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Productivity and nutritional value of common beans with organic fertilization in Durango, Mexico

Productividad y valor nutricional de frijol común con fertilización orgánica en Durango, México

Produtividade e valor nutricional do feijão comum com adubação orgânica em Durango, México

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Abstract

Biofertilizers help to increase crop yields and nutritional quality, reducing the use of agrochemicals that affect ecosystems and human health. The objective of this study was to evaluate the yield and nutritional value of the Pinto Rarámuri variety bean, under an organic fertilization scheme in rainfed conditions in Durango, Mexico. Sowing was carried out in open fields in Villa Montemorelos, Durango, using a randomized complete block design with six treatments [manure tea (tea), sewage sludge (sludge), super lean (lean), commercial organic fertilizer (foc), chemical fertilizer (fqf) and control] five repetitions, 30 plots and five plants per plot as experimental unit. The variables were: emergence percentage, height and pods per plant, seeds per pod, seed thickness and length, weight of 100 seeds, yield, crude fiber percentage, protein, ash, fat, and nitrogen-free extract. A two-way analysis of variance and Tukey's comparison of means ($p \leq 0.05$) were performed. The treatments showed statistical difference, the highest yield and weight of 100 seeds was presented by sludge, fqf and foc; while the highest number of pods and plant height was obtained by sludge and fqf. The lowest yield, pods per plant, seeds per pod and plant height were observed in control. The nutritional value presented statistical equality between treatments. The use of organic fertilization is a sustainable alternative to increase bean productivity in the state of Durango, without disturbing its nutritional quality.

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Resumen

Los biofertilizantes ayudan a aumentar el rendimiento y la calidad nutricional de los cultivos, permitiendo disminuir el uso de agroquímicos que afectan los ecosistemas y la salud humana. El objetivo del presente estudio fue evaluar el rendimiento y el valor nutricional del frijol variedad Pinto Rarámuri, bajo un esquema de fertilización orgánica en condiciones de temporal en Durango, México. La siembra se realizó en campo abierto en Villa Montemorelos, Durango, utilizando un diseño en bloques completos al azar con seis tratamientos [té de estiércol (té), lodos residuales (lodos), súper magro (magro), fertilizante orgánico comercial (foc), fertilizante químico (fqf) y control], cinco réplicas, 30 parcelas y cinco plantas por parcela como unidad experimental. Las variables fueron:porcentaje de emergencia, altura y vainas por planta, semillas por vaina, grosor y longitud de semilla, peso de 100 semillas, rendimiento, porcentaje de fibra cruda, proteína, ceniza, grasa y extracto libre de nitrógeno. Se realizó un análisis de varianza doble y la comparación de medias de Tukey ($p \leq 0,05$). Los tratamientos mostraron diferencia estadística, el mayor rendimiento y peso de 100 semillas fue para lodos, fqf y foc, mientras que el mayor número de vainas y altura de planta fue para lodos y fqf. El menor rendimiento, vainas por planta, semillas por vaina y altura de planta se observó en el control. El valor nutricional presentó igualdad estadística entre tratamientos. La utilización de fertilización orgánica es una alternativa sustentable para elevar la productividad de frijol en el estado de Durango, sin afectar su calidad nutricional.

Palabras clave: rendimiento, calidad, biofertilizantes.

Resumo

Os biofertilizantes ajudam a aumentar o rendimento e a qualidade nutricional das culturas, permitindo reducindo o uso de agroquímicos que afetam os ecossistemas e a saúde humana. O objetivo deste estudo foi avaliar o rendimento e o valor nutricional do feijão da variedade Pinto Rarámuri, sob um esquema de adubação orgânica sob condições de sequeiro em Durango, México. O plantio foi realizado em campos abertos em Villa Montemorelos, Durango, usando um delineamento de blocos completo aleatórios com seis tratamentos [infusão de esterco (tea), mud of esgoto (sludge), super lean (lean), adubo orgânico comercial (foc), adubação (fqf) e testemunha (control)] cinco replicados, 30 parcelas e cinco plantas por parcela como unidade experimental. As variáveis foram: porcentagem de emergência, altura e vagens por planta, sementes por vagem, espessura e comprimento das sementes, peso de 100 sementes, rendimento, porcentagem de fibra cruruta, proteína, cinzas, gordura e extrato livre de nitrogênio. Foi realizada análise de variância duplo e comparação de médias de Tukey ($p \leq 0,05$). Os tratamentos apresentaram diferença estatística, a maior rendimento e peso de 100 sementes foi para lodos, fqf e foc; Enquanto o maior número de vagens e altura de planta foi para sludge e fqf. Os menores rendimentos, vagens por planta, sementes por vagem e altura da planta foram observados na control. O valor nutricional apresentou igualdade estatística entre os tratamentos. A utilização da adubação orgânica é uma alternativa sustentável para aumentar a produtividade do feijão no estado de Durango, sem afetar sua qualidade nutricional.

