Evaluation of the effect of diatomaceous earth as a sustainable alternative in commercial interest crops in Colombia

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Abstract

Current production of seasonal crops needs to have more efficient integrated handling to obtain expected returns, contribute to sustainability and the environment, as an alternative incorporating in bio-agricultural inputs. The aim of this research was to evaluate the effect of diatomaceous earth (TDDA) as bioinput, fertilization and biological control in commercial crops: corn (*Zea mays*), bean (*Phaseolus vulgaris* L.), carrot (*Daucus carota* L.) and yellow potato (*Solanum phureja*). We compared the following treatments: TDDA + commercial compost, TDDA + chemical fertilizer, TDDA + compost and control (traditional chemical). The fieldwork was conducted in private property located in Guchipas, a municipality of Pasca, (Cundinamarca department). We performed a Latin square design for each crop. Chemical analyses were made at the private Calderon's soil laboratory. For data processing we used MEANS in SAS statistical package (version 9.0). When a significant effect ($\alpha=0.05$) was shown by the Tukey means test, significant differences between crops for physiological variables (leaf area index, relative growth rate, dry weight, fresh weight and height) were found ($P<0.05$). The best results for phenological variables and productivity were obtained for TDDA + chemical fertilizer, and TDDA + compost treatments. Pests as whitefly (*T. vaporariorum*) and thrips (*Thrips tabaci*) were controlled. Diatomaceous earth application allows the dose of chemical fertilizers, thereby promoting healthier environmental management.
Keywords: diatomaceous earth, sustainability, commercial crops, productivity and environment.

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1 Introduction

Organic fertilizers have been used since ancient times and their influence on soil fertility has been demonstrated, although chemical composition, contribution of nutrients to crops, and effect on soil vary according to origin, age, and management moisture content (Tester [1]). Diatomaceous earth is a product obtained from unicellular algae remains which are fossilized diatoms found mainly in sediment. TDDA consists in 65.61% of silicon dioxide (SiO_2) with 29 trace elements in different proportion (Gunes *et al.* [2]). Miligan and Morel [3] reported that TDAA can be used as a complement and not a substitute for agricultural inputs applied. The silica is not considered an essential element for plants, but is reported to benefit crops by inducing resistance and protection against biotic and abiotic environmental factors, and improving yields and quality of crops. Other studies [2, 4, 5], showed increased quality of soil by adding nutrients.

Environmental pollution and productive soil implement alternatives that do not alter the balance of the system giving rise to the expected beneficial in soil and the environment. In this context, this research had a special interest in implementing diatomaceous earth or diatomite as a bioinput in the Sumapaz area. For these reasons, this study aims to answer the following question: What is the effect of using diatomaceous earth as a bioinput in commercial crops (corn, beans, carrots and yellow potatoes) under environmental conditions of the municipality of Pasca?

2 Methodology

2.1 Study area

The private land for evaluating diatomaceous earth (TDDA) is located in Guchipas village, which is approximately 2 kilometers from the municipality of Pasca (Cundinamarca department). Agricultural production is completely rural; the main crops being onions, beans, corn, potato, tomato, peas, carrots and blackberries. Guchipas is 1900 meters above sea level, with a cold-temperate climate and temperatures of between 16 and 18ºC.

2.2 Experimental design

This research took place in an area of 308 m^2, where the following species were planted and evaluated: maize (*Zea mays*), bean (*Phaseolus vulgaris* L.), carrot (*Daucus carota* L.) and yellow potato *(Solanum phureja*). We compared the following treatments: TDDA + commercial compost, TDDA + chemist fertilizer, TDDA + compost, and a control (traditional chemical). We used a Latin square design for each crop and every treatment had four replicates in 10 experimental units. This type of design is used to conduct experiments under heterogeneous conditions where the properties change in two directions. Experimental units were grouped in two directions (rows and columns) and were treated randomly.

To evaluate treatment, the GLM procedure in a SAS statistical package (version 9.0) was applied.

2.3 Field phase

Seeds of species were mixed with diatomaceous earth 24 hours before sowing. The bio-input ratio used was 15g per kg of seed; the seeds were mixed in dry. Four fertilizers were divided over different plant vegetative states; these fertilizers were put on, on the same date for different crops.

The leaf areas – fresh and dry weight – were taken after fertilization, in order to obtain the performance of physiological and morphological variables for comparative analysis of each treatment by using the bio-input. Best treatment on yields was determined by counting pods per plant, weight and number of grains per pod (for the beans case), weight and number of ears (for corn), and weight and number (for carrot and yellow potatoes).

The use of crop protection products was given under the parameters of visual damage (severity) and the incidence of different pests and diseases, field annotations were made for monitoring pests during the crop growth.

2.4 Laboratory phase

The chemical parameters (OM, OC, macro and microelements) were determined in the private Calderon's soil laboratory.

