

# Yield and nutritional quality of castilla bean (*Vigna unguiculata* L. Walp) under the application of liquid organic fertilizers

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## ABSTRACT

**Objective:** To evaluate the effectiveness of liquid organic fertilizers on *Vigna unguiculata* under field conditions.

**Design/methodology/approach:** A randomized block design was used with the following treatments: bovine biol (5% and 10%), worm leachate (25% and 50%), and compost tea (20% and 40%), alongside a chemical foliar fertilizer control and a water control. Performance variables assessed included plant height (cm), days to flowering (days), grain yield (g/plant; kg/ha), weight of 100 seeds (g), plant dry matter (kg/ha), NPK content in grains and stems-leaves (%), and crude protein percentage of harvested beans. Most variables were measured at harvest.

**Results:** The results indicate that bovine biol (5% and 10%) and worm leachate (25% and 50%) were the most effective treatments for grain yield, achieving 640.30 kg/ha, 582.39 kg/ha, 1,519.68 kg/ha, and 509.73 kg/ha, respectively. These yields surpassed those of the chemical treatment (373.77 kg/ha) and the water control (352.49 kg/ha). Additionally, the 25% and 50% worm leachate treatments promoted greater NPK absorption compared to other treatments, resulting in higher crude protein content in the harvested biomass.

**Limitations/implications:** In the Chontalpa region of Tabasco, Mexico, small-scale farmers have largely abandoned *V. unguiculata* cultivation due to declining yields, primarily caused by poor agronomic management. Liquid organic fertilizers represent eco-friendly alternatives for foliar fertilization, with demonstrated efficacy in various crops, and can partially or fully replace chemical fertilizers.

**Findings/conclusions:** The findings suggest that applying bovine biol or worm leachate at the evaluated concentrations as foliar fertilizers can enhance both the yield and nutritional quality of *V. unguiculata* compared to chemical fertilization.

**Keywords:** Field yield, plant nutrition, fertilization, leachate, liquid organic fertilizers, agroecology.

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## INTRODUCTION

Organic agriculture is the result of a series of biochemical and microbiological transformations undergone by organic matter to recycle and utilize nutrients. When these

