Brazilian Journal of Biology®

ISSN 1519-6984 (Print)
ISSN 1678-4375 (Online)

Original Article

Biological and chemical characterization in relation to the yield of radish (*Raphanus sativus* L.) nourished with humus from plant residues

Caracterização biológica e química em relação à produtividade de rabanete (*Raphanus sativus* L.) nutrido com húmus de resíduos vegetais

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Abstract

The increase in prices of fertilizers, energy and other materials necessary for the industry triggered a global economic crisis. Reason that was investigated on the biological and chemical characteristics in relation to the yield of radish nourished with humus from plant residue. The objective was to determine the appropriate dose of humus to obtain greater yield and its relationship with the chemical and biological characteristics of the radish. It is based on applied methodology with an experimental approach; Therefore, the Completely Random Block Design model was used, which consisted of 3 blocks and 5 treatments that were T_1 with 0, T_2 with 4, T_3 with 6, T_4 with 8 and T_5 with 10 t/ha of humus and They applied 15 days after sowing. The physical characteristics of the radish were evaluated and processed using analysis of variance and Duncan. Concentration of elements in leaves and stomatal density were also analyzed. It was determined that T_5 stood out in total plant length with 28.95 cm, plant weight with 76.87 g, equatorial diameter with 4,404 cm and commercial yield with 20,296 t/ha. Nitrogen consumption in relation to yield with 247.44 kg/ha. Stomatal density 459 stomata/mm2 and profitability with 150% and nutrient concentration in leaves highlighted T_4 with N, K, Ca, Mg, Mo and Zn. It concludes that T_5 stood out with 20,296 t/ha, which differed by 26.04% in relation to the control (T_1) with 15,011 t/ha. Therefore, this dose added nutrients to the soil that improved the availability for plant absorption and this influenced the concentration of nutrients in leaves such as N, P and Fe and stomatal density with 459 stomata/mm^2, which had a response in good development, strengthening against environmental stress and therefore greater performance.

Keywords: plant residue, humus, nutrition, stomata and yield.

Resumo

O aumento dos preços dos fertilizantes, energia e outros materiais necessários à indústria desencadeou uma crise econômica global. Motivo que foi investigado sobre as características biológicas e químicas em relação ao rendimento de rabanete nutrido com húmus de resíduo vegetal. O objetivo foi determinar a dose adequada de húmus para obtenção de maior rendimento e sua relação com as características químicas e biológicas do rabanete. Baseia-se em metodologia aplicada com abordagem experimental. Para tanto, utilizou-se o modelo de Delineamento em Blocos Completamente Aleatórios, que consistiu de 3 blocos e 5 tratamentos, que foram T1 com 0, T2 com 4, T3 com 6, T4 com 8 e T5 com 10 t/ha de húmus, e aplicaram 15 dias após a semeadura. As características físicas do rabanete foram avaliadas e processadas por meio de análise de variância e Duncan. Também foram analisadas a concentração de elementos nas folhas e a densidade estomática. Foi determinado que o T5 se destacou no comprimento total da planta com 28,95 cm, peso da planta com 76,87 g, diâmetro equatorial com 4.404 cm e produtividade comercial

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Received: December 8, 2023 – Accepted: March 12, 2024

com 20.296 t/ha. Consumo de nitrogênio em relação à produtividade com 247,44 kg/ha. Densidade estomática 459 estômatos/mm2 e rentabilidade com 150% e concentração de nutrientes nas folhas destacadas T4 com N, K, Ca, Mg, Mo e Zn. Conclui que o T5 se destacou com 20.296 t/ha, que diferiu em 26,04% em relação ao controle (T1) com 15.011 t/ha. Portanto, esta dose adicionou nutrientes ao solo que melhoraram a disponibilidade para absorção pelas plantas e isso influenciou na concentração de nutrientes nas folhas como N, P e Fe e na densidade estomática com 459 estômatos/mm2, que teve resposta em bom desenvolvimento, fortalecendo contra o estresse ambiental e, portanto, maior desempenho.

Palavras-chave: resíduos vegetais, húmus, nutrição, estômatos e produtividade.

