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Edaphic source and tillage systems on yield and nutritional quality of green bean in Ecuadorian volcanic soils

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The main objective of this paper was to determine the effects of four edaphic sources and two tillage systems on the yield and nutritional properties of green beans in volcanic soil in the Ecuadorian Andes. For this propose, an experimental design of complete random blocks was established in the field according to the treatments in divided plots, where the main plots were the tillage systems and the subplots the following: edaphic sources such as chemical, organic fertilizers, and biofertilizers. The evaluation of the yield, the plant height, and the nutritional content of the green beans was carried out. Nutritional quality is not affected by the nutrient supply source used, chemical fertilization, organic or biofertilizers. However, the best yield results were obtained for the treatment of compost enriched with Mexican *Rhizobium spp.* (84.64 g per plant), and minimum tillage with the edaphic amendment of compost enriched with Ecuadorian *Rhizobium spp*., (93.49 g per plant). The application of rhizobia and compost did not present statistically significant differences in the plant growth response variable. The Ecuadorian rhizobia strain had a better performance than the Mexican strain, which is related to its level of adaptation to agroclimatic conditions.

Keywords: fertilization sources, organic fertilizers, biofertilizers, *Rhizobium spp*., ecuadorian strain

INTRODUCTION

The population increase at the global level, foreseen for this century, requires urgent attention and solutions; in the coming years, agricultural production should be increased in a more sustainable and environmentally friendly way (Del Pozo, 2020). The debate about the technologies that should be applied, for example, in the search for profitable production, a sector of farmers has tried to use the methods and principles of conventional agriculture, which require high use of external inputs, particularly synthetic fertilizer sources, but they have not been able to meet their objective because the cost of production is high compared to relatively low yields, especially in legumes. However, without the proper technology, the potential for environmental damage is significant. Another productive sector has tried to adopt agroecological principles of production, particularly organic production systems (Altieri y Nicholls, 2007a; Altieri y Uphoff, 1999; Palioff y Gornitzky, 2012; Palm et al. 2014); however, the returns are disappointing, due to the limitations of this production concept.

The challenge is to find management systems that favor the fertility, conservation, and potentization of soil microorganisms. In the last 20 years, a large amount of scientific literature on topics related to plant growth-promoting rhizobacteria (PGPR) and, different microorganisms that act in a wide variety of plants and the mechanisms of plant growth promotion are described. However, it is unknown which of the different mechanisms of action of biofertilizers is responsible for the positive effects in the field.

In the last decade, analyzes of both molecular and morphological traits, including nodulation, have led to important changes in our understanding of legume taxonomy. In parallel, there has been an explosion in the number of genera and species of rhizobia that are known to nodule in symbiosis with legumes. (Vincent, 1981; Somasegaran y Hoben, 1985; Granda Mora, 2010; Hansen et al. 2017; Tong et al. 2018; Tang y Capela, 2020). However, its practical application in horticulture is very limited and its dissemination to farmers is inefficient.

The volcanic soils of the Sierra del Ecuador represent 30% of the total surface of the country, they are soils where the main crops that constitute the basic basket of Ecuadorian families are located, such as: beans, broad beans, peas, barley, oats, Andean wheat, corn, and tubers (Calvache, 2020). To increase yields, it is necessary to carry out research with the application of conventional and unconventional techniques, in this research it is proposed to enrich the debate on the transition of production systems by evaluating the effects of tillage systems and edaphic sources on production. and nutritional quality of green beans (*Phaseolus vulgaris*), in the volcanic soil of the ecuadorian andes, contrasting conservation agriculture, such as the minimum tillage system and the application of organic fertilizer (compost) and compost enriched with biofertilizers, opposite to conventional tillage and application of chemical fertilization, techniques typical of the conventional production system.