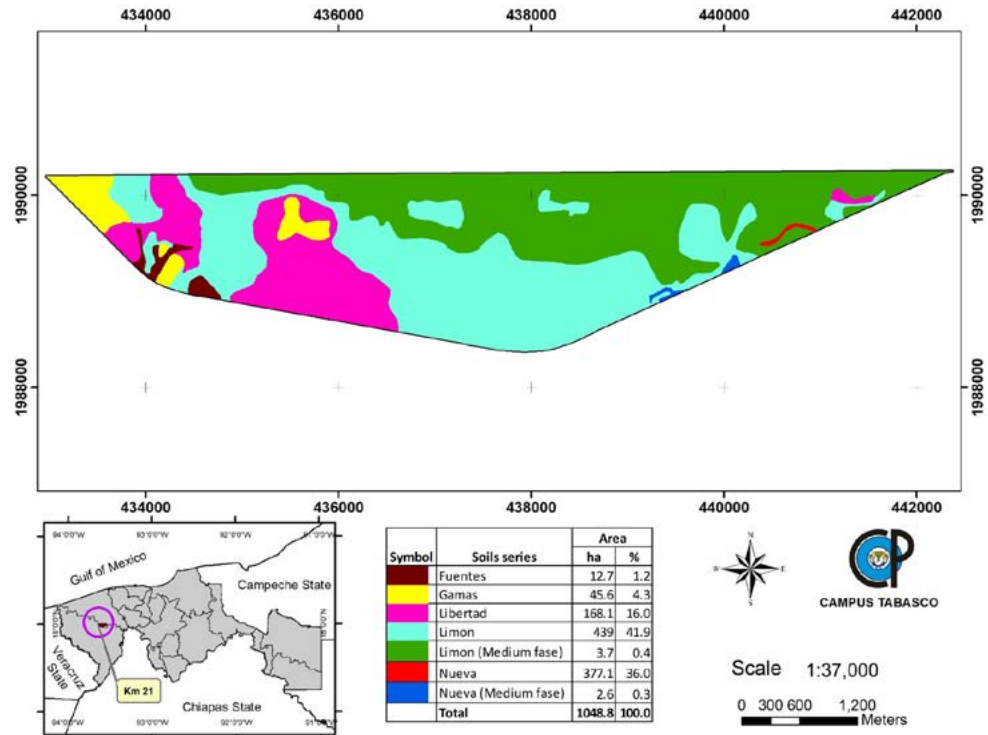


processes are managed by humans, one of the byproducts of organic matter recycling is the production of liquid organic fertilizers, such as biols, worm leachates, and compost teas (Soto, 2003). The use of liquid organic materials (biols) is an alternative to meet the nutritional demands of crops due to their high total and ammoniacal nitrogen content and high chemical oxygen demand. Additionally, they can reduce production costs and dependency on mineral fertilizers (Jara-Samaniego *et al.*, 2021). Applying these effluents via foliar spray or soil incorporation increases crop yield and fruit quality while promoting plant health. This is attributed to the presence of beneficial microorganisms capable of suppressing certain crop diseases (Pant *et al.*, 2009). The Castilla bean (*Vigna unguiculata* L. Walp) remains essential to the economy of communities in the La Chontalpa region of Tabasco, Mexico. For the primary sector in this region, it serves as an important source of employment and income, as well as a key element of food security through self-consumption for low-income populations in both urban and rural areas, where it represents their main source of protein (Lagunes-Espinoza *et al.*, 2008; Estrada-Domínguez *et al.*, 2018). This crop provides significant amounts of protein, dietary fiber, carbohydrates, vitamins, and phytochemicals (Devi *et al.*, 2015). Almost the entire *V. unguiculata* plant is utilized: dry grains, green pods, growing tips, and the whole plant as forage. Its yield depends on various anatomical and morphological characteristics, such as the number of pods per branch, pods per plant, seeds per pod, and seed weight (Márquez-Quiroz *et al.*, 2015). The *V. unguiculata* bean is also a critical food source for rural populations in the states of Campeche, Chiapas, Guerrero, Jalisco, Oaxaca, Tabasco, Veracruz, Yucatán, and Tamaulipas (Lagunes-Espinoza *et al.*, 2008; Apáez-Barríos *et al.*, 2011). However, due to the higher commercial value of other bean varieties in the region, the primary use of *V. unguiculata* in La Chontalpa is for self-consumption (Estrada-Domínguez *et al.*, 2018). This study aimed to develop technology for the cultivation of Castilla beans by implementing new strategies for applying liquid organic foliar fertilizers to increase crop yields, maintain crop safety, and reduce the use of chemical inputs that can harm consumer health. Simultaneously, the research seeks to generate technologies for nutrient recycling by reusing raw materials available in the region.

## MATERIALS AND METHODS

### Description of the study area

The present study was conducted at the experimental field of the Tabasco Campus of the Colegio de Postgraduados, located at 18° 01' N and 93° 03' W, 21 kilometers from the city of Cárdenas along Federal Highway 180 toward Coatzacoalcos. The region has a humid tropical climate, classified as Am(g)w according to the Köppen system modified by García (1988), with abundant rainfall in summer and a prolonged dry season during March and April, accompanied by “nortes” (cold fronts) at the end of the year. The average annual temperature is 26 °C, with minimal variation. In the municipality of Cárdenas, the average annual rainfall is 2,324 mm. During the dry months (March and April), less than 50 mm of rain falls per month, while in the rainiest months (September and October), monthly precipitation reaches approximately 400 mm. The average annual evaporation is 1,400 mm (Rivera-Hernández *et al.*, 2016). The Figure 1 shows the



**Figure 1.** Representation of the soil series in the vicinity of the experimental field of the Colegio de Postgraduados Campus Tabasco. Source: Own elaboration.

soil series present in the experimental field. The study site corresponds to the Libertad soil series, classified as Cambisol Eutric in the World Reference Base for Soil Resources (Palma-López *et al.*, 2017).

The experiment was conducted on soil with a history of crop rotation, including cassava and legumes, used for green manure purposes. The soil was prepared using two passes of a heavy harrow in a cross pattern, followed by two passes of a light harrow and furrowing with 1.3 m spacing between rows. At the start of the experiment, a composite soil sample was collected using a Dutch auger at a depth of 0-30 cm. The composite sample consisted of 15 subsamples taken in a zig-zag pattern, covering the entire area designated for cultivation (Salgado-García *et al.*, 2013). The sample was mixed until homogeneous, dried in the shade on a plastic tray, manually ground, and sieved through a 2 mm (mesh 10) steel sieve. It was then stored in a plastic bag, ready for the following analyses: pH in water (1:2 ratio) using the potentiometric method, organic matter (OM) via the Walkley and Black AS-07 method, soil texture determined using the AS-09 method, cation exchange capacity (CEC) using the AS-12 method with ammonium acetate, electrical conductivity (EC) using the potentiometric method, total nitrogen (Nt) analyzed by the micro-Kjeldahl method (Bremner, 1965), phosphorus (P) by the Olsen method, and exchangeable potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) using the AS-12 method with ammonium acetate, measured by atomic absorption spectroscopy (Perkin Elmer 400). All methodologies followed the recommendations of NOM-021-RECNAT-2000 (DOF, 2002).