3 Results and discussion

3.1 Chemical parameters

The elemental composition of fertilizer is shown in table 1. Organic matter (OM), was significantly higher ($P<0.05$) in soil after fertilization (15.76%). As indicated by Huang *et al.* [6], the value of the compost mixed with TDDA in all forms comes from contributing the soil organic matter, with optimum values of between 15 and 35%, thereby increasing water retention capacity; being a rich source of nutrients for plants. The range of values mentioned is close to those obtained.

The three macro-nutrients (NPK) show differences significantly ($P<0.05$) higher after fertilization. These results show a similar trend to that reported by Paredes *et al.* [7], where P and K contents are higher in mixtures with animal manure fertilization. After fertilization the soil shows better chemical conditions. One factor that influenced and its increase was the incorporation of organic matter into compost applications, because they produced humic substances chemically and biologically modified, constituting the most active fraction of organic matter to most organic reactions. Other results [8, 9], showed chemical conditions in soil after fertilization.

Table 1: Results of chemical parameters before and after fertilization.

Parameters	Unit	Before fertilization	After fertilization
Organic matter	% OM	13.21b	15.76a
pH		5.4a	5.9a
Potassium	% K	0.36b	0.73a
Nitrogen	% N	30b	40a
Phosphorus	% P	28b	34a
Calcium	meq/100g	4.31b	5.18a
Magnesium	meq/100g	1.17a	2.0a
Iron	meq/100g	136b	150a
Sodium	meq/100g	0.37b	1.45a
Manganese	meq/100g	13.21b	14.76a

Different letters indicate significant differences ($P<0.05$).

3.2 Phenological variables

In all crops, the process of seed germination can be affected by seed quality, the environmental conditions (water, temperature, oxygen and light), free seed dormancy and absence of pathogens (Salisbury and Ross [10]).

We found germination percentages in all crops with TDDA + compost was significantly higher ($P<0.05$) than other treatments (Tables 2, 3, 4 and 5). One reason implies that the organic fertilizers in such compost have a lot of moisture which is absorbed by the generating seed germination in less time; the use of good quality seeds also supports. The poor quality seeds have poor growth and vigor which is affected by external factors such as nutrition of the mother plant, mechanical damage caused by processing, and seed storage that can be important in establishing a culture (Vargas *et al.* [11]).

Table 2: Corn phenological variables.

Treatments	Germination (%)	Leaf area Index	Relative growth rate	Fresh weight (g)	Dry Weight (g)
TDDA + chemical fertilizer	95.2a	0.17ab	0.098a	86.3a	19a
TDDA+commercial compost	78.3bc	0.15bc	0.030c	76.4c	9.9c
TDDA + compost	94.3a	0.21a	0.08b	85.4a	18.2b
Control-traditional chemical	80.2b	0.16b	0.09b	77.9b	15.7bc

Different letters indicate significant differences ($P <0.05$).

Table 3: Bean phenological variables.

Treatments	Germination (%)	Leaf area index	Relative growth rate	Fresh weight (g)	Dry weight (g)
TDDA + chemical fertilizer	93.6^{b}	0.016 a	0.07 a	28.9 a	29.98 a
TDDA+commercial compost	92.9^{b}	0.013 b	0.044 c	15.9 c	19.93 c
TDDA + compost	95.2^{a}	0.016 a	0.061 b	26.7ab	28. 7 b
Control-traditional chemical	92.4b	0.011 b	0.059 bc	19.3 b	22.1 bc

Different letters indicate significant differences (P <0.05).

Table 4: Carrot phenological variables.

Treatments	Germination (%)	Leaf area index	Relative growth rate	Fresh weight (g)	Dry weight (g)
TDDA + chemical fertilizer	63.4ab	0.013a	0.05ab	48.9a	43.8a
TDDA+commercial compost	45.9c	0.010b	0.022c	32.9c	34.7c
TDDA + compost	72.9a	0.011ab	0.07a	42.4b	41.8ab
Control-traditional chemical	56.3bc	0.018ab	0.48ab	39.8b	37.7b

Different letters indicate significant differences (P <0.05).

Table 5: Yellow potato phenological variables.

Treatments	Germination (%)	Leaf area Index	Relative growth rate	Fresh weight (%)	Dry Weight (%)
TDDA + chemical fertilizer	76.7ab	0.18ab	0.08b	57.7a	31.3ab
TDDA+commercia l compost	73.9ab	0.13bc	0.06c	46.4a	29.9a
TDDA + compost	88.7a	0.21a	0.09a	45.4a	28.2a
Control-traditional chemical	70.5ab	0.11c	0.08b	46.6a	35.7a

Different letters indicate significant differences (P <0.05).

Compost applied was a mix of chicken and cattle manure. The results obtained could be due to fertilizers and chicken manure; they are the best nitrogen-fixing providing nutrients to soil and have positive influences on soil structure. Sánchez *et al.* [12] mentioned that manure can alter the microbial population allowing a greater exchange of nutrients by the formation of aggregates at the roots of plants.