Legumes are a low-cost, accessible food, and relatively easy to grow, not to mention the positive impact that these crops have with reference to soil maintenance (García et al. 2009). Green bean are one of the most important crops due to their nutritional quality, but since they register low yields, it is necessary to investigate strategies that allow increasing their yield per hectare; For this, the integrated use of fertilizers, organic matter, and efficient microorganisms in agricultural practices has been chosen to provide nutrients in sufficient quantities, balanced proportions, in the available form and in the period that the plants require it to favor the good development of the crop and finally, improve the yield and quality of the product (Estévez Ayala, 2018; FAO y IFA, 2002). The main objective of this paper was to determine the effects of four edaphic sources and two tillage systems on the yield and nutritional properties of green beans in volcanic soil in the ecuadorian andes.

MATERIALS AND METHODS

Study site

This study was conducted in lot 4.2 of the Campo Docente Experimental "La Tola" (CADET) of Facultad de Ciencias Agrícolas de la Universidad Central del Ecuador, located at S 0°13´28.04545´´, W 78°22´16.74608´´, at 2 457 msnm, during the period 2019 to 2021. The CADET is located in the ecological transition zone of low montane dry forest and low montane humid forest (Cañadas, 1983; MAGAP, 2013).

The taxonomic characterization of the CADET soils corresponds to soils of the great group Durustolls (Mejía, 1986), Soils that are generally eroded, shallow, are found on a hard sedimented layer (cangahua) less than one meter deep, located between 2,400 - 2,800 meters above sea level, dark brown to black in color, generally clay-sandy loam texture and neutral pH, they are found in dry climates. In the plot understudy, studies of the soil profile of 1.50 m by 150 width in length and 1.00 m in depth were carried out, using the guide for the description of soils of the FAO (2009) and keys to soil taxonomy (USDA y NRCS, 2014). Horizon A is a 25 cm Molisol epipedon, taxonomically corresponding to Molisol of volcanic origin (Quispe Mamani, 2017).

The climatological data were taken from the Meteorological Station M002 "La Tola" of the National Institute of Meteorology and Hydrology (INAMHI); Figure 1 shows the average, maximum, and minimum temperature (Figure 1. A) as well as the rainfall regime (Figure 1. B) of the area during the period 2013 to 2020.

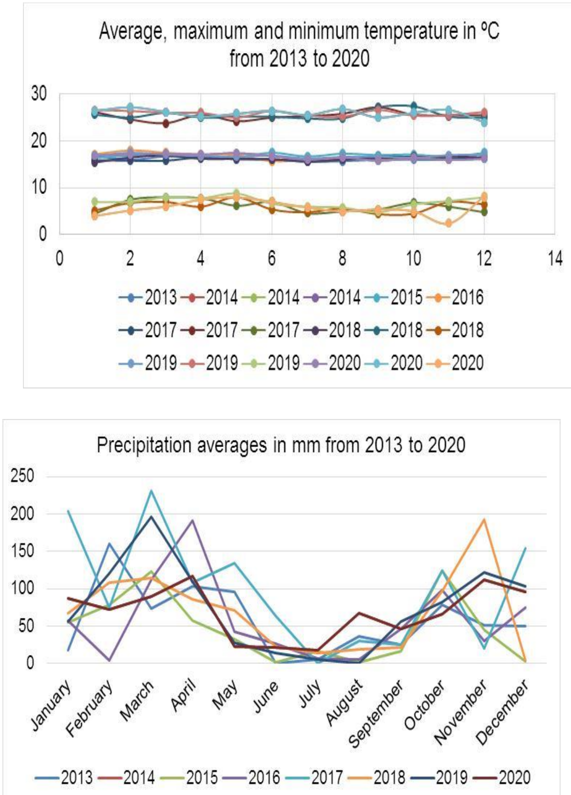

Figure 1: (A) Average, maximum and minimum temperature in ° C. (B) Average precipitation in millimeters. Data for the period 2013 - 2020. Source: INAMHI (2021).