### Study variables, experimental design and treatments

An experiment was established using a randomized block design with a total of eight treatments, each with four replications. The treatments included: biol at 5% (B5), biol at 10% (B10), worm leachate at 25% (WL25), worm leachate at 50% (WL50), compost tea at 25% (CT25), compost tea at 50% (CT50), chemical control (CC), and absolute control (AC). The chemical control consisted of a foliar application of Grow Feed<sup>®</sup> (20-30-10 NPK), while the absolute control involved a foliar application of water. Treatments were randomly distributed using R Studio 3.4.1 statistical software. Each experimental unit consisted of 25 *Vigna unguiculata* (Castilla bean) plants in a plot area of 6.25 m<sup>2</sup> (2.5 m × 2.5 m), at a density of 40,000 plants/ha, equivalent to 50 × 50 cm spacing between plants. Treatments were applied foliarly every 15 days, for a total of six applications. To standardize experimental units, a basal fertilization of 00-14-14 (N-P-K) was applied 15 days after germination (DAG). Each experimental unit was composed of 25 plants, and border plants were used to avoid contamination from neighboring treatment applications. Although treatments were applied to all 25 plants, only the 9 central plants constituted the usable plot.

The comparative variables of the experiment were: plant height in cm (PH), days to flowering (DF), grain yield in g/plant and kg/ha (GY), weight of 100 seeds in g (SW), dry matter in kg/ha (DM), and nitrogen, phosphorus, and potassium content in grains and stems-leaves (%) (NPK%). These variables were measured at harvest. At the end of the Castilla bean crop cycle, 100 g of grain along with 3 plants from each replication of each treatment were collected to estimate nutrient extraction. The collected samples were stored in paper bags and dried in an oven at 65 °C for 72 hours. The dried samples were pulverized using a Wiley LABORATORY MILL, Model 4, equipped with a 1 mm sieve, to prepare them for nutrient quantification. For nitrogen and phosphorus, the Semi-micro Kjeldahl and Vanadium-Molybdate methods were used, respectively. Potassium was determined after digestion and analyzed using an Atomic Absorption Spectrophotometer (Perkin Elmer 400). The collected data were recorded in Microsoft Excel (Office 365, Microsoft Corporation, USA).

### Statistical analysis

The data were organized to evaluate the assumptions of normality (Shapiro-Wilk) and homoscedasticity (Levene), which were met. The data were then subjected to an analysis of variance (ANOVA) using the general linear model procedure for the completely randomized block design. To determine the best treatments from a statistical perspective, the treatment means were subjected to Tukey's multiple mean comparison test ( $\alpha=0.05$ ). All statistical analyses were performed using R Studio 3.4.1 (Posit, USA).

## RESULTS AND DISCUSSION

The Table 1 shows the results of the physical and chemical analyses of the soil samples from the Castilla bean experiment. The soil was found to have a moderately acidic pH. Total nitrogen, organic matter, potassium, and cation exchange capacity were at medium levels, while phosphorus and calcium were at high levels, as per NOM-021-RECNAT-2000 (DOF, 2002). The soil texture was classified as loam, which is considered

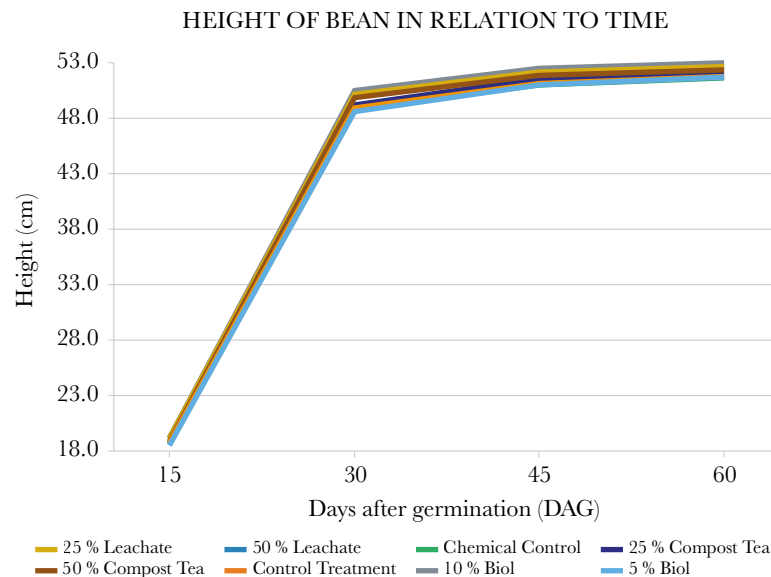
**Table 1.** Results of soil analysis from the experimental area for the Castilla bean crop. Electrical conductivity (EC), bulk density (BD), organic matter (OM), cation exchange capacity (CEC).