Palavras-chave: produtividade, qualidade, biofertilizers.

Introduction

The bean (*Phaseolus vulgaris* L.) is distributed worldwide and is considered a staple food in the human diet due to its high nutrient content (24.7 % protein, 69.4 % carbohydrates and 1.7 % lipids) (SAGARPA-CONACyT, 2018).

Mexico ranked ninth in bean exports worldwide (1,288,806.47 $t.year^{-1}$), representing a contribution of 4.65 % of production (FAO, 2021). In Durango, this crop is one of the main economic activities; during the period 2015 to 2019, an average area of 228 thousand ha was planted with an average temporary yield of 460 $kg.ha^{-1}$ (INFOSIAP, 2020).

Agriculture in Mexico presents a serious problem derived from the inappropriate use of technology (machinery, fertilizers, pesticides, among others); this has led to higher production costs and soil deterioration (SADER-INIFAP, 2021a); the latter influences the nutritional quality of food that directly impacts human health (Steffan *et al.*, 2017). In turn, bean production and nutritional quality are affected by precipitation, soil fertility, and pathogenic organisms that cause pests and diseases (Rosales-Serna *et al.*, 2019).

The integrated knowledge of producers and scientists has allowed the development of processes for the production of low-cost organic inputs, as a sustainable option to minimize the damage caused by the use of synthetic products in crop nutrition (SADER-INIFAP, 2021a).

These products are obtained from the microbial decomposition of organic remains of animal and plant origin (Ladrón de Guevara *et al.*, 2017), as is the case of super lean fertilizer, which is prepared with bovine rumen fluid, water, whey, molasses, and ash, which are anaerobically fermented (SADER-INIFAP, 2021a) and manure tea, which results from the aerobic fermentation of manure, fish meal, molasses, and water; both contain beneficial microorganisms and nutrients that act as plant growth enhancers, enrich the microflora, restore the structure of the soil and strengthen the defense system of plants helping them to deal with pests and diseases, thus reducing the use of agrochemicals (SADER-INIFAP, 2021b).

Favorable results have been obtained with the use of these organic products, as is the case of rice production (*Oryza sativa* L.) with manure tea (Diaz and Contreras, 2022), hybrid maize (*Zea mays)* under the application of biocompost and vermicompost (Fortis-Hernández *et al.,* 2009), maize (*Zea mays*), tomato (*Solanum lycopersicum*), chili (*Capsicum annuum*), sorghum (*Sorghum bicolor*), common bean (*Phaseolus vulgaris*), pea (*Pisum sativum*), pumpkin (*Cucurbita pepo*) and watermelon (*Citrullus lanatus*) with leachate of vermicompost and soil microorganisms, which decreased the dose of chemical fertilization by up to 35 % (Guardiola-Márquez *et al.,* 2019). Alvarado *et al.* (2017) concluded in their study, that the use of mycorrhizal-based biofertilizer in common beans achieved increases of 15 %, in the number of pods and grain weight per plant, as well as the yield per hectare.

The information that people have about the effect of organic fertilizers on bean production is scarce, however, products similar to those of this work (manure tea and super lean fertilizer) have been evaluated in the production of bananas (*Musa acuminata* AA) (Jiménez-Esparza *et al.,* 2019) and watermelon (*Citrullus lanatus*) (González *et al.,* 2015), respectively, highlighting the use of these biofertilizers over control treatments.

More studies are required to demonstrate the feasibility of using organic fertilizers to increase crop production and quality that help mitigate the negative effects of agrochemicals. Therefore, the objective of this research was to evaluate the yield and nutritional value of the Pinto Rarámuri variety bean, under a scheme of organic fertilization in rainfed conditions in Durango, Mexico.

