations up to 50% has allowed to reduce lime applications, providing a partial solution to this restriction, but without solving the P fixation problem. It is also uncertain whether the use of long periods of time of Al-tolerant and /or P-efficient plants will continue enhancing acidification until devastation or it will maintain and even enhance soil fertility.

Working with plants in nutrient solutions, several researchers (Hargrove and Thomas, 1981; Ahmad and Tan, 1986) have found that additions of organic matter (OM) decreased the availability of Al for plants even in a more efficient way than lime does. Similar results were obtained by Rodriguez et al. (1997); the authors also found that from five organic matter sources studied, such as rice straw, rice polishings earth warm manure, cowpea and chicken manure, the last two sources decreased the Al in the soil and plants in a more effective way compared to the other OM sources.
However, while the efficiency of liming and inorganic fertilizers application is comparatively well established, the role of organic matter and organic matter transformation is still far for being clear. Long term sustainability may required both, the acid soil-tolerant cultivars and the adaptation of additional agronomic practices. Little quantitative data are available so far, which allow conclusions about the comparative advantage to use any of these strategies or their combination.

On many acid soils P deficiency is the second most important factor limiting grain yield, not only because of the low inherent soil P content but also because of low contents of plant-available P due to the high fixation capacity of the soils.
It has been established that the roots are the natural indicator to identify edaphic restrictions which affect growth and development of plants. Therefore, do exist technical difficulties to quantify the spatial and temporal growth and distribution of roots at field conditions. Box (1996) describes many ways to measure the Roots Length Density (RLD), but their field application demands expensive techniques and the results obtained until now are not representatives of the roots development in a population of plants. Some researchers suggest that a shallow rooting and susceptibility to drought are caused, at least in part, by acidity (pH<5.5, 1:1 soil-water) and by the toxic levels of Al in the subsoil (Foy, 1992). The toxic effect of aluminum in the plants can be related to factors like: drought, P and calcium (Ca) deficiencies (Foy, 1994), and some soil physical properties associated not only to an increment of the soil bulk density (1.44 and 1.50 g cm^{-3}) but also to water-logging related to oxygen deficiency in the roots (Foy *et al.,* 1999).

The main objectives of this research were **1)** to study the effect on soil properties of maize cultivars differing in acid-soil tolerance and to evaluate agronomic practices, such as lime, P fertilizer and organic matter applications on the inhibition of Al and the availability of P, in a long term experiment established on acid soils of the Eastern plains of Colombia (**experiment A**) and **2)** to evaluate the effect of two organic matter sources on root growth and root distribution of two maize varieties on these acid soils (**experiment B**)

2. Activities

The field experiments were carried out in a soil classified as Tropeptic Haplorthox from the piedmont of the Eastern Acid plains of Colombia (located at La Libertad, experimental station of Corpoica) at 320 m.o.s.l., with a mean temperature of 27^{o}C and a relative humidity of 70-90%. Soil characterization is shown in table 1. The treatments were as follows: three organic matter rates (no OM, chicken manure and cowpea), two phosphorus levels (25 and 50 kg /ha), two lime levels (0 and 1.5 ton /ha) and three maize varieties with differential resistance to Al toxicity: Sikuani (Improved acid-soil resistant variety), Clavito (local variety) and ICA V-109 (Acid-soil sensitive) that we will call just ICA. The experimental design was factorial with randomized complete blocks with 36 treatments (12 for each variety and 4 replications) and 144 total experimental plots. The size of the plot was 5 X 5 meters, plant distance: 50 cm, furrow distance 80cm. (60 plants per plot) A basic fertilization was performed by adding to the soil nitrogen (N), potassium (K), Ca, Mg zinc (Zn) and boron (B). Maize was grown during five consecutive semesters, from 97a through 99a. After harvest plant residues were incorporated to the soil in all treatments. The 36 treatments were evaluated on the survival of maize seedlings at 5, 15 and 25 days after emergence (d.a.e.); on the agronomic parameters (plant height, leaves, stem and root weight, root volume and leaf area), on leaves elements concentration (ten elements) and on soil characterization (13 determinations) at female anthesis. Enough number of maize seeds were sowed, in such a way that once plants survival was checked, same number of plants continued growing in all treatments, 25 d.a.e. The agronomic parameter, grain yield was measured at harvest. Measurements were made by taking 18 plants per plot. After two semesters of fallow (99b and 00a) the residual effect of the treatments was evaluated in August 2000 (00a) by measuring the soil characteristics. This experiment (97a through 00a) will be called **experiment A** (long-term experiment) in the present report**.**