The maximum temperatures fluctuate between 25 ° C, the minimum temperatures fall between 10 to 5 ° C, on average the temperatures are between 15 to 18 ° C. On the other hand, in terms of rainfall regime, it is observed that the period with the highest rainfall is between January to May, with a maximum between March and April; When rainfall exceeds 200 mm, it begins to decrease in the dry season that occurs between June to August, then in the last four months of the year, rainfall increases progressively. These sources of Spatio-temporal variability are important considerations in the cultivation cycles in the Ecuadorian Andes, temperatures below 10 ºC and high rainfall negatively affect the cultivation of green beans (Toledo, 2003).

Experimental design

The experiment consisted of a conventional tillage system versus a minimum tillage system with four sources or edaphic amendments: complete chemical fertilizer 10% N, 29% P_2O_5, 11% K_2O, 0% Ca, 3% MgO, 10% S, and 0.71% Zn, in doses of 190 N-30 P-120 K-18 Ca-20 Mg-30 Zn, Compost 2 - 2.5% N, 1.8% P, 1.3 - 1.8% K and two commercial strains of *Rhizobium spp*., one from Mexico and another from Ecuador. The randomized complete blocks (DBCA) experimental design was used with four replications and the treatments were distributed in an arrangement of divided plots, with net plots of 25 m^2, rows separated at 0.60 and 0.30 m between plants, where bean seed was sown. of the Blue Like variety, imported from the United States of North America.

Yield, plant height and, proximal and mineralogical analysis

Proximal and mineralogical analysis of green beans was carried out to determine their nutritional profile, in order to determine the effects of tillage systems and edaphic sources; in the same way, the variable response, yield, and plant height was evaluated during its development, whose values are discussed in the results section.

Statistic analysis

For the productivity analysis of the different treatments, a full factor analysis model was used according to the Y ~ X model, where Y corresponds to the weight of the green beans and X to a matrix with the following description: X1 = days to harvest with two levels (55 days and 65 days after sowing); X2 = type of tillage with two levels (conventional tillage and minimum tillage); and, X3 = fertilization with four levels (chemical fertilization, compost, compost + *Rhizobium* (Mexican strain) and compost + *Rhizobium* (Ecuadorian strain), from which the first, second and third-level effects were obtained to find the optimal region around to the variables that made up the model. The variance analyzes were carried out using the SAS Studio computer tool and the proposed model through the R-Studio computer tool. Additionally, the unidirectional growth analysis of the plants was considered using the height of the plant as variable Y in an ANCOVA regression model as follows Y ~ X1 + X2 + X3, according to the recommendations of several authors, so that the linear relationship between growth and time can be estimated, and observed if the factors under study caused significant changes during plant development (Heijungs y Frischknecht, 2005; FAO, 2013; Matteo et al. 2020).

RESULTS AND DISCUSSION

Yield and plant height

Table 1 shows that the Compost + Rh. Mexico presents highly significant differences, with a positive increase over the mean of 15.4638 g at 65 days after sowing, and minimal tillage with the compost + rh Mexico treatment, presents an increase of 6.4688 g; with these data it is shown that the biofertilizer strains from Mexico gave better results in the productivity of green beans or green beans.

It is important to consider that the model applied for the productivity analysis is of the Full Factorial Design type, which requires that the variable Y be balanced in such a way that Y ~ X1 + X2 + X3. The Compost + Rh treatment. Total Mexico results from the sum of the intercept, days after sowing 65 (DDS65), DDS65: Compost + Rh México and Compost + Rh. Mexico, that is 76.7588 g + 5.3412 g +15.4638 g -7.9238 g = 84.6400 g total for Compost enriched with *Rhizobium* sp. of Mexican origin.

