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Use of clinoptilolite aluminosilicate (ZeoterA) in the cultivation of beans (Phaseolus vulgaris) controlling anthracnose (Colletotrichum lindemuthianum) under different doses of phosphorus

Uso de alumininosilicato clinoptilolita (ZeoterA) en el cultivo de frijol (Phaseolus vulgaris) controlando antracnosis (Colletotrichum lindemuthianum) bajo diferentes dosis de fósforo

Edison Marcelo Pazmiño Muñoz [1] * ; Angel Lázaro Sánchez Iznaga [2] ; José Antonio Realpe Iduarte [3] ; Gregorio Justino Baldeon Prieto [4] ; Yomaira Alexandra Romero Troya [5]

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* Corresponding autor.

Abstract:
The objective of this research was to evaluate the use of clinoptilolite aluminosilicate (ZeoterA) in the bean (Phaseolus vulgaris) crop controlling anthracnose (Colletotrichum lindemuthianum) under different doses of phosphorus. The design used was Completely Random Blocks (DBCA) with six treatments with different doses of ZeoterA. They were divided into two applications of fertilizers and ZeoterA during the trial and different agronomic variables were evaluated. The different agronomic variables were subjected to Analysis of Variance using Tukey's test at 95% probability. The severity of C. lindemuthianum was evaluated by applying visual scales and the Leaf Doctor software. At the end of the test, it was determined that the application of 70 - 15 - 40 kg/ha (N-P-K) + Zeolite (150 kg/ha) has a positive effect on the health of the bean pod and decreases pod rot. This treatment presented the highest yield 2.45 kg/ha and a greater productive response in agronomic variables such as plant height (30.90 cm) and weight of 100 seeds (68 g). This treatment also presented a better Benefit/Cost Ratio of 36% over the control.

Key words: Colletotrichum lindemuthianum, Zeolite, Phosphorus, Leaf Doctor.

Resumen:
El objetivo de esta investigación fue evaluar el uso de alumininosilicato clinoptilolita (ZeoterA) en el cultivo de frijol (Phaseolus vulgaris) controlando antracnosis (Colletotrichum lindemuthianum) bajo diferentes dosis de fósforo. El diseño utilizado fue Bloques Completamente al Azar (DBCA) con seis tratamientos con diferentes dosis de ZeoterA. Se fraccionaron en dos aplicaciones de fertilizantes y ZeoterA durante el ensayo y se evaluaron distintas variables agronómicas. Las diferentes variables agronómicas fueron sometidas al Análisis de Varianza usando la prueba de Tukey al 95% de probabilidad. La severidad de C. lindemuthianum fue evaluada mediante la aplicación de escalas visuales y el software Leaf Doctor. Al finalizar el ensayo se determinó que la aplicación de 70 - 15 - 40 kg/ha (N-P-K) + Zeolita (150 kg/ha) posee un efecto positivo en la sanidad de la vaina del frijol y disminución en la pudrición de la vaina. Este tratamiento presentó el mayor rendimiento 2.45 kg/ha y una mayor respuesta productiva en las variables agronómicas como altura de planta de (30.90 cm) y peso de 100 semillas (68 g). Este tratamiento también presentó una mejor Relación Beneficio/Costo de 36% sobre el control.

Palabras clave: Colletotrichum lindemuthianum, Zeolita, fósforo, Leaf Doctor.

1. Introduction

Beans are the most important legume in the world, representing 87% of the legumes that are consumed at the international level [1].

It is considered the major source of protein due to its protein content, which is between 25 and 35% of the world's protein intake [2].