Parameter	pH (H <sub>2</sub> O)	EC	BD	P Olsen	K	Ca	Mg	Na	CIC	MO	N total	Clay	Silt	Sand	Classification
	rel. 1:2	dS m <sup>-1</sup>	g cm <sup>-3</sup>	mg kg <sup>-1</sup>	Cmol(+) kg <sup>-1</sup>					%				Texture	
Experimental Field Km 21 Depth 0-30 cm	5.6	0.05	1.37	12.78	0.49	15.21	0.47	0.06	27.48	3.1	0.12	21	1	48	Loam

suitable for bean cultivation, and the bulk density indicated slight compaction issues (Salgado-García *et al.*, 2013).

Visually, the treatments with liquid organic fertilizers, compared to the chemical and water treatments, exhibited less stress due to changes in temperature and humidity. The plants remained more vigorous during high temperatures and rainy days, were more resistant to wind gusts, and showed faster recovery from damage caused by cultural practices and treatment applications. This aligns with Jara-Samaniego *et al.* (2021), who reported that the microorganisms produced during the preparation of biols may be responsible for chemical reactions that enable plants to withstand adverse environmental conditions. Figure 2 shows the growth in height of the Castilla bean plants over time.

The plants germinated seven days after sowing, and data were collected biweekly starting on day 15 after germination (DAG). During the first 30 days, growth was exponential across all treatments. At this stage, the plants reached their maximum vegetative growth



**Figure 2.** Height (cm) of Castilla bean plants in relation to treatments over time (DAG=Days After Germination). Source: Own elaboration.

and began their flowering process, consistent with the findings of Guillén-Molina *et al.* (2016), who reported that flowering in Castilla beans occurs between 44.16 and 53.16 days. At 60 days after germination, the maximum average plant height was 57.4 cm, while the plant vines reached lengths of up to 100 cm.

The population of pests and the incidence of pathogens varied across treatments, with the control and chemical treatments being the most affected. All treatments showed the presence of insects such as the fall armyworm (*Spodoptera albula*), cucumber beetle (*Ceratomyza fascialis*), green leafhopper (*Empoasca kraemeri*), black aphid of legumes (*Aphis craccivora*), and pod weevils (*Trichapion godmani* and *Trichapion auricalcium*). The application of bovine biol had a greater effect on the resistance of the beans to insect attacks, similar to the findings of Huallpa *et al.* (2016) and Cruz *et al.* (2021) for oats and forage grasses, respectively. Meanwhile, the application of compost tea appeared to enhance resistance to bacterial and fungal pathogens, as no diseases were observed in plants sprayed with this liquid fertilizer. This aligns with Ronga *et al.* (2021), who noted that compost tea has been used to prevent diseases both through foliar spraying and direct substrate application, resulting in vigorous and resilient crops.

The application of organic fertilizers such as biol, leachates, and compost tea had positive effects on inducing flowering between 30 and 45 days after germination (DAG). For this effect to be considered, at least 50% flowering in the treatments was required. The treatment with 5% biol induced flowering at 30 DAG across all four replications, followed by 10% biol, which initiated flowering at 34 DAG, both considered early flowering treatments. The water control treatment showed the latest flowering, occurring at 48 DAG, an 18-day delay compared to 5% biol. All treatments, except the water control, fell within the suggested range of 27-45 days for on-time flowering (Estrada-Domínguez *et al.*, 2018).

Table 2 shows the statistical differences for each yield variable used to evaluate the performance of Castilla bean under applications of liquid organic fertilizers. For variables such as the number of pods, grain yield (g/plant and kg/ha), and weight of 100 seeds, no significant statistical differences were found between treatments. However, the 5% biol treatment achieved the highest values, with 16.0 g/plant and 640.3 kg/ha, particularly when compared to the absolute control (water), which had a yield of 352.49 kg/ha, representing a difference of 287.81 kg/ha. Regarding biofortification of *V. unguiculata* with iron and zinc, Guillén-Molina *et al.* (2016) reported grain yield values per plant across all treatments ranging from 8.28 g/plant to 14.45 g/plant. These results were similar to those obtained with leachates, compost tea, and controls in this experiment, but lower than those achieved with biol treatments, highlighting that bovine manure biol may have a positive effect on grain yield. The weight of 100 seeds varies when compared to the ecotypes of *V. unguiculata* found in the region, such as: chickpea bean (19.12 g); “sin tiempo” bean (11.25 g and 13.67 g); “pelón criollo” bean (11.77 g); cowpea bean (12.41 g); Castilla bean with brown hilum (10.26 g); Castilla cow bean (18.11 g); and Castilla bean (17.56 g) (Lagunes-Espinoza *et al.*, 2008). In this study, the average weight of 100 seeds across all treatments ranged from 11.10 g to 12.83 g.

These results were intermediate compared to those reported in a collection for the registration of genetic diversity in beans from the Chontalpa region (Lagunés-Espinoza

**Table 2.** Grain yield and dry matter of Castilla bean (*V. unguiculata*) at the conclusion of the experiment. CV=Coefficient of Variation; Pr(>F)=Significance Value; NS=Not Significant; <.0001=Highly Significant, Tukey p≤0.05.