For minimum tillage with total compost, the values of the intercept are added, days after sowing 65 (DDS65), Minimum tillage, DDS65: Minimum tillage: Compost and Compost, that is: 76.7588 g + 5.3412 g + 3.7962 g + 13.5532 - 4.6038 g = 94.8456 total g for Minimum Tillage with Compost amendment. Finally, regarding minimum tillage with Compost + Rh, total Ecuador is obtained from the sum of the Intercept, Days after sowing 65 (DDS65), Compost + Rh. Ecuador and DDS65: Minimum tillage: Compost + Rh Ecuador, that is: 76.7588 g + 5.3412 g - 0.7138 g + 12.1112 g = 93.4974 g total. In this way, the compared real averages are obtained. Figure 2 shows the validation of the ANCOVA Regression model with an adjusted R2 equal to 0.92. The standard error of the residuals is equal to 2.29 over 87 degrees of freedom. In figure 2 you can see the validation graphs of the model of both the Frequency vs. Residuals (Figure 2. A) as well as the distribution of the predicted data based on the measured data (Figure 2. B).

In table 2 it can be seen that there are only significant differences in the plant height response variable in the minimum tillage system, this is probably due to the bioavailability of organic matter and the continuous and slow mineralization process, a characteristic factor of soils. and climatic systems of the Ecuadorian Andes. The cultivation of green beans in the open field is not efficient since it is a crop that prefers the greenhouse or tropical places; some efficient cultivars may respond to inoculation, which negatively affects nitrogen and nitrogen content accumulated by the sprout, but can increase the number of nodules, specific nodulation, and the efficiency of nitrogen utilization (Viçosi et al., 2020).

Organic farmers recognize the importance of using bio-inputs to meet the N-fertility needs of crops and to reduce the use of chemical fertilizers. These results clearly indicate that the symbiotic yield and dry bean grain yield can be significantly increased by using Rhizobium inoculation in organic farming systems (Abou-Shanab et al., 2019). That they can even exceed the yields achieved with the application of chemical fertilizers, under certain conditions of technical handling, as we confirm with the present investigation. It should also be considered that under the agrometeorological conditions of CADET, it is possible to carry out up to three cultivation cycles per year and therefore triple the yield reports of a single annual crop of the countries that present four seasons.

Nutrimental quality

In Ecuador and Mexico there is a strong culture and tradition around the consumption of beans, not so for green beans also called green beans or green beans, despite their high content of proteins, carbohydrates, fibers, calcium, and vitamins (Fernández and Sánchez, 2017a; Ramírez et al. 2008; Salinas et al. 2012; Salinas-Ramírez et al. 2013); if this legume is compared with the mature grain produced by the same plant, there is greater benefit since the green bean is also attributed nutraceutical properties (Fernández y Sánchez, 2017), have a low calorie content (Adsule, Deshpande y Sthe 2004), for this reason it is considered an ally food in the management of overweight and obesity; In a complementary way, the high values of fiber content allow to reduce the time of intestinal transit, the absorption of fats and optimal values in the postprandial blood glucose rate, this food is included in the list of preventive foods for gastrointestinal diseases (Yvestirilly, 2002).

Therefore, in table 3 the p-value obtained for the proximal analysis of the green beans can be observed, where for humidity they do not present significant differences between the tillage systems, sources of nutrients, or interaction; for ash, ether extract and N-free extract, highly significant differences associated with tillage systems are observed; Regarding protein and crude fiber, relevant parameters in nutraceuticals, significant differences are observed associated with tillage systems, contradicting what was stated by Altieri and Nicholls (2007), who mention that fertilization practices can change the composition of nutrients in the crop.

When performing the Tukey test, Table 3 identifies two ranges of statistical significance; placing the minimum tillage system in the first range and conventional tillage in the second, this response is surely related to the availability of water and nutrients due to the accumulation of organic matter and its slow mineralization (Estévez Ayala, 2018; Ghisolfi, 2011; IPNI, 2013; Julca-Otiniano et al. 2006; Peixoto et al. 2002).