1. Introduction

The increase in prices of fertilizers, energy and other materials necessary for the industry has triggered a global economic crisis. This is due to the post-pandemic context, the war between Russia and Ukraine and the hegemonic confrontation between the United States and China. In Peru, the effects of the rise in prices of food and other products necessary for well-being have also been felt. According to Zea et al. (2022) affirm that the rise in prices is due to the health crisis caused by Covid-19 and the conflict between Russia and Ukraine.

Specifically, the increase in the price of synthetic fertilizers and other nutritional inputs necessary for agricultural production stands out, which has increased the cost of production. This situation has led to an economic and food crisis that has considerably affected sectors in the interior of the country. In this regard, Castañeda Chirre et al. (2022) mention that the increase in the prices of fertilizers, such as Urea, Diammonium Phosphate, Potassium Sulfate, Nitrate and other products necessary for agriculture in Peru, has affected vegetable production. This, in turn, influences food prices.

Due to the overvaluation of the price of synthetic fertilizers, it is necessary to innovate in sustainable and viable alternatives for agricultural production. A viable option would be the use of humus from compost based on plant waste and beef guano, since it contains nitrogen, phosphorus, potassium and other elements necessary for the development of the plant. According to Dueñas and Hornas (2019), chicken waste and cow manure with effective microorganisms directly influenced the production of humus and allowed the lettuce to develop better than the control. Abreu et al. (2018) state that the replacement of 25% chemical fertilizer with vermicompost (4 t/ha and 6 t/ha) raised the yield of *Capsicum annuum* to values similar to the treatment with 100% chemical fertilizer in the second harvest. Furthermore, other research has shown that organic fertilization with components of herbs and animal waste did not cause deficiencies in the nutritional content and yield of vegetables compared to conventional fertilization, demonstrating that ecological management can be used effectively. effective (Herencia and Maqueda, 2016).

It is necessary to mention that the continuous use of synthetic fertilizers affects the chemical property of the soil, accumulating nitrate concentrations. When irrigated, these concentrations deepen to the water table, contaminating water sources. According to Yepis et al. (1999), there are losses of nitrogen through leaching to the deeper layers, where it becomes inaccessible to plants, causing nutritional deficiency and resulting in economic consequences and possible environmental contamination.

Also the continuous use of synthetic fertilizers affects pH conditions, the carbon-nitrogen ratio and other factors that are important for the propagation of beneficial organisms whose function is to improve the availability of elements necessary for plant development. In this regard, Altieri and Nicholls (2008) mention that the ability of a plant to tolerate the incidence of pests or diseases is linked to optimal soil conditions, in particular to biological properties. Crops that grow in soils with a high content of organic matter and with high biological activity generally exhibit a lower incidence of pests.

For this reason, an investigation was carried out on the biological and chemical characterization of radish in relation to the yield nourished with humus from compost based on plant residues and beef guano. The objective was to determine the appropriate dose of humus to obtain greater yield and its relationship with the chemical and biological characteristics of the radish. In addition, it is necessary to mention that the purpose of this research is to take advantage of the humus obtained from the excretion of the Californian worm, from compost based on plant residues and beef guano, which are available to farmers, to improve the properties of the floor. Therefore, this result will serve as a recommendation

2. Materials and Methods

2.1. Type of research

The experiment is based on the type of applied research with an experimental approach; since through field and laboratory evaluations and statistical processing, the appropriate dose of humus was determined to increase radish yield.

2.2. Population

The population refers to radish plants that develop from 0 to 150 meters above sea level; Therefore, the data obtained were validated.

2.3. Sample

26 plants were taken, which is equivalent to 40% of the plants in the plot. These plants were selected from the central rows in order to avoid the edge effect and were marked with tape to evaluate them from planting to harvest.

2.4. Study factor

The doses were established according to the soil analysis and the dose applied by farmers in the area, which is 6 to 8 t/ha of compost. The recommendation of Hirzel and Salazar (2016) was also taken into account, who mention that 6 to 12 t/ha of compost based on waste and/or plant by-products, as well as compost from a mixture of animal and plant by-products, are needed to radish cultivation. Therefore, the standard dose of 6 t/ha of humus from plant residues and beef guano was established (see Table 1).