Treatments	No. of pods per plant	Grain yield (g plant <sup>-1</sup> )	Dry grain yield (kg ha <sup>-1</sup> )	Dry grain yield (kg ha <sup>-1</sup> )	Dry Vegetable Matter (g plant <sup>-1</sup> )	Aboveground biomass (kg ha <sup>-1</sup> )
5% Bovine Biol	13 <sup>a</sup>	16.0 <sup>a</sup>	640.30 <sup>a</sup>	11.57	6.68 <sup>a</sup>	267.00 <sup>a</sup>
10% Bovine Biol	15 <sup>a</sup>	14.56 <sup>a</sup>	582.39 <sup>a</sup>	12.05 <sup>a</sup>	6.80 <sup>a</sup>	271.66 <sup>a</sup>
25% Worm Leachate	17 <sup>a</sup>	12.99 <sup>a</sup>	519.68 <sup>a</sup>	12.60 <sup>a</sup>	6.90 <sup>a</sup>	276.11 <sup>a</sup>
50% Worm Leachate	11 <sup>a</sup>	12.74 <sup>a</sup>	509.73 <sup>a</sup>	12.68 <sup>a</sup>	6.14 <sup>ab</sup>	206.11 <sup>bc</sup>
25% Compost Tea	15 <sup>a</sup>	12.59 <sup>a</sup>	503.68 <sup>a</sup>	11.45 <sup>a</sup>	6.25 <sup>ab</sup>	250.11 <sup>ab</sup>
50% Compost Tea	12 <sup>a</sup>	11.46 <sup>a</sup>	458.66 <sup>a</sup>	12.08 <sup>a</sup>	5.64 <sup>b</sup>	225.67 <sup>ab</sup>
Chemical Foliar Fertilization (Grow Feed®)	18 <sup>a</sup>	9.34 <sup>a</sup>	373.77 <sup>a</sup>	12.83 <sup>a</sup>	6.14 <sup>ab</sup>	245.67 <sup>ab</sup>
Absolute Control	11 <sup>a</sup>	8.81 <sup>a</sup>	352.49 <sup>a</sup>	11.10 <sup>a</sup>	4.03 <sup>c</sup>	161.22 <sup>c</sup>
Mean	13.84	12.31	492.59	12.04	5.95	237.94
CV	47.02	40.90	40.90	9.54	9.25	9.25
Pr(>F)	0.674 NS	0.503 NS	0.503 NS	0.338 NS	<.0001	<.0001

*et al.*, 2008; Apácz-Barrios *et al.*, 2011). Differences were observed in the dry matter variable, where the treatments with 10% biol, 5% biol, and 25% worm leachate showed the highest values, with 6.68 g/plant, 6.68 g/plant, and 6.90 g/plant, respectively. These values corresponded to yields of 271.66 kg/ha, 267.00 kg/ha, and 276.11 kg/ha, as shown in Table 2. The 50% worm leachate and absolute control treatments recorded the lowest values compared to the other treatments.

The nutritional quality of crops is a crucial parameter for human nutrition, as they provide proteins, vitamins, minerals, and essential compounds. Table 3 presents the macronutrient concentrations found in grains and aerial biomass (stems and leaves) of

**Table 3.** Nutrient content of N, P, and K expressed as a percentage in grains and aerial biomass of the Castilla bean crop. CV=Coefficient of Variation; Pr(>F)=Probability of F; NS=Not Significant; <0.01\*=Highly Significant; (Tukey <0.05).

Treatments	Nutrient Concentration in Grains			Nutrient Concentration in Stem-Leaf Biomass		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
5% Bovine Biol	3.19 <sup>d</sup>	0.48 <sup>de</sup>	1.19 <sup>e</sup>	2.46 <sup>d</sup>	0.33 <sup>d</sup>	1.08 <sup>cd</sup>
10% Bovine Biol	3.28 <sup>cd</sup>	0.54 <sup>e</sup>	1.22 <sup>e</sup>	2.62 <sup>c</sup>	0.36 <sup>cd</sup>	1.15 <sup>bc</sup>
25% Worm Leachate	3.39 <sup>bc</sup>	0.64 <sup>bc</sup>	1.45 <sup>c</sup>	2.71 <sup>bc</sup>	0.46 <sup>b</sup>	1.23 <sup>b</sup>
50% Worm Leachate	3.59 <sup>a</sup>	0.74 <sup>a</sup>	1.74 <sup>a</sup>	2.83 <sup>a</sup>	0.58 <sup>a</sup>	1.49 <sup>a</sup>
25% Compost Tea	3.30 <sup>cd</sup>	0.60 <sup>c</sup>	1.35 <sup>d</sup>	2.69 <sup>c</sup>	0.43 <sup>bc</sup>	1.22 <sup>b</sup>
50% Compost Tea	3.50 <sup>ab</sup>	0.67 <sup>b</sup>	1.57 <sup>b</sup>	2.78 <sup>ab</sup>	0.49 <sup>b</sup>	1.43 <sup>a</sup>
Grow Feed® (20-30-10 NPK)	3.00 <sup>e</sup>	0.45 <sup>ef</sup>	1.35 <sup>d</sup>	2.41 <sup>d</sup>	0.29 <sup>de</sup>	1.16 <sup>bc</sup>
Absolute Control (Water)	2.87 <sup>f</sup>	0.39 <sup>f</sup>	1.01 <sup>f</sup>	2.30 <sup>e</sup>	0.25 <sup>e</sup>	1.06 <sup>d</sup>
Mean	3.26	0.56	1.36	2.60	0.40	1.23
CV	1.50	4.50	2.67	1.46	7.54	2.99
Pr(>F)	0.001**	0.001**	0.001**	0.001**	<0.001**	0.001**

the Castilla bean crop. The treatment with 50% worm leachate stood out with the highest concentrations of NPK in grains: 3.59% for N, 0.74% for P, and 1.74% for K. This was followed by the 25% worm leachate and 50% compost tea treatments. The absolute control treatment recorded the lowest concentrations of N, P, and K, with 2.87%, 0.39%, and 1.01%, respectively.

In this study, the nitrogen content under liquid organic fertilizer applications ranged from 3.19% to 3.59%, equivalent to 17.38% and 19.56% crude protein, using the conversion factor of 5.45 proposed by Muranaka *et al.* (2016) for *V. unguiculata*. These values fall within the nitrogen content ranges reported for *V. unguiculata* grain by Muranaka *et al.* (2015) and Guillén-Molina *et al.* (2016), which ranged from 3,150 to 3,730 mg/100 g, equivalent to 3.15% to 3.373%, and 17.2% to 20.3% crude protein, respectively.

It has also been reported that protein content is negatively correlated with grain yield (Olunike, 2014), which was observed in this study. The 10% bovine biol and 5% bovine biol treatments had the highest grain yields but lower crude protein (nitrogen) content, as shown in Table 4. Crude protein (CP%) is calculated by multiplying the total nitrogen content of a food by the factor 5.45, as proteins contain, on average, 18.35% nitrogen. The factor 5.45 derives from the ratio 100/18.35. The CP value includes both true protein and other non-protein nitrogenous compounds, obtained via the Kjeldahl method (Muranaka *et al.*, 2016). Guillén-Molina *et al.* (2016) reported that phosphorus

**Table 4.** Nitrogen and crude protein percentage implemented with the conversion factor of 5.45 of Muranaka *et al.*, (2016) for *V. unguiculata*. Uneven letters in the columns indicate significant differences ( $p < 0.05$ ).

Treatments	Nutrient Concentration in Grains		
	Grain yield ( $\text{kg ha}^{-1}$ )	Nitrogen (%)	Raw Protein (%)
5% Bovine Biol	640.30 <sup>a</sup>	3.19 <sup>d</sup>	17.35 <sup>c</sup>
10% Bovine Biol	582.39 <sup>a</sup>	3.28 <sup>cd</sup>	17.85 <sup>de</sup>
25% Worm Leachate	519.68 <sup>a</sup>	3.39 <sup>bc</sup>	18.47 <sup>bc</sup>
50% Worm Leachate	509.73 <sup>a</sup>	3.59 <sup>a</sup>	19.55 <sup>a</sup>
25% Compost Tea	503.68 <sup>a</sup>	3.30 <sup>cd</sup>	17.98 <sup>cd</sup>
50% Compost Tea	458.66 <sup>a</sup>	3.50 <sup>ab</sup>	19.06 <sup>ab</sup>
Grow Feed <sup>®</sup> (20-30-10 NPK)	373.77 <sup>a</sup>	3.00 <sup>e</sup>	16.34 <sup>f</sup>
Absolute Control (Water)	352.49 <sup>a</sup>	2.87 <sup>f</sup>	15.62 <sup>g</sup>
Treatments	Nutrient Concentration in Stem-Leaf Biomass		
	Stem-leaf biomass yield ( $\text{kg ha}^{-1}$ )	Nitrogen (%)	Raw Protein (%)
5% Bovine Biol	267.00 <sup>a</sup>	2.46 <sup>d</sup>	13.38 <sup>c</sup>
10% Bovine Biol	271.66 <sup>a</sup>	2.62 <sup>c</sup>	14.27 <sup>d</sup>
25% Worm Leachate	267.00 <sup>a</sup>	2.71 <sup>bc</sup>	14.76 <sup>bc</sup>
50% Worm Leachate	206.11 <sup>bc</sup>	2.83 <sup>a</sup>	15.40 <sup>a</sup>
25% Compost Tea	250.11 <sup>ab</sup>	2.69 <sup>c</sup>	14.64 <sup>cd</sup>
50% Compost Tea	225.67 <sup>ab</sup>	2.78 <sup>ab</sup>	15.18 <sup>ab</sup>
Grow Feed <sup>®</sup> (20-30-10 NPK)	245.67 <sup>ab</sup>	2.41 <sup>d</sup>	13.09 <sup>e</sup>
Absolute Control (Water)	161.22 <sup>ab</sup>	2.30 <sup>e</sup>	12.50 <sup>f</sup>