The values of the means in Table 3 are comparable with the results of Salinas *et al*. (2012), who mention that the caloric content of green beans is low, as well as high quality and protein concentration, this makes it a food that promises to contribute to the problems of overweight and obesity that today affect Mexico, Ecuador and other countries; It is observed that the protein and fiber contents are high and comparable with the values reported in the literature, there are significant differences between the tillage systems for the protein and fiber values, with minimum tillage being the factor with the highest protein content (22.43 g) and fiber (15.86 g) followed by conventional tillage with 21.01 g and 11.77 g respectively, values that, as evidenced in the ANOVA table, are not associated with the edaphic source used. The reported values confirm that the consumption of these foods provides opportunities to fight malnutrition and obesity, considering that the fiber concentration in legumes is much more significant than in grain, as shown in values reported by Fernández and Sánchez (2017), who affirm that the whole bean has a fiber concentration of 18.60%, its pod without grain 13.24%, so they are statistically different, compared to the beans of other varieties such as Bayo (5.55%), Pinto (7.18%) , Peruvian (7.09%) or Flor de Mayo (7.57%); However, it does not present statistical differences of significance in the Bean variety (19.86%).

The Health and Nutrition Survey of Ecuador states that one in 10 children under the age of five suffers from overweight or obesity conditions, this figure increases with age, for example, 1 in 3 school-age children and 1 in 4 adolescents records this abnormal health condition associated with bad eating habits (Ministerio de Salud Pública y Instituto Nacional de Estadística y Censos, 2014), This condition is associated with the consumption of foods with high caloric content. When the power supply; That is, the number of calories provided by food exceeds the immediate needs of the body, it tends to store its excess in the form of fat or carbohydrates, as a result of this the individual gains body weight (Youdim, 2019). In this context, green beans have low caloric value as reported Fernández and Sánchez (2017) of 221.55 kcal, a value that is statistically lower than the bean beans of the Bayo and Pinto varieties (337.46 and 326.56 kcal, respectively).

The Spanish Food Composition Database (BEDCA) reports an even lower content for green beans (green beans), of 28 kcal per 100 g of edible portion (BEDCA, 2021c), differing from the energy content of white beans in grain, which present 242 kcal and 21.1 g of protein per 100 g of edible portion (BEDCA, 2021b). Regarding protein content, Fernández y Sánchez (2017) report for whole beans 36.33 g (for every 100 g of edible portion); The protein value reported for green beans in this study, per plant, is 21.01 g in conventional tillage and 22.43 g in minimum tillage, these values are quite close to the report for raw beef, 23.5 g per 100 g edible portion (BEDCA, 2021g). Differences in protein and calories are also evident when green beans are contrasted with important cereals such as quinoa (13.8 g - 306 kcal) (BEDCA, 2021e), raw whole wheat (11.7 g - 314 kcal) (BEDCA, 2021f), raw corn on the cob (8.4 g - 392 kcal) (BEDCA, 2021d) and rye (14.8 g - 408 kcal) (BEDCA, 2021a), demonstrating that green beans exceed their protein content in grain as well as several staple cereals and is equated with beef, but with a much lower caloric value, confirming that it is a key food In food sovereignty as well as the fight against obesity and other diseases associated with human nutrition, this food is part of the basic basket legumes.

Table 4 shows the p-value with α of 0.05 obtained from the mineral analysis of P, K, Ca, Mg, and Na of the green bean samples, it is observed that there are no statistical differences, which allows confirming that it is more importantly the application of the principle of the 4Rs of plant nutrition; that is, the most appropriate nutrient source (Right source), with the correct doses (Right rate), at the right time (Right time), in the right way and place of application (Right place) (IPNI, 2013) to guarantee adequate nutrition of the bean crop, maximizing the absorption of the cultivation system, mainly of the macronutrients in the green beans that the way

Table 1: Coefficients for the factorial model Y ~ X, where the intercept corresponds to the levels 55 days, conventional tillage, chemical fertilization (of the matrix X of viable regressors), and the variable weight of green beans as a response (Y).

