Effect of conventional and organic vegetable production systems on soil chemical properties in the Bogota Plateau (Colombia)

Efecto de los sistemas de producción convencional y orgánico de hortalizas en las propiedades químicas del suelo en la Sabana de Bogotá (Colombia)

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ABSTRACT

At present there are two systems of vegetable production in the Bogota Plateau, the conventional production systems (CPS) and the organic production systems (OPS). Soil samples were collected from both production systems. Each soil sample was performed and analyses of fertility based on data mining of nutrients were diagnosed with various aspects of the fertility of the soil chemistry. These were compared them with the standards of fertility and to supply tools to increase the productivity organic production system. The two systems of vegetables productions present pH adapted that fluctuant between 5.5 and 6.6. In the OPS presented deficient contents of phosphorus in the 92% of the soil samples, objected to CPS where it prevailed the deficiency in 73 % of the soil samples. In the OPS presented deficient contents of sulphur in the 81% of the soil samples, contrasted with the 19% of CPS. The two systems of vegetables productions present deficient contents of manganese, reflecting the low contribution of this element in the plan nutrition, since the zone is deficient the contents natural.

Key words: ecologic, conventional, excesses, deficiencies, nutrition.

RESUMEN

En la actualidad se identifican dos sistemas de producción de hortalizas destacados en la Sabana de Bogotá, el convencional (SPC) y el sistema de producción ecológica (SPE). En cada sistema se tomaron muestras de suelo a las que se les realizó un análisis de fertilidad y en base a los datos de extracción de nutrientes se les diagnosticaron diferentes aspectos de la fertilidad química del suelo con el fin de compararlo con los estándares de fertilidad y suministrar herramientas para incrementar la productividad bajo el esquema ecológico. Se encontró que en ambos sistemas se presentan ambientes adecuados cultivo de hortalizas ya que el pH fluctúa entre 5,5 y 6,6. Se presentaron excesos de fósforo en el 92% de las muestras del SPE, lo cual es totalmente opuesto a lo ocurrido en el SPC donde predomina la deficiencia en el 73% de las muestras. En el SPE el 81% de las muestras presentaron deficientes contenidos de azufre en el suelo, mientras en el SPC el 19% las presenta. Ambos sistemas de producción presentan deficiencias en contenidos de manganeso reflejando el bajo aporte de estos elementos en el plan de manejo de fertilidad ya que los contenidos naturales de las zonas son deficientes.

Palabras claves: ecológico, convencional, excesos, deficiencias, nutrición.

Introduction

The world population growth has brought along an increasing demand for food, which led to the development of modern forms of agriculture and an increased use of soil resources. This has gradually led to "intensive management" with the use of highly developed technology and tools, inevitably resulting in the process of soil degradation in agricultural systems (Mileti *et al*., 1998).

These intensive cropping systems seek for better results through optimizing the use of resources, which allows them to yield more annual crops out of a smaller selection of products. Repeated nutrient extraction by these products naturally determines a gradual impoverishment of the elements found in the soil.

Located west of the Bogota Plateau in the department of Cundinamarca, the municipalities with larger acreage in vegetable production systems are Madrid (436.3 ha), Mosquera (304.8 ha), Cota (263.6 ha), Cajicá (207.6 ha), Facatativá (140.1 ha) and Soacha (133.71 ha), which stand out for their yields and cultivated areas in Swiss chard, celery, broccoli, coriander, cauliflower, spinach, lettuce, parsley and cabbage (DANE, 2002).

These cultivated species are highly nutrient demanding (Tab. 1), especially regarding nitrogen, which is a very important element for successful development of the aerial part of the plant. This element is extracted at an average of 590 kg ha^{-1} - year, depending on crop species and rotation (CIAA, 2008). Repeatedly planting the same crops over time generates nutrient imbalances and results in yield reductions that in turn determine economic losses.

Recceived for publication: 25 February, 2009. Accepted for publication: 13 November, 2010.

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Direct indicators commonly used to measure edaphic constraints correspond to physical, chemical and biological soil properties (SAG, 2005). Said constraints should always be viewed altogether and never separately, because they are closely related to one another, and combine to create specific functions such as soil stability, potential production, plant growth limitations, microbial activity and nutrient availability (SAG, 2005).

Chemical indicators of soil quality include properties that affect soil-plant relation, water quality, soil buffering capacity and availability of water and nutrients for plants and microorganisms. Since these important fertility standards determine crop productivity (Tab. 2), this work intends to lay the groundwork for a diagnosis of the processes that affect such standards, in order to increase productivity under the organic farming scheme.