The average international yields of beans have been located at 0,83 t ha^{-1}, while in the United States, China, Myanmar,

[1] Instituto Superior Tecnológico Babahoyo, Producción agrícola, Docente, +593 93 968 8731, epazmino@istb.edu.ec, Babahoyo, Los Ríos, Ecuador; Orcid: https://orcid.org/0009-0007-3055-2227
[2] Instituto Superior Tecnológico Babahoyo, Producción agrícola, Docente, +593 98 448 1690, asanchez@istb.edu.ec, Babahoyo, Los Ríos, Ecuador; Orcid: https://orcid.org/0000-0003-0729-8340
[3] Instituto Superior Tecnológico Babahoyo, Producción agrícola, Docente, +593 96 747 1595, jrealpe@istb.edu.ec, Babahoyo, Los Ríos, Ecuador; Orcid: https://orcid.org/0000-0002-4321-7133
[4] Instituto Superior Tecnológico Babahoyo, Producción agrícola, Docente, +593 99 004 6021, gbaldeon@istb.edu.ec, Babahoyo, Los Ríos, Ecuador; Orcid: https://orcid.org/0009-0006-9722-6007
[5] Instituto Superior Tecnológico Babahoyo, Producción agrícola, Docente, +593 96 731 6435, yromero@istb.edu.ec, Babahoyo, Los Ríos, Ecuador; Orcid: https://orcid.org/0009-0000-5167-1195

Tanzania and Brazil have reported higher values; however, in countries such as Mexico and India were lower, according to [3] in Ecuador dry bean yields are reported between 0,3 hasta 2,2 t ha^{-1} according to the National Institute of Statistics and Census [4].

In Ecuador, beans (Phaseolus vulgaris L.) is a legume widely consumed by the population, included among the 22 agricultural products with the highest demand in the country, mainly by people with low resources [5].

Beans grow best in soils with pH 6.5 to 7.5, a range in which most plant nutrients are at their maximum availability. However, beans can tolerate low pH levels between 4.5 and 5.5, but at lower levels, aluminum and/or manganese toxicity usually occurs. In alkaline soils, it can tolerate pH levels around 8.2. It develops well between average temperatures of 15 to 27 °C, which generally prevail at elevations of 400 to 1,200 m above sea level, there is a wide range of tolerance among different varieties [6].

The nutritional requirements of the bean crop to produce 2.5 ton/ha/harvest are 105 kg/ha of nitrogen (N), 10 kg/ha of phosphorus (P_2O_5), 120 kg/ha of potassium (K_2O) y 1210 kg/ha of magnesium (MgO). The nutritional requirements of a crop will be directly proportional to the yield. Therefore, the fertilizer dose will depend on the expected production potential or yield, which in turn is determined by genetic potential, soil productivity, climatic conditions, and the level of technology applied to the crop [7].

The increase in fertilizer production is causing, at an accelerated rate, the depletion of high and medium quality phosphorus reserves worldwide [8].

In Ecuador, it is one of the foods preferred by the population due to its high nutritional content [9].
Phosphorus (P) is an essential element for animal and plant nutrition.

Zeolite has been used worldwide in agriculture since the 1960s, mainly in countries such as Japan and the United States [10].

Among the basic grains, beans are one of the most important for their contribution of protein in the diet of the Ecuadorian population. However, it presents several problems in production related to the high incidence of diseases and pests, which when generalized with the inadequate use of fertilizers represents a crop susceptible to the indiscriminate use of pesticides that bring unfavorable consequences for the farmer and the consumer.

Likewise, the inadequate management of fertilizers is the main drawback in yield losses, and pests such as anthracnose have a limiting effect since the presence of the disease becomes an economic loss for the producer.

Considering the above, the present work is carried out with the objective of evaluating the effect of clinoptilolite aluminosilicate in the cultivation of beans under different doses of phosphorus.

2. Materials and Methods

The present research will be carried out at the facilities of the "La María" Campus of the Quevedo State Technical University, located at Km 7 via Quevedo.

The type of research will be experimental, because the implementation of different doses of zeolite in the bean crop was evaluated to assess the efficient management of phosphorus in the bean crop and control of anthracnose. The inductive method was used to delimit the different variables that were evaluated in the trial. The deductive method was also used, since this method made it possible to use different bibliographic sources to analyze the effect of zeolite on the development of the bean crop under different doses [11].