	Estimator	Standard error	T value	p-value
Intercept	76.7588	2.2973	33.413	< 2e-16 ***
Days after sowing 65 (DDS65)	5.3412	3.2447	1.646	0.099840 •
Minimum tillage	3.7962	3.2447	1.170	0.242106
Compost	-4.6038	3.2447	-1.419	0.156042
Compost + Rh. Mexico	-7.9238	3.2447	-2.442	0.014659 *
Compost + Rh. Ecuador	-0.7138	3.2447	-0.220	0.825897
DDS65: Minimum tillage	-6.6012	4.5859	-1.439	0.150118
DDS65: Compost	-3.3712	4.5859	-0.735	0.462316
DDS65: Compost + Rh. Mexico	15.4638	4.5859	3.372	0.000755 ***
DDS65: Compost + Rh. Ecuador	-2.4662	4.5859	-0.538	0.590765
Minimum tillage: Compost	2.7788	4.5859	0.606	0.544594
Minimum tillage: Compost + Rh. Mexico	6.4688	4.5859	1.411	0.158464
Minimum tillage: Compost + Rh. Ecuador	-1.4412	4.5859	-0.314	0.753337
DDS65: Minimum tillage: Compost	13.5532	6.4834	2.091	0.036615 *
DDS65: Minimum tillage: Compost + Rh. Mexico	-2.4938	6.4834	-0.385	0.700527
DDS65: Minimum tillage: Compost + Rh. Ecuador	12.1112	6.4834	1.868	0.061849 •
Signif. Codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "•" 0.1 "***" 1 " "				
Standard Residual Error: 32.41 of 3189 degrees of freedom				

* The asterisks (*) indicate the existence of statistically significant differences between sources of variation and the evaluated parameters.difference between sources of variation and the evaluated parameters.

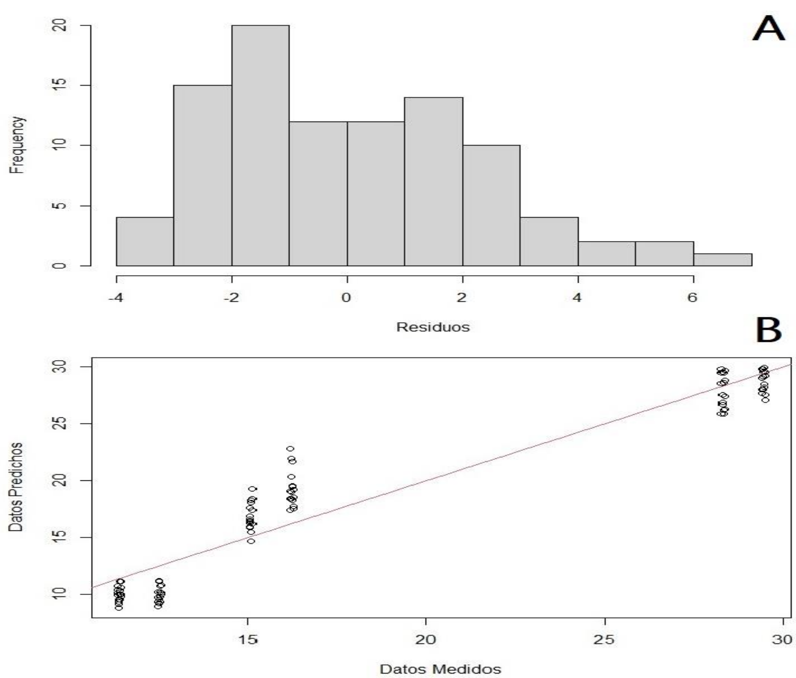

Figure 2: Validation charts. (A) Histogram of Frequencies vs. Waste. (B) Distribution of predicted data vs. Measured data.