content in *V. unguiculata* grains ranged from 56 to 90 mg/100 g of grain, equivalent to 0.056% to 0.09%. These values are far below the averages of all treatments in this study, which ranged from 0.39% for the absolute control to 0.74% for the 50% worm leachate treatment (Table 3).

Potassium (K) levels in liquid organic fertilizer treatments ranged from 1.19% to 1.74% in Castilla bean grains, values that fall within the ranges reported for *V. unguiculata* by Márquez-Quiroz *et al.* (2015) and Guillén-Molina *et al.* (2016), which varied between 1,180 and 1,520 mg/100 g of grains, equivalent to 1.18% and 1.52% K. These same ranges have remained stable over 13 years (Frota *et al.*, 2008). For nutrient concentrations in aerial biomass (stems and leaves), the 50% worm leachate treatment showed the most significant differences, with 2.83% N, 0.58% P, and 1.49% K, followed by the 50% compost tea treatment. The 5% and 10% bovine biol treatments showed intermediate values compared to all treatments, while the absolute control treatment consistently showed the lowest nutrient percentages. Table 5 presents the nitrogen, phosphorus, and potassium composition (in kilograms) in the total aerial biomass of Castilla bean, including grains, stems, and leaves. Estimating nutrient extractions of nitrogen, phosphorus, and potassium is crucial to understanding the crop's requirements. For NPK in grains, no statistical differences were observed across treatments. However, the 5% biol treatment recorded the highest nitrogen value at 20.41 kg N/ha, while the absolute control showed the lowest value at 10.10 kg N/ha. For phosphorus in grains, the 50% worm leachate treatment had the highest value (3.78 kg P/ha), while the absolute control recorded the lowest (1.37 kg P/ha). For potassium, the 50% worm leachate treatment again showed the highest value, at

**Table 5.** Extraction of kg ha<sup>-1</sup> of N, P, and K in grain and aerial biomass of castilla bean. CV=Coefficient of Variation; Pr(>F)=Probability of F; NS=Not Significant; <0.01\*\*=Highly Significant; (Tukey <0.05).

Treatments	Nutrient Extraction in Grains (kg ha <sup>-1</sup> )				Nutrient Extraction in Stem-Leaf Biomass (kg ha <sup>-1</sup> )				Total Nutrient Extraction (kg ha <sup>-1</sup> )		
	Grain yield (kg ha <sup>-1</sup> )	N	P	K	Biomass yield (kg ha <sup>-1</sup> )	N	P	K	N	P	K
5% Bovine Biol	640.30 <sup>a</sup>	20.41 <sup>a</sup>	3.07 <sup>a</sup>	7.64 <sup>a</sup>	267.00 <sup>a</sup>	5.55 <sup>ab</sup>	0.74 <sup>cd</sup>	2.43 <sup>a</sup>	26.88 <sup>a</sup>	3.93 <sup>ab</sup>	10.47 <sup>ab</sup>
10% Bovine Biol	582.39 <sup>a</sup>	19.09 <sup>a</sup>	3.12 <sup>a</sup>	7.12 <sup>a</sup>	271.66 <sup>a</sup>	7.12 <sup>ab</sup>	0.98 <sup>bcd</sup>	3.13 <sup>a</sup>	26.28 <sup>a</sup>	4.06 <sup>ab</sup>	10.17 <sup>ab</sup>
25% Vermicompost Leachate	519.68 <sup>a</sup>	17.62 <sup>a</sup>	3.34 <sup>a</sup>	7.55 <sup>a</sup>	267.00 <sup>a</sup>	7.24 <sup>a</sup>	1.23 <sup>a</sup>	3.28 <sup>a</sup>	25.12 <sup>a</sup>	4.65 <sup>a</sup>	10.89 <sup>a</sup>
50% Vermicompost Leachate	509.73 <sup>a</sup>	18.30 <sup>a</sup>	3.78 <sup>a</sup>	8.87 <sup>a</sup>	206.11 <sup>bc</sup>	6.95 <sup>b</sup>	1.42 <sup>ab</sup>	3.65 <sup>a</sup>	24.14 <sup>a</sup>	4.97 <sup>a</sup>	11.89 <sup>a</sup>
25% Compost Tea	503.68 <sup>a</sup>	16.61 <sup>a</sup>	3.00 <sup>a</sup>	6.79 <sup>a</sup>	250.11 <sup>ab</sup>	5.54 <sup>ab</sup>	0.89 <sup>abc</sup>	2.52 <sup>a</sup>	23.34 <sup>a</sup>	4.06 <sup>ab</sup>	9.80 <sup>ab</sup>
50% Compost Tea	458.66 <sup>a</sup>	16.05 <sup>a</sup>	3.05 <sup>a</sup>	7.26 <sup>a</sup>	225.67 <sup>ab</sup>	6.96 <sup>ab</sup>	1.21 <sup>abc</sup>	3.56 <sup>a</sup>	22.27 <sup>a</sup>	4.15 <sup>ab</sup>	10.49 <sup>ab</sup>
Grow Feed <sup>®</sup> (20-30-10 NPK)	373.77 <sup>a</sup>	11.21 <sup>a</sup>	1.66 <sup>a</sup>	5.06 <sup>a</sup>	245.67 <sup>ab</sup>	6.64 <sup>b</sup>	0.80 <sup>d</sup>	3.20 <sup>a</sup>	17.12 <sup>a</sup>	2.37 <sup>ab</sup>	5.28 <sup>c</sup>
Absolute Control (Water)	352.49 <sup>a</sup>	10.10 <sup>a</sup>	1.37 <sup>a</sup>	3.55 <sup>a</sup>	161.22 <sup>ab</sup>	3.70 <sup>c</sup>	0.39 <sup>e</sup>	1.71 <sup>b</sup>	13.84 <sup>a</sup>	1.81 <sup>b</sup>	5.26 <sup>c</sup>
Mean	492.59	16.18	2.8012	6.69	237.94	6.19	0.94	2.91	22.37	3.75	9.60
CV	40.90	40.77	40.01	39.30	9.25	9.40	12.14	2.99	28.64	29.83	26.53
Pr(>F)	0.503 NS	NS	NS	NS	0.001**	0.001**	0.001**	0.001**	NS	0.0064**	0.0338 *