The experimental method allowed the manipulation of the variables of the treatments studied. While the analytical method helped to interpret and analyze all the data obtained through the process of measuring the different variables under study [12].

The design used was a Completely Randomized Block Design (RCBD) with 6 treatments with different doses of ZeoterA . They were divided into two applications of fertilizers and ZeoterA during the trial and different agronomic and yield variables were evaluated. An economic analysis of the treatments was carried out according to yield level. The different agronomic variables were subjected to analysis of variance using Tukey's test at 95% probability.The severity of C. lindemuthianum was evaluated using visual scales and Leaf Doctor software.

Climatic characteristics of the study área

Table 1. Climatic characteristics of the canton of Mocache.

Parameters	Average

Humidity (%)	88
Temperature (°C)	27
Precipitation (mm)	2270
Heliophany (h/light/year)	915
Average annual evaporation (mm/día)	3

Experimental research design

Table 2. Analysis of variance (ANOVA) of the completely randomized block design (RCBD).

Parameters	Average
Source of variation	Degrees of freedom
Blocks	2
Treatments	5
Error	10

Table 3. Treatments to be applied to each crop in the research.

Treatment	Description
T_1	N-P-K (70 - 60 - 40 Kg/ha)
T_2	N-P(100%) -K (70 - 60 - 40 Kg/ha) + Zeolite (150 kg/ha)
T_3	N-P(75%) -K (70 - 45 - 40 Kg/ha) + Zeolite (150 kg/ha)
T_4	N-P(50%) -K (70 - 30 - 40 Kg/ha) + Zeolite (150 kg/ha)
T_5	N-P(25%) -K (70 - 15 - 40 Kg/ha) + Zeolite (150 kg/ha)
T_6	N-P(0%) -K (70 - 0 - 40 Kg/ha) + Zeolite (150 kg/ha)

Research development

- **Land preparation**

The area where the experiment will be carried out will be delimited, and the measuring tape will be used to measure and distribute the plots according to their dimensions. The soil will be prepared mechanically to eliminate unwanted plant material; in addition, two passes of harrowing will be carried out so that the soil is loose. A post-emergent chemical control will be applied, using Glyphosate, at a dose of 2 L/ha in 200 L of water.

- **Sowing**

Prior to sowing, the seed will be disinfected with Vitavax 300 at a dose of 1 g/kg of seed to avoid the presence of fungal diseases that may prevent the development of the seeds.

The sowing will be done manually, using a mirror, depositing two seeds per hole, at a depth of 2 cm. with a distance of 0.20 m between plants x 0.50 m between rows.

- **Thinning**

After 15 days after planting, thinning was carried out so that there was only one plant per site.

- **Irrigation and weed control**

Irrigation will be done locally by sprinkling once a week. Weeds will be eliminated manually, using a machete to avoid nutritional competition with the crop; the frequency will be every 10 days.

- **Pest control**

Control will be carried out with the broad-spectrum insecticide Benfurol at a dose of 4 ml/L. The first one will be applied after 15 days. The first one will be applied 15 days after sowing (das) and the second one at 45 days.

- **Application of treatments**

The application rate will be divided in two parts, 60% in the first application and 40% in the second, which will be done at 15 and 45 das.
Fertilization will be edaphic, and a hole will be made 5 cm away from the plant where the fertilizer will be placed. In the case of zeolite, it will be applied to the contour of the stem, at a distance of 5 cm.

- **Irrigation and weed control**

Irrigation will be done in a localized manner by sprinkling once a week. Weeds will be controlled manually, using a machete to avoid nutritional competition with the crop, the frequency will be every 10 days.

- **Pest control**

Controls were carried out with the broad-spectrum insecticide Benfurol at a dose of 4 ml/L. The first application will be at 15 days after sowing (das) and the second at 45 days.

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Figure 1. Distribution of treatments and field replications for planting the peanut crop.

