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Original Article

Analysis of the biological and chemical characteristics of cabbage (*Brassica oleracea* var. Capitata L.) Fed with compost based on sugarcane residues

Análise das características biológicas e químicas do repolho (*Brassica Oleracea* var. Capitata L.) alimentado com composto à base de resíduos da cana-de-açