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AGRONOMY

RESPONSE OF THE PEA CROP (*Pisum sativum* L.) TO THE APPLICATION OF ORGANIC FERTILIZERS IN THE MUNICIPALITY OF PAMPLONA, NORTH OF SANTANDER

RESPUESTA DEL CULTIVO DE ARVEJA (*Pisum sativum* L.) A LA APLICACIÓN DE ABONOS ORGÁNICOS EN EL MUNICIPIO PAMPLONA, NORTE DE SANTANDER

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Abstract

In Pamplona pea production is based on the use of high doses of chemical fertilizers that cause environmental damage and human health. Therefore, in this study the effect of different organic fertilizers was compared with chemical fertilization through six treatments: T0: control; T1: vermicompost full dose (7831,00 kg/ha); T2: vermicompost half dose (3915.50 kg/ha) + chemical fertilizer (FQ 15N 15P_2O_5 15K_2O) half the dose (703.50 kg/ha); T3: chicken manure + goat manure + sugarcane residues full dose (ABOB: 10573.00 kg/ha): T4: ABOB half dose (1407.00 kg/ha) plus CF half dose (703.50 kg/ha); T5: CF full dose (1407.00 kg/ha); T6: CF half the dose (703.50 kg/ha). It was evaluated: plant height (AP), pods per plant (NVP); pod length (LV) and yield (kg/ha). A 5% analysis of variance and a Tukey test for separation of means were applied. The mean AP was higher in T2 (172.27 cm). NVP was higher in T3 and T5 with respect to the control, however, between treatments no statistical differences were observed. LV was statistically higher in the treatments compared to the control, although there was no variation between treatments. Although no statistical differences were observed in the performance between treatments, T1 and T4 presented a performance superior to the control of 42.85% and 39.99%, respectively. It is possible to substitute or supplement chemical fertilizer with organic amendments and reduce the negative effect of pollution that they generate on the environment and the health of the people.

Keywords: Vermicompost, yield, chemical fertilization.

Resumen

La producción de arveja en Pamplona se basa en el uso de altas dosis de fertilizantes químicos que generan daños ambientales y a la salud humana. Por lo tanto, en este estudio se comparó el efecto de diferentes abonos orgánicos con la fertilización química mediante seis tratamientos: T0: control; T1: vermicompost dosis completa (7831,00 kg/ha); T2: vermicompost mitad de la dosis (3915,50 kg/ha) + fertilizante químico (FQ 15N $15P_2O_5$ $15K_2O$) mitad de la dosis (703,50 kg/ha); T3: gallinaza + caprinaza + residuos de caña de azúcar dosis completa (ABOB: 10573,00 kg/ha): T4: ABOB mitad dosis (1407,00 kg/ha) más FQ mitad de la dosis (703,50 kg/ha); T5: FQ dosis completa (1407,00 kg/ha); T6: FQ mitad de la dosis (703,50 kg/ha). Se evaluó: altura de la planta (AP), vainas por planta (NVP); longitud de las vainas (LV) y rendimiento (kg/ha). Se aplicó un análisis de varianza al 5 % y una prueba de Tukey para la separación de medias. La AP promedio fue mayor en T2 (172,27 cm). El NVP fue más alto en T3 y T5 con respecto al control, sin embargo, no se observaron diferencias estadísticas entre tratamientos. La LV fue estadísticamente más alta en los tratamientos con respecto al control, aunque no hubo variación entre tratamientos. Sin embargo, no se observaron diferencias estadísticas en el rendimiento entre tratamientos, y T1 y T4 presentaron un rendimiento superior al control de 42,85 % y 39,99 %, respectivamente. Es posible sustituir o complementar el fertilizante químico con enmiendas orgánicas y reducir el efecto negativo de contaminación que generan sobre el ambiente y la salud de las personas.

Palabras clave: Vermicompost, rendimiento, fertilización química.

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1 Introduction

Growth of population leads to an increase in the demand of food, which must be met by increased agricultural production. In conventional agriculture it is achieved through the use of large quantities of chemical inputs, including fertilizers, which allows rapid plant growth. However, these products generate serious soil, water and air pollution problems (FAO, 2019; Latorre and Villamizar, 2019).

Pea (*Pisum sativum* L.) belongs to the Fabaceae family and it is an important source of protein (22-25 %), carbohydrates, phosphorus, iron, magnesium, calcium, riboflavin, niacin, thiamine and ascorbic acid (Watt and Merrill, 1993; Dahl et al., 2012). Regarding agriculture, it plays an important role for its contribution to nitrogen fixation and soil fertility improvement (Davies et al., 1985; Gopinath and Mina, 2011).

In Colombia, it is the most important legume after beans. It is grown mainly in high altitudes with cold and medium climates (2200 and 3000 masl) and it is produced in Cundinamarca, Boyacá, Nariño and Tolima (Peñaranda and Molina, 2011; DANE, 2015; FENALCE, 2015). Small and medium producers crop this legume and it is considered a staple food in the family basket. Ninety-five percent of pea production at the national level is destined for direct human and animal consumption as a grain rich in protein and the remaining 5 % for the production of dry peas as seed (Buitrago et al., 2006; FENALCE, 2015).

In the province of Pamplona, peas represent an alternative for the development of the local economy and the generation of employment and income. In addition, the area has optimal climatic conditions (between 10 and 17 °C) and the availability of labor for production (Peñaranda and Molina, 2011). In this crop, farmers traditionally fertilize with chemical formulas because they allow a rapid availability of elements for the plant, favoring some growth and yield variables. However, this implies high costs for obtaining inputs in addition to the environmental damage caused by chemical fertilization (González et al., 2015).

There is a growing awareness of the environmental damage caused by the use of non-renewable chemical resources in agriculture. Therefore, research has been directed towards alternatives such as the implementation of organic fertilizers, which is rapidly expanding worldwide (Willer et al., 2020; Flores et al., 2021; González-García et al., 2021). These techniques are less expensive and more environmentally friendly, so that the agricultural products obtained under these conditions are healthier and with better quality.

Additionally, the use of single or combined organic fertilizers with chemical fertilizers contributes to improve the physical, chemical and biological properties of soils (Heinze et al., 2010; Lalito et al., 2018; Mohammed et al., 2019; Flores et al., 2021). Specifically, they increase soil organic carbon content, provide nutrients necessary for the growth of microorganisms, temporarily reduce the toxicity of soluble and exchangeable aluminum due to the formation of chelates with organic substances in acid soils, all of which are observed in an increase in vegetative growth and plant yield (Suresh et al., 2004; Al-Bayati et al., 2019; Mohammed et al., 2019; Mátyás et al., 2020).

The aim of this research is to evaluate the effect of two organic fertilizers on the yield of pea (*Pisum sativum* L.) in the municipality of Pamplona, North of Santander, in comparison with chemical fertilization in order to offer an environmentally friendly, economically viable and socially acceptable production alternative.