8.87 kg K/ha. For stem-leaf biomass, the 25% worm leachate treatment showed the most significant differences, with 7.24 kg N/ha and 1.23 kg P/ha, statistically different from the chemical and absolute control treatments. Regarding potassium in stem-leaf biomass, the absolute control treatment had the lowest yield at 1.71 kg K/ha, while all other treatments were statistically similar in potassium content for stem-leaf biomass.

Regarding the total nutrient concentration, no statistical differences were observed for nitrogen across treatments, but the bovine biol treatments at 5% and 10% showed the highest values with 26.88 kg N ha<sup>-1</sup> and 26.28 kg N ha<sup>-1</sup>, respectively, while the absolute control treatment had the lowest value with 13.84 kg N ha<sup>-1</sup>. Phosphorus and potassium showed a similar trend, with the control treatment differing the most from the others. The vermicompost leachates at 25% and 50% had the highest phosphorus values, with 4.65 kg P ha<sup>-1</sup> and 4.97 kg P ha<sup>-1</sup>, respectively, while the vermicompost leachate at 50% and bovine biol at 5% had the highest potassium values, with 11.89 kg K ha<sup>-1</sup> and 10.47 kg K ha<sup>-1</sup>, respectively. This corresponds to the sum of the results for each NPK repetition in grains and NPK in stem-leaf biomass. Espinosa *et al.* (2000) conducted studies on the collection of legume diversity in the state of Tabasco with the aim of preserving culinary culture. However, since 2008, there have been no studies documenting local knowledge on the production and conservation of native grain legume varieties in the region (Lagunes-Espinoza *et al.*, 2008). Species of the genus *V. unguiculata* ranked second among legumes consumed in the region. The reported native varieties include “criollo negro,” “Castilla,” and “sin tiempo” (Lagunes-Espinoza *et al.*, 2008). Unfortunately, despite these native varieties achieving higher yields, small producers are abandoning them in favor of more commercial crops with lower yields for the region (Lagunes-Espinoza *et al.*, 2008; Delgado-Salinas *et al.*, 2021). The results of this study could help increase the use and production of this regional bean in La Chontalpa, Tabasco, Mexico; however, further studies focused on its nutritional qualities are needed to promote its consumption among local producers, as is done with common beans in other regions of Mexico (Florvil *et al.*, 2022).

## CONCLUSIONS

Based on the grain yield and stem-leaf biomass, it is concluded that bovine manure biol treatments at 5% and 10% and vermicompost leachate at 25% and 50% are the best liquid organic nutrition alternatives for the Castilla bean crop. These treatments showed better field performance, growth, and nutritional quality compared to the chemical treatment and did not result in significant infections or damage from pest insects or diseases. The results suggest a positive impact on the yield of Castilla beans in La Chontalpa, Tabasco, Mexico, offering an agroecological alternative for managing this crop with lower impact on cultivated soils and reduced chemical fertilizer expenses.

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