3. Results

Percentage of survival

According to the analysis of variance in the variable of percentage of survival of the bean crop, the number of live plants per treatment was counted thirty days after sowing. There is no significant difference between treatments T1, T2, T3, T4, T5 and T6 (Table 4 and 5).

Plant height (cm)

Twenty plants were chosen completely at random in each experimental plot 90 days after sowing.

The measurement from soil level to the apex of the youngest leaf in response to the application of different doses of clinoptilolite aluminosilicate was taken as a reference, whose analysis of variance determined statistical differences for the treatments evaluated.

When the dose of 150 kg/ha of Zeolite + NPK was applied with a phosphorus percentage of 100% for treatment (T2), a greater increase in plant height was recorded with 30.90 cm, surpassing treatment 1 (T1), treatment 3 (T3), treatment 4 (T4) and treatment 6 (T6) with values ranging from 27.47 to 29.80 cm in relation to treatment 5 (T5), which maintained lower values of 26.40 cm (Table 4 and 5).

Yield (kg/ha)

Crop yield showed statistical differences for the treatments evaluated.

The treatments containing a phosphorus percentage of 75% and 25% (T3 and T2) with the addition of 150 kg/ha of Zeolite + NPK recorded a higher yield of 2.45 kg ha^{-1} compared to the rest of the treatments evaluated (Table 4 and 5).

Table 4. Analysis of agronomic variables of interest in the bean crop (Phaseolus vulgaris) under zeolite application.

Description	(T1) N-P-K (70 - 60 - 40 kg/ha)	(T2) N-P(100%)-K (70 - 60 - 40 kg/ha) + Zeolite (150 kg/ha)	(T3) N-P(75%)-K (70 - 45 - 40 kg/ha) + Zeolite (150 kg/ha)
Percentage of survival	75.33a	76.33a	79.67a
Plant height (cm)	28.83ab	30.90b	29.80ab
Yield (kg/ha)	1.56ab	1.27a	2.45b

Table 5. Analysis of agronomic variables of interest in beans (Phaseolus vulgaris) under zeolite application.

Description	(T4) N-P(50%)-K (70 - 30 - 40 Kg/ha) + Zeolite (150 kg/ha)	(T1) N-P-K (70 - 60 - 40 kg/ha)	(T2) N-P(100%)-K (70 - 60 - 40 Kg/ha) + Zeolite (150 kg/ha)
Percentage of survival	76.33a	74.33a	73.33a
Plant height (cm)	27.47ab	26.40a	29.73ab
Yield (kg/ha)	1.76ab	2.45b	1.97ab

To determine the damage of the disease *C. lindemuthianum*, the bean crop (*Phaseolus vulgaris* a correlation analysis was carried out between the visual evaluation and the Leaf Doctor program. n Figure 1 it can be seen that there is a positive correlation factor R or Pearson's factor which was 0.96.

Visual Correlation vs *Colletotrichum lindemuthianum* Program

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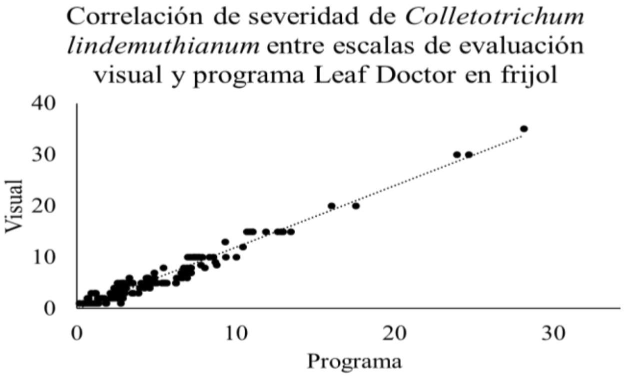

Figure 1. Correlation analysis between two evaluation methods on *Colletotrichum lindemuthianum*

To determine the damage of *C. lindemuthianum*, pods from each treatment were harvested 40 days after fertilizer application. Both visual and program evaluation recorded similar statistical results. Treatment 2 (N-P(100%) -K (70 - 60 - 40 Kg/ha) + Zeolite (150 kg/ha presented a higher severity of pod disease compared to treatment 1, 4 and 5 (Figure 2).