2 Materials and Methods

2.1 Study area

The study was carried out in the experimental plots of Plant Health and Bioinputs Research Center (CISVEB) of Universidad de Pamplona, municipality of Pamplona, North of Santander. This area is located at 2331 meters above sea level; the climate in Pamplona is warm and temperate and according to the Köppen-Geiger climate classification it is maritime west coast (oceanic) (Cfb). The average annual temperature oscillates around 14.4 °C, with May being the hottest month of the year with an average of 15.0 °C and January the coldest month of the year with an average temperature of 13.3 °C. The average annual precipitation is 921 mm, there is precipitation throughout the year with the driest month being in January with 21 mm and the wettest month in April with an average of 141 mm (Climate-Data.Org, 2020).

Table 1 shows the results of the laboratory analysis of the soils in the area where the experiment was carried out.

Table 1. Physical and chemical characteristics of the soils of the Plant Health and Bioinputs Research Center (CISVEB) of Universidad de Pamplona, Pamplona municipality, North of Santander.

Soil variables	Value
Textural class	Sandy loam
Sand (%)	62.00
Clay (%)	22.00
Silt (%)	16.00
pH	6.00
Organic carbon (%)	2.46
Phosphorus (ppm)	15.1
Calcium (meq/100 g)	17.1
Magnesium (meq/100 g)	1.09
Sodium (meq/100 g)	0.12
Potassium (meq/100 g)	0.29
Boron (ppm)	0.24
Iron (ppm)	83.8
Manganese (ppm	2.76
Copper (ppm)	0.67
Zinc (ppm)	1.36

Source: Laboratorio químico de suelos (2018). Universidad Industrial de Santander.

2.2 Experimental design

A randomized block design with seven treatments and three replications was used. An experimental area of 504 m^2 was selected and divided into three blocks of 21 m × 7 m each (147 m^2 each block) and a separation of 1.5 m between blocks. Each block was divided into seven 7 m × 3 m (21 m^2/plot) for the distribution of treatments with a separation of 30 cm between plots. Three furrows were planted in each plot at a distance of one meter between them and approximately three centimeters between seeds, resulting in a population density of 333333.00 plants/ha.

Seven treatments were applied as described below: T0: Control; T1: Vermicompost full dose (VC100% = 7831.00 kg/ha or 16.44 kg/plot of 21 m^2); T2: Vermicompost half dose (VC50% = 3915.50 kg/ha or 8.22 kg/plot of 21 m^2) + Chemical Fertilizer (15N 15P_2O_5 15K_2O) half dose (FQ50% = 703.50 kg/ha or 1.48 kg/plot of 21 m^2); T3: Hen manure + goat manure + sugarcane residues full dose (GCR100% = 10573.00 kg/ha or 22.20 kg/plot of 21 m^2): T4: GCR half dose (GCR50% = 5286.50 kg/ha or 11.10 kg/plot of 21 m^2) + Chemical Fertilizer (15N 15P_2O_5 15K_2O) half dose (FQ50% = 703.50 kg/ha or 1.48 kg/plot of 21 m^2); T5: Chemical fertilizer full dose (FQ100% = 1407.00 kg/ha or 2.95 kg/plot of 21 m^2); T6: Chemical fertilizer (15N 15P_2O_5 15K_2O) half dose (FQ50% = 703.50 kg/ha or 1.48 kg/plot of 21 m^2).

The calculation of the doses of organic and chemical fertilizers in kg/ha was made based on the amount of nutrients available in the soil, according to the results obtained in the laboratory analysis and the nutritional requirements of the crop.

2.3 Application of organic manures, chemical fertilizer and crop management.

Two commercial organic fertilizers were used:

- Vermicompost: made from worm compost and commercially known as Ferticampo. This compost has a total nitrogen percentage of 2.70%, 0.82% total phosphorus, 3.06% total potassium, 2.63% calcium oxide, 0.68% magnesium, 13.70% total oxidizable carbon, a C/N ratio of 10.77 and a cation exchange capacity of 34.42 cmol(+)/kg of soil. The calculated dose of vermicompost was 7831.00 kg/ha according to the results of the soil analysis, while the equivalent dose was 16.44 kg/plot of 21 m^2 for the experimental area.

- GCR: organic fertilizer composed of hen manure, goat manure and sugarcane residues, commercially known as *Abonos orgánicos de Boyacá* (ABOB). This fertilizer has 2.00% of total nitrogen, 5.00% of total phosphorus (P_2O_5), 3.0% of water soluble potassium (K_2O), 10.00% of calcium (CaO), 24.00% of silicon (SiO_2), 35.00% of organic fertilizer, 9.00% oxidizable carbon, C/N ratio of 7.50 and cation exchange capacity of 25.00 cmol(+)/kg of soil. The calculated dose per hectare was 10573.00 kg, while it was 22.20 kg for the area of each plot.

- Chemical fertilizer: Triple 15 chemical fertilizer (15% N 15% P_2O_5 15% K_2O) was used at a calculated dose of 1407.00 kg/ha (2.95 kg/plot of 21 m^2).

The soil was prepared with a power tiller for a better soil conditioning at the time of planting, following the planting methods of the producers in the area. Both chemical and organic fertilization was carried out 15 days after planting. The trellising was established thirty days after planting to hang the pea plants to facilitate the crop and better manage weed and disease control. Weed control was carried out manually every eight days, removing weeds that could compete and reduce crop yield, since peas are not very competitive and needed strict weed control to avoid low yields at the end of the harvest.

Pest and disease control was carried out at the beginning of the crop due to the presence of slugs, birds and cuttings; it was done chemically and manually by applying different products such as Babosil at a dose of 20 kg/ha every 15 days. Lorsban (2.50% × 1 kg (Chlorpyrifos) of 3.00 to 5.00 cc/L) was applied to minimize damage to the plants during growth and development. In addition, scarecrows were placed in several points of the lots. For the control of diseases caused by some fungi such as anthracnose (*Ascochyta* spp), Mancoz33ed (dispersible granules: WG 75%) was applied preventively at a dose of 200 g/100 L of water during the initial growth stage of the plants and with a frequency of seven to 10 days. For the control of downy mildew (*Peronospora corda*), Ziram (zinc dimethyl-dithiocarbamate 760 g/Kg in dispersible granules: WG 76%) was applied at a dose of 240 to 300 g/100 L of water preventively before and after flowering, especially due to the climatic conditions of high rainfall that occurred during the development of the experiment.

Irrigation was carried out manually with an irrigation frequency of every two days depending on weather conditions. Approximately 250 to 380 mm of water were applied throughout the crop cycle, always guaranteeing good soil moisture availability. Harvesting was carried out 105 days after manual planting when the pea pods had reached maturity and was filled with fruit.

2.4 Study variables

Pea seeds (*Pisum sativum* L.) of *Rabo de gallo* variety were used for sowing, which is well known and preferred by local producers in Monte Adentro district due to its characteristics of good quality, large grain, large number of grains per pod and high resistance to pest attack. The variables evaluated were:

2.4.1 Plant height (AP)

Plant height was measured at 30, 60 and 90 (AP30, AP60 and AP90, respectively) days after planting. For this purpose, 20 plants were taken at random per experimental unit and the height was measured from the base of the plant to the last leaflet on the days indicated above, using a tape measure. The data were expressed in cm.