Another two field experiments were performed, in the same kind of soil of experiment A, during the two semesters of 1999. This experiment comprised the following treatments: three organic matter rates, (0, cowpea, chicken manure) and two maize varieties (Sikuani and ICA), six treatments in total, with a basic fertilization as follows for 99a semester: 100 kg/ha of N as urea, 50 kg/ha of P_20_5 as triple superphosphate and 75 kg/ha of K_2O as KCl. There was no basic fertilization during the 99b semester. The experimental design was factorial, with complete randomized blocks. In the present report, this experiment is going to be called **experiment B** which was used for two activities. The first activity was to evaluate a new technology in order to estimate root length density and root exploration from root counts (grid method) though the soil profile. This method includes a computer model, which has been developed by Chopart and Siband, (1999l called "RACINE" which was previously validated under African conditions, and then validated in the eastern plains of Colombia. The second activity was related to the effect of agronomic practices on root growth and root distribution in the soil.

The data of the experiments were submitted to statistical analysis, which comprised a general analysis of variance and Tukey test.

3. Results achieved

3.1. Experiment A

The discussion of the results in the present report for experiment A, will be based not only on the evaluation of the treatments effect on the dependent variables (soil characteristics, agronomic parameters and elements concentration in plant leaves) during each semester, but also on the variation or on the different tendencies of the responses to these treatments with time (among the five semesters).

3.2. Soil Characteristics

As shown in table1 the soil chosen for this study was very acid (low pH), with low OM content, as well as soil bases (Ca, Mg, K, Na) not only as exchangeable cations but when considered their saturation percentage, in relation to the cation exchange capacity (CEC) which is also low. It can be noticed that due to its high values, the dominant cation in the soil is Al, not only as exchangeable cation but also as saturation percentage related to the CEC. On the other hand, P and micronutrients are also deficient in the soil. From the chemical point of view it is a soil with very low fertility.

Tab. 1: Soil characterization

pH	OM	Al	Ca	Mg	K	Na	CEC	Al sat	Ca sat	Mg sat	K sat
	%	cmol+/kg						%			
4.5	1.8	2.1	0.40	0.15	0.09	0.13	4.06	73	9.9	3.7	2.2

P	Fe	Cu	Mn	Zn	B	Texture sand	silt	clay
		mg/Kg					%	
6.0	35	0.7	5.3	0.4	0.18	50	30	20

Under treatments effect soil characteristics were changed as follows:

- No effect of maize varieties on soil characteristics was registered.

- Applications of 50 kg/ha of P did not increase the available P (extracted by the Bray II method) in the soil when compared to the application of 25 kg/ha, in any of the semesters, with the exception of semester 00a, whose available P soil values were 21 and 36 mg/kg (with significant differences), when 25 and 50 kg/ha were applied respectively. There was no significant difference in the P available soil values when cowpea as organic matter source and lime were added, compared to their respective check treatments. The highest available P soil values were obtained when chicken manure was applied as organic matter source in all semesters with a mean value of 29 mg/kg compared to those obtained with cowpea and no OM treatments whose mean value for both sources was of 17 mg/kg, this was probably due to the higher total P content in the chicken manure compare to that of cowpea (table2). According to Melo et al (1999) most of the P content in the chicken manure is present in inorganic form, so this may help to increase the available P in the soil. Considering that the mean P content in the chicken manure is around 2%, with the 5 ton/ha of this amendment applied to the soil, 100 kg/ha of P were applied each semester. It was also observed that due to the residual effect of lime application (7.5 ton/ha) there was a decrease of the available P soil with time. Values of 24.8 (with lime) and 28.8 mg/kg (with no lime) were found in the 00a semester. The initial value of available P soil (8 mg/kg) registered at the beginning of 97a semester, increased along time with all treatments. There were registered 20, 23 and 32 mg/kg as mean values for the check treatment (25 kg/ha treatment), lime and chicken manure treatments respectively.