2.5. Calculation of nitrogen in the soil

To calculate nitrogen in the soil, the following procedures were carried out:

Calculation of soil weight.

To calculate the weight of soil, the Formula 1 (Ipanaqué, 2023) was applied.

$$\left[Ha\ Weight\right] = \left(Soil\ depth\right)\ x\ \left(D.Ap.\right)\ x\ \left(Ha\right) \quad (1)$$

where: Weight Ha: weight of soil of the arable layer per hectare; Soil depth: Soil depth (0.20 m); D.Ap.: Apparent density (1.4 g/cm^3); Ha: Hectare (10,000 m^2); Ha Weight: 2800 t/ha of land; Organic carbon calculation.

It was operated with the Van Bemmelen formula which is (Formulas 2 and 3):

$$\left[C.\ Organic\right] = \left(M.O.x\ 0.58\right)$$

(Vela Blanco et al., 2012) (2)

$$\left[Organic\ C.\right] = \left(M.O.\ x\ 0.58\right) = \left(1.42\%*0.58\right) = 0.8236\%$$

(Vela Blanco et al., 2012) (3)

Table 1. Dosage of humus for radish cultivation.

Treatments	t/ha	g/plant
T_1	0	0
T_2	4	10
T_3	6	15
T_4	8	20
T_5	10	25

where: Organic C.: Organic carbon; M.O.: Organic matter with 1.42% (Table 2) (INIA, 2023a); Calculation of the carbon/nitrogen ratio (C/N).

The values are replaced (Formula 4)

$$C/N = \left(1.42\%\ x\ 0.58\right)/0.07\% = 0.8236/0.07 = 11.76$$

(Ipanaqué, 2023) (4)

where: C: Organic carbon; N: 0.07% N (nitrogen) (Table 2) (INIA, 2023a); C/N: Carbon/Nitrogen Ratio 11.76.

Once the value of the C/N ratio was determined, which is 11.76, it was compared and determined to be within the C/N ratio range of 10 to 12; so the result is 140 ppm (parts per million) of nitrogen (See Table 3).

After carrying out the conversion factor, 140 ppm of nitrogen were obtained, which are indicated in the table. Next, the formula $Available\ Nitrogen\ \left(N.D\right) = 140\ ppm\ \left(converted\ nitrogen\right) * 0.07$ was applied (Table 2) (INIA, 2023a), obtaining 9.8 ppm of N.D. Then, this value was projected with the weight of soil or weight of arable layer, which is 2800 t/ha of land, obtaining 27.44 kg/ha of N.D.S. (Available Soil Nitrogen)

2.6. Quantification of the standard dose of humus with respect to nitrogen

The standard dose of humus from compost based on plant residues and beef guano was calculated as follows.

The nitrogen value was taken from the INIA-Huaral fertilization recommendation for the radish crop, which is 180 N kg/ha (Table 4) (INIA, 2023b) and 27.44 kg/ha N.D.S. was subtracted. obtaining 152.56 kg/ha of N.D.A. (Available Nitrogen Applied)

Then the value of the chemical analysis of the humus was taken, which is 2.20% nitrogen (Table 5) (INIA, 2023c), this value was projected to 6 and 8 t/ha of humus, which is equivalent to 132 and 176 kg. /ha of nitrogen in fertilizer.

Once the recommendation nitrogen data was obtained and the available nitrogen of the soil was subtracted, 152.56 kg/ha of N.D.A. was obtained. Then, it was compared with the nitrogen of the humus, which is projected to be 6 and 8 t/ha of humus, which is equivalent to 132 and 176 kg/ha of nitrogen. Therefore, 6 t/ha of humus from plant residues and cattle guano was taken as a standard dose.

2.7. Statistical analysis

2.7.1. Variance analysis

Once the data on the physical characteristics of the radish were obtained from sowing to harvest, they were

Table 2. Soil analysis of the radish experimental area.