Materials and methods

The experiment was carried out in the experimental field and laboratories of agrochemistry and plant biotechnology of the National Technological Institute of México, Valle del Guadiana campus, located at km 22.5 of the Durango-Mexico highway, Villa Montemorelos, Durango, Mexico (latitude 24°00'18.25" N and longitude 104°26'42.13", 1,860 meters above sea level). At the experimental site, an average temperature of 21.5 °C (SMN, 2021) and accumulated precipitation of 632 mm were presented during the evaluation period (spring-summer agricultural cycle).

The Pinto Rarámuri variety was used, short-cycle, drought-tolerant crop. In rainfed conditions, maturity occurs between 90-95 days after sowing (dds) and irrigation 95-105 dds (Cruz *et al.*, 2021). The sowing was carried out on June 29th, 2020, in a vertisol soil, according to the classification made by the *World Reference Base for soil resources* (IUSS, 2015), with clay textural class. A precision seeder (John Deere®, USA) was used with four rows separated at 0.76 m between them and 0.10 m between plants.

The cultural practices of the soil were carried out according to the specifications of the agricultural technical guide Durango and La Laguna (SAGARPA-COFUPRO-INIFAP, 2017), under rainfed conditions. For weed control, 50 % of the dose recommended by the manufacturer of an herbicide based on fluazifop-p-butyl and fomesafen was applied; subsequently, a weeding was carried out manually. Chemical pest control was made with a product based on imidacloprid-beta-cyfluthrin. The harvest was done at 106 dds.

For the production of the super lean biofertilizer, the methodology described by SADER-INIFAP (2021a) was followed, adding inocula of *Azospirillum* spp. and *Trichoderma* spp. with a minimum concentration of $1x10^6$ UFC.mL^{-1} and $1x10^8$ UFC.mL^{-1}, respectively, both native to the Guadiana Valley, isolated and reproduced in the plant biotechnology laboratory of the aforementioned institute.

Manure tea was prepared with bovine manure, under the methodology of SADER-INIFAP (2021b); the mixture obtained was inoculated with *Azotobacter* spp. ($1x10^5$ UFC.mL^{-1}), *Azospirillum brasilense* ($1x10^5$ UFC.mL^{-1}) and *Pseudomonas fluorescens* ($1x10^5$ UFC.mL^{-1}), from Agribest®.

To evaluate the effect of organic fertilizers on crop productivity and nutritional quality, a randomized complete block design was used, with six treatments (table 1), five blocks, and 30 plots, covering a total experimental area of 19,863.36 m^2. The experimental sample consisted of five plants, harvested from the center of each experimental plot.

Table 1. Fertilization treatments evaluated in the production of Pinto Rarámuri beans.

Identification	Treatment	Dose
Tea	Manure tea	100 L.ha^{-1}
Sludge	Sewage sludge	24 t.ha^{-1}
Lean	Super lean biofertilizer	100 L.ha^{-1}
Foc	Commercial organic fertilizer	40 L.ha^{-1}
Fqf	Foliar chemical fertilizer	2 L.ha^{-1}
Control	Control	Unfertilized

The sludge was provided by the South Wastewater Treatment Plant of the city of Durango, Mexico and was applied with a mechanical shovel 15 days before sowing, distributing it uniformly over the corresponding plots; Once dry, two steps of drag were made to incorporate it into the soil. The rest of the treatments were applied by foliar application using a 15 L hand sprinkler (Swissmex®, Mexico). Lean, tea, and foc were applied at 0, 15, 30 and 45 (dds); fqf was applied at 38 and 50 dds. The doses of organic treatments were established based on previous research (Salcedo-Pérez *et al.*, 2007).

Table 2 shows the chemical, physical and/or biological composition of each of the fertilization treatments evaluated.

Table 2. Chemical, physical and/or biological composition of fertilization treatments evaluated in the production of Pinto Rarámuri beans.