2.4.2 Length of green pods (cm) (LV)

The length of the pods was measured at the time of harvest. Twenty plants were taken from each experimental plot. From each plant, 5-10 pods were selected from the second third where the most developed pods were concentrated and the average length expressed in cm was obtained.

2.4.3 Number of green pods per plant (VP)

The total number of green pods per plant was counted from the 20 plants selected in each experimental plot.

2.4.4 Yield (kg/ha)

It was determined by weighing the total number of pods per experimental plot. The crop was harvested when the plants were at main stage number 7, code 79 according to the BBCH scale, in which the pods have already reached the typical size (green maturity), and were fully formed (Enz and Dachler, 1998).

2.5 Statistical analysis

For the statistical analysis of the data, a one-way analysis of variance (ANOVA) was applied. When the ANOVA was significant ($p<0.05$) a Tukey test was applied for separating means. Pearson's linear correlation analysis was used to analyze the relationship between the study variables. The SPSS version 21 statistical package was used to analyze the data at a significance level of 0.05.

3 Results and discussion

3.1 Plant height

According to the results presented in Table 2, 30 days after planting in the field, plant height (AP) in T0 was significantly higher ($p<0.05$) than the rest of the treatments, excepting T6, which did not show differences with T0.

AP was statistically lower 60 days after sowing ($p<0.05$) in T4 with respect to T2, T3 and T6, while no significant differences were observed between T0, T1, T2, T3, T5 and T6 ($p>0.05$). The AP at 60 days showed a better response of the crop to the treatments. The greatest height was observed in T6 (FQ50%) and T2 (VC50% + FQ50%), but there were no differences between them. The lowest height was observed in T4 with the mixture GCR + 50% + FQ50%, which shows that plants did not respond favorably to this combination.

The greatest plant height was found in T2 90 days after planting (172.27±12.70 cm) which was statistically higher than T0, T4 and T6 (Table 2). According to these results, maybe the PA in T0 was higher at the beginning of the trial because the organic fertilizers and the chemical fertilizer were not applied during sowing but 15 days after, therefore, they did not have enough time to solubilize (Álvarez-Sánchez et al., 2006; Flores et al., 2021).

Table 2. Height of pea plants at 30, 60 and 90 days after planting in response to organic and chemical fertilization in the municipality of Pamplona, North of Santander.

Treatments	Plant height (cm)		
	30 days	**60 days**	**90 days**
T0	25.72 ± 2.94^{ac}	97.80 ± 9.04^{ab}	144.36 ± 18.97^{a}
T1	23.81 ± 2.74^{b}	97.43 ± 12.75^{ab}	165.85 ± 14.92^{b}
T2	23.67 ± 2.99^{b}	102.13 ± 8.34^{b}	172.27 ± 12.70^{b}
T3	22.73 ± 2.98^{b}	101.88 ± 13.24^{b}	171.76 ± 20.43^{b}
T4	22.56 ± 3.33^{b}	93.96 ± 9.41^{a}	155.37 ± 16.10^{a}
T5	22.33 ± 3.03^{b}	99.56 ± 10.03^{ab}	165.55 ± 19.76^{b}
T6	24.81 ± 3.30^{c}	103.41 ± 12.18^{b}	162.13 ± 22.75^{a}

Mean values ± standard deviation accompanied by different lowercase letters indicate statistical differences ($p<0.05$) between treatments. T0: Control; T1: Vermicompost full dose (VC100% = 7831.00 kg/ha or 16.44 kg/plot of 21 m^2); T2: Vermicompost half dose (VC50% = 3915.50 kg/ha or 8.22 kg/plot of 21 m^2) + Chemical Fertilizer (15N $15P_2O_5$ $15K_2O$) half dose (FQ50% = 703.50 kg/ha or 1.48 kg/plot of 21 m^2); T3: Hen manure + goat manure + sugarcane residues full dose (GCR100% = 10573.00 kg/ha or 22.20 kg/plot of 21 m^2): T4: GCR half dose (GCR50% = 5286.50 kg/ha or 11.10 kg/plot of 21 m^2) + Chemical Fertilizer (15N $15P_2O_5$ $15K_2O$) half dose (FQ50% = 703.50 kg/ha or 1.48 kg/plot of 21 m^2); T5: Chemical fertilizer full dose (FQ100% = 1407.00 kg/ha or 2.95 kg/plot of 21 m^2); T6: Chemical fertilizer (15N $15P_2O_5$ $15K_2O$) half dose (FQ50% = 703.5 kg/ha or 1.48 kg/plot of 21 m^2).

On the other hand, the height of pea plants was 19.33% higher 90 days after planting in the treatment that used the combination of half the recommended dose of vermicompost organic fertilizer equivalent to 3915.50 kg/ha plus half the dose of triple 15 chemical fertilizer (703.50 kg/ha) suggested according to the results of the soil analysis, with respect to the control treatment where no treatment was applied. In this sense, the combined use of the organic fertilizer based on vermicompost with the chemical fertilizer had a significant positive effect on plant height compared to the control treatment.

The literature has indicated that organic fertilizer can increase the efficiency of chemical fertilizer use when applied combined, being a strategy for the high costs of chemical fertilizers or when are not easy to find, since it allows maintaining and increasing yields in the long term (Van Zwieten, 2018; El-Salehein et al., 2019).

Although the use of vermicompost plus chemical fertilizer (T2) was statistically superior to the control, there was no difference between the treatments using full dose vermicompost (T1: 7831.00 kg/ha); full dose of commercial fertilizer composed of hen manure, goat manure and sugar cane residues (T3: 10573.00 kg/ha) and the full dose of triple 15 chemical fertilizer (T5: 1407 kg/ha). The fact that no differences in plant height were found among these treatments (T1, T2, T3 and T5) shows that the use of chemical fertilizers can be reduced or substituted by organic fertilizer, always taking into account that the availability of nutrients from organic fertilizers such as animal manure and compost is usually low in the short term, so the response of the crop is more visible in the long term.

On the other hand, the application of the mixture of half the dose of ABOB commercial fertilizer (T4: 5286.50 kg/ha) plus half the dose of triple 15 chemical fertilizer (T4: 703.50 kg/ha), and the use of only triple 15 chemical fertilizer at half the recommended dose (703.50 kg/ha^2) did not represent a significant increase in plant height compared to the control treatment. In this regard, scientific evidence points out that the supply of nutrients from organic fertilizer depends largely on the source and quality of organic fertilizers used, as well as on the mineralization rate of the organic compounds present (Mukai, 2018; Van Zwieten, 2018).