Tab. 2: Organic materials characterization.

	N%		C%		C/N		P(%)		K (%)		Ca (%)		Mg (%)		Al (%)	
Sem	Cowpea	Chick. Man.	Cowpea	Chick. Man.	Cowpea	Chick. Man.	Cowpea	Chick. Man.	Cowpea	Chick. Man.	Cowpea	Chick. Man.	Cowpea	Chick. Man.	Cowpea	Chick. Man.
97a	2.2	2.4	40	26	18	11	0.11	1.26	3.02	1.9	0.8	11.0	0.21	0.41	0.08	0.04
97b	3.1	2.3	44	28	15	12	0.8	2	0.9	2.3	0.9	12	0.21	0.71	0.14	0.1
98a	2.2	3.8	43	26	20	7	0.3	2	1.91	2.7	1.6	18.2	0.45	0.86	0.09	0.12
98b	2.6	2.4	40	25	15	7	0.2	1.8	2.15	2.8	1.9	10.3	0.34	1.12	0.1	0.25
99a	3.0	2.6	41	27	14	11	0.2	1.5	2.2	2.3	1.2	10.1	0.41	0.81	0.07	0.18

- The different forms of Al such as exchangeable Al (represented as Al), exchangeable acidity (represented as Al+H) and Al percentage saturation (represented as Al%) had responses to the treatments with significant differences, for most of the growing seasons (semesters) as follows: when OM, and lime were applied to the soil, the values were lower than those where none of these amendments were applied (check treatments). The soil treated with chicken manure as OM source presented lower values than that treated with cowpea. The values of these Al forms decreased along the time, not only in the soil under OM and lime treatments but also in those where no amendments were incorporated, however, the decrease was faster in the soil treated with OM and lime. The sulphate anion coming from the magnesium and calcium sulphates could help to precipitate the Al in the form of Al sulphate as was observed by other authors working in Brazilian Oxisols (Pavan et al. 1984). At the end of the fifth semester (99a) there were no significant differences among treatments. After two semesters of fallow (00a) without amendments addition, a decrease of the Al species was registered when compared to the values obtained in the 99a semester, specially in those soils where amendments were added. The values showed significant differences among treatments. Since the three Al forms (Al, A+H and Al%) analyzed showed the same tendency, only the Al saturation will be discussed as an example. The soil initial value (measured at the beginning of 97a, before sowing the first maize crop) of the Al% was 73%, this value in 99a (expressed as a mean of OM and lime treatments) was 6.5%. In the semester 00a this variable showed the value of 4.2%. It should be pointed out that Al was not detectable in the soil where lime was used as amendment when this parameter was measured in 00a. On the other hand, the pH initial value, 4.5 (beginning of 97a) increased up to values of 5.2 (99a) in all plots. Values of 5.74 and 5.80 were found in the soil plots where chicken manure and lime were applied in the 00a semester. From the previous, it may concluded that there was a strong residual effect of amendments on soil pH and soil aluminum.