Table 2: Coefficients for the factorial model Y ~ X, where the intercept corresponds to the levels 55 days, conventional tillage, chemical fertilization (of the matrix X of viable regressors) and the variable plant height as a response (Y)

	Estimator	Standard error	T value	p-value
Intercept	7.19185	0.62803	11.451	< 2e-16 ***
DDS	0.53001	0.01688	31.399	<2e-16***
Minimum tillage	1.12844	0.46370	2.434	0.0169*
Compost	-0.01604	0.65578	-0.024	0.9805
Compost + Rh. Mexico	-0.12042	0.65578	-0.184	0.8547
Compost + Rh. Ecuador	-0.06667	0.65578	-0.102	0.9193
Signif. Codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "•" 0.1 "***" 1 " "				
Standard Residual Error: 32.41 of 3189 degrees of freedom				

* The asterisks (*) indicate the existence of statistically significant differences between sources of variation and the evaluated parameters.

Table 3: ANOVA and Tukey's test in the proximal analysis of green beans, p-value with α of 0.05.

ANOVA						
Fuente de variación	**Humidity**	**Ashes**	**Ethereal Extract**	**Protein**	**Crude fiber**	**N-free extract**
Model	0,99ns	0,07ns	0,09ns	0,31ns	0,40ns	0,15ns
Tillage system	0,50ns	0,00**	0,04*	0,03*	0,03*	0,00**
Edaphic source	0,98ns	0,47ns	0,69ns	0,84ns	0,76ns	0,80ns
Sistema x Source	0,93ns	0,52ns	0,07ns	0,47ns	0,78ns	0,56ns
CV	1,54	11,26	22,00	8,00	8,65	8,18
Tukey's test						
Tillage system	**Humidity (%)**	**Ashes**	**Ethereal Extract**	**Protein**	**Crude fiber**	**N-free extract**
		(g 100 g^{-1} edible portion)				
Conventional	91,77	8,94b	1,77b	21,01b	14,77b	53,50a
Minimum	92,11	10,16a	2,09a	22,43a	15,86a	49,08b
DMS	1,04	0,78	0,31	1,27	0,97	3,06

* The asterisks (*) indicate the existence of statistically significant differences and (**) indicates a high significant difference between sources of variation and the evaluated parameters. The initials (ns) indicate that statistically significant differences were not determined. Means with different letters (a and b) are different according to Tukey's test with P ≤ 0.05.

Table 4: Results of the ANOVA of macronutrient analysis of green beans, p-value with α of 0.05.

Variation source	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)
Model	0,81ns	0,61ns	0,91ns	0,59ns	0,00**
Tillage system	0,76ns	0,14ns	0,35ns	0,21ns	0,02*
Edaphic source	0,75ns	0,90ns	0,89ns	0,76ns	0,00**
System X Source	0,51ns	0,48ns	0,79ns	0,43ns	0,00**
CV	20,02	18,18	14,22	14,36	29,21

* The initials ns indicate that no statistically significant differences were determined.

Table 3. Results of the ANOVA of the micronutrient analysis of the green beans, p-value with α of 0.05.

Variation source	Copper (Cu)	Iron (Fe)	Manganese (Mn)	Zinc (Zn)
Model	0,26ns	0,00**	0,00**	0,05*
Tillage system	0,02*	0,06ns	0,00**	0,75ns
Edaphic source	0,90ns	0,26ns	0,02*	0,12ns
System X Source	0,41ns	0,00**	0,21**	0,04*
CV	26,63	16,32	13,31	13,39

* The asterisks (*) indicate the existence of statistically significant differences and (**) indicates a high significant d.

We apply these fertilizers to the soil; that is, edaphic amendments of a different nature, chemical, organic or biofertilizer in order to reduce losses and, therefore, mitigate negative impacts on the environment.