Similar results were reported by El-Salehein et al. (2019), where treatment with farmyard manure + NPK fertilizer at half the recommended dose resulted in significant increases in *Pisum sativum* L. growth, fruit set, leaf chemical content, green pod yield and its components, and seed quality. Lalito et al. (2018) also found that the combination of chemical fertilization, vermicompost and plant debris improved growth attributes, yield and soil properties relative to the control, such as: greater plant height, number of leaves per plant, number of branches per plant, number of pods per plant, number of seeds per pod, seed yield, higher values of N, P_2O_5 and K_2O available in the soil after crop harvest.

Bautista-Zamora et al. (2017) also found an analogous response in the effect evaluation of the application of organic fertilizer (compost and vermicompost) and commercial fertilizer on the growth and development of *Phaseolus vulgaris* var. Cerinza, where plant height 56 days after planting was significantly higher in the compost and vermicompost treatments compared to commercial fertilization.

When comparing the plant height observed in this study with other studies, it was found that it was much higher than the one by Checa et al. (2017), in an investigation in which they carried out an agronomic evaluation of different pea varieties at different sowing times. Santamaría et al. (2010) also obtained plant height values below those found in this study 60 days after sowing, although it is worth noting that the best response they found in plant height was when using organic manure compared to chemical fertilizer.

This result is probably due to the type of seed used. In this case, it is the variety known locally as *Rabo de gallo*, which is highly adaptable to the soil and climatic conditions of the area and has good yields. This is a non-certified seed, which is obtained by farmers in the area and marketed in different agricultural stores in municipalities such as Pamplona and Ragonvalia in the North of Santander (Amaya, 2017).

3.2 Number of pods per plant (NVP)

Figure 1 shows that T5 presented a higher number of pods per plant (NVP) compared to the rest of the treatments ($p<0.05$), except T3 where the full dose of commercial fertilizer composed of hen manure, goat manure and sugarcane residues was used (ABOB: 10573.00 kg/ha). T0 presented lower NVP ($p<0.05$) compared to T1, T2, T3, T5 and T6, but did not differ from T4. On the other hand, no differences were observed between T1, T2 and T4 as well as between T3 and T6. Finally, T4 resulted in lower NVP compared to T3, T5 and T6 ($p<0.05$).

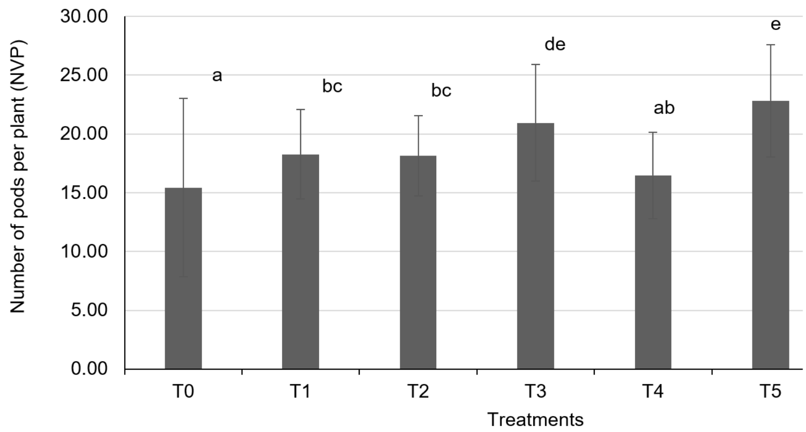

Figure 1. Number of pods per plant (NVP) in the pea crop in response to organic and chemical fertilization in the municipality of Pamplona, North of Santander. Bars with mean values ± standard deviation accompanied with different lowercase letters indicate statistical differences ($p<0.05$) among treatments. T0: Control; T1: Vermicompost full dose (VC100 % = 7831.00 kg/ha or 16.44 kg/plot of 21 m^2); T2: Vermicompost half dose (VC50 % = 3915.50 kg/ha or 8.22 kg/plot of 21 m^2) + Chemical Fertilizer (15N 15P_2O_5 15K_2O) half dose (FQ50 % = 703.50 kg/ha or 1.48 kg/plot of 21 m^2); T3: Hen manure + goat manure + sugarcane residues full dose (GCR100 % = 10573.00 kg/ha or 22.20 kg/plot of 21 m^2): T4: GCR half dose (GCR50 % = 5286.50 kg/ha or 11.10 kg/plot of 21 m^2) + Chemical Fertilizer (15N 15P_2O_5 15K_2O) half dose (FQ50 % = 703.50 kg/ha or 1.48 kg/plot of 21 m^2); T5: Chemical fertilizer full dose (FQ100 % = 1407.00 kg/ha or 2.95 kg/plot of 21 m^2); T6: Chemical fertilizer (15N 15P_2O_5 15K_2O) half dose (FQ50 % = 703.5 kg/ha or 1.48 kg/plot of 21 m^2).

The number of pods per plant is a very important yield component that determines crop productivity. The average NVP varied from 15.43 in the control treatment to 20.93 with the commercial fertilizer composed of hen manure, goat manure and sugarcane residues full dose (ABOB: 10573.00 kg/ha) and 22.83 with the full dose of the chemical fertilizer triple 15, finding no difference between the last two. In this regard, Jasim et al. (2016) found that both chemical and organic fertilization led to a significant increase in the number of pods per plant, pod length and seed yield of bean plants (*Visia faba* L.).

Likewise, Al-Bayati et al. (2019) found that the single or combined application of different doses of organic fertilizers and chemical fertilizers generated different responses in the pea crop (*Pisum sativum* L.). For example, the application of single organic fertilizer at 100 % of the required dose increased biological yield, number of seeds per pod and green seed yield. The combination of 3/4 chemical + 1/4 organic increased the number of branches per plant, dry matter percentage during vegetative growth, pod weight and pod length. The mixture of 1/4 chemical + 3/4 organic increased the number of pods per plant, pod yield per plant and total pod yield.

Additionally, there was a different response to the different sources of organic fertilizer, being the ABOB fertilizer the one that generated a better response. In this sense, Mukai (2018) showed that there can be a high variability in nutrient supply even within similar organic products, compared to chemical fertilizers where nutrients are immediately available to crops, so they are quickly absorbed by plants. Nevertheless, nutrient availability and crop yields can become similar for both organic and chemical fertilization when long-term effects are evaluated.

The average number of pods per plant obtained in the different treatments evaluated, as well as in the control was below those reported by Checa et al. (2017) who presented average values of number of pods per plant between 33 and 35 for the rainy seasons of the year under conditions of adequate moisture availability similar to those of this study. While Casanova et al. (2012) obtained average number of pods per plant (NVP) of 19.20, 20.25 and 20.10 at planting densities of 333333.00;

250000.00; and 200000.00 plants/ha, respectively. While in the treatment with the highest number of plants (666666.00 plants/ha) the NVP was statistically lower (16.05 pods per plant) in seven lines of bush pea (*Pisum sativum* L.).

The number of pods per plant is a variable sensitive to population density because the higher the density of plants, the greater the intraspecific competition and the lower the production of pods per plant. In this study, the population density was not evaluated, however, the population density was 333333.00 plants/ha equal for all treatments, and the values of number of pods per plant ranged from 15.43 in the control treatment to 22.83 in the chemical fertilization treatment at 100 % of the dose, indicating that the number of pods per plant is sensitive to the different doses and sources of both organic and chemical fertilization.