- In an opposite way to the Al forms, the soil cations Ca and Mg as in their exchangeable content, as well as in their saturation percentage in relation to the CEC showed higher values in those soils treated with chicken manure as OM source and lime than in those not treated with these amendments. The values of these parameters increased with time, mainly under the OM and lime treatments. Taking the beginning of the semester 97a, the semester 99a and the semester 00a (mean values under OM and lime treatments) as a kind of time sequence, the values for Ca as exchangeable cation were: 0.4, 1.13 and 2.19 cmol+/kg and as saturation percentage were: 14, 36 and 59%. For the same time sequence, these values for Mg as exchangeable cation were 0.16, 0.32 and 0.63 cmol+/kg and 5.3, 9.13 and 17% as saturation percentage. It is convenient to remember that the Al saturation percentage values for this time sequence were 73, 16.5 and 4.2%. It is also remarkable to mention that CEC showed higher values on soils treated with OM and lime than in those not treated with these amendments. The mean values obtained for 97a, 99a, and 00a were 2.84, 3.15 and 3.68 % respectively. Even CEC had a low increase, it is important to notice that the colloidal complex of the soil, which was dominated by Al, which is a toxic cation to plants is now mainly saturated with Ca and Mg which are nutrient cations; meaning in that way, that soil fertility is increasing.

- Contrary to what was expected, OM applications did not increase the OM content of the soil (which was analyzed as organic carbon) even after the application of 25 ton/ha (during the five semesters). This was probably due to the very fast decomposition of organic materials coming from their narrow C:N relation especially chicken manure (table 2), which is convenient for nutrient supply to the plants but not to increase the humus content of the soil. The results obtained in the present study agree with those obtained by Estrada et al (1995), these authors worked with soy leaves in an Oxisol of Brazil.

- In relation to micronutrients, it was observed that there was no effect of the OM and lime treatments on their soil content. Mn decreased with time in all plots, may be due to its absorption by plants. Cu and Zn increased due to their soil application every semester as basic fertilization.

3.3. Agronomic parameters

Seedlings survival. According to the analysis of variance (ANOVA) it was observed a significant difference in the number of alive seedlings among varieties in all semesters and for the three checking times (5, 15 and 25 d.a.e.). There was effect of OM application at 5 d.a.e., but there was no effect of P and lime applications except for the 99a semester. Treatments (OM, P and lime applications) had a positive effect for all semesters at 15 and 25 d.a.e. The Tukey test showed that the means of the alive plants given as percentages, with all treatments were 80, 70 and 60 for Sikuani, Clavito and ICA maize varieties respectively from the mean of 15 and 25 d.a.e. Even the highest percentage of alive seedlings was obtained with the Sikuani variety, the highest response was obtained with the ICA variety. A statistical analysis of orthogonal comparisons, showed increments in percentage of alive plants, inside each maize variety compared with its own check treatment as follows: 5, 15 and 22% for Sikuani, Clavito and ICA respectively when organic matter was applied. The chicken manure was more effective on this parameter, with a significant difference of 3, 5 and 7%, inside Sikuani, Clavito and ICA respectively. When lime was applied the increments in percentage of alive plants inside each maize variety compared with its own check treatment were as follows: 0.7, 3 and 5%. When P was applied the increments even significant were lower than those obtained with lime. The previous agrees with the results obtained in Brazil with some of this practices with lime (Horst,1997), however, the use of OM is more effective than lime on the increase of plant survival in acid soils, especially for those maize varieties sensitive to Al toxicity.

According to the Tukey test, the mean values of the other agronomic parameters plant height, leaves, stem and root weight, root volume and leaf area, showed the following order of magnitude Clavito > ICA > Sikuani, with significant difference under all treatments. Lime and OM applications had a positive effect on these agronomic parameters which gave responses with significant differences compared to the check treatments. The effect of the chicken manure as OM source, was higher than that of cowpea. On the other hand, the grain yield obtained for the three maize varieties was in the following order: Sikuani > ICA > Clavito with values of 3586, 3220 and 2645 kg/ha respectively, however, the ICA variety had the greatest response in grain yield when compared to its check treatment, followed by Clavito and Sikuani varieties due to the lime, P and OM applications. Higher responses were obtained when OM alone or with lime was applied, than when lime alone was used. The effect of P X lime X OM on grain yield can be observed in table 3, where it can be noticed that the increase in percentage related to the check treatment for the ICA variety had very high values (between 124 and 245%) when the OM source was chicken manure, reaching grain yields up to 4843 kg/ha. The grain yields produced by the sensitive acid soil variety ICA, were similar or higher than those produced by the tolerant variety Sikuani, when chicken manure was applied as OM source.