Treatment	Composition
tea	pH: 4.8; electrical conductivity (CE): 4.02 dS.m^{-1}; Potassium (K): 516 ppm; Calcium (Ca): 380 ppm; Magnesium (mg): 48 ppm; Sulfates ($S-SO_4$): 890 ppm; Bicarbonates (HCO_3): 414 ppm; Phosphates ($P-PO_4$): 27.6 ppm; Nitrates ($N-NO_3$): Zn: 0.81 ppm.
lean	pH: 7.73; organic matter (MO): 0.48 %; Potassium (K): 0.188 %; Calcium (Ca): 0.117 %; Magnesium (mg): 0.04 %; Total nitrogen: 0.017 %; Phosphorus (P): 0.028 %; Sodium (Na): 0.038 % (Phosphates ($P-PO_4$): 27.6 ppm; Nitrates ($N-NO_3$): Zn: 0.81 ppm; Chlorides (Cl): 135 ppm; Fe (10.32 ppm); Mn (1.48 ppm); Humic material: 0.14 %; Humic acid: 0.03 %; Fulvic acids: 0.07 %.
sludge	pH: 6.8; organic matter (OM): 14.11 %; electrical conductivity (EC):3.52 dS.m^{-1}; Nitrogen (N): 0.70 %; Phosphorus (P): 247.92 mg. Kg^{-1}; Potassium (K): 55 ppm; Arsenic (As):<0.1 ppm; Cadmium (Cd):<0.34 ppm; Chromium (Cr):<124 ppm; Copper (Cu): 66.48 ppm; Lead (Pb):<64 ppm, Mercury (Hg):<0.6 ppm; Nickel (Ni): <56 ppm; Zinc (Zn): 429.43 ppm; Fecal coliforms: <300 NMP.g^{-1} Dry base; *Salmonella*: <300 NMP.g^{-1} Dry base; Helminth eggs: 0 Eggs.2 g^{-1} g St; Moisture lost by drying: 77 %.
fqf	Potassium (K): 5.0 %; Calcium (Ca): 207 ppm; Magnesium (mg): 207 ppm; Total nitrogen: 9.1 %; Phosphorus (P): 6.6 %; Sulfur (S): 1250 ppm; Boron (B): 332 ppm; Cobalt (Co): 17 ppm; Zn: 666 ppm; Copper (Cu): 332 ppm; Molybdenum (Mo): 42 ppm; Manganese (Mn): 332 ppm; Iron (Fe): 415 ppm; Thiamine hydrochloride: 33 ppm; Indoleacetic acid: 25 ppm.
foc	*Bacillus subtillis, Trichoderma*, *Azospirillum*, *Azotobacter*, *Rhizobium*, Amino Acid Enzymes, Auxins.

tea: manure tea; sludge: sewage sludge; lean: super lean; foc: commercial organic fertilizer; fqf: chemical fertilizer; ppm: parts per million.

The response variables were: emergence percentage (%) at 13 dds; plant height (cm) at 55 dds; number of pods per plant and number of seeds per pod (Morel *et al*., 2021); weight of 100 seeds (g) and yield (t.ha^{-1}) (Rosales-Serna *et al.*, 2019); seed thickness and length (cm) (Espinosa-Pérez *et al.,* 2015).

The nutritional value of the bean grain was determined by laboratory tests established in the manuals *of the Association of Official Analytical Chemists* (AOAC, 2002). The samples consisted of 100 bean seeds randomly selected in each treatment, which were ground in a mill (Thomas-Wiley®, Laboratory Mill Mod. 4 type, USA), to obtain homogeneous particles of 1 mm. The flours were placed in sealed and labeled paper bags until the time of analysis. The variables of nutritional value were: percentage of crude fiber, protein, fat, ash, and nitrogen-free extract.

Statistical analysis

A two-way analysis of variance (ANOVA) was performed and significant differences between treatments ($p \leq 0.05$) were compared with Tukey's test ($p = 0.05$), using InfoStat software (Di Rienzo *et al.*, 2018).

Results and discussion

In the ANOVA, significant differences ($p \leq 0.05$) were found between treatments for the variables evaluated. Table 3 shows the comparison of means.

The emergence of plants was 100 % in control treatments, fqf, and foc, lean treatment presented 90 % and tea and sludge 80 %, this negative effect of inoculated organic fertilizers (tea and lean), can be attributed to imbalances in the synthesis of enzymes, due to the competition for nutrients between seeds and inoculated bacteria, as well as the presence of volatile metabolites that can positively and negatively affect the emergence and vegetative development of seedlings (León and Rojas, 2015).

When evaluating the plant height at 55 dds, it was observed that the best treatments were sludge (27.80 cm) and fqf (22.95 cm); Control plants and those treated with lean presented the lowest height. The behavior observed in plants with the application of sludge (Table 2) can be attributed to the contribution of organic matter and macro and micronutrients by sludge (Salcedo-Pérez *et al.*, 2007), as well as in fqf, which in addition to nutrients, contains thiamine hydrochloride and indoleacetic acid, both plant growth factors. The results observed in treatments with lean (Table 2) contrast with those reported by Martínez *et al.* (2016) and Quintero *et al.* (2018), who reported that bean plants treated with commercial biofertilizer, alone or combined with biostimulants, significantly increased plant height, compared to those unfertilized plants.