Galindo and Clavijo (2009) obtained average values between 9.70 and 9.90 pods/plant, relatively lower than those obtained in this study. These differences are probably due to factors such as natural soil fertility and the behavior of each of the varieties grown in each study area.

According to the results obtained in this study, it can be deduced that *Rabo de gallo* variety responds positively to both chemical fertilization and organic fertilization and that it has a good pod production both without fertilization and with organic or chemical fertilization, reason for which it is preferred by farmers in the area.

3.3 Length of green pods (LV)

Figure 2 shows that the LV of the pea crop was significantly lower in T0 than in the rest of the treatments, except in T1, which had no significant differences between them ($p>0.05$). No differences were observed among the rest of the treatments ($p>0.05$). This indicates that the pea crop responded favorably to the treatments applied with respect to the control, and the highest average value in the length of green pods was obtained (10.87 ± 0.947 cm) when applying organic fertilizer GCR100 % (T3).

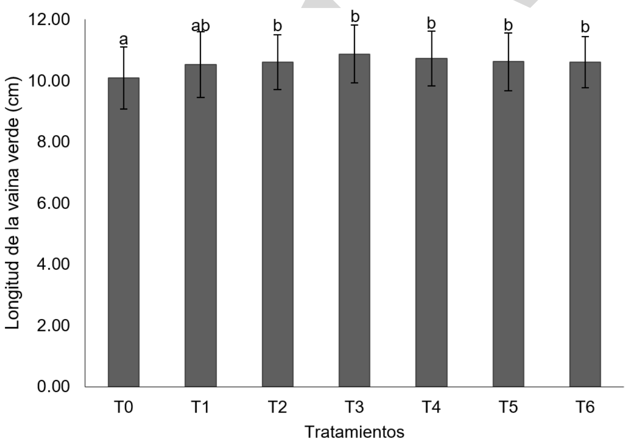

Figure 2. Length of green pods (LV) in the pea crop in response to organic and chemical fertilization in the municipality of Pamplona, North of Santander. Bars with mean values ± standard deviation accompanied with different lowercase letters indicate statistical differences ($p<0.05$) among treatments. T0: Control; T1: Vermicompost full dose (VC100 % = 7831.00 kg/ha or 16.44 kg/plot of 21 m^2); T2: Vermicompost half dose (VC50 % = 3915.50 kg/ha or 8.22 kg/plot of 21 m^2) + Chemical Fertilizer (15N $15P_2O_5$ $15K_2O$) half dose (FQ50 % = 703.50 kg/ha or 1.48 kg/plot of 21 m^2); T3: Hen manure + goat manure + sugarcane residues full dose (GCR100 % = 10573.00 kg/ha or 22.20 kg/plot of 21 m^2): T4: GCR half dose (GCR50 % = 5286.50 kg/ha or 11.10 kg/plot of 21 m^2) + Chemical Fertilizer (15N $15P_2O_5$ $15K_2O$) half dose (FQ50 % = 703.50 kg/ha or 1.48 kg/plot of 21 m^2); T5: Chemical fertilizer full dose (FQ100 % = 1407.00 kg/ha or 2.95 kg/plot of 21 m^2); T6: Chemical fertilizer (15N $15P_2O_5$ $15K_2O$) half dose (FQ50 % = 703.5 kg/ha or 1.48 kg/plot of 21 m^2).

According to the results, pod length was statistically lower ($p<0.05$) in the control treatment where no fertilizer was used than in the treatments with organic fertilizer and chemical fertilizer, except in treatment where 100% vermicompost was used. However, no differences were observed between treatments. Therefore, as with the variable number of days to flowering, it is likely that this variety presents a genetic condition that makes it more stable for this parameter, despite the different doses and sources of organic fertilizers, as well as chemical fertilizer used.

The values obtained in this study are above the data reported by DANE (2015) for the Santa Isabel and Guatecana varieties with pod length of 4 to 6 cm long, 4 to 5 cm for Piquinegra, 4 to 8 cm for the Sindamanoy variety, while the Obonuco San Isidro and Alcalá varieties present green pod length of 7.00 to 9.60 cm and 7.00 to 9.20 cm, respectively. This is another reason why farmers prefer using it in the area, so it is necessary to delve deeper into the origin of the seeds, their proper identification, as well as the possibilities of carrying out a certification and marketing process.

3.4 Crop yield

The crop was harvested when the plants were at main stage number 7, code 79 according to the BBCH scale, in which the pods have already reached the typical size (green maturity), and were fully formed (Enz and Dachler, 1998).

According to the results presented in Table 3 regarding the effect of organic and chemical fertilization on pea crop yield, no statistically significant differences ($p>0.05$) were found between the different treatments. Yield ranged from 5079.36 kg/ha for T6 as the lowest value to 7936.51 kg/ha for T4 as the highest value.

The yield values (kg/ha) obtained in this study are relatively higher than the national average, especially in the treatments with organic fertilization. For example, according to data published by DANE (2015) in Colombia green pod yields of 4000 to 5600 kg/ha have been reported for the Santa Isabel variety; the yield for the Piquinegra variety is between 2000 to 4500 kg/ha; yields for the Guatecana variety range from 3000 to 5000 kg/ha; yield for the Sindamanoy variety is 4197 kg/ha; meanwhile the Andean Obonuco variety can reach yields of up to 6608 kg/ha; the highest yields are obtained with Alcalá and Sureña varieties with 12000 and 14990 kg/ha, respectively.

Table 3. Pea crop yield (kg/ha) in response to organic and chemical fertilization in the municipality of Pamplona, North of Santander.

Treatment	Performance (kg/ha)
T0	5555.56 ± 3993.57^{a}
T1	7777.78 ± 991.27^{a}
T2	7460.32 ± 1198.38^{a}
T3	6031.74 ± 1454.78^{a}
T4	7936.51 ± 3170.63^{a}
T5	6190.47 ± 4151.33^{a}
T6	5079.36 ± 1672.32^{a}

Bars with mean values ± standard deviation accompanied by different lowercase letters indicate statistical differences ($p<0.05$) between treatments. T0: Control; T1: Vermicompost full dose (VC100% = 7831.00 kg/ha or 16.44 kg/plot of 21 m^2); T2: Vermicompost half dose (VC50% = 3915.50 kg/ha or 8.22 kg/plot of 21 m^2) + Chemical Fertilizer (15N $15P_2O_5$ $15K_2O$) half dose (FQ50% = 703.50 kg/ha or 1.48 kg/plot of 21 m^2); T3: Hen manure + goat manure + sugarcane residues full dose (GCR100% = 10573.00 kg/ha or 22.20 kg/plot of 21 m^2): T4: GCR half dose (GCR50% = 5286.50 kg/ha or 11.10 kg/plot of 21 m^2) + Chemical Fertilizer (15N $15P_2O_5$ $15K_2O$) half dose (FQ50% = 703.50 kg/ha or 1.48 kg/plot of 21 m^2); T5: Chemical fertilizer full dose (FQ100% = 1407.00 kg/ha or 2.95 kg/plot of 21 m^2); T6: Chemical fertilizer (15N $15P_2O_5$ $15K_2O$) half dose (FQ50% = 703.5 kg/ha or 1.48 kg/plot of 21 m^2).