Tab. 3: Grain yield (kg/ha) for the treatment interaction lime x P x OM and the increase pertence with respect to the check treatment for the experiments 97A – 99A.

VARIETY	CHECK TREATMENT					LIME X P X COWPEA					LIME X P X CHICKEN MANURE				
	97A	97B	98A	98B	99A	97A	97B	98A	98B	99A	97A	97B	98A	98B	99A
SIKUANI	3760	2666	2451	2912	4062	4049 (8)	3656 (37)	3137 (28)	3901(34)	4362 (7)	4576 (22)	3423 (28)	3310 (35)	3668 (26)	4741 (17)
CLAVITO	1803	1661	1185	1836	2062	2774 (54)	2774 (54)	3288 (177)	3083 (68)	2993 (45)	3620 (101)	3388 (78)	2899 (145)	3193 (74)	3789 (84)
ICA V-109	1630	1488	1051	1833	1849	3402 (109)	3402 (109)	3002 (186)	3867 (110)	3656 (98)	4430 (172)	3741 (151)	3636 (245)	4098 (124)	4843 (162)

The agronomic parameter grain yield was not stable in value in relation to time (figure 1). There was a deep decrease in the check treatment for Clavito and ICA varieties during 98a semester and for Sikuani during 97b through 98b semesters. These variability, probably due to the climate variations (El Niño phenomenon) was less drastic when OM and lime amendments were applied as can be observed in figure 1.

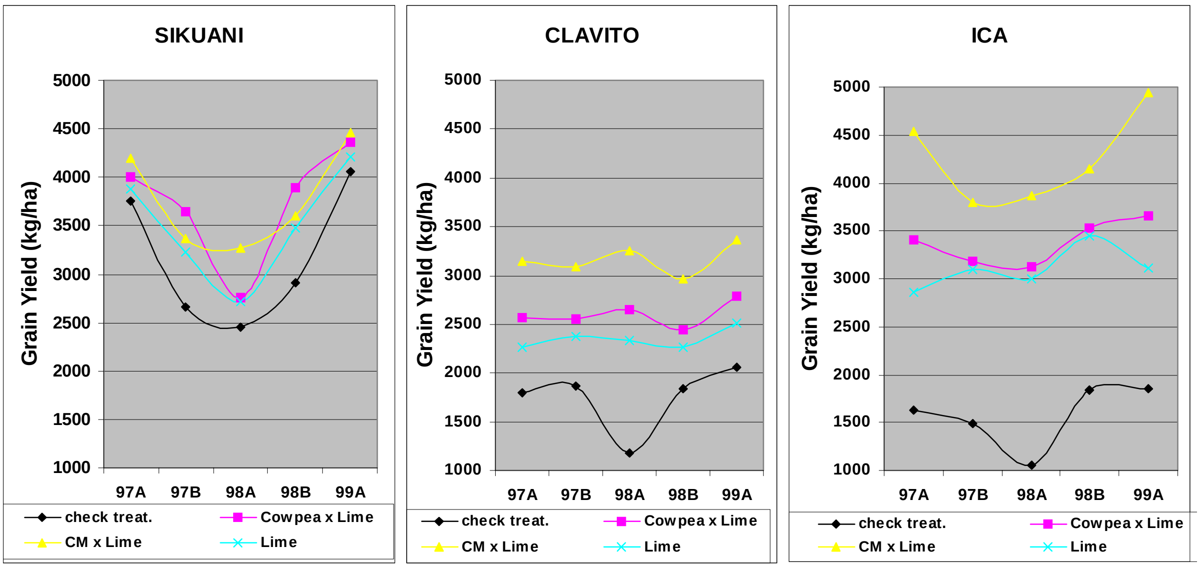

Fig. 1: Effect of organic matter and lime on grain yield for the three maize varieties.