No. Lab.	C.E. 1:2:5 mS/cm	pH 1:2:5	O.M. %	N %	P ppm	K ppm	$CaCO_{3\%}$	Cation exchange (mEq/100 g suelo)				CEC
								Ca	Mg	Na	K	
SU422-DO-23	0.228	8.31	1.42	0.07	14.25	241.37	1.81	6.36	0.71	0.29	0.62	7.98

CEC: Cation Exchange Capacity; O.M.: Organic matter; C.E: Electrical conductivity.
Source: INIA (2023a) "Soil analysis".

processed using variance analysis. This determined the calculated F, and it was compared with the data from Fisher's table at 5% error (Fcal < Ftab 5%). In this way, it was determined whether it is significant or not, that is, whether there is a dose effect of humus from beef guano residues and plant residues on the biometric variables of the plant or not.

2.7.2. Duncan's test

After processing the data on the physical characteristics of the radish plant from each plot through analysis of variance, the Duncan test was carried out at a 5% error. This determined whether there is differentiation or homogeneity between the treatments classified and grouped by letters. It was also specified which treatment stood out compared to the others.

2.8. Data collection

To collect data on the physical characteristics of the radish from sowing to harvest, observation and measurement techniques were used. For this, precision instruments such as digital balance, vernier, ruler, scanning electron microscope and other laboratory materials were used to quantify nutrient concentration and stomatal density.

2.9. Procedures

The compost was made with waste from 60 kg of beef guano and 40 kg of dry pea and canary bean plants for 3 months (until adequate decomposition was reached). Then Californian red worms (Eisenia foetida) were placed and left for another 3 months (approximate time), thus obtaining the humus.

Next, the land was prepared in a conventional manner, in the Tres Piedras sector, Supe Puerto district, Barranca province. Then, soil samples were taken at a depth of 25 cm in a zig-zag manner within the experimental area. This was poured into a blanket and the soil was removed and 1 kg was taken and taken to the National Institute of Agrarian Innovation (INIA) – Huaral.

After installing and implementing the experimental area, the statistical model of the Completely Randomized Block Design was used, which consisted of 3 blocks and 5 treatments. Each treatment was measured in an area 1.6 m long and 1 m wide, and a space of 0.5 m was left between blocks.

From there, the radish seeds were broadcast sown on October 11, 2023. After 1 week, they were plucked between the plants at a distance of 0.1 m and between the twin rows at a distance of 0.5 m. After 15 days, the doses of humus were applied as indicated in Table 1.

Plants were evaluated until harvest, which was November 10, 2023. During this time, data on physical characteristics, such as plant height, bulb diameter, and yield, were collected. Subsequently, they were processed using analysis of variance and Duncan's test.

Samples of radish leaves from each treatment were then taken to AGQ Perú SAC, which determined the nutrient concentration. At another time, leaf samples were also taken to the Scanning Electron Microscope which determined the stomatal density, for which the Formula 5 was applied.

$$De = \frac{Ne}{Al.} 100 \tag{5}$$

where: I = stomatal index; Ne = Number of stomata; Al. = Lens area (0.133mm^2).

Finally, the profitable analysis was carried out, which consisted of projecting costs and performance. The commercial yield was then multiplied by the unit price in kg. In this way, the total income was obtained and the cost of production was subtracted, resulting in profit. Once these values were obtained, the profitability Formula 6 was applied.

$$\text{E.C.} = \frac{U}{Cp} * 100 \tag{6}$$

where: E.C.: Cost effectiveness; U: Utility; P.C.: Production cost.

Table 3. Conversion factor from total to available nitrogen in ppm in relation (C/N).

Margin C/N Ratio	Conversion factor from total Nitrogen (N.T.) in percentage, to Nitrogen in ppm
Greater than 12	11.2
From 10 to 12	140
Under 12	225

Source: Kass (1998).

Table 4. Macronutrient recommendation for radish cultivation.

Items	Radish		
	N	P_2O_5	K_2O
kg/ha	180	80	60

Source: INIA (2023b) "Macronutrient recommendation for radishes".

Table 5. Nutrient analysis of humus.

No. Lab.	ID Sample	pH	C.E. mS/cm	Humidity (%)	O.M. (%)	N (%)	P_2O_5 (%)	K_2O (%)	CaO (%)	MgO (%)	C/N
AO143-DO-23	Humus	7.68	1.94	32.70	45.68	2.20	2.68	2.12	6.85	1.00	10.13

C.E: Electrical conductivity; O.M.: Organic matter.
Source: INIA (2023c) "Complete humus analysis".

