Recibido, 23/07/2025 Aceptado, 12/09/2025 DOI: 10.25127/agrops.20251.1126 Artículo original

Effect of poultry manure on germination and biometrics of *H. sabdariffa* in Loreto, Peru

Gallinaza y su efecto en germinación y biometría de *H. sabdariffa* en Loreto, Perú

Alberto Torres-Hidalgo[1*], Héctor G. Pezo-Gálvez[1], Abraham J. Ruiz-Cerrón[1],

George S. Icahuate-Pérez[1]

ABSTRACT

The objective of this study was to evaluate the effect of different doses of poultry manure (5, 5.5, 6.5 and 7.5 kg/m^2) on agronomic parameters such as germination, number of flowers, yield per plant, height, stem diameter, number of shoots and number of leaves, under the agroclimatic conditions of the Loreto region, Peru. The experiment was developed using a completely randomized block design, using seeds from the forest nursery of the Instituto de Educación Superior Tecnológico Público El Milagro. The results revealed that the dose of 7.5 kg/m^2 of poultry manure significantly favored germination (87%), as well as a consistent increase in plant height, stem diameter and number of leaves during the nine evaluations carried out. However, the treatment with 6.5 kg/m^2 of poultry manure presented the highest yield per plant (1.28 kg/plant). On the other hand, the highest number of shoots and flowers was recorded with the 5 kg/m^2 treatment. The correlations observed indicated significant relationships between yield and number of flowers (r = 0.80), height and number of leaves (r = 0.74), height and stem diameter (r = 0.87), as well as between stem diameter and number of leaves (r = 0.77). In conclusion, an application rate of 6.5 kg/m^2 of chicken manure is a viable option if our goal is to maximize yield without compromising the physiological characteristics of the crop in conditions similar to those found in the Loreto region and other regions with similar soil and climate conditions.

Keywords: tropical crop; organic amendment; hibiscus flower; agricultural yield; Peruvian Amazon.

RESUMEN

Este estudio tuvo como objetivo evaluar el efecto de diferentes dosis de gallinaza (5, 5.5, 6.5 y 7.5 kg/m^2) sobre parámetros agronómicos como germinación, número de flores, rendimiento por planta, altura, diámetro del tallo, número de brotes y número de hojas, bajo las condiciones agroclimáticas de la región de Loreto, Perú. El experimento se desarrolló empleando un diseño de bloques completamente al azar, utilizando semillas provenientes del vivero forestal del Instituto de Educación Superior Tecnológico Público El Milagro. Los resultados revelaron que la dosis de 7.5 kg/m^2 de gallinaza favoreció significativamente la germinación (87%), así como un incremento consistente en la altura de la planta, el diámetro del tallo y el número de hojas durante las nueve evaluaciones realizadas. Sin embargo, el tratamiento con 6.5 kg/m^2 de gallinaza presentó el mayor rendimiento por planta (1.28 kg/planta). Por otro lado, la mayor cantidad de brotes y flores se registró con el tratamiento de 5 kg/m^2. Las correlaciones observadas indicaron relaciones significativas entre rendimiento y número de flores (r = 0.80), altura y número de hojas (r = 0.74), altura y diámetro del tallo (r = 0.87), así como entre el diámetro del tallo y el número de hojas (r = 0.77). En conclusión, una dosis de aplicación de 6.5 kg/m^2 de gallinaza es una opción viable si nuestro objetivo es maximizar el rendimiento sin comprometer las características fisiológicas del cultivo en condiciones de la región Loreto y otras regiones con condiciones edafoclimáticas similares.

Palabras clave: cultivo tropical, enmienda orgánica, flor de Jamaica, rendimiento agrícola, Amazonía peruana.

[1]Instituto de Educación Superior Tecnológico Público El Milagro, San Juan Bautista, Maynas, Loreto, 16000, Perú.

*Autor de correspondencia. E-mail: atorres@iestpfeyalegria47.edu.pe

I. INTRODUCTION

In any part of the world, the plant component is an indispensable element within the ecosystem, due to its multiple relationships with the fauna and the physical environment (Correia and Lopes, 2023). Plant species also stand out for their potential medicinal, nutritional and agricultural uses, such is the case of *Hibiscus sabdariffa* L. (Onyeukwu et al., 2023), a plant of African origin that successfully adapted in many regions globally; it enjoys great acceptance for its edible calyxes and the fiber of its stems that are used in the pharmaceutical, food, textile and even papermaking industries (Islam, 2019; Adam et al., 2021).

In the climate change scenario that we have been experiencing in recent years, crops such as *H. sabdariffa* have aroused the interest of scientists and producers, not only for their commercial value, but also for their ability to be integrated into sustainable and resilient agricultural systems in the face of different climate change scenarios (Richardson and Arlotta, 2021). This crop showed an ability to adapt to soils with low fertility and also showed tolerance to moderate drought and high temperatures; conditions increasingly common in many tropical and subtropical regions (Taghvaei et al., 2022; Bahgat et al., 2023). All these attributes make this crop a viable option for diverisifying agricultural production systems under agroclimatic conditions where other crops present limitations or are even unable to thrive (Mohamed et al., 2015; Liu et al., 2021). The incorporation of *H. sabdariffa* in agroforestry systems would be particularly useful for diversifying local biodiversity, recovering degraded soils and ecosystem services linked to biodiversity, laying the foundations for ecological agriculture (Silva-Galicia et al., 2023).

H. sabdariffa also enjoys very good acceptance in the field of human medicine, as its calyxes contain high levels of bioactive compounds such as ascorbic acid, anthocyanins and polyphenols, which endow these calyxes with antioxidant and antihypertensive properties (Ilyas et al., 2021). This crop is also an attractive option from an economic point of view, as it is short-cycle and has a wide variety of derived products (Akubueze et al., 2019). However, knowledge on the agronomic management of this crop under diverse edaphoclimatic conditions such as those of Peru is still scarce and needs to be deepened. In regions such as Cuzco and San Martin, research has been conducted to evaluate how the variables of planting density and substrate types influence the yield of *H. sabdariffa* (Estrada, 2023; Asenjo, 2023). Although these studies provide initial results on the interaction of these factors with crop yield, they cannot be generalized to other regions of Peru, such as Loreto, due to the diversity of soil and climatic conditions and agricultural practices that exist in the country.

The Loreto region, due to its particular characteristics of high humidity, high temperatures and soils of heterogeneous fertility and geology, has been little explored to install the cultivation of *H. sabdariffa*, a crop that could become an economic alternative for producers in the region since it has short flowering cycles of four to five months (Dourojeanni, 2013). However, factors such as substrate quality, availability of nutrients in the soil and climatic conditions that could influence germination, biometry and yield of calyxes are unknown.

Previous studies have shown that organic amendments, such as poultry manure, improve soil structure, increase nutrient availability and promote beneficial microbial activity, which positively impacts plant growth (Javaid et al., 2021). In tropical conditions, chicken manure has proven effective in improving soil fertility and crop productivity. Its high content of available nutrients, such as nitrogen, phosphorus, and potassium, promotes crop growth and yield in tropical regions that lack these nutrients (Cairo-Cairo et al., 2023; Sani et al., 2024). In addition, chicken manure improves soil water retention capacity and soil microorganism activity, key aspects in counteracting frequent torrential rains and leaching in tropical regions (Semenov et al., 2023; Liu et al., 2025). These characteristics make it a promising fertilizer for sustainable agricultural production in regions such as Loreto.

In this sense, the general objective of the research was to evaluate the germination percentage and biometry of *Hibiscus sabdariffa* under different concentrations of poultry manure in Loreto, Peru, with the purpose of contributing to good agricultural practices and with relevant information for agricultural managers, thus promoting the agricultural sustainability of this crop in the region.

II. MATERIAL AND METHODS

Location of the study

The experiment was carried out in the forest nursery of the Instituto de Educación Superior Tecnológico Público El Milagro, located in the district of San Juan Bautista, Maynas province, Loreto region, Peru. The experimental area is located at coordinates 3°56'14.23" S and 73°22'17.35" W (Figure 1). During the study period between April and November 2024, warm and humid weather conditions were recorded in the district of San Juan Bautista, Loreto, Peru. Maximum temperatures ranged between 30°C and 36°C, while minimum temperatures remained between 21°C and 24°C according to the Servicio Nacional de Meteorología e Hidrología del Perú (2024). Precipitation was frequent and significant throughout all months, with events of heavy rain, thunderstorms, fog, and mist. These conditions were particularly favorable for the phenological development of *H. sabdariffa*, especially during its vegetative and reproductive phases.

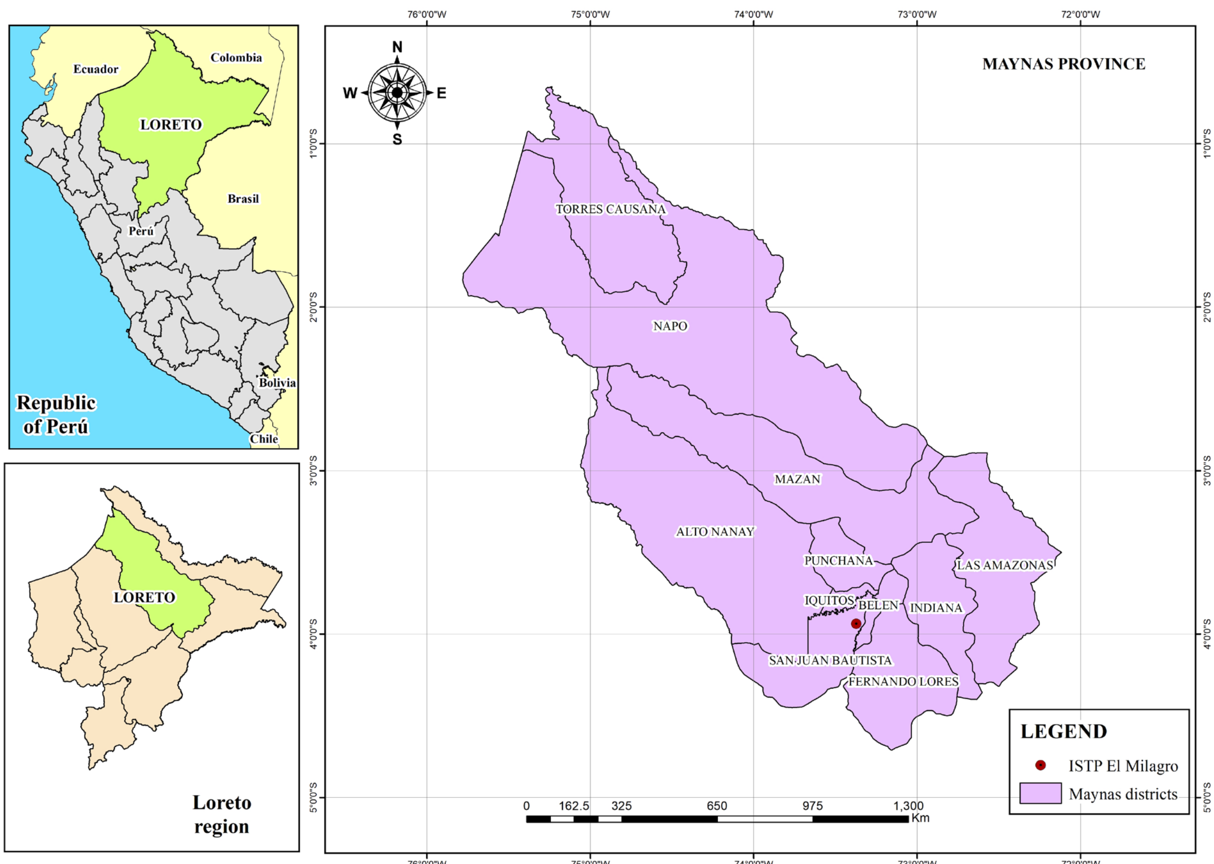

Figure 1. Location of the experimental area.

Experimental design

The experimental area, measuring 50 m x 40 m, was delimited and conditioned to implement a completely randomized block design (CRD), with four treatments and four blocks, totaling 16 experimental units. Each experimental unit had dimensions of 5 m x 6 m, with a space of 2 m between blocks to facilitate management and evaluations. In each experimental unit, 25 plants were established, distributed with a distance of 1.2 m between plants and 1 m between rows. The experimental units were identified by wooden stakes and colored plastic raffia, assigning a specific color to each treatment for clear differentiation. The treatments consisted of the application of different doses of poultry manure: treatment 1 (5 kg/m^2); treatment 2 (5.5 kg/m^2); treatment 3 (6.5 kg/m^2) and treatment 4 (7.5 kg/m^2).

The experimental design was aimed at evaluating the comparative effect of different types of organic fertilization on the agronomic yield of *H. sabdariffa*. An absolute control treatment was not used, since previous studies under similar agroecological conditions had already established reference parameters. This methodological decision allowed the analysis to focus on the variability between organic treatments. The experimental design was aimed at evaluating the comparative effect of different types of organic fertilization on the agronomic yield of *H. sabdariffa*. An absolute control treatment was not used, since previous studies under similar agroecological conditions had already established reference parameters. This methodological decision allowed the analysis to focus on the variability between organic treatments.

Plant material

Hibiscus sabdariffa seeds obtained from the forest nursery of the Instituto de Educación Superior Tecnológico Público El Milagro were used. A total of 400 seeds were selected, prioritizing those that presented characteristics of vigor and visual quality, such as uniform size, absence of visible damage and characteristic coloration. The selected seeds had between 8 and 10 days of storage, discarding those that did not meet the previously established quality standards. The seeds were stored in kraft paper bags in a dry environment at an average temperature of 22°C and relative humidity of 60% for one month prior to sowing. This protocol was applied in accordance with international recommendations for the conservation of tropical seeds, ensuring their physiological viability (FAO, 2018).

Land preparation

Prior to the installation of the treatments, a representative sample of the soil was taken for physicochemical characterization, which was analyzed at the Instituto de Cultivos Tropicales (ICT) Laboratory, accredited under registration No. LE-229. The analyses determined that the soil corresponds to a sandy clay loam texture, with an acid pH of 4.3 and an electrical conductivity of 0.08 dS/cm. The organic matter content was 2.59%, accompanied by 0.13 ppm nitrogen (N), 14.12 ppm phosphorus (P), and 54 ppm potassium (K). Other parameters included a cation exchange capacity of 8.06 cmol/kg, with specific values of 0.96 cmol/kg calcium (Ca), 0.27 cmol/kg magnesium (Mg), 0.14 cmol/kg potassium (K), 0.10 cmol/kg sodium (Na), and 5.40 cmol/kg aluminum (Al). Likewise, a base saturation of 18.16% and an aluminum saturation of 78.66% were recorded. Regarding the presence of heavy metals, the results revealed concentrations of 0.49 ppm cadmium (Cd), 28.50 ppm chromium (Cr), 7.32 ppm lead (Pb), and 2.77 ppm nickel (Ni). Based on this initial characterization, land preparation work was carried out, which included clearing and leveling the experimental area to ensure uniform conditions for the installation of the treatments.

Composition of poultry manure

The chicken manure was purchased from "Don Pollo" company, a nearby farm that provided us with 18 m^3. The chicken manure used was composted for 45 days, reaching temperatures above 55°C, with weekly turning. This process allowed for the reduction of pathogens and the stabilization of nutrients, following the technical protocol of the National Institute of Agricultural Innovation (INIA, 2020).

Similar to the soil analysis, a physicochemical characterization of the poultry manure sample was carried out at the Instituto de Cultivos Tropicales (ICT) laboratory. The results indicated that the poultry manure had a pH of 8.20 and an electrical conductivity of 4.05 µS/cm. Its composition included 4.07% organic matter, 1.55% nitrogen (N), 1.58% phosphorus pentoxide (P_2O_5), and 1.07% potassium oxide (K_2O). In addition, 1.54% calcium oxide (CaO), 0.50% magnesium oxide (MgO), 1.01% sulfur (S), and 0.14% sodium (Na) were detected. As for micronutrients, the manure contained 9.15 ppm boron (B), 100.67 ppm copper (Cu), 1698.29 ppm iron (Fe), 347.77 ppm manganese (Mn), and 236.42 ppm zinc (Zn). These parameters guaranteed the quality and nutritional content of the organic material used in the experimental treatments.

Experimental setup

For the implementation of the treatments, the previously determined doses of poultry manure were applied. The seeds were sown at a depth of 3 cm, maintaining a spacing of 1.2 m between plants and 1 m between rows, in order to ensure adequate distribution and optimize growth conditions.

Variables evaluated

Fifteen days after sowing, the germination percentage was evaluated. In subsequent evaluations, plant biometry was measured, considering variables such as plant height (cm), stem diameter (cm), number of shoots and number of leaves. To evaluate floral yield, the number of flowers and total flower weight per plant were recorded. Nine plants were randomly selected from each experimental unit for measurements. In total, nine evaluations were made during a period of approximately five months from planting.

Manual weed control was implemented every 10 days to maintain optimal growing conditions. Harvesting was carried out when 90% leaf defoliation was reached, icated the right time for harvesting.

Data analysis

We began by verifying the normality of the data and the homoscedasticity of the variances using the Shapiro-Wilk and Levene tests, respectively. After confirming compliance with these assumptions, an analysis of variance followed by Duncan's test at 95% confidence was applied to identify significant differences between treatments. These procedures were performed using InfoStat/Professional statistical software version 2018 p (Di Rienzo, 2009). In addition, a Pearson correlation analysis was performed using the ggplot2 library (Wickham, 2016) in R software version 4.3.3 (R Core Team, 2024), with a significance level of 5%.

III. RESULTS AND DISCUSSION

Germination

Figure 2 shows the germination percentages under four different treatments, with average values and their respective standard deviations. The results indicate that treatment 4 (7.5 kg/m^2 of poultry manure) achieved the highest germination percentage (87%), significantly higher than treatment 1 (5 kg/m^2 of poultry manure) with 83.25%, while treatments 2 and 3 presented intermediate values.

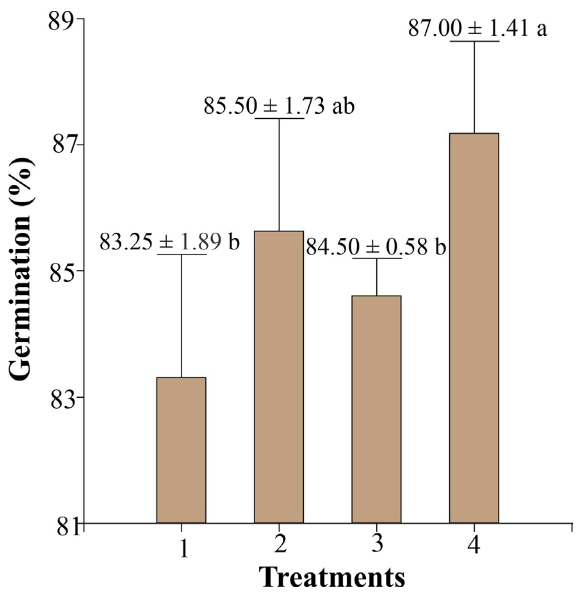

Figure 2. Germination of *H. sabdariffa* by treatment.

The use of organic amendments, such as poultry manure, has been widely studied for its ability to improve soil physical, chemical and biological properties, which in turn positively influences seed germination (Luo et al., 2018). In this study, treatment 4 showed the highest germination percentage, which could be related to an optimal dosage of poultry manure that promoted an adequate nutrient balance and an improvement in soil structure, favoring an ideal environment for initial seedling development (Abumere et al., 2019). The main nutrient provided by chicken manure is nitrogen, which plays an important role during germination, as it is involved in the synthesis and activation of amylases and proteases, enzymes that break down starches and proteins stored in the endosperm of seeds (He et al., 2013). These enzymes are responsible for converting complex molecules into simpler compounds that are used by the growing embryo (Botcha and Prattipati, 2020). Therefore, in this study, adequate nitrogen availability may have contributed to faster and more uniform germination. Similar results have been reported by Norhayati et al. (2019), who observed that the application of moderate doses of poultry manure significantly increased germination by improving the availability of nitrogen and other essential micronutrients. On the other hand, the lower germination percentages observed in treatment 1 suggest that insufficient doses or inadequate management of poultry manure may limit the expected benefits.

***Hibiscus sabdariffa* biometrics**

The data show the means and standard deviations of three key morphological variables: plant height, stem diameter and number of leaves, evaluated at different stages of development and subjected to four poultry manure treatments. The results highlight significant differences between treatments and stages. In general, treatments 2 and 4 (5.5 and 7.5 kg/m^2 of poultry manure) presented higher values in the three variables studied, particularly in the final stages of development (evaluations 7, 8 and 9). For example, in evaluation 9, treatment 4 reached an average height of 154.61 ± 20.53 cm, significantly greater than treatment 1 (128.14 ± 55.74 cm) as shown in Table 1. In addition, the number of leaves was higher in treatment 4 (1497.64 ± 452.72) compared to the other treatments (Table 1).

Table 1. Biometric characteristics of *H. sabdariffa*

Evaluation	Treatment	Height (cm)	Stem diameter (cm)	Number of leaves
1	1	14.37 ± 8.65 a	2.54 ± 1.28 a	15.94 ± 10.32 a
1	2	17.39 ± 8.37 a	2.94 ± 1.20 a	19.08 ± 11.45 a
1	3	13.75 ± 7.06 a	2.52 ± 1.23 a	15.69 ± 9.88 a
1	4	16.83 ± 6.68 a	3.09 ± 1.05 a	19.11 ± 9.46 a
2	1	28.49 ± 16.84 b	5.54 ± 3.44 b	51.23 ± 39.37 b
2	2	36.03 ± 13.85 a	7.11 ± 2.88 a	69.56 ± 40.50 a
2	3	32.32 ± 14.29 ab	6.63 ± 3.14 ab	61.03 ± 34.94 ab
2	4	37.09 ± 11.04 a	6.91 ± 2.65 ab	70.31 ± 32.03 a
3	1	36.37 ± 20.62 b	7.70 ± 4.77 b	52.08 ± 43.55 b
3	2	46.61 ± 16.53 a	9.31 ± 3.91 ab	74.14 ± 44.46 a
3	3	41.69 ± 18.01 ab	8.84 ± 4.13 ab	78.53 ± 48.67 a
3	4	47.81 ± 12.11 a	9.84 ± 2.73 a	69.31 ± 42.13 ab
4	1	52.90 ± 27.66 b	11.82 ± 6.98 a	127.64 ± 89.80 a
4	2	63.70 ± 21.30 ab	13.90 ± 5.47 a	138.56 ± 70.14 a
4	3	57.31 ± 25.56 ab	13.67 ± 6.45 a	151.94 ± 87.97 a
4	4	67.17 ± 12.73 a	14.73 ± 3.95 a	153.61 ± 68.75 a
5	1	107.60 ± 49.27 b	20.38 ± 9.98 b	523.61 ± 411.75 a

5	2	122.68 ± 42.62 ab	21.29 ± 8.00 ab	488.58 ± 316.62 a
5	3	114.97 ± 46.60 ab	22.25 ± 9.05 ab	608.72 ± 372.98 a
5	4	131.01 ±14.19 a	24.56 ± 4.04 a	473.36 ± 243.81 a
6	1	117.17 ± 52.55 b	25.54 ± 11.63 a	724.36 ± 363.54 b
6	2	142.62 ± 38.60 a	28.35 ± 8.52 a	890.70 ± 436.25 ab
6	3	130.31 ± 49.84 ab	27.46 ± 11.09 a	939.31 ± 420.90 a
6	4	148.74 ± 15.91 a	29.28 ± 4.47 a	982.49 ± 288.92 a
7	1	124.61 ± 54.84 a	26.61 ± 12.23 a	1014.03 ± 678.50 c
7	2	143.31 ± 37.19 a	29.02 ± 9.03 a	1375.50 ± 416.89 a
7	3	127.43 ± 51.82 a	29.59 ± 11.35 a	1122.25 ± 439.95 bc
7	4	145.25 ± 20.53 a	31.13 ± 3.63 a	1252.94 ± 301.28 ab
8	1	128.14 ± 55.74 b	28.33 ± 12.51 b	1137.75 ±612.53 b
8	2	140.83 ± 45.66 ab	31.64 ± 10.34 ab	1267.86 ± 525.41 ab
8	3	129.58 ± 49.38 b	30.75 ± 11.81 ab	1197.25 ± 485.47 ab
8	4	154.61 ± 20.53 a	33.53 ± 4.44 a	1448.61 ± 450.67 a
9	1	128.14 ±55.74 b	28.33 ± 12.51 b	1190.06 ± 635.40 b
9	2	140.83 ± 45.66 ab	31.64 ± 10.34 ab	1315.36 ± 532.63 ab
9	3	129.58 ± 49.38 b	30.75 ± 11.81 ab	1245.94 ± 499.98 ab
9	4	154.61 ± 20.53 a	33.53 ± 4.44 a	1497.64 ± 452.72 ab

The higher values shown by treatments 2 and 4, especially in the advanced stages of development, can be attributed to differences in the composition and dosage of the poultry manure used. Poultry manure contains high concentrations of nitrogen, phosphorus and potassium, essential nutrients that favor the development of vegetative tissues and structures such as stems and leaves (Almeida et al., 2019).

Particularly, the superiority of treatment 4 could be related to an optimal nutrient ratio and a more efficient release of nutrients throughout the crop cycle (de Souza et al., 2018). On the other hand, the lower values observed in treatment 1 suggest insufficient dosing or lower nutrient bioavailability, which is in agreement with research reporting that suboptimal applications of poultry manure can limit early development and final plant yield (Sindhu, 2021).

As for stem diameter, treatments 2 and 4 again showed higher values, indicating a positive effect of poultry manure on plant structural vigor. This result is consistent with reports indicating that the use of organic amendments improves the ability of plants to withstand abiotic and biological stresses, thanks to an increase in tissue thickness and structural stability (Khan et al., 2023; Jiang et al., 2020; Azim, 2019).

Leaf number, an indicator of photosynthetic potential and overall plant health, was also higher in treatments 2 and 4. Research such as that of Awal et al. (2021) has indicated that application of poultry manure improves macronutrient availability and increases levels of micronutrients such as zinc and iron, which are essential for chlorophyll synthesis and leaf development.

Figure 3 shows the evolution of the number of shoots in four treatments during three consecutive evaluations. A progressive increase in the number of shoots is observed in all treatments throughout the evaluations, although with marked differences among them. Although no significant differences were detected, it can be seen that treatment 1 consistently shows the highest number of shoots, reaching its highest value in evaluation 9 (422.83 ± 249.26). In contrast, treatments 3 and 4 show the lowest values throughout all evaluations, with less pronounced differences between them.

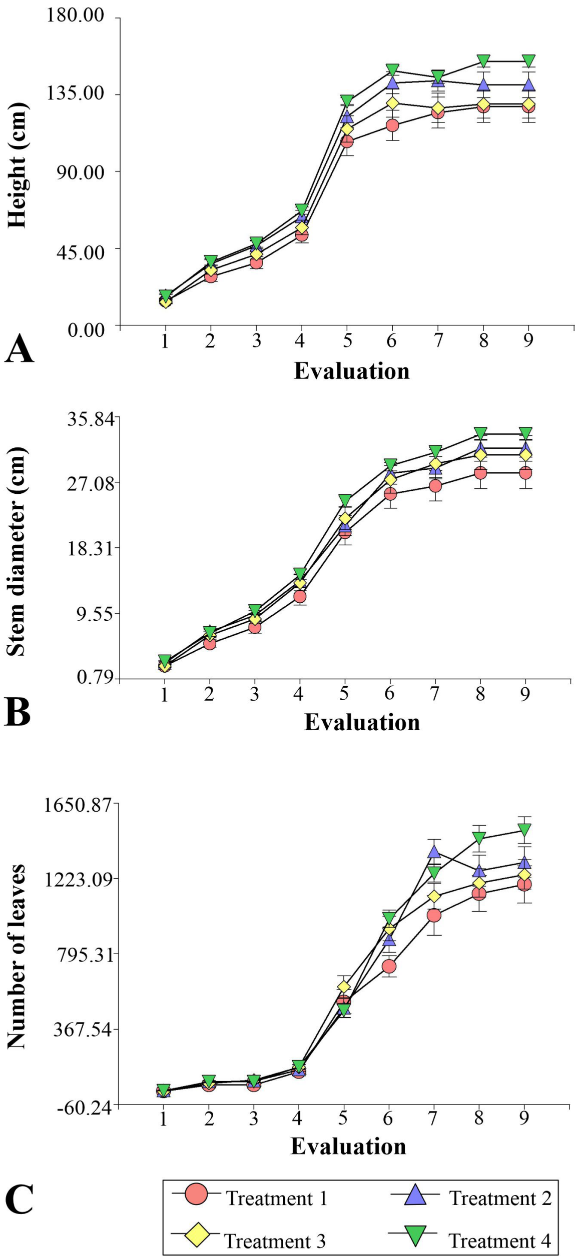

Figure 3. Number of *H. sabdariffa* shoots per evaluation.

The number of shoots observed in the treatments evaluated reflects the direct influence of the fertilizer dose applied, with progressively higher values as the doses increased. This suggests that lower or higher doses of fertilization positively influence shoot development, although the optimal balance between available nutrients and plant needs seems to vary according to specific conditions (Medza-Mve et al., 2018).

The superiority of treatment 1 could be due to the fact that the moderate dose of fertilizer applied avoids phenomena such as osmotic stress or excess nutrient toxicity, which is consistent with previous reports by Singh (2018), who documented those optimal doses of nitrogen fertilization improve vegetative development and soil health.

However, it is important to note that the use of chicken manure has certain limitations that could influence the physiological response of crops and soil quality in the medium and long term. Excessive applications of chicken manure can lead to the accumulation of soluble salts that cause osmotic stress and reduce water and nutrient absorption (Yost et al., 2022). In addition, high doses of ammoniacal nitrogen can cause leaf toxicity and alter hormonal balance, negatively interfering with processes such as flowering and fruit set (Bayu, 2020). In the soil, improper management of chicken manure can promote the accumulation of phosphorus above crop requirements, increasing the risk of leaching and eutrophication of water bodies near the plantation (Sharpley et al., 2002). In addition, there are reports that high and continuous applications of chicken manure can alter the carbon-nitrogen ratio, modifying the microbial community and affecting nutrient mineralization and soil health (Ghimire et al., 2017).

Flowers and yield

Figure 4 shows the differences in the number of flowers under four treatments. Although variations between the mean values are observed, there were no significant statistical differences. This suggests that none of the treatments produces a substantial differential effect on flower production. Treatments 1 and 3 show slightly higher averages (297.86 and 315.92, respectively) compared to treatments 2 and 4 (280.31 and 238.75). However, the variability of the data within each treatment is wide, as indicated by the interquartile ranges and the presence of outliers.

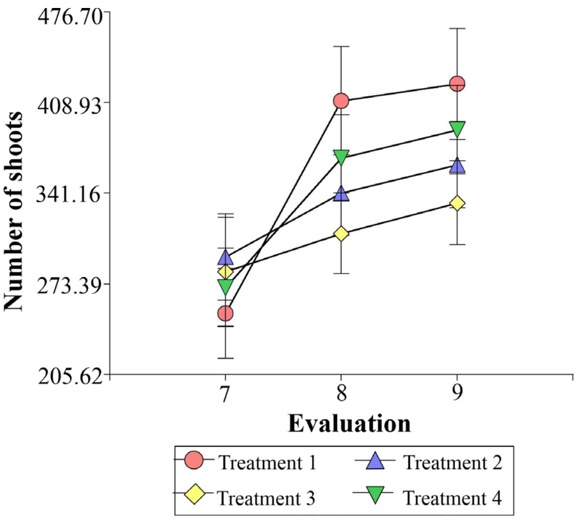

Figure 4. Number of flowers per treatment.

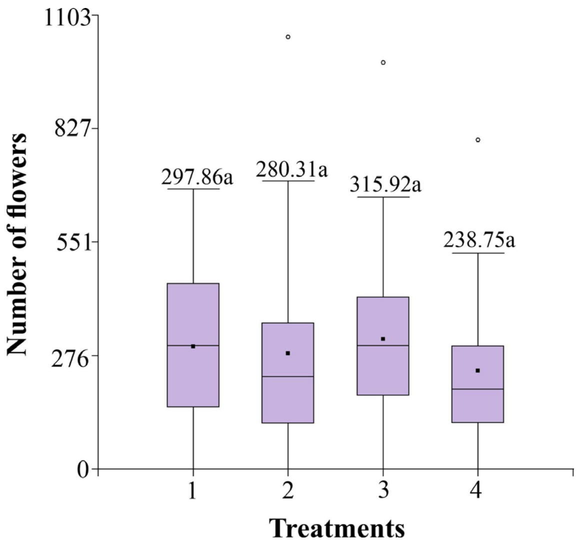

Figure 5. Yield of *H. sabdariffa* by treatments.

The absence of significant differences among treatments suggests that the experimental conditions implemented in this research did not have a sufficient impact on flowering. This finding is consistent with previous studies that have reported that factors such as agronomic management, crop genetics, and environmental conditions may have more determinant effects on flower production (Richardson and Arlotta, 2021; Bakasso et al., 2010).

Although the results do not show statistical differences, treatments 1 and 3 show slightly superior trends. In future studies, it would be advisable to use complementary methods, such as genomic analysis, to evaluate genotype-environment interactions, as proposed by Ullah (2024). Finally, the results highlight the need to further explore the specific conditions under which applied treatments could exert a significant effect on flowering. For example, recent research has indicated that factors such as planting density and irrigation management have a considerable impact on flowering of *H. sabdariffa* (Zand-Silakhoor et al., 2022; Mohd et al., 2019).

The average yield varied among the treatments evaluated. Treatment 3 (6.5 kg/m^2 of poultry manure) showed the highest average yield (1.28 kg/plant) and the lowest yield was recorded for treatment 4 (7.5 kg/m^2 of poultry manure) with 0.84 kg/plant, with significant differences between treatments (Figure 5).

The highest yield observed in treatment 3 (6.5 kg/m^2 of poultry manure) suggests that this dose provides an adequate amount of nutrients for optimal crop development, favoring vegetative growth and biomass distribution to productive structures. Previous studies have shown that organic fertilizers such as poultry manure improve soil fertility by increasing organic matter, gradually releasing nutrients and stimulating microbial activity (Sha et al., 2023). Also, this organic amendment contains high concentrations of N and P, which are essential nutrients in the photosynthetic process and formation of reproductive structures (Rech et al., 2020).

The low values recorded with treatment 4 (7.5 kg/m^2 of poultry manure) could indicate that applying an excessive dose of poultry manure produces negative effects on the crop such as salt accumulation or soil nutrient imbalance. In this regard, Zayed et al. (2023) also reported that an excessive application of organic fertilizer induced osmotic root stress in plants and altered their metabolism, thus showing that high doses of fertilizers are not always the best option for a crop. Therefore, it is important to establish the appropriate doses of organic fertilizers according to the specific needs of the crop, since this way higher yields will be achieved. Several researches point out that a strategy that gives good results is the combination of organic and inorganic fertilizers; since in this way a better use of nutrients is achieved and thus mitigate the environmental damage caused by agricultural activity (Urmi et al., 2022; Xie et al., 2022; Peng et al., 2019). In the future, it would be good to explore the impact of long-term organic fertilizer doses to understand the dynamics of soil nutrient and carbon accumulation, and how these determine the biodiversity of soil fauna. In addition, other planting factors such as plant density and irrigation rates should be evaluated.

On the other hand, it is necessary to be aware that the use of chicken manure can have adverse effects. For example, continuous applications at very high doses can cause the accumulation of copper and zinc, which come from mineral supplements in the birds' diet, leading to accumulation in the soil and posing a risk of phytotoxicity (Deng et al., 2020). However, this risk is reduced when chicken manure is composted before application, as was done in this study. In addition, excessive application of ammoniacal nitrogen can alter the relationship between vegetative and reproductive growth of the crop, causing damage to floral and productive structures (Sun et al., 2023). Finally, a high organic load can alter soil microorganisms, favoring the development of pathogenic or opportunistic species (Chen et al., 2023). These potential adverse effects highlight the need for balanced chicken manure management to increase crop yields without compromising soil health and agroecosystem stability.

Correlation of biometric variables and performance

The biometric variables and yield exhibited different degrees of correlation as shown in Figure 6. There were direct correlations between the number of flowers and yield (r=0.80), between plant height and stem diameter (r=0.87), and between plant height and number of leaves (r=0.74). Other significant correlations include the relationship between number of shoots and number of leaves (r=0.61) and between plant height and yield (r=0.46). These relationships suggest that vegetative development and reproductive capacity are closely linked in this management system.

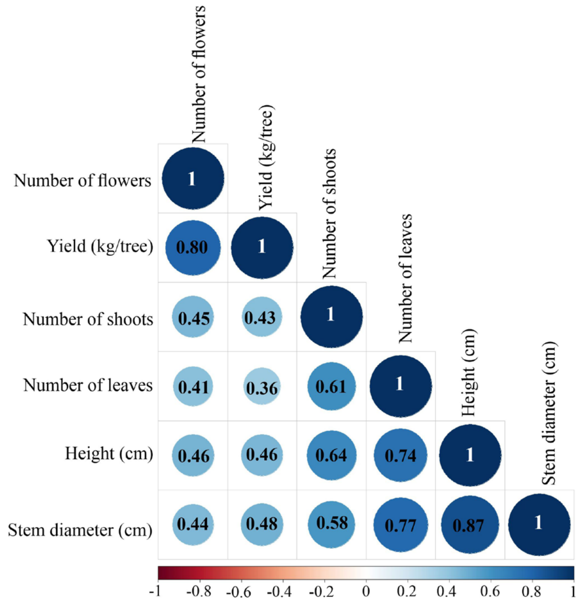

Figure 6. Pearson's correlation of biometric variables and yield of *H. sabdariffa*.

The strong correlation between flower number and yield (r = 0.80) highlights the importance of flowering as an indicator of crop production potential. This finding is consistent with research that has shown that a higher number of flowers is usually positively correlated with final yield, provided that environmental conditions and management are adequate to optimize pollination and fruit development (Richardson and Arlotta, 2021; Bakasso et al., 2010).

The moderate direct correlation between yield and plant height indicates that the taller a plant is the higher the yield, since the plant would be accumulating more photosynthetic resources. This coincides with previous studies indicating that more vigorous plants tend to allocate more resources towards reproductive structures in crops under balanced organic fertilization conditions (Gillet and Gregorius, 2020).

A direct correlation was also observed between stem diameter and plant height, indicating that the more robust a plant is the more height it will reach and therefore the more likely it is to achieve higher yields; this would point to them as reliable variables to evaluate the vigor of *H. sabdariffa*. Stem diameter is a variable of great interest according to reports from researchers who point out that this plant structure is responsible for the efficient transport of water and nutrients to the other structures and have a direct impact on yield (Meng et al., 2017; De Swaef et al., 2015). In addition, the direct relationship observed between the number of leaves and shoots, highlight the importance of good leaf development for the generation of growing points that then contribute to productivity (Medza-Mve et al., 2018).

The results obtained highlight the importance of knowing the correct dose of poultry manure to maximize the yield of *H. sabdariffa* without affecting soil and plant health. Indicators such as number of flowers, stem diameter, number of leaves and plant height are also useful to evaluate the performance of the crop.

Although the correlations observed give us clues about the relationship between variables, it is important to interpret them with caution. For example, the correlation between the number of flowers and yield may be due to the balanced availability of nutrients or the soil's ability to retain water, which in turn are influenced by the physicochemical characteristics of chicken manure (Agegnehu et al., 2016). Similarly, the relationship between plant height and stem diameter could be due to adequate aeration and soil structure, improved by the addition of organic matter, and not only to vigorous crop growth (Haiti et al., 2006). However, excessive doses of chicken manure can cause surface compaction, alter hydraulic conductivity, and limit root development (Dube et al., 2012).

IV. CONCLUSIONS

The most appropriate concentration of poultry manure according to yield results was the one set in treatment 3 (6.5 kg/m^2), with this concentration a good vegetative yield and higher yield figures were obtained. On the other hand, it was observed that higher doses of poultry manure as in treatment 4 (7.5 kg/m^2) can negatively influence variables such as yield, possibly due to an excess of nutrients that affect crop physiology. This research aims to contribute to the field of agronomic management of *H. sabdariffa* in soil and climatic conditions such as those of Loreto and to show that an adequate dose of poultry manure will improve crop yield.

On the other hand, the results obtained will serve as a basis for establishing fertilization programs or plans for *H. sabdariffa* in regions with similar soil and climatic conditions, thus promoting the development of sustainable agriculture in line with the challenges of climate change. In the near future, it would be important to evaluate the combined action of poultry manure with inorganic fertilizers widely used in the region, in order to enhance the efficiency of these fertilizers. It would also be important to evaluate the impact on soil health of organic amendments in the long term, their repercussion on soil fauna and on the physicochemical quality of products derived from *H. sabdariffa*. Finally, it would be important to study the combined effect of fertilizer dose, planting density and irrigation dose on *H. sabdariffa* for the future establishment of integrated and sustainable agroforestry systems.

AUTHOR CONTRIBUTION

Conceptualization, methodology, project administration writing original draft; A.T.H. supervision, data curation, writing original draft; H.G.P.G. investigation, formal analysis, visualization; A.J.J.R.C. Conceptualization, validation, writing review and editing; G.S.I.P.

V. REFERENCES

Abumere, V. I., Dada, O. A., Adebayo, A. G., Kutu, F. R., & Togun, A. O. (2019). Different Rates of Chicken Manure and NPK 15-15-15 Enhanced Performance of Sunflower (*Helianthus annuus* L.) on Ferruginous Soil. *International Journal of Agronomy, 2019*(1), 3580562. https://doi.org/10.1155/2019/3580562

Adam, A., Elrasheid, H., Komla, G. (2021). Roselle (*Hibiscus sabdariffa*) Chemistry, Production, Products, and Utilization. Academic Press, London. https://doi.org/10.1016/C2019-0-04589-X

Agegnehu, G., Bass, A. M., Nelson, P. N., & Bird, M. I. (2016). Benefits of biochar, compost and biochar–compost for soil quality, maize yield and greenhouse gas emissions in a tropical agricultural soil. *Science of The Total Environment, 543*, 295-306. https://doi.org/10.1016/j.scitotenv.2015.11.054

Akubueze, E. U., Ezeanyanaso, C. S., Muniru, O. S., Nwaeche, F. C., Tumbi, M. I., Igwe, C. C., Elemo, G. N. (2019). Extraction and Characterization of Bast Fibres from Roselle (*Hibiscus sabdariffa*) Stem for Industrial Application. *J. Mater. Sci. Res. Rev. 2*(2), 169–175. https://doi.org/10.9734/jmsrr/2019/v2i24

Almeida, R.F., Queiroz, I.D.S., Mikhael, J.E.R., Oliveira, R.C., Borges, E.N. (2019). Enriched animal manure as a source of phosphorus in sustainable agriculture. *International Journal of Recycling of Organic Waste in Agriculture, 8*(4), 203–210. https://doi.org/10.1007/s40093-019-00291-x

Asenjo, D. E. (2023). *Optimización de la densidad de siembra para mejorar la producción de flor de Jamaica (Hibiscus sabdariffa L.)*. [Tesis de grado, Universidad Nacional de San Martín, San Martin, Perú]. https://repositorio.unsm.edu.pe/backend/api/core/bitstreams/e812f815-42e9-43db-8634-b8e42e85b717/content

Awal, R., Hassan, A. E., Abbas, F., Fares, A., Bayabil, H. K., Ray, R. L., & Woldesenbet, S. (2021). Patterns of Nutrient Dynamics within and below the Rootzone of Collard Greens Grown under Different Organic Amendment Types and Rates. *Sustainability, 13*(12), 6857. https://doi.org/10.3390/su13126857

Azim, K. (2019). Organic Amendments to Alleviate Plant Biotic Stress, in: Ansari, R.A., Mahmood, I. (Eds.), *Plant Health Under Biotic Stress*. *Springer Singapore*, Singapore, pp. 147–165. https://doi.org/10.1007/978-981-13-6043-5_8

Bahgat, A.-R., Dahab, A.A., Elhakem, A., Gururani, M.A., El-Serafy, R.S. (2023). Integrated Action of Rhizobacteria with Aloe vera and Moringa Leaf Extracts Improves Defense Mechanisms in *Hibiscus sabdariffa* L. Cultivated in Saline Soil. *Plants, 12*, 3684. https://doi.org/10.3390/plants12213684

Bakasso, Y., Saadou, M., Zongo, J.-D., Forso, J., Toujan, A. (2010). Preliminary assessment of the influence of environment on growth parameters and yield in some genotypes of *Hibiscus sabdariffa* L. from Niger. *International Journal of Biological and Chemical Sciences, 3*(5), 1133-1140. https://doi.org/10.4314/ijbcs.v3i5.51091

Bayu, T. (2020). Review on contribution of integrated soil fertility management for climate change mitigation and agricultural sustainability. *Cogent Environmental Science, 6*(1), 2-21. https://doi.org/10.1080/23311843.2020.1823631

Botcha, S., Prattipati, S. D: (2020). Role of amylase and protease in germinating *Sterculia urens* Roxb. *Bangladesh Journal of Scientific and Industrial Research, 55*(2), 107-112.

Cairo-Cairo, P., Diaz-Martin, B., Machado-de-Armas, J., & Rodriguez-Lopez, O. (2023). Effects of poultry manure on structure and some indicators of fertility in tropical soils. *Archives of Agronomy and Soil Science, 69*(13), 2692–2702. https://doi.org/10.1080/03650340.2023.2171020

Chen, D., Zou, J., Chen, D., He, X., Zhang, C., Li, J., Lan, S., Liu, Z., Zou, S., & Qian, X. (2023). Chicken manure application alters microbial community structure and the distribution of antibiotic-resistance genes in rhizosphere soil of *Cinnamomum camphora* forests. *FEMS Microbiology Ecology, 99*(12). https://doi.org/10.1093/femsec/fiad155

Correia, A. M., & Lopes, L. F. (2023). Revisiting Biodiversity and Ecosystem Functioning through the Lens of Complex Adaptive Systems. *Diversity*, *15*(8), 895. https://doi.org/10.3390/d15080895

de Souza, Á.H.C., Rezende, R., Zolin Lorenzoni, M., Castro, C., Silva, F.A. (2018). Agronomic efficiency and growth of eggplant crop under different potassium and nitrogen doses. *Revista Caatinga, 31*(3), 737–747. https://doi.org/10.1590/1983-21252018v31n324rc

De Swaef, T., De Schepper, V., Vandegehuchte, M. W., & Steppe, K. (2015). Stem diameter variations as a versatile research tool in ecophysiology. *Tree Physiology, 35*(10), 1047-1061. https://doi.org/10.1093/treephys/tpv080

Deng, W., Zhang, A., Chen, S., He, X., Jin, L., Yu, X., Yang, S., Li, B., Fan, L., Ji, L., Pan, X., & Zou, L. (2020). Heavy metals, antibiotics and nutrients affect the bacterial community and resistance genes in chicken manure composting and fertilized soil. *Journal of Environmental Management, 257*, 109980. https://doi.org/10.1016/j.jenvman.2019.109980

Di Rienzo, J. A. (2009). *InfoStat versión 2009*. https://www.infostat.com.ar/

Dourojeanni, M. (2013). *Loreto sostenible al 2021*. https://www.dar.org.pe/archivos/publicacion/Loreto2021_completo2.pdf

Dube, E., Chiduza, C., & Muchaonyerwa, P. (2012). Conservation agriculture effects on soil organic matter on a Haplic Cambisol after four years of maize–oat and maize–grazing vetch rotations in South Africa. *Soil and Tillage Research, 123*, 21-28. https://doi.org/10.1016/j.still.2012.02.008

Estrada, E. L. (2023). *Comparativo de rendimiento con 4 sustratos diferentes en producción de flor de Jamaica (Hibiscus sabdariffa L.) en Huyro – Huayopata – provincia La Convención- Cusco.* [Tesis de grado, Universidad Nacional de San Antonio Abad del Cusco, Cusco, Perú]. https://repositorio.unsaac.edu.pe/bitstream/handle/20.500.12918/7651/253T20230263_TC.pdf?sequence=1&isAllowed=y

FAO (2018). *Manual de recolección, procesamiento y almacenamiento de semillas de plantas silvestres. Proyecto Banco de Semillas de Boyacá, Colombia. Junio de 2018 V1.*2. https://brahmsonline.kew.org/Content/Projects/msbp/resources/Training/Manual-de-SemillasV1.2_Esp.pdf

Ghimire, R., Machado, S., & Bista, P. (2017). Soil pH, Soil Organic Matter, and Crop Yields in Winter Wheat–Summer Fallow Systems. *Agronomy Journal, 109*(2), 706-717. https://doi.org/10.2134/agronj2016.08.0462

Gillet, E.M., Gregorius, H.-R. (2020). Effects of reproductive resource allocation and pollen density on fertilization success in plants. *BMC Ecology, 20*, 26. https://doi.org/10.1186/s12898-020-00290-x

Haiti, K., Mandal, K., Misra, A., Ghosh, P., & Bandyopadhyay, K. (2006). Effect of inorganic fertilizer and farmyard manure on soil physical properties, root distribution, and water-use efficiency of soybean in Vertisols of central India. *Bioresource Technology, 97*(16), 2182-2188. https://doi.org/10.1016/j.biortech.2005.09.033

He, Y., Xie, K., Xu, P., Huang, X., Gu, W., Zhang, F., & Tang, S. (2013). Evolution of microbial community diversity and enzymatic activity during composting. *Research in Microbiology, 164*(2), 189-198. https://doi.org/10.1016/j.resmic.2012.11.001

Ilyas, R.A., Sapuan, S.M., Kirubaanand, W., Zahfiq, Z.M., Atikah, M.S.N., Ibrahim, R., Radzi, A.M., Nadlene, R., Asyraf, M.R.M., Hazrol, M.D., Sherwani, S.F.K., Harussani, M.M., Tarique, J., Nazrin, A., Syafiq, R. (2021). Roselle: Production, Product Development, and Composites, in: Roselle. *Elsevier*, pp. 1–23. https://doi.org/10.1016/B978-0-323-85213-5.00009-3

INIA [Instituto Nacional de Innovación Agraria]. (2020). *Guía práctica para la producción de Compost*. https://repositorio.inia.gob.pe/bitstreams/4baa8890-8e40-43c8-b93c-5ecf685af659/download

Islam, M. (2019). Food and Medicinal Values of Roselle (*Hibiscus sabdariffa* L. Linne Malvaceae) Plant Parts: A Review. *Open Journal of Nutrition and Food Sciences, 1*(1), 14-20.

Javaid Siddiqui, H., Gul, S., Kakar, A.-R., Shaheen, U., Bano Rehman, G., Khan, N., Samiullah. (2021). Poultry Manure as an Organic Fertilizer with or without Biochar Amendment: Influence on Growth and Heavy Metal Accumulation in Lettuce and Spinach and Soil Nutrients. *Phyton-International Journal of Experimental Botany, 90*(2), 651–676. https://doi.org/10.32604/phyton.2021.011413

Jiang, L., Bonkowski, M., Luo, L., Kardol, P., Zhang, Y., Chen, X., Li, D., Xiao, Z., Hu, F., Liu, M. (2020). Combined addition of chemical and organic amendments enhances plant resistance to aboveground herbivores through increasing microbial abundance and diversity. *Biology and Fertility of Soils, 56*, 1007–1022. https://doi.org/10.1007/s00374-020-01473-w

Khan, I., Mahmood, S., Chattha, M. U., Bilal Chattha, M., Ahmad, S., Awan, M. I., Alqahtani, F. M., Hashem, M., Alhaithloul, H. A., Qari, S. H., Mahmood, F., & Hassan, M. U.

(2023). Organic Amendments Improved the Productivity and Bio-Fortification of Fine Rice by Improving Physiological Responses and Nutrient Homeostasis under Salinity Stress. *Plants, 12*(8), 1644. https://doi.org/10.3390/plants12081644

Liu, D., Ding, Z., Ali, E. F., Kheir, A. M., Eissa, M. A., & Ibrahim, O. H. (2021). Biochar and compost enhance soil quality and growth of roselle (*Hibiscus sabdariffa* L.) under saline conditions. *Scientific Reports, 11*(1), 1-11. https://doi.org/10.1038/s41598-021-88293-6

Liu, Y., Xu, M., Liu, M., Cheng, C., Qiao, L., Li, Y., & Li, Z. (2025). Responses of soil available nutrients and microbial performance in a newly established apple orchard after five-year fertilization with different sources of livestock manure. *Journal of Agriculture and Food Research, 19*, 101635. https://doi.org/10.1016/j.jafr.2025.101635

Luo, G., Li, L., Friman, V., Guo, J., Guo, S., Shen, Q., & Ling, N. (2018). Organic amendments increase crop yields by improving microbe-mediated soil functioning of agroecosystems: A meta-analysis. *Soil Biology and Biochemistry, 124*, 105-115. https://doi.org/10.1016/j.soilbio.2018.06.002

Medza-Mve, S.D., Ognalaga, M., Moupela, C., Stamby, O., Souza, A., Nzungize, J., Toussaint, A. (2018). Effect of sugarcane scum and ashes of *Chromolena odorata* L. on the aptitude of *Hibiscus sabdariffa* L. production. *International Journal of Biological and Chemical Sciences, 11*(6), 2867. https://doi.org/10.4314/ijbcs.v11i6.24

Meng, Z., Duan, A., Chen, D., Dassanayake, K. B., Wang, X., Liu, Z., Liu, H., & Gao, S. (2017). Suitable indicators using stem diameter variation-derived indices to monitor the water status of greenhouse tomato plants. *PLOS ONE, 12*(2), e0171423. https://doi.org/10.1371/journal.pone.0171423

Mohamed, B. B., Sarwar, M. B., Hassan, S., Rashid, B., Aftab, B., Husnain, T. (2015). Tolerance of Roselle (*Hibiscus sabdariffa* L.) Genotypes to Drought Stress at Vegetative Stage. *Advancements in Life Sciences, 2*(2), 74–82.