In terms of the number of pods per plant, all treatments exceeded control (13.55 pods), highlighting sludge treatment (26.61 pods). These results show that the use of some type of fertilization, including organic, stimulates the greater production of pods, indicating that the nutrients present in the fertilizer are successfully assimilated by the plant, as reported by Morel *et al.* (2021), who obtained a greater number of pods when applying an organic fertilizer on common beans.

In the variable seeds per pod, plants treated with foc presented 4.33 seeds, followed by lean and sludge ($p \leq 0.05$); in the third statistical group, tea, fqf, and control treatments showed no statistical difference between them. The number of seeds per pod is an important component of the yield that, together with the number of pods, results in an important factor of elevation of the same according to De la Fé *et al.* (2016), contrary to this, in the present work an effect was observed on the weight of seeds and not on the number of these (Table 3).

The weight of 100 seeds and yield showed statistical differences ($p \leq 0.05$) between treatments, however, all are in the category of medium seeds (between 25 to 40 g), according to Singh *et al.* (1991a, b). The treatments with the highest weight of 100 seeds, were sludge, fqf, and foc (39.00; 37.94, and 36.33 g, respectively), which also presented the highest yields (3.96; 3.29 and 3.23 $t.ha^{-1}$) and exceed the average annual production under rainfed conditions in the entity (0.460 $t.ha^{-1}$) (INFOSIAP, 2020); in addition, the treatment with sludge exceeded 38.00 g corresponding to the weight of 100 seeds and 0.7-1.5 $t.ha^{-1}$ yield under rainfed conditions in beans reported by Cruz *et al.* (2021).

The lowest weight of 100 seeds and yield was observed in the control treatment (26.00 g and 1.21 $t.ha^{-1}$, respectively). The yield of the crop with sludge was higher than the rest of the other treatments (Table 2), and was probably due to the contribution of macro and micronutrients (N, P, K, Zn, among others), as well as organic matter, which when assimilated by the plant during the seed filling stage, contribute to its weight significantly; as stated by Salcedo-Pérez *et al.* (2007), when evaluating sewage sludge as organic fertilizer in maize. Similarly, Arellano-Arciniega *et al.* (2015) obtained the highest yield, number of pods, and weight of 100 seeds in common bean crops fertilized with bovine manure.

In this work it was found that not necessarily the seeds with larger dimensions show the highest yields, as was the case of the treatment with sludge which obtained the smallest seeds with the highest yield, as well as the highest plant height, number of pods and weight of 100 seeds, coinciding with the work of Quintero *et al.* (2018), who applied biostimulants by foliar application on common beans and observed the increase in morphophysiological parameters, directly related to yield.

It has been reported that these types of products act as stimulators of the physiological processes of plants, promoting their growth and development (Calero *et al.*, 2016), thus offering a greater photosynthetic surface for the production of biomass that

Table 3. Comparison of means of emergence, plant height, pods per plant, seeds per pod, seed thickness and length, weight of 100 grains, and yield of Pinto Rarámuri beans influenced by biofertilizers.

Productivity Variables	control	fqf	lean	tea	foc	sludge	CV
Emergence (%)	100a	100a	90ab	80b	100a	80b	5.14
Plant height (cm)	16.7cd	22.95ab	15.10d	21.16bc	19.03bcd	27.80a	10.87
Pods per plant	13.55c	24.75ab	20.95b	21.25b	20.55b	26.61a	10.81
Seeds per pod	3.44c	3.51c	4.12ab	3.51c	4.33a	3.82bc	5.08
Seed thickness (cm)	0.75b	0.84a	0.74b	0.64c	0.86a	0.61c	4.76
Seed length (cm)	1.22a	1.26a	1.22a	1.06b	1.25a	1.06b	2.63
P100S (G)	26.00b	37.94a	29.22b	27.50b	36.33a	39.00a	6.11
Yield ($t.ha^{-1}$)	1.21d	3.29ab	2.59bc	2.05cd	3.23ab	3.96a	16.63

Values with different letters in the same row are statistically different, according to Tukey ($p \leq 0.05$). tea: manure tea; sludge: sewage sludge; lean: super lean; foc: commercial organic fertilizer; fqf, chemical fertilizer; p100s: weight of 100 seeds, CV: coefficient of variation.

is subsequently redirected to pods and seeds (Pumalpa *et al.*, 2020; Quintero *et al.* 2018); they also work as anti-stress agents and favor the formation and filling of fruits (López and Pouza, 2014).