3. Results

3.1. Soil analysis and fertilization recommendation

The soil analysis consisted of taking soil samples using the zig-zag method within the experimental area. Then, it was poured onto a blanket and stirred. From there a 1 kg sample was taken and taken to INIA – Huaral. The results determined that the pH is moderately alkaline, high in phosphorus and potassium, but low in organic matter and nitrogen, according to the values of Prialé (2016). Regarding the exchangeable elements in medium concentration, calcium, magnesium and sodium were found, but high in potassium. Regarding the Cation Exchange Capacity (CEC), it is low according to the values of McKean (1993). Therefore, the chemical result indicates that it is appropriate for sowing radish; However, it is necessary to apply organic matter to improve soil properties (See Table 2).

Regarding the recommendation for macronutrient fertilization, the INIA – Huaral determined that a considerable amount of nitrogen is required for radish cultivation, which is N = 180 kg/ha. This amount was also taken into account to establish the standard dose (see Table 4).

3.2. Humus analysis

After the fertilizer analysis was carried out by INIA – Huaral, which is detailed in Table 5, it was determined that it has a low concentration of nitrogen, phosphorus and potassium. However, the C/N ratio = 10.13 in the final stage of the process or mature compost indicates that it is within adequate ranges and that nitrogen is available for plant nutrition. According to Bernai et al. (1998) suggest that in the composting process: in the initial mixture, in the thermophilic phase, at the end of the active phase and after two months of maturation they established the following maturity indices: C/N < 12.

In the INIA – Huaral microelement analysis, it was determined that there is a high concentration of iron and a low concentration of copper and manganese (See Table 6). This result is compared with the study by Román et al. (2013), who mention that the vermicompost obtained from plant residues, fatty tissues and other organic components presented a concentration of 200 ppm of iron, 60 ppm of manganese and 500 ppm of copper. Therefore, it can be stated that the values obtained in the analysis are within the appropriate range.

3.3. Physical characteristics of radish

Processing the data on the physical characteristics of the radish through statistical analysis, it was determined that T_5 with 10 t/ha of humus excels in size, quality and yield of the plant. Therefore, it is interpreted that this dose of humus had an efficient response compared to the other treatments (See Table 7).

3.4. Nitrogen consumption in relation to performance

Regarding nitrogen consumption in relation to radish yield, T_5 stood out with 247.44 kg/ha of nitrogen, which represents a difference of 88.91% compared to T_1 with 27.44 kg. Therefore, it is evident that T_5 provided a greater amount of nitrogen, which had a response in the higher radish yield (See Table 8).

3.5. Concentration of nutrients in radish leaves

In the analysis of nutrients in radish leaves, it can be seen that T_4 stood out in most nutrients, such as N, K, Ca, Mg, Mo and Zn. However, these concentrations did not

Table 6. Analysis of humus microelements.

Items	Iron	Zinc	Copper	Manganese
Quantity (mg/kg)	486.00	68.50	15.20	186.00

Note: (mg/kg) equal to ppm (Parts per million).
Source: INIA (2023d) "Analysis of microelements of humus".

Table 7. Physical characteristics of radish by treatment.

Treatment	Dose (t/ha)	Total plant length (cm)	Weight of a plant (g)	Equatorial diameter (cm)	Commercial yield (t/ha)
T_5	10	28.95 a	76.87 a	4.4043 a	20.296 a
T_4	8	28.53 a	73.56 a	4.3617 a	17.820 a
T_3	6	28.25 a	67.56 a	4.3017 a	16.924 a
T_2	4	27.88 a	63.96 a	4.2423 a	15.631 a
T_1	0	27.08 a	57.92 a	4.2007 a	15.011 a
C.V. (%)		6.98	29.32	11.01	19.92
Significance		N.S.	N.S.	N.S.	N.S.

Note: (S) significant and (N.S.) non-significant, C.V.: Coefficient of variation and (a) score obtained through Duncan's test which indicates that there was homogeneity that there were equal letters.