Overall analysis of variance Visual vs Program C. lindemuthianum

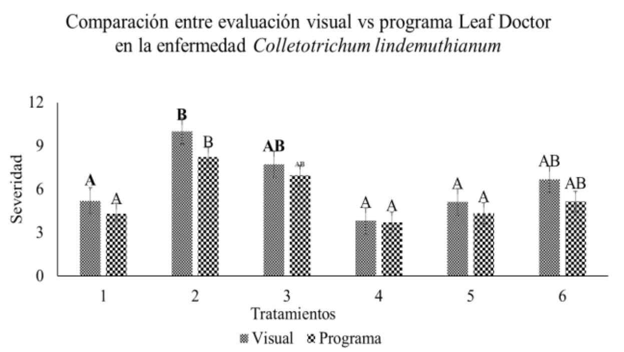

Figure 2. Comparison of Colletotrichum lindemuthianum severity using visual assessment scales and Leaf Doctor software. Error bars indicate ±ES; different letters indicate significant differences between the averages presented by each treatment (Tukey p<0.05).

Discussion

In the present investigation, the capacity of Zeolite to increase the agronomic, phytosanitary and productivity characteristics of the bean crop was evaluated the application of the treatments was fractioned, 60% for the first and 40% for the second application, carried out 15 and 45 days after sowing, respectively.

In studies [11] it is highlighted that zeolite contributes to improve N use efficiency in the soil at 100 kg/ha of urea under 3 applications 15, 25 and 35 kg/ha. Fresh grain yields ranged from 4.21 (T1) to 7.56 mg/ha (T6), while dry grain (12% moisture) yields were 3.72 and 6.65 mg/ha. In agreement with what was proposed by [12] in the corn crop, using the nitrogen fertilizer ammonium nitrate 102 kg/ha, 68 kg/ha, 76.5 kg/ha y Zeolite at the same proportion of 300, 200, 225 kg/ha, the best harvest of corn grain was observed in treatment 4 (T4) where the harvest in the recording area reached an average of 92,6 kg In this study, superior results were obtained when N-P was reduced to 25% together with zeolite.

Increasing the zeolite dosage increases the moisture content of the sandy loam soil efficiently increasing the ear weight and growth of the corn crop [13]. According to the studies of [14] it was demonstrated that zeolites significantly adsorb NH4, and P establishing their use as soil improvers to treat salinity and have a positive effect on soil fertility. The above mentioned coincides with the results obtained in this research, where high phosphorus efficiency was achieved.

Study by [15] on rice detailed that all treatments with clinoptilolite zeolite G2 20 g, G3 40 g and G4 60 g per liter of water significantly increased seedling root elongation compared to sand alone (G1). With the exception of shoot elongation, the effects of all treatments on seed germination rate and germination index were statistically similar. The development and application of new fertilizers using innovative nanotechnology are one of the potentially effective options to significantly improve agronomic crop yields and/or minimize environmental pollution [15].

4. Conclusions

- The application of Zeolite 150 kg/ha + NPK (70-15-40 kg/ha) produced taller plants 40 days after application, with an average length of 30.90 cm, number of pods per plant 16.43 and a greater increase in crop yield of 2.45 kg ha-1.
- The use of aluminosilicate clinoptilolite (ZeoterA) is involved in the lower incidence of C. lindemuthianum, presenting significant differences among treatments in the incidence of C. lindemuthianum. Zeolite acts efficiently in the health of the bean crop, because it presented the highest number of healthy pods.
- The economic analysis showed that treatment 5 and 3 obtained a better cost-benefit analysis with a value of 1.36. Treatment 5 (N-P (25 %)-K (70-15-40 kg/ha) +

Zeolite (150 kg/ha) can have beneficial effects to the soil by decreasing the amount of fertilizer dose applied.

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