The application of organic matter to the soil favors some physical characteristics such as the stability of aggregates, bulk density, and porosity that improve the flow of air, water, and the radical development of plants (Arellano-Arciniega *et al.,* 2015). For their part, the beneficial microorganisms of agronomic interest present in these bioproducts (Table 2), improve the physicochemical conditions of the soil and favor the availability of nutrients for the plant, by being directly or indirectly associated with its root system (Calero-Hurtado *et al.,* 2022). They are also capable of providing greater protection and resistance against the attack of external agents (Morel *et al.,*2021), and some genera such as *Azospirillum* and *Rhizobium* which act as nitrogen-fixing bacteria (Rangel *et al*., 2014).

In relation to the parameters evaluated on the nutritional value of the bean, the analysis of variance did not find statistically significant differences ($p \geq 0.05$); however, for some variables, the results tend to be higher in organic treatments compared to chemical ones (Table 4).

Table 4. Comparison of means of variables of the nutritional value of Pinto Rarámuri beans influenced by biofertilizers.

Variable (%)	control	fqf	lean	tea	foc	sludge	CV
Crude fiber	2.65	3.29	3.89	3.04	2.86	3.32	19.80
Protein	23.21	22.91	22.34	23.85	24.39	23.08	12.08
Ash	4.89	4.97	4.63	4.40	4.65	4.48	15.98
Fat	1.17	1.13	1.17	1.44	1.06	1.10	16.22
Nitrogen-free extract	68.07	67.71	67.97	67.27	67.04	68.02	4.25

tea: manure tea; sludge: sewage sludge; lean: super lean; foc: commercial organic fertilizer; fqf, chemical fertilizer; CV: coefficient of variation.

The percentage of crude fiber ranged from 2.65 to 3.89, with the highest values in lean treatment (3.89 %), followed by sludge (3.32 %), while crude protein was higher in foc (24.39 %). As for ash, the highest results were for fqf (4.97 %), followed by the control (4.89 %). The fat content was presented in a higher percentage for tea treatments (1.44) and the proportion of nitrogen-free extract (carbohydrates) was higher in the control (68.07 %).

Most of the treatments evaluated in this study exceeded the results reported by Rosales-Serna *et al.* (2019), for the Pinto Saltillo bean variety with chemical fertilization under irrigation conditions, where they obtained 2.5 % crude fiber, 22.4 % protein, 4.1 % ash, 1.6 % fat, and 69.5 % nitrogen-free extract, while the fat content was similar. On the other hand, Fernandez and Sánchez (2017), obtained in Pinto Saltillo beans, low values of ash, fat, and carbohydrates (2.53 %, 0.85 %, 39.02 %, respectively) and high in crude fiber (7.18 %) and protein (48.98 %) compared to those obtained in this study.

The percentage of protein obtained with the foc treatment may be due to the fact that it is made from beneficial microorganisms, including *Azospirillum* spp. and *Rhizobium* spp. (table 2), bacteria that contribute to improving plant nutrition by fixing nitrogen (Rangel et *al*., 2014) during the reproductive stage, affecting performance and nutritional quality (Apáez *et al.*, 2016), due to the increased protein formation (Kozera *et al*., 2013).

Beans are one of the staple foods of the Mexican people and an important source of protein, which allows it to be used as a substitute for meat products and other foods with high protein content (FAO, 2018).

Chemical fertilization is used to provide micro and macronutrientes to the plant, which is why in the fqf treatment (Table 2) the highest percentage of ashes was obtained (Alayón *et al.*, 2014). On the other hand, the fiber contained in the beans helps the digestion process favoring intestinal transit and providing greater satiety (Brouns *et al*., 2017).

Conclusions

The organic fertilization treatments evaluated in this study (sludge, tea, lean, and foc) showed a positive effect on the production variables with respect to chemical fertilization (fqf) and the control (without fertilization). Residual sludge exceeded chemical fertilization by 0.67 $t.ha^{-1}$, and any of the rest of the fertilizers to the control. Depending on the type of fertilization, whether chemical or organic, and the composition of the latter, the height of the plant, the number of pods, the number of seeds per pod, and the weight of 100 seeds were increased, variables that influenced the yield. The use of organic fertilizers did not alter the nutritional quality of the bean seed. Organic fertilization is a sustainable alternative to increase bean productivity in the state of Durango.

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