Authors such as Khan et al. (2013), found yields ranging from 3.74 to 10.43 $t\cdot ha^{-1}$ in rainy conditions; while Checa et al. (2017) reported yields between 6.04 $t\cdot ha^{-1}$ for the dry season; and values between 10.21 and 12.96 $t\cdot ha^{-1}$ during the rainy season. On the other hand, Mishra (2014) reported yields of 5.5 $t\cdot ha^{-1}$, while Celis and Prett (1995), obtained yields of 20 $t\cdot ha^{-1}$ for the pea crop, which is much higher than that reported in this research. Casanova et al. (2012) reported green pod yields between 4076.90, 4725.56, 5968.61 kg/ha for planting densities of 666666, 333333 and 200000 plants/ha.

Despite not finding statistical differences between treatments, it is important to highlight a trend in which the use of single vermicompost at 100 % of the recommended dose (T1: 7831 kg/ha) represented an increase in yield with respect to the control treatment of 39.99 %. The combined use of vermicompost at half the dose (3915.50 kg/ha) + triple chemical fertilizer 15 half the dose (703.50 kg/ha) resulted in an increase of 34.28 %; while at T4 in which the combination of ABOB fertilizer at 50 % (5286.50 kg/ha) plus half the dose of chemical fertilizer FQ50 % (703.50 kg/ha) was applied, the yield was 42.85 % higher than the control. The lowest yield increase corresponded to T3 (ABOB: 10573.00 kg/ha) with 8.57 %, however in T5 with chemical fertilization at a dose of 1407.00 kg/ha of triple 15 the increase was only 11.42 %. When half the chemical fertilizer dose was used, yield was 8.58 % below the control.

A meta-analysis by Chivenge et al. (2011) reports yields of up to 60 % with the use of organic fertilizers compared to the unamended control, while the combined use of organic fertilizers and nitrogen fertilizers can result in yield increases of up to 114 %.

Relatively similar results were found by Rojas (2017) in agroclimatic conditions of Tiabaya-Arequipa, Peru, where the highest production of green pods of pea var. Quantum was obtained with organic fertilization in a mixture of 6 t·ha^{-1} of earthworm humus and 1 t·ha^{-1} of island guano and biol (liquid produced by a biodigester and used as foliar fertilizer at a concentration of 40 %) with yields up to 12.80 t·ha^{-1} significantly higher than those obtained in this study. Santamaría et al. (2010) also found higher green pea pod yields when using Fertigran liquid organic fertilizer at three phenological stages of the crop, compared to conventional fertilization.

A review conducted by Van Zwieten (2018) explored the long-term role of organic fertilizers and presented strong evidence on the yield benefits of organic fertilizers compared to unfertilized controls. Organic fertilizers may not provide an adequate or balanced nutrient dose, so the amount of nutrients present in the fertilizer and the application of some additional fertilizer must be taken into account. Therefore, a basic understanding of the characteristics of the type of fertilizer used is needed, especially in the total N and P contents provided.

Vermicompost is an organic fertilizer obtained from the action of the Californian earthworm, also known as solid earthworm humus. The fertilizer used in this study is a certified product with adequate percentages of nitrogen, phosphorus, potassium, calcium and magnesium, as well as a high cation exchange capacity (34.42 cmol(+)/kg of soil). On the other hand, ABOB is a certified fertilizer produced commercially from hen manure, goat manure and sugar cane residues with a nitrogen and potassium content similar to vermicompost, but with much higher concentrations of phosphorus and silicon, and with a lower cation exchange capacity than vermicompost (25.00 cmol(+)/kg of soil).

Since these are fertilizers with different sources of organic material, the contribution and release of nutrients is different between these, which is expressed in differential increases in yield. In this study, the best performance was with single vermicompost and with the combination of ABOB with the chemical fertilizer.

3.4.1 Pearson correlation analysis between yield and the different development and growth variables evaluated in the pea crop in response to the treatments

Table 4 presents the Pearson correlation analysis performed on the data obtained in the different treatments. Yield was significantly and positively correlated with plant height at 90 days ($p<0.05$ and Pearson correlation 0.53), while the number of pods per plant (VP) presented a highly significant and positive correlation ($p<0.01$ and Pearson correlation 0.55) with plant height at 90 days (AP90D).

The analysis presented in Table 4 states that as plant height increases in response to the treatments, the number of pods per plant also increases and, consequently, yield is higher.

Table 4. Pearson correlation analysis between yield and the different growth and development variables evaluated in the pea crop in response to organic and chemical fertilization in the municipality of Pamplona, North of Santander.

Correlations								
		Performance	AP30D	AP60D	AP90D	DF	VP	LV
Performance	Pearson correlation	1	-0.06	0.27	**0.53***	-0.08	0.2	-0.12
	Sig. (bilateral)		0.81	0.23	**0.01**	0.72	0.4	0.62
	N	21	21	21	21	21	21	21
AP30D	Pearson correlation	-0.06	1	0.50*	0.04	-0.26	-0.07	-0.43
	Sig. (bilateral)	0.81		0.02	0.87	0.26	0.75	0.06
	N	21	21	21	21	21	21	21
AP60D	Pearson correlation	0.27	0.50*	1	0.72**	-0.06	0.51*	0.07
	Sig. (bilateral)	0.23	0.02		0	0.8	0.02	0.77
	N	21	21	21	21	21	21	21
AP90D	Pearson correlation	0.53*	0.04	0.72**	1	0.19	0.56**	0.32
	Sig. (bilateral)	0.01	0.87	0		0.42	0.01	0.16
	N	21	21	21	21	21	21	21
DF	Pearson correlation	-0.08	-0.26	-0.06	0.19	1	-0.23	0.43
	Sig. (bilateral)	0.73	0.26	0.8	0.42		0.31	0.05
	N	21	21	21	21	21	21	21
VP	Pearson correlation	0.2	-0.07	0.51*	**0.56****	-0.23	1	0.18
	Sig. (bilateral)	0.4	0.75	0.02	**0.01**	0.31		0.43
	N	21	21	21	21	21	21	21
LVS	Pearson correlation	-0.12	-0.43	0.07	0.32	0.43	0.18	1
	Sig. (bilateral)	0.62	0.06	0.77	0.16	0.05	0.43	
	N	21	21	21	21	21	21	21

*.The correlation is significant at the 0.05 level (bilateral).
**. The correlation is significant at the 0.01 level (bilateral).
AP30D: Plant height at 30 days; AP60D: Plant height at 60 days; AP90D: Plant height at 90 days; DF: Number of days to flowering; VP: Number of pods per plant; LV: Length of green pod.