Mohd Ali, S.A., Latip, J., Mohd Zain, C.R.C. (2019). *Growth and phenolic constituents production in roselle (Hibiscus sabdariffa var. UKMR-2) as influenced by irrigation treatment.* Presented at the THE 2018 UKM FST POSTGRADUATE COLLOQUIUM: Proceedings of the Universiti Kebangsaan Malaysia, Faculty of Science and Technology 2018 Postgraduate Colloquium, Selangor, Malaysia, p. 050013. https://doi.org/10.1063/1.5111261

Norhayati, Y., NG, W. H., Dzemi, M. A. (2019). Effects of organic fertilizers on growth and yield of roselle (*Hibiscus sabdariffa* L.) on bris soil. *Malaysian Applied Biology, 48*(1), 177–184.

Onyeukwu, O. B., Dibie, D. C., & Njideaka, O. T. (2023). *Hibiscus sabdariffa* - uses, nutritional and therapeutic benefits - A review. *Journal of Bioscience and Biotechnology Discovery, 8*(2), 18-23. https://doi.org/10.31248/JBBD2023.178

Peng, S., Li, H., Xu, Q., Lin, X., Wang, Y. (2019). Addition of zeolite and superphosphate to windrow composting of chicken manure improves fertilizer efficiency and reduces greenhouse gas emission. *Environmental Science and Pollution Research, 26*, 36845–36856. https://doi.org/10.1007/s11356-019-06544-6

R Core Team. (2024). *R: A language and environment for statistical computing. R Foundation for Statistical Computing*. https://www.R-project.org/

Rech, I., Kamogawa, M. Y., Jones, D. L., & Pavinato, P. S. (2020). Synthesis and characterization of struvite derived from poultry manure as a mineral fertilizer. *Journal of Environmental Management, 272*, 111072. https://doi.org/10.1016/j.jenvman.2020.111072

Richardson, M. L., & Arlotta, C. G. (2021). Differential yield and nutrients of *Hibiscus sabdariffa* L. Genotypes when grown in urban production systems. *Scientia Horticulturae, 288*, 110349. https://doi.org/10.1016/j.scienta.2021.110349

Sani, S., Ibrahim, A., Lawal, A., Prakash, O. (2024). Assessment of Integrated Poultry Manure and Synthetic Fertilizer Effects on Maize (*Zea mays*) Growth and Soil Properties: A Study from Bayero University, Kano. *International*

Journal of Innovative Science and Research Technology, 9(5), 1722-1736. https://doi.org/10.38124/ijisrt/IJISRT24MAY1434

Semenov, M., Zhelezova, A., Ksenofontova, N., Ivanova, E., & Nikitin, D. (2023). Chicken manure as an organic fertilizer: composting technologies and impact on soil properties (a review). *Dokuchaev Soil Bulletin*. https://doi.org/10.19047/0136-1694-2023-115-160-198.

SENAMHI [Servicio Nacional de Meteorología e Hidrología del Perú]. (2024). *Datos Hidrometeorológicos a nivel nacional*. https://www.senamhi.gob.pe/?p=estaciones

Sha, C., Wu, J., Wu, J., Ye, C., Shen, C., Su, J., & Wang, M. (2023). Effects of Different Fertilizers on Soil Microbial Diversity during Long-Term Fertilization of a Corn Field in Shanghai, China. *Diversity, 15*(1), 78. https://doi.org/10.3390/d15010078

Sharpley, A. N., Kleinman, P. J. A., McDowell, R. W., Gitau, M., & Bryant, R. B. (2002). Modeling phosphorus transport in agricultural watersheds: Processes and possibilities. *Journal of Soil and Water Conservation, 57*(6), 425–439. https://doi.org/10.1080/00224561.2002.12457475

Silva-Galicia, A., Larsen, J., Álvarez-Espino, R., Ceccon, E. (2023). Agroecological and agroforestry strategies to improve organic *hibiscus* productivity in an Indigenous non-governmental organization from Mexico. *Renewable Agriculture and Food Systems, 38*, e3. https://doi.org/10.1017/S1742170522000369

Sindhu, S. A., Haripriya, K., Kamalakannan, S. (2021). Effect of organic inputs and mulching on growth and yield of roselle (*Hibiscus sabdariffa* var. *sabdariffa*). *Annals of Plant and Soil Research, 23*(2), 219–222. https://doi.org/10.47815/apsr.2021.10061

Singh, B. (2018). Are Nitrogen Fertilizers Deleterious to Soil Health? *Agronomy, 8*, 48. https://doi.org/10.3390/agronomy8040048

Sun, J., Jin, L., Li, R., Meng, X., Jin, N., Wang, S., Xu, Z., Liu, Z., Lyu, J., & Yu, J. (2023). Effects of Different Forms and Proportions of Nitrogen on the Growth, Photosynthetic Characteristics, and Carbon and Nitrogen Metabolism in Tomato. *Plants, 12*(24), 4175. https://doi.org/10.3390/plants12244175

Taghvaei, M., Nasrolahizadehi, A., Mastinu, A. (2022). Effect of Light, Temperature, Salinity, and Halopriming on Seed Germination and Seedling Growth of *Hibiscus sabdariffa* under Salinity Stress. *Agronomy, 12*, 2491. https://doi.org/10.3390/agronomy12102491

Ullah, M.Z. (2024). Genetic variability of roselle (*Hibiscus sabdariffa* L.) genotypes. *Innovare Journal of Agricultural Sciences, 12*(1), 1–6. https://doi.org/10.22159/ijags.2024.v12i1.49802

Urmi, T. A., Rahman, M. M., Islam, M. M., Islam, M. A., Jahan, N. A., Mia, M. A., Akhter, S., Siddiqui, M. H., & Kalaji, H. M. (2022). Integrated Nutrient Management for Rice Yield, Soil Fertility, and Carbon Sequestration. *Plants, 11*(1), 138. https://doi.org/10.3390/plants11010138

Wickham, H. (2016). *ggplot2: Elegant graphics for data analysis*. Springer-Verlag. https://ggplot2.tidyverse.org

Xie, J., Evgenia, B., Zhang, Y., Wang, J., Wan, Y., & Shi, X. J. (2022). Fertilization strategies to improve crop yields and N use efficiency depending on soil pH. *Archives of Agronomy and Soil Science, 69*(10), 1893–1905. https://doi.org/10.1080/03650340.2022.2126457

Yost, J. L., Schmidt, A. M., Koelsch, R., & Schott, L. R. (2022). Effect of swine manure on soil health properties: A systematic review. *Soil Science Society of America Journal, 86*(2), 450-486. https://doi.org/10.1002/saj2.20359

Zand-Silakhoor, A., Madani, H., Heidari Sharifabad, H., Mahmoudi, M., Nourmohammadi, G. (2022). Influence of different irrigation regimes and planting times on the quality and quantity of calyx, seed oil content and water use efficiency of roselle (*Hibiscus sabdariffa* L.). *Grasas y Aceites, 73*(3), e472. https://doi.org/10.3989/gya.0564211

Zayed, O., Hewedy, O. A., Abdelmoteleb, A., Ali, M., Youssef, M. S., Roumia, A. F., Seymour, D., & Yuan, Z. (2023). Nitrogen Journey in Plants: From Uptake to Metabolism, Stress Response, and Microbe Interaction. *Biomolecules, 13*(10), 1443. https://doi.org/10.3390/biom13101443