Table 8. Nitrogen consumption in relation to radish yield per treatment.

Treatment	Humus dose (t/ha)	Amount of nitrogen in soil (kg/ha)	Nitrogen concentration in humus (kg/ha)	Total nitrogen consumed (kg/ha)	Performance (t/ha)
T_1	0	27.44	0	27.44	15.011
T_2	4	27.44	88	115.44	15.631
T_3	6	27.44	132	159.44	16.924
T_4	8	27.44	176	203.44	17.820
T_5	10	27.44	220	247.44	20.296

Note: Humus has 2.20% nitrogen (Table 5) (INIA, 2023c). Projected at 10 t/ha, it is equivalent to 220 kg/ha of nitrogen.

Table 9. Nutrient concentration in radish leaves by treatment.

	T_1	T_2	T_3	T_4	T_5
Macronutrients (%)					
Total Nitrogen	2.9	3.6	2.8	3.1	3.1
Potassium	1.63	2.09	1.43	1.95	1.81
Match	0.302	0.390	0.308	0.272	0.321
Calcium	3.97	3.21	4.03	4.36	4.07
Magnesium	0.520	0.457	0.518	0.600	0.546
Sulfur	0.93	1.03	0.96	1.02	1.00
Micronutrients (mg/kg)					
Molybdenum	1.97	1.88	2.08	3.08	2.17
Iron	> 1 000	> 1 000	> 1 000	869	> 1 000
Manganese	197	105	172	131	146
Copper	12.1	9.80	11.3	8.36	10.9
Zinc	73.0	62.4	72.6	64.7	69.6
Boron	60.7	61.1	62.2	74.6	64.2
Phytotoxic elements (mg/kg)					
Chlorides	26 374	25 229	26 979	27 098	27 172
Sodium	20 029	12 566	18 914	13 048	17 378

Source: AGQ Perú SAC (2023) Test Report - Plant Material.

influence the performance, since at a higher dose, which is T_5, it stood out in N, P and Fe. Therefore, it is evident that a higher dose of humus influenced raising the concentration of macronutrients such as N and P, which obtained a higher radish yield (see Table 9).

3.6. Stomatal density in radish leaves

Quantifying the stomata in the radish leaves, it can be seen that as the doses of humus increased, the density of stomata increased, highlighting T_5 with 459 stomata/mm^2. Therefore, this density is set as an indicator that influenced the strengthening of the plant against environmental stress and therefore the highest yield (see Table 10 and Figure 1).

3.7. Economic analysis of profitability

Regarding the profitability per treatment indicated in Table 11, it can be seen that T_5 stood out with 150%, which differs by 6% with respect to T_1, which has 141%. Therefore, it is interpreted that at a higher dose of humus there was an increase of 6% compared to the control, and a gain of 50% more than the total investment was obtained; this result being favorable.

4. Discussion

4.1. Physical characteristics of radish

Processing the data on the physical characteristics of the radish through analysis of variance, it was determined that there was no effect of humus dose; that is, it did not influence the development, yield and quality of the bulb. However, T_5 with a dose of 10 t/ha of humus stood out in yield with 20,296 t/ha, which differs by 26.04% in relation to T_1 with 15,011 t/ha (See Table 7). Therefore, at this dose

Table 10. Stomatal index in radish leaves by treatment.

	T_1	T_2	T_3	T_4	T_5
Number of stomata (0.133 mm^2, lens area)	33	36	48	56	61
Stomatal density (number of stomata/mm^2)	248.1	270.7	360.9	421.1	458.6
Stomatal index %	51.56	54.55	59.26	66.67	69.32
Number of cells (0.133 mm^2)	64	66	81	84	88

Note: Projected lens area equals 0.133 mm^2.

Table 11. Economic analysis of profitability by treatment.