Two vegetable production systems can be currently identified in the Bogota Plateau: the conventional system (CPS), which is the most representative; and the organic production system (EPS), whose acreage has increased considerably.

Description of the production systems

Conventional production system, CPS

The priority in conventional agriculture is productivity. Consequently, its purpose is to increase yield per unit area. This implies a high dependence on external inputs such as synthetic fertilizers and agrochemicals, in order to control the threat posed by pests and diseases on productivity.

However, this production system has shown serious problems of sustainability, as observed after twenty or thirty

TABLE 1. Soil extraction of macronutrients (Kg ha^{-1}) by the main leafy vegetables and brassicas (cycle).

Crop	N	P_2O_5	K_2O	CaO	MgO	S
Swiss chard	150	70	220	128	50	10
Celery	200	80	300	175	25	13
Broccoli	198	65	295	172	20	13
Coriander	130	55	55	32	-	8
Cauliflower	250	100	350	204	30	16
Spinach	120	45	200	116	35	8
Lettuce	90	40	160	90	20	10
Parsley	130	55	55	32	-	8
Radish	276	89	389	76	226	18
Cabbage	120	35	110	21	5	8

Source: CIAA (2008).

TABLE 2. General criteria for the interpretation of soil analysis results.

Element	Units	Deficient	Optimum	Excess
min-N	mg kg^{-1}	50	60	70
P (Bray II)	mg kg^{-1}	20	30	40
S	mg kg^{-1}	45	60	75
K	cmol kg^{-1}	1	1.4	1.8
Ca	cmol kg^{-1}	6	10	14
Mg	cmol kg^{-1}	3	4	5
Na	cmol kg^{-1}	-	-	0.2
CIC	cmol kg^{-1}	10	15	20
Fe	mg kg^{-1}	15	20	25
Mn	mg kg^{-1}	11.3	15.0	18.8
Cu	mg kg^{-1}	1.1	1.5	1.9
Zn	mg kg^{-1}	3.4	4.5	5.6
B	mg kg^{-1}	0.34	0.45	0.56

Source: Gómez (2005); CIAA (2008).

years of intensive use in cotton growing areas in Central America, banana plantations in the south of Costa Rica or onion fields in the department of Boyaca in Colombia. The CPS is also credited to have caused not only the destruction of natural resources and landscape, but also the disappearance of small farmers in some areas (FIDA, 2003).

As for fertilization, there is a wide variety of products available in the market of the Bogota Plateau, but the use of poultry manure mixed with compound fertilizers clearly stands out, especially 15-15-15, which is used by 84% of the producers applying synthetic fertilizers, while the remaining 16% uses 13-26-6 and ammonium nitrate (Escobar *et al*., 2008).

Ecological production systems, EPS

Ecological production constitutes a trend framing all agricultural systems (EPSs) devoted to the healthy and safe production of food and fibers as assessed from an environmental, social and economical standpoint. These systems base agricultural production on soil fertility (COAG, 2006).

Organic farming greatly reduces the need for external inputs by not using pesticides and synthetic fertilizers. On the other hand, consumers of organic products are guaranteed that all techniques used in the production process are consistent with a certification system.

Colombia has been making inroads in the market of organic agricultural products since 1998. In 1999, the country had 20,000 ha certified as organic; in 2001, they were 25,000 ha; in 2003, they reached close to 30,000 ha, and in 2005, almost 37,000 ha (MARD, 2005).

Organic production systems lack adequate technologies to address production problems, especially those regarding nutrition and plant health. Producers working under this scheme compensate for this deficiency with scarcely validated information usually transmitted orally among producers, without the corresponding scientific support.

Developments in nutrition of organic crops are scarce. Farmers generally use an ample variety of organic materials, which, together with the broad biodiversity of the tropics, hinders the process of scientific validation.

Materials and methods

Fifty-two soil samples were collected from organic and conventional production systems in different places of the Bogota Plateau, specifically the municipalities of Madrid, Subachoque, Sopó, Cajicá, Soacha, Chía, Cota and Sibaté. The samples were taken from plots with more than three years producing tomato in greenhouse, leafy vegetables, brassicas or onion.