The application of single or combined organic fertilizers with chemical fertilizer generated different effects on the growth and yield evaluated. Authors such as Pandey (2017), point out that the organic and inorganic combination of nutrient supply can be synergistic in pea crop because the organic source improves the physical and biological environment of the soil, increasing the availability of nutrients from the inorganic source. The increase in seed yield is due to the effect of growth and yield attributes.

Although the soils in this study have good fertility, it was possible to observe a positive response of the types of single or combined fertilizers with chemical fertilization. Organic fertilizers provide organic carbon to the soil, which is important for stimulating the growth of soil microbial biomass, especially in the long term. Increases in soil organic carbon of up to 49% have been reported after adding organic fertilizers compared to an unfertilized control and 29% over a fertilized control (Chen et al., 2018; Murillo-Montoya et al., 2020). Similarly, organic fertilizers can directly supply both macro and micronutrients, and as for the long-term supply of N, it is regulated by the mineralization rate of the added organic compounds. Additionally, the nutrient content depends on the source and quality of the added organic compounds (Van Zwieten, 2018).

4 Conclusions

Plant height was positively affected by the combined use of vermicompost at half the recommended dose (3915.50 kg/ha) plus half the dose of triple 15 chemical fertilizer (703.50 kg/ha) compared to the control treatment.

The number of pods per plant was higher with the fertilizer based on hen manure, goat manure and sugarcane residues at the full dose compared to chemical fertilization.

The length of green pods was above the national average and responded very well to the single or combined application of organic fertilizers and chemical fertilizers compared to the control. Although no statistical differences in yield were found among the different treatments, T1 and T4 presented a yield higher than the control of 42.85 % and 39.99 %, respectively.

Regarding vermicompost, the combination with chemical fertilizer favored plant height, probably due to faster nutrient availability.

The combination of organic fertilizers with chemical fertilizers generated positive effects on the pea crop. The *Rabo de gallo* variety responded very well to single or combined application of organic and chemical fertilizers, reason for which it is preferred by farmers in the area. Therefore, it is possible to substitute or complement chemical fertilizer with organic fertilizers and reduce the negative effect of contamination on the environment and people's health.

5 Recommendations

Combine the use of organic fertilizer with chemical fertilizer, due to the better response obtained in crop variables.

Evaluate different doses of organic fertilizer on crop growth variables.

Study the *Rabo de gallo* pea variety, investigate its origin, study different planting distances, different types of soils, include a greater number of crop variables and compare it with other varieties used at the national level.

Analyze the effect of organic fertilizer on the physical, chemical and biological properties of soils in the short, medium and long term.

References

Al-Bayati, H., Ibraheem, F., Allela, W., and AL-Taey, D. (2019). Role of organic and chemical fertilizer on growth and yield of two cultivars of pea (pisum sativum l.). *Plant Archives*, 19(Supplement 1):1249–1253. Online:https://bit.ly/3rH7rzM.

Álvarez-Sánchez, E., Vázquez-Alarcón, A., Castellanos, J., and Cueto-Wong, J. (2006). Efectividad biológica de abonos orgánicos en el crecimiento de trigo. *Terra Latinoamericana*, 24(2):261–268. Online:https://bit.ly/3vD1ULV.

Amaya, C. (2017). Establecimiento de un proyecto productivo de arveja (pisum sativum l.) en un área de 5.000 m2 como alternativa económica ante la deforestación en el municipio de ragonvalia, norte de santander. Master's thesis, Universidad de La Salle, Yopal, Casanare.

Bautista-Zamora, D., Chavarro-Rodríguez, C., Cáceres-Zambrano, J., and Buitrago-Mora, S. (2017). Efecto de la fertilización edáfica en el crecimiento y desarrollo de phaseolus vulgaris cv. ica cerinza. *Revista Colombiana de Ciencias Hortícolas*, 11(1):122–132. Online:https://n9.cl/2zoda.

Buitrago, J. Y., Duarte, C. J., and Sarmiento, A. (2006). *El cultivo de la arveja en Colombia*. Ed. Produmedios.

Casanova, L., Solarte, J., and Checa, O. (2012). Evaluación de cuatro densidades de siembra en siete líneas promisorias de arveja arbustiva (pisum sativum l.). *Revista de Ciencias Agrícolas*, 29(2):129–140. Online:https://bit.ly/3Mo3Qic.

Celis, A. and Prett, G. (1995). Producción estival de arvejas en la costa interior en la décima región. instituto de investigaciones agropecuarias. *Boletín Técnico Remehue*, (232).

Checa, O., Narváez, C., and Bastidas, J. (2017). Evaluación agronómica y económica de arveja arbustiva (pisum sativum l.) en diferentes épocas de siembra y sistemas de tutorado. *Revista UDCA Actualidad y divulgación científica*, 20(2):279–288. Online:https://bit.ly/3ETBpGc.

Chen, Y., Camps-Arbestain, M., Shen, Q., Singh, B., and Cayuela, M. (2018). The long-term role of organic amendments in building soil nutrient fertility: a meta-analysis and review. *Nutrient Cycling in Agroecosystems*, 111(2):103–125. Online:https://bit.ly/37TrtAi.

Chivenge, P., Vanlauwe, B., and Six, J. (2011). Does the combined application of organic and mineral nutrient sources influence maize productivity? a meta-analysis. *PloS one*, 342:1–30. Online:https://bit.ly/3rVDYlE.

Climate-Data.Org (2020). Clima Pamplona, Norte de Santander Colombia. INEC. Online:https://bit.ly/3Mub1oW.

Dahl, W., Foster, L., and Tyler, R. (2012). Review of the health benefits of peas (pisum sativum l.). *British Journal of Nutrition*, 108(S1):S3–S10. Online:https://bit.ly/3vZ6fZN.

DANE (2015). El cultivo de la arveja en Colombia. *Boletín mensual Insumos y Factores Asociados a la Producción Agropecuaria*, (33):1–78. Online:https://bit.ly/3MxuYv5.

Davies, D., Berry, G., Heath, M., and Dawkins, T. (1985). *Grain Legume Crops*, chapter Pea (*Pisum sativum L.*). Collins, London.

El-Salehein, E., El-Gammal, M., Salem, I., and Omar, E. (2019). Utilization of friendly fertilizers as an organic and npk fertilizers on peas (pisum sativum l.). *Int. J. Environ*, 8(2):85–94. Online:https://bit.ly/3y5MJO5.

Enz, M. and Dachler, C. (1998). Compendio para la identificación de los estadios fenológicos de especies mono- y dicotiledóneas cultivadas escala BBCH extendida. BBCH. Online:https://on.basf.com/3vWDJIr.

FAO (2019). El estado mundial de la agricultura y la alimentación. progresos en la lucha contra la pérdida y el desperdicio de alimentos. FAO. Online:https://bit.ly/3vyLR2R.

FENALCE (2015). Catálogo de semillas. FENALCE.