Treatment	Dose of humus (t/ha)	Commercial yield (kg/ha)	Unit value ($)	Total income ($)	Product Cost ($)	Utility ($)	Cost effectiveness (%)
T_1	0	15011	0.35	5203.8	2158.6	3045.2	141.0
T_2	4	15631	0.35	5418.7	2422.5	2996.	123.7
T_3	6	16924	0.35	5867.0	2554.5	3312.5	129.7
T_4	8	17820	0.35	6177.6	2686.5	3491.1	130.0
T_5	10	20296	0.35	7035.9	2818.4	4217.5	150.0

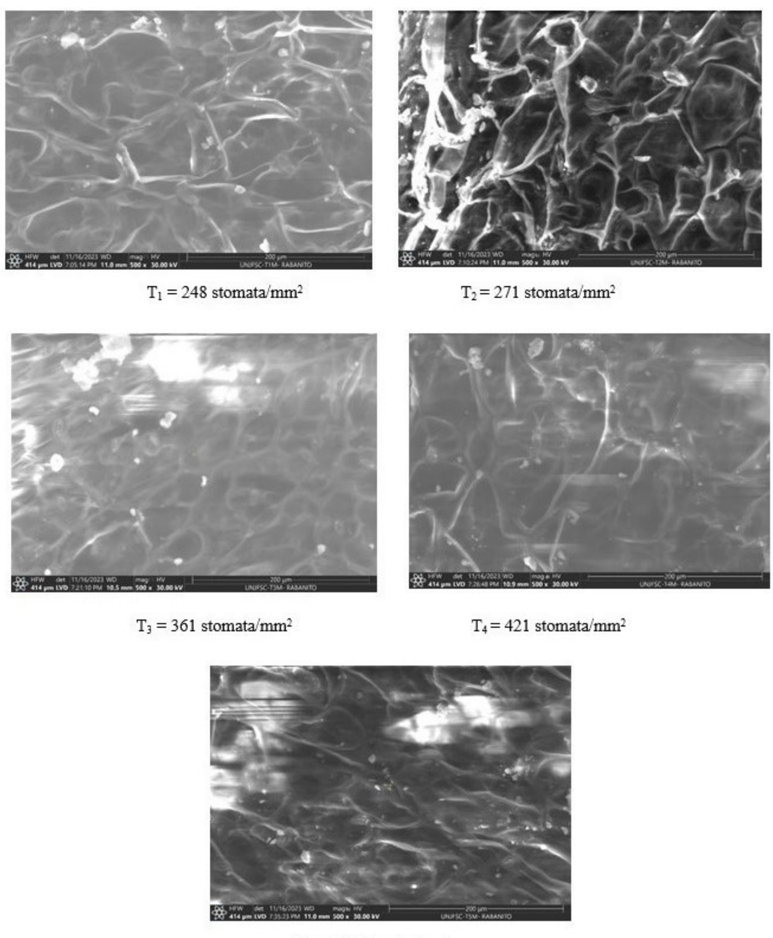

Figure 1. Micrograph of stomata density in radish leaves by treatment.

of humus, macro and micro nutrients were incorporated into the soil, which improved nutritional availability for greater absorption by the plant. This influenced good development, strengthening against environmental stress and, therefore, greater performance. This analysis is based on Fertilab (2021), which mentions that humus has a humidity of 30-60%, a pH of 6.8-7.2 and a concentration of nutrients such as nitrogen of 1-2.6%, phosphorus of 2-8%, 1-2.5% potassium, 2-8% calcium, 1-2.5% magnesium, 30-70% organic matter, 14-30% organic carbon, 14-30% fulvonic acid, 2.8- humic acid 5.8% and 0.02% sodium. Perhaps humus does not contain all the nutrients that plants need for proper growth, but the existence of other materials in humus help and regulate plant nutrition (Arce and Mori, 2020). Therefore, Pinchi (2008) determined that T_3 with 6 t/ha of humus obtained the best result with 29.31 t/ha of paprika, being superior to the other treatments that are applied in worm humus and chemical treatment of nitrogen, phosphorus and potassium, which obtained good production but below the indicated treatment.