EPS soil samples were taken from farms belonging to "Asociación de Productos Ecológicos Huertos Verdes"[1] and " Cooperativa de Trabajo Asociado para el Desarrollo Integral del Tequendama - Coomutsoa". Information about the CPS soil samples was obtained from the database of the CIAA[2] soils laboratory, making sure the plots had been devoted to the conventional production of the crops in question for at least three years.

Soil sample fertility was analyzed in the Soils Laboratory of the CIAA, in order to determine pH, electrical conductivity, CEC, cationic ratios and macro and micronutrients. The methodologies implemented for the assessment of these parameters were: pH in water (1:1), CEC and exchangeable bases in ammonium acetate (1:20), minor elements in DTPA (1:2), boron (B) and EC in saturation extract, S by turbidimetry, phosphorus (P) by Bray II and mineral N in KCl (1N).

Based on soil nutrient uptake and optimum level data for each crop, which were taken from the database of the laboratory, we diagnosed different aspects of soil fertility such as acidity and alkalinity, salinity, sodicity, cationic balances, and nutrient levels and excesses or deficiencies.

Results and discussion

The results of each production system, namely a) conventional, b) ecological, are then discussed in terms of the parallel between them.

CPS

The soils of the sampled CPSs of the Bogota plateau exhibit moderately acid pH values averaging 5.8, and an electrical conductivity of 1.01 dS m^{-1}.

In 88% of the sampled farms we found nutrient excesses caused by at least one of the major elements. Fifty percent of these excesses correspond to N, mainly resulting from the contribution of large doses of N-based fertilizers. This situation is caused by ignorance about the availability and efficiency of existing fertilizer sources, and about the actual fertilizer needs of the different crop cycles. Tagliavini *et al*. (2004) mentions that fertilizer amount reduction

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1 "Green Gardens", Ecological Product Association

2 CIAA stands for "Centro de Investigaciones y Asesorías Agroindustriales", that is, "Centre for Agroindustrial Research and Consulting"

TABLE 3. Percentage of CPS soil samples found to have excesses or deficiencies in farms of the Bogota Plateau.

Element	Excess (%)	Adequate (%)	Deficiency (%)
min-N	65.38	23.08	11.54
P	7.69	23.08	69.23
K	61.54	26.92	11.54
Ca	15.38	57.70	26.92
Mg	23.08	61.54	15.38
S	26.92	53.85	19.23
Fe	100.00	0.00	0.00
Mn	3.85	61.53	34.62
Cu	23.08	50.00	26.92
Zn	46.15	42.31	11.54
B	0.00	46.15	53.85

TABLE 4. Percentage of EPS soil samples found to have nutrient excess or deficiency in vegetable farms of the Bogota Plateau.

Element	Excess (%)	Adequate (%)	Deficiency (%)
min-N	38.46	38.46	23.08
P	65.38	19.24	15.38
K	53.85	42.3	3.85
Ca	34.62	46.15	19.23
Mg	42.31	46.15	11.54
S	7.69	11.54	80.77
Fe	92.31	7.69	0
Mn	0	23.08	76.92
Cu	23.08	34.61	42.31
Zn	61.54	26.92	11.54
B	7.69	19.23	73.08

constitutes part of the process leading to the sustainable production of vegetables.

As for the contents of P in soil, 73% of the samples proved to be deficient. These systems are receiving low contributions of this element, mainly because of the high prices of phosphorus fertilizers, among which that of triple superphosphate has been observed to rise by nearly 315% in several South American countries along a period of 8 years (Saldías, 2008). In the case of the Bogota Plateau, P-based fertilizer compounds such as 10-30-10 increased their prices by 224% over a period of two years (SIPSA, 2008 and SIPSA, 2006). Also noteworthy is to recall that vegetable producers in Cundinamarca have reduced the use of synthetic fertilizers by 26% in recent years (Escobar *et al*., 2008).

In this system, the contribution of organic material mainly comes from poultry manure, as the agroindustry of the region and its surroundings is permanent supplier of this material (Forero *et al*., 2008).

As for the minor elements, we could observe a consistent excess of iron (Fe), which is a common feature in these soils. As the content of boron (B) is deficient in about half of the samples, it is necessary to supply this element in the fertilizing programs at the recommended doses, since it easily passes from deficiency to excess, and is likely to be toxic for the crop.

EPS

The sampled soils under this production system are characterized by pH values around 6.0 and an average electrical conductivity of 0.58 dS m^{-1}. It is worth noting the poor nitrogen content of these soils, which was observed in 77% of the samples. Under this system N is supplied through a continuous provision of different organic materials, among whose disadvantages when compared to synthetic chemical fertilizers is their uncertain contribution of mineralized N. This is so because the availability of this element after the application of an organic fertilizer cannot be estimated from total N content in the added material, but is conditioned by a number of factors affecting its release, which are capable of either slowing or speeding it up.

The use of organic materials in different production systems has spread widely. However, no scientific or technical criteria have been developed to base their application on their chemical properties, specifically the contribution of N, which is the most appreciated element when assessing the quality of an organic fertilizer (Gómez, 2000). Forero *et al*. (2008) mention that in the case of the Bogota Plateau, the most representative total N contents can be found in rabbit (2.43%) and cow (2.40%) manures, and in rose compost (2.27%).

In 96.1% of the samples we found major element excesses mainly due to phosphorus (92% of the cases). The most common source of this element is phosphate rock (23% P_2O_5, 18% CaO), which is provided in doses above 100 g m^{-2}, ya que el fósforo no es disponible por la planta.

Only a few productive units under this production system proved to be P, K or Mg deficient, reaching respective percentages of 3.85, 3.85 and 11.54% of all sampled units. These numbers are consistent with findings by FAO (2005), in the sense of the accumulation of 50 to 75% of these elements in the soil surface due to the decomposition of crop residues, which takes place mainly at this level.

Sulfur (S) deficiency was detected in 81% of the sampled farms. This being a mobile element in soil (Gómez, 2005), it is easily lost by leaching, runoff or volatilization (Burbidge, 2001). Although the application of sulfates such as agricultural gypsum and magnesium sulfate are allowed by the regulations of these systems, ignorance about timing and doses has determined the prevalence of this deficiency.

On the other hand, it is worth mentioning the deficiencies of Mn (77% of the samples) and B (73% of samples), resulting from the scarce sources of these elements that are allowed under the ecological scheme of production. Currently, products such as manganese sulfate (30% Mn) and Boraxita® (13% B) are being incorporated into the development of fertilization strategies for these systems, in order to correct these deficiencies in the soil.

Parallel between CPS and EPS

The optimum pH value for leafy vegetable production is 6.6, an infrequent value in the farms under either of the studied production systems. In most organic production systems pH ranges from 5.5 to 6.6, whereas under the conventional scheme it oscillates between 5.5 and 6.3. In the conventional system this parameter fluctuates more than in the organic one because most nitrogen fertilizers used in the conventional scheme such as ammonium nitrate and ammonium sulfate, which have an acidifying effect (Burbidge, 2001).

According to Medina (2005), under the CPS usual doses of poultry manure in vegetable crops can vary between 15 and 70 t ha^{-1}, depending on the crop and the area. In characterizing the organic materials used as fertilizers in the Bogota Plateau, this author has established that this type of manure has respective K and Ca average contents of 1.8 and 8.4% (dry basis), thus corroborating that the application criteria of the producers are quite empirical.

Escobar *et al.* (2008) mention that 83% of vegetable growers are using organic materials, out of which poultry manure corresponds to 63% of the cases. These inputs produce a moderate soil pH increase, reflected in our CPS pH records.

TABLE 5. Analysis of variance for pH, EC and min-N assessed in vegetable production farms of the Bogota Plateau.

FV	DF	Mean square values		
		pH	EC	min-N
Tratament	1	0.8125	0.2490*	2.4645*
Variation coefficient		9.2594	20.8352	22.9617

* Significant differences $P \leq 0.05$;

TABLE 6. Behavior of pH, EC and min-N average values in ecological and conventional production systems in the Bogota Plateau.

System	pH	CE	min-N
CPS	5,7846 a	0,8894 a	68,2635 a
EPS	6,0346 a	0,6471 b	35,3872 b

Means in the same column followed by different letter indicate a significant difference accordihg to Tukey test ($P \leq 0.05$).

Electrical conductivity in conventional production systems is higher than that of organic production systems, driven primarily by excessive liming and synthetic fertilization in some areas of the Bogota Plateau, resulting in soil Ca surplus. This has led to increased cationic ratios, namely Ca to Mg in conventional production systems, and K to Ca and Mg in organic production systems.

In turn, sodium (Na) excessive levels were observed to be proper of farms under the conventional scheme. In some cases the content of this mineral, whose excess comes from irrigation water, can be found above 1,000 mg kg^{-1}. Sodium surplus has an adverse effect on soil structure and makes it more difficult to manage fertility, as the soil contents of Ca, Mg and K have to be concomitantly raised, with the consequent alteration of their cationic balance.