3.4. Nutrients concentration in plant leaves

In relation to the nutrients concentration in plants leaves, the following was observed: the three varieties showed the same concentration for all nutrients, with the exception of the acid tolerant variety Sikuani, which presented more N and less K concentration than the other two varieties with significant difference; the organic material chicken manure induced more P and Ca concentration in plants leaves than cowpea and no OM treatments, due to the relative high content of these elements in that manure (table 2). The treatment of 1,5 ton/ha of dolomitic lime increased the leaves absorption of Mg and decreased the leaves absorption of Mn. The previous agrees with soil results for Mg but not for Mn. Lime increased available soil Mg but had no effect on available soil Mn as was expected. The previous was may be due to the basic fertilization applies, which was probably high enough to supply the amount of nutrients demanded by the plant

There was not an increasing or decreasing sequence with time in the nutrients content of plants leaves, but there were variations, may be due to the climate or some other conditions which will be investigated in future experiments.

About the Al concentration in plant leaves there was a decrease between the first (mean value of 186 mg/kg) and the second semester (mean value of 62 mg/kg) in the three varieties. There was no variation of these values with treatments nor time.

It should pointed out that as the nutrients concentration values as well as the Al concentration values found in plant leaves are in the range of values reported in the literature for the maize crop at anthesis time.

3.5. Experiment B

The discussion of the results from experiment B, related to the first activity about the RACINE model will be presented in the Dr. Jean Louis Chopart's report. In the second activity related to root growth, it was observed the following:

The principal differences in RLD among treatments in topsoil were due to the effect produced by the organic matter applications (caupí and chicken manure) when compared to the check treatments. Organic matter, especially chicken manure incremented roots length by soil volume, but not root front. There were no detected significant differences among treatments related to maize varieties, with exception of the check treatments, when Sikuani variety (acid soil tolerant) showed lower roots density than ICA variety (acid soil susceptible).

Experimental results showed that under all treatments, there was a shallow roots system, in such a way that 96% of it was found in the first 22.5 cm depth in both semesters. In fertile and deep soil conditions it is possible to find roots of maize plants at depths longer than one meter. Therefore, the experimental results showed a shallow rooting system during anthesis phase. In order to explain this inhibition, two hypothesis related to the presence of possible physical and/or chemical barriers coming from soils properties were analyzed.

On one hand, soil physical characteristics were considered, then, were taken some determinations about resistance to the soil penetration and its relation to depth in conditions of Field Capacity. The experimental results showed a direct relation of the Penetration Resistance with soils depth, with variations from 0.03 Mpa in the first 3,5 cm and 2,1 Mpa at a 43cm depth. This relation is opposite to roots development, because it was found that roots of maize plants have a limited or null growing when penetration resistance is higher than 1.33 Mpa.

On the other hand, some chemical properties of soil profile were evaluated (0, 10, 20 and 30 cm depth), OM, P, K, Mg, Ca, and Al soil content. The average values and the results of variance analysis and Duncan's Multiple Ranges Test expressed as the effect of the diverse variation sources (maize variety, organic matter and soil depth) of field experiments in 1999a and 1999a were analyzed. The statistical analysis showed that there were not significant differences in the soil chemical properties due to treatments (maize variety or organic matter applications) with exception of P and K concentrations when organic matter was applied to the soil, thus phosphorus increased from 13.5 to 25.5 mg/kg with cowpea and to 45.5 mg/Kg with chicken manure. However, values with significant differences were registered along the soil profile (30 cm depth). The highest differences in nutrient concentration were registered in P, K, Mg and Ca, when compared 0-10 and 20-30 cm horizons. P changed from 28 to 5 mg/Kg, K and Mg showed reductions of 50% from 0.16 to 0.08 cmol+/Kg and from 0.73 to 0.35 cmol+/Kg, and Ca between from 2.67 to 1.37cmol+/Kg during semester a. A similar behavior was observed during semester b, when two depths were analyzed: from 0-10 and 10-20 cm.