In tables 3 and, 4 the p values with a significance alpha of 0.05 from the mineralogical analysis show highly significant statistical differences for the model, for the edaphic source factor and system-by-source interaction; for the factor under study tillage system in Na and Cu there are significant differences; for Fe highly, significant differences for the model and interaction. In Mn highly, significant differences are observed for the model, tillage system and interaction and significant for the nutrient source; finally, in Zn significant differences are observed only for the model and nutritional source. In this analysis, the effect of tillage systems and nutrient sources is evidenced, for which means comparison is made. In the case of the Tukey significance test for the variables of the mineral analysis of the green beans, only ranges are presented in the tillage systems for Cu, in the range (a) the minimum tillage. BEDCA reports for raw green beans the following macronutrient values per 100 g of edible portion: 38 mg of P, 243 mg of K, 39 mg of Ca and 25 mg of Mg, as well as the micronutrient values: 4 mg of Na, 1 mg of Fe and 0.2 mg of Zn (BEDCA, 2021c), consistent with the low values obtained in this investigation.

Beans, according to Janssen (1988), provide the vitamins and minerals that other basic foods do not contain, being a product with an upward trend in world consumption. Unfortunately, overall yields for both beans and green beans are low. Despite the great importance of the protein content of this vegetable for human nutrition, in Ecuador, there is no detailed information on this product, so it is worth strengthening this line of research. This is most likely the result of millennia of stable performance selection, and as such is a problem that can be solved using modern genetic techniques (Broughton et al. 2003) together with an adequate management of soil fertility.

Janssen (1988), In addition, it makes a comparison of the nutritional composition of dry beans, green beans (green beans), bean leaves and tender beans, the results indicate that the percentage of protein in dry beans is 20.4%, 7.0 - 10.5% for green beans, 3.6% of foliar origin and 2.1% in tender beans; However, the differences in vitamin A become noticeable in the foliar composition of beans with 10 to 20%, compared to 0% in dry grain and 0.4% for green beans. Fernández y Sánchez (2017) determined that the content of Cu and Zn in the pod also presents minimum concentrations, the authors conclude by mentioning that the bean seed presented the maximum concentrations in protein, N, P, K, Mg, Fe and Zn, while the bean varieties of grain studied excelled in fiber (Beans), proteins (Pinto and Bay Beans) and in Fe (Flor de Mayo Beans).

Along with the chlorophyll content, green beans also provide other phytonutrients like carotenoids, phenols, and flavonoids. All of these phytochemicals function as antioxidant and anti-inflammatory agents in the metabolism of the human body. (Coronado et al., 2015).Within this research, the quantification of these substances was not considered, which leaves open an opportunity to deepen the nutraceutical study of green beans in what has to do with their phytochemical profile. Additionally, several research studies suggest that these phytonutrients help reduce the risk of a wide range of chronic diseases including cardiovascular disease, high blood pressure, arthritis, diabetes, Alzheimer's disease, and cancer (Chaurasia, 2020), increasing interest in this type of crop as a source of nutrients in environments that are increasingly vulnerable to access to high-value food sources, especially basic basket legumes.

CONCLUSION

The parameters related to the nutritional quality of the green beans were not affected by the source of supply of the nutrient used in their production, that is, chemical, organic fertilization or biofertilizers do not present significant differences between them in the mentioned parameters, the best recommendation is the comprehensive management of nutrient sources with the application of the principle of the 4Rs of plant nutrition, that is, use of the most appropriate nutrients, in the correct doses, at the right time as well as in the form and place of application suitable.

The yield obtained for the edaphic amendment of Compost enriched with *Rhizobium spp*., of Mexican origin, was 84.64 g per plant. For minimum tillage with edaphic amendment of Compost enriched with *Rhizobium spp*., of Ecuadorian origin, an increase of 93.49 g per plant is obtained, so the positive impact of the application of biofertilizers on the yield of basic basket legumes is evident. When complementing the rhizobia inoculation with compost applications, no statistically significant differences were observed in the variable plant growth response.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

All authors collaborated in treatments design and preparation of research. CE, AJ, and AA collaborated in monitoring, evaluating, and executing, research in the field and laboratory phase. RL collaborated in the statistical analysis. CR, CM, JM, and MO collaborated in the writing, and original draft paper. All authors read and approved the final version.

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