Flores, Y., Romero, A., Torres, A., Briceño, F., and García, A. (2021). Efecto de abonos biológicos y fertilizantes químicos en el cultivo de maíz, flasa cojedes venezuela: Effect of biological fertilizers and chemical fertilizers in corn cultivation, flasa cojedes venezuela. *Ciencia y Tecnología Agropecuaria*, 6(1):21–27. Online:https://bit.ly/3F40NsV.

Galindo, J. and Clavijo, J. (2009). Fenología del cultivo de arveja (pisum sativum l. var. santa isabel) en la sabana de bogotá en campo abierto y bajo cubierta plástica. *Ciencia y Tecnología Agropecuaria*, 10(1):5–15. Online:https://bit.ly/3LyOBCX.

González, J., Mosquera, J., and Trujillo, A. (2015). Efectos e impactos ambientales en la producción y aplicación del abono supermagro en el cultivo de sandía. *Ingeniería y Región*, 13:103–111. Online:https://bit.ly/3vw9MQw.

González-García, H., Chirinos-García, C., Soto-Bracho, A., and Pineda-Zambrano, M. (2021). Efecto de la tiamina sobre el crecimiento y desarrollo del pimentón (capsicum annuum l.) en el sector la grita, estado táchira, venezuela: Effect of thiamine on the growth and development of paprika (capsicum annuum l.) in the la grita sector, táchira state, venezuela. *Ciencia y Tecnología Agropecuaria*, 6(1):3–8. Online:https://bit.ly/3Kz0pDX.

Gopinath, K. and Mina, B. (2011). Effect of organic manures on agronomic and economic performance of garden pea (pisum sativum) and on soil properties. *Indian Journal of Agricultural Sciences*, 81(3):236–239. Online:https://bit.ly/3s3VB38.

Heinze, S., Raupp, J., and Joergensen, R. (2010). Effects of fertilizer and spatial heterogeneity in soil ph on microbial biomass indices in a long-term field trial of organic agriculture. *Plant and Soil*, 328(1):203–215. Online:https://bit.ly/3LufUyd.

Jasim, A., Atab, H., and Abed, H. (2016). Effect of organic and chemical fertilizers and their interaction with foliar fertilizers on yield of broad bean (*Visia faba L.*). *TEuphrates Journal of Agriculture Science*, 4(7):44–48. Online:https://bit.ly/3vLRQ4y.

Khan, T., Ramzan, A., Jillani, G., and Mehmood, T. (2013). Morphological performance of peas (pisum sativum) genotypes under rainfed conditions of potowar region. *J. Agric. Res*, 51(1):51–60. Online:https://bit.ly/37WVEXm.

Laboratorio químico de suelos, editor (2018). *Resultado análisis de suelos*, volume 1. Universidad Industrial de Santander.

Lalito, C., Bhandari, S., Sharma, V., and Yadav, S. (2018). Effect of different organic and inorganic nitrogenous fertilizers on growth, yield and soil properties of pea (pisum sativum, l.). *J. Pharmacognosy and Phytochemistry*, 7(4):2114–2118. Online:https://bit.ly/3vTuqsA.

Latorre, A. and Villamizar, Q. (2019). Evaluación del efecto de la fertilización en el rendimiento de cuatro clones promisorios de papa criolla (solanum phureja juz. et. buk) en mutiscua, norte de santander: Evaluation of the effect of fertilization on the yield of four promising creole potato clones (solanum phureja jud. et. buk) in mutiscua, norte de santander. *Ciencia y Tecnología Agropecuaria*, 4(1):3–9. Online:https://bit.ly/3s8ySTp.

Mátyás, B., Lowy, D., Singla, A., Melendez, J., and Sándor, Z. (2020). Comparación de los efectos ejercidos por los biofertilizantes, los fertilizantes npk y los métodos de cultivo sobre la respiración del suelo en el suelo de chernozem. *La Granja. Revista de Ciencias de la Vida*, 32(2):8–18. Online:https://n9.cl/mijxg.

Mishra, N. (2014). Growth and yield response of pea (pisum sativum l.) to integrated nutrient management-a review. *Journal of plant and pest science*, 1(2):87–95. Online:https://bit.ly/3s8OV3L.

Mohammed, H., Sarheed, B., Salum, M., and Alshaheen, M. (2019). The effect of the source and the level of residues in some of the characteristics of the soil and yield of broad bean (vicia faba l.). *Plant Archives*, 19(1):898–903. Online:https://bit.ly/3KzMkpD.

Mukai, S. (2018). Historical role of manure application and its influence on soil nutrients and maize productivity in the semi-arid ethiopian rift valley. *Nutrient Cycling in Agroecosystems*, 111(2):127–139. Online:https://bit.ly/38M79AY.

Murillo-Montoya, S., Mendoza-Mora, A., and Fadul-Vásquez, C. (2020). La importancia de las enmiendas orgánicas en la conservación del suelo y la producción agrícola. *Revista Colombiana de Investigaciones Agroindustriales*, 7(1):58–68. Online:https://bit.ly/3ygnJE5.

Pandey, V. (2017). Impact of integrated nutrient management on seed yield and its attributes in field pea (pisum sativum l.). *Chemical Science Review and Letters*, 6(23):1428–1431. Online:https://bit.ly/38GLU3D.

Peñaranda, G. and Molina, G. (2011). La producción de arveja (pisum sativum l.) en la vereda monteadentro, provincia de pamplona, norte de santander. *Revista Face*, 11(1):43–56. Online:https://bit.ly/3LNmaBu.

Rojas, H. (2017). Producción de arveja verde "quantum" (pisum sativum l.) con aplicaciones de humus de lombriz, guano de islas y biol en condiciones agroclimáticas de tiabaya – arequipa. Master's thesis, Universidad Nacional de San Agustín de Arequipa. Facultad de Agronomía.

Santamaría, M., Niño, E., Blanco, E., Prieto, Y., and Galeano, J. (2010). Evaluación de dos fertilizantes orgánicos frente al fertilizante compuesto mineral 10 30 10 y sus mezclas, en el cultivo de arveja pisum sativum l. en madrid cundinamarca. *Inventum*, 5(9):14–18. Online:https://bit.ly/3y9bicY.

Suresh, K., Sneh, G., Krishn, K., and Mool, C. (2004). Microbial biomass carbon and microbial activities of soils receiving chemical fertilizers and organic amendments. *Arch. Agron. Soil Sci*, 50(7):641–647. Online:https://bit.ly/382kHbF.

Van Zwieten, L. (2018). The long-term role of organic amendments in addressing soil constraints to production. *Nutrient cycling in Agroecosystems*, 111(2):99–102. Online:https://bit.ly/3OPlMUZ.

Watt, B. and Merrill, A. (1993). *Composition of Foods*. Number 8.

Willer, H., Schlatter, B., Trávnicek, J., Kemper, L., and Lernoud, J. (2020). The world of organic agriculture. statistics and emerging trend 2020. Research Institute of Organic Agriculture (FiBL), Frick and IFOAM-Organics International, Bonn. Online:https://bit.ly/3MMm1Ov.