The opposite was registered in the case of aluminum in the soil, the exchangeable acidity (Al+H) increased from 0.78 to 2.26 cmol+/Kg (semester a) and from 1.34 to 2.10 cmol+/Kg (semester b), when measured at 0-10 and 10-20 cm, aspect caused principally by aluminum, which increased from 0.25 and 1.14 cmol+/Kg at the same depth ranges (semester a) and from 0.70 and 1.30 cmol+/Kg (semester b); this fact rebound in the aluminum saturation which changed from 5.7 to 28.6% (semester a) and from 14.6 to 37.2% (semester b).

In relation to the chemical soil properties, it can be concluded that a toxic effect inhibited roots development of maize plants due to the increment of aluminium levels with soil. These aluminium increments through the soil profile was related to low nutrients availability in the soil. Similar interactions between aluminium and soil bases have been reported by Foy (1992, 1994).

4. Conclusions and perspectives

4.1. Experiment A

- According to the results, there was no influence of the varieties on soil characteristics during the five semesters of growing maize.

- Lime and organic matter treatments (especially chicken manure) decreased the exchangeable Al in the soil diminishing therefore both, soil acidity and Al saturation percentage from 72 to 4.2%. Lime and OM combination decreased the Al concentration up to no detectable values.

- The sulphate anion added to all treatments (even to the check treatment) as calcium and magnesium sulphates, in order to have same levels of this cations, could help to decrease the exchangeable Al.

- Lime and organic matter increased the exchangeable form and the saturation percentage of Ca (from 14 to 34%) and Mg (from 5.3 to 9.13%) in relation to the CEC. According to ICA (1992), the adequate mean values of these parameters in the soil are 30-50% for Ca and 15-25% for Mg.

- CEC increased from 2.84 to 3.15 cmol+/kg still classified as very low, however, the colloidal complex of the soil even small is saturated mainly with the Ca and Mg cations instead of the toxic Al as it was at the beginning of the experiment.

- Lime (1.5 ton/ha) and P applications (50 kg/ha) did not help to increase the available P in the soil. Increments were registered when chicken manure (with or without lime) and cowpea with lime were applied.

- The decrement of the toxic aluminum and the increment of nutrients (exchangeable bases and phosphorus) induced an increase in soil fertility.

- Due to their fast mineralization, the organic materials used in the present study did not help to increase soil organic matter.

- In relation to the agronomic parameters, it can be concluded that the organic materials allowed to increase the number of alive seedlings especially for the variety sensitive to aluminum toxicity (ICA), Organic materials also allowed to increase plant height, leaves, stem and root weight, root volume and leaf area inside the three varieties, compared to their respective check treatment.

- The agronomic variable grain yield was sensitively increased by OM applications, especially for Al toxicity sensitive varieties with increments between 124 and 245% and grain yields up to 4843 kg Ha.

- Even OM increased the grain yield in a paramount form, especially for acid soil sensitive varieties, research is still needed to evaluate the relationship of this parameter with the plant nutrient uptake, soil processes and climate

4.2. Experiment B

- Experimental results indicate that drastic reduction in roots development of maize plants at the anthesis phase is related to the presence of physical and chemical restrictions, which were incremented in the same way as depth is incremented, finding that between 20 and 30 cm do exist extreme adverse conditions with a null or scarce development of roots in both varieties, spite of the positive effects of the organic matter additions to the soil that stimulated roots development, only on the topsoil. Increments of the Penetration Resistance in soils higher than 1.33 Mpa inhibit roots growing, suggesting compaction processes associated to aluminum toxicity problems caused by the increment of aluminum saturation (>28%) with soil depth. These aluminum variations in soils profile were related to the decrement of nutrients availability in the soil.

- Organic matter only affected soil chemical properties in the first 20 cm, especially P and Al concentrations. The reduction of Al toxicity into the soil profile and the increment of P available promoted root length and root exploration area in the top soil (22 cm). Such behavior had clear consequences in plant nutrient uptake (N, P, K, Ca, Mg,) and biomass accumulation in leaves and stems.

- In order to model soil-plant interactions, in the INCO II project, it will be considered to use the methodology RLD estimation and root exploration area as the main results obtained in the experiment B of this project (INCO I)

5. Puplications and thesis

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