In general, the best results of the growth variables in the vegetative stage occurred in the TDDA + chemical treatment, partly due to the chemical components and their contribution containing minerals in the soil. Also TDDA + compost has important results, indicating that the organic fertilizer effect was almost similar to the chemical, allowing an alternative fertilization to generate, especially in corn, beans and carrots. Bernal *et al.* [13] conducted an assessment of the effect of mineral and organic fertilizer (manure) on growth and yield of maize and beans, achieving the best returns in the manure treatment. Other studies [14–17] showed that compost is an alternative fertilizer.

A constant behavior in the early stages of plants was shown, probably due to production of sheets which could be synthesized by a charge of nutrients. Barraza *et al.* [18] and Abad *et al.* [19] reported a correlation between the process of growth and development of various parts of the plant, which can be explained in terms of supply and demand, so it is spending its reserves mainly endospermically and additionally begins to extract the nutrients available in the soil. As a result, the metabolism is accelerated in order to produce the carbon skeletons for growth.

3.3 Productivity

The best treatments measured by crop yields were TDDA + chemical fertilizer for carrots and corn (table 6). TDDA + compost for beans, and Traditional chemical for potatoes, TDDA + commercial compost treatment, shows significant differences ($P < 0.05$), probably for nutrient deficiencies.

The crop yields are seriously compromised by environment conditions, such as weed presence, low solar radiation, relative humidity, water retention, genetic soil type and fertilization. The crop yield reduction also is determined by distribution of assimilates produced in the secondary structures during the initial development phase, where it competes strongly for available assimilates to developing fruits (Biederbeck *et al.* [20]).

For the beans crops, TDDA + compost was better. Estrada and Peralta [21] show two types of organic fertilizers (chicken manure and cow manure) and mineral growth and crop yield of the common bean (*Phaseolus vulgaris* L.) variety DOR-364: the best results with organic fertilizers, mentioned that the presence of organic substrates in both instances (bioassay, rhizosphere) enhance the growth of microorganisms (especially bacteria), which immobilize nutrients to increase biomass. Immobilized nutrients can be available to other microorganisms and plants during their growth cycle. Other studies [22, 23], reported an increase of productivity by using compost in crops systems.

Table 6: Crop yields.

Crops	Corn		Bean		Carrot	Yellow potatoes	
Treatments	ears no.	ears wt.(g)	pods no.	pods wt. (g)	wt. (g)	no.	wt. (g)
TDDA + chemical fertilizer	2.1a	397.5a	19.5a	40.1b	84.9a	8.4ab	58.3ab
TDDA+ commercial compost	1.4b	299.2c	10.1 c	37.2b	65.5 c	5.3bc	49.9 c
TDDA + compost	2.0a	378ab	18.2ab	41.3a	72.8ab	5.4bc	55.2ab
Control-traditional chemical	1.7b	303.2b	15.7b	39.6ab	77.9b	9.7a	65.7a

Different letters indicate significant differences ($P < 0.05$).

Organic fertilizers can be an alternative to replace inorganic fertilizer, as indicated above, additionally to supplying organic fertilizers to the soil with nutrients like N and other essential elements contained in the compost and TDDA. De Bertoldi *et al.* [24], Eghball *et al.* [25] and Illner *et al.* [26] indicated that manure mineralized at around 70% after the first year of application, and residual soil effects over two years and that remaining was transformed into humus, which is incorporated into the soil and produces a beneficial effect in the structure of the soil during the first year.

Only yellow potato crops showed better results with chemical fertilizer; this might be caused by demands of crop, seed quality and environmental conditions. Rodríguez and Ñústez [27] found that chemical fertilizer components in potato crops were slowly absorbed, thus allowing the continuous incorporation of minerals in the ground and reflecting an increased production.

3.4 Biological control

The higher incidence of crop pests in beans showed similar proportions in each treatment, especially whitefly and thrips (*Thrips tabaci*). The diatomaceous earth combined with natural or chemical insecticides acting effectively control the whitefly (*Trialeurodes vaporariorum*), reducing significantly pest populations and avoiding damage of the cultivation. The products are effective in controlling adults but not in the stationary state of the pest.

Diatomaceous earth seems to be a good biological control in beans, probably by its composition, especially silicon. Goren *et al.* [28] reported that the presence of silicon benefited crop resistance, and induction of protection against biotic and abiotic environmental factors. Other studies [29, 30] indicated that apparently the role of silicon has been attributed in part to its accumulation and polymerization in cell walls which provides a mechanical barrier against attack by pathogens and pests as well as being an accumulator of compounds that generate natural plant reactions to a decrease in insect attack. In organic agriculture it is used as a natural pesticide to combat non-poisonous and external parasites on pets, directly applying powder on the animal's hair.

4 Conclusions

The results of our study showed that the best treatments measured by crop yields were TDDA + chemical fertilizer. The diatomaceous earth combined with natural or chemical insecticides acting effectively control the whitefly (*Trialeurodes vaporariorum*), reducing significantly pest populations and avoiding damage of the cultivation. Diatomaceous earth has reduced doses of chemical fertilizers on crops of commercial interest, and thus becomes an alternative environmental management to contribute to the reduction of chemicals in air, water and soil. We should continue to evaluate doses, fertilizers and effects they can generate diatomaceous earth in tropical crops in different climatic conditions.

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