In the organic production systems 27% of the farms showed excessive Na levels, which has favored the emergence of symptoms of Ca deficiency in species such as Swiss chard and spinach. Ca being an immobile element in the plant (Medina, 2003), its deficiency determines curled and size-reduced young leaves.

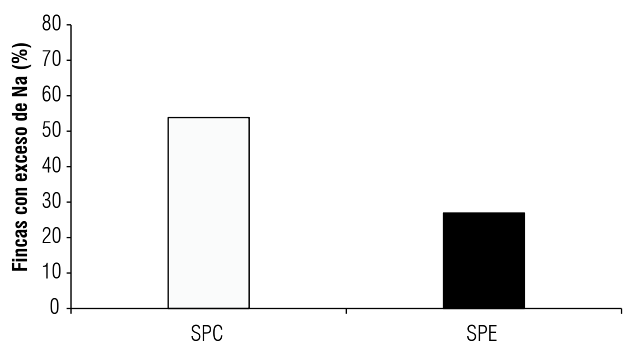

FIGURE 1. Sodium excesses in the vegetable production systems of the Bogota Plateau.

The soils of the surveyed organic production systems have an average organic matter content of 6.8%, which is high and is reflected in correspondingly elevated CEC and total nitrogen records. In the conventional production systems CEC averaged 39.3, a lower value than that of the organic production systems, explained by the continuous supply of organic materials that is proper of the EPS.

There was a sharp contrast in the management of P in the studied systems. It was in excess in 92% of the soils sampled in the EPS, and deficient in 73% of CPS samples. Soil P is mostly unavailable to plants, as it is in the form of iron and aluminum phosphates. For this reason, phosphate rock amendments considerably increase the content of this element, but do not guarantee the correction of its deficiency.

A similar situation was observed with regards too S, whose deficiency was observed in 81% of the EPS samples, and in 19% of the CPS ones. This is mainly due to the fact that S contents rarely reach values higher than 0.2% in organic materials (Cuesta, 1990), and therefore is a low-value parameter in these materials (Gómez, 2000). S content (dry basis) of the organic materials obtained in the surroundings of the Bogota Plateau reaches an average 0.29% (Forero *et al.* 2008).

Compound fertilizers such as 15-15-15 and 10-30-10, widely used in the cultivation of leafy vegetables, have no S in their chemical composition. This has led to the use of sources such as ammonium sulfate (21-0-0 -24S) and agricultural lime (0-0-0-26Ca-14S) to meet the need for this element.

The organic production systems were found to be deficient in Mn, mainly due to misinterpretation of fertility analyses and to the products used to supply it to the soil.

A continuous input of organic materials, mainly rabbit, pig and poultry manure, among others, imply an elevated Zn supply, which is reflected in the excesses of this element that we found in both systems. Gómez (2000) mentions that among the strengths of poultry manure is an elevated Zn content, ranging between 250 and 450 mg kg^{-1}, while Forero *et al.* (2008) found that when this type of manure is obtained in the surroundings of the Bogota Plateau it has Zn contents of 307 mg kg^{-1} in average, reaching maximum values of 542 mg kg^{-1}.

Conclusiones

The results reflect a contrasting management of P in the two systems. In the CPS soils it was found to be deficient due to the limited use of fertilizing materials containing this element; while in the excesses found in the organic scheme are due to continuous inputs of phosphate rock.

It is important to highlight the N deficiencies found in the EPS, since this is a very mobile soil nutrient that is lost mainly by leaching and crop harvesting. On the other hand, there is very little research on the mineralization of this element in Colombian soils. N excesses are more common than deficiencies in the conventional scheme as the management of fertility is very empirical and does not take into account the needs of the crop or the properties of each soil. Sulfur is the most commonly observed deficiency in the organic production farms. This indicates the lack of soil analyses, since this deficiency can be fairly corrected through the use of agricultural lime and sulfates, which are authorized for these systems.

The elevated Na contents detected in the CPS soils are mainly due irrigation water.

Most of the farms studied in both production systems in the Bogota Plateau showed deficiencies in the contents of Mn and B, mainly due to the lack of chemical analyses and inadequate soil fertility management with the products that have been traditionally used. It is necessary to supply these elements at recommended doses.

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