4.2. Nitrogen consumption in relation to performance

In total nitrogen consumption per treatment, T_5 stood out with 247.44 kg/ha, which differs by 88.91% with respect to T_1, which only had 27.44 kg/ha of nitrogen. This greater nitrogen consumption influenced the yield of the radish (see Table 8). Therefore, it is analyzed that a greater amount of nitrogen was added to this dose of compost, which resulted in greater availability for absorption by the plant. This resulted in better development and strengthening of the plant against environmental stress, and consequently, greater yield. This analysis is supported by the research of Castañeda Chirre et al. (2022), who investigated sustainability with compost based on market waste to obtain higher yields, determined that T_5 with 194.44 kg/ha had the highest use of total nitrogen and obtained the highest yield with 12,051 t/ha. Also, Cruz Nieto et al. (2022a) determined that a higher dose of compost based on market waste increased the total nitrogen in the soil, with T_5 having 200.40 kg/ha; Therefore, at this concentration its availability increased, absorption increased and the biochemical reactions that influenced performance were optimized.

4.3. Concentration of nutrients in radish leaves

Concerning the evaluation of nutrient concentration in radish leaves, it was determined that T_4 stood out in most nutrients, such as N, K, Ca, Mg, Mo and Zn. However, at a higher dose than T_5, N, P, Fe and elements, such as K, Mg, Mn, Cu and Zn, are within normal values, according to the foliar analysis values of radish from (Legua Cárdenas et al., 2023) (see Table 9), which influenced performance. Therefore, it is analyzed that higher concentrations of N, P and Fe, and normal values of K, Mg, Mn, Cu and Zn, influenced the optimal biochemical reactions, such as photosynthesis, evapotranspiration and carbohydrate translocation, which had a response in the good development of the plant, strengthening against environmental stress, pests and diseases, and in this way, obtained a higher yield.

4.4. Stomatal density in radish leaves

In the evaluation of the density of stomata in radish leaves by treatment, which is indicated in Table 10 and Figure 1, it was determined that at a higher dose of humus (T_5), 459 stomata/mm^2 were obtained, which differed by 46% in relation to T_1, which presented 248 stomata/mm^2. This result shows that the higher the dose of humus, the greater the availability of nutrients in the soil, which influenced the greater absorption for the plant. Therefore, this addition of elements had a response in the increase of stomata, which favored optimal biochemical reactions such as photosynthesis, evapotranspiration, carbohydrate translocation and, therefore, greater yield. In this regard, Li et al. (2022) consider that stomata play important roles in gas and water exchange in leaves. In addition. Fernández et al. (2015) maintain that stomata are modified epidermal cells that control gas exchange and water losses through transpiration. Álvarez-Holguín et al. (2018) mention that the characteristics of the stomata and their concentration can be determining factors in the differences in biomass production. Therefore, the higher the dose of humus, the greater the increase in stomata, which is corroborated by Cruz Nieto et al. (2022b) who determined that by increasing the doses until T_4 with 8 t/ha of compost based on market waste, it increased to 63 stomata, which is equivalent to 444.60 stomata/mm2, and this amount influenced the higher radish yield.

4.5. Economic analysis of profitability

Regarding the economic analysis of profitability seen in Table 11, it was specified that T_5 with 150% differs by 6% in relation to T_1 with 141%. Therefore, it is analyzed that at this dose there was a gain of more than 5% compared to the control. Therefore, this dose generates a greater economic profit, which benefits the farmer in the area by applying this dose to the radish crop.

5. Conclusion

It was determined that the T_5 dose with 10 t/ha of humus from plant residues produced the highest radish yield, with 20,296 t/ha. Therefore, this dose was effective since it added nutrients to the soil, increasing its availability for absorption by the plant. This favored optimal biological and chemical reactions, such as improved nutrition and increased stomata, which resulted in good development and strengthening of the plant, and therefore greater yield.

It was also determined that T_4 excelled in most nutrients, such as N, K, Ca, Mg, Mo and Zn. However, at a higher dose, T_5 stood out in N, P and Fe. Therefore, these measurements of N, P and Fe influenced the optimal biochemical reactions that responded to the good development of the plant, strengthening against stress. environmental, pests, diseases and, therefore, the highest radish yield.

Finally, it is concluded that in stomatal density, T_5 stood out with 459 stomata/mm^2, differing by 46% with respect to T_1 (control) with 248 stomata/mm^2. Therefore, this number of stomata is established as an indicator, since it influenced the optimal biological and chemical reactions, resulting in good strengthening against environmental factors and therefore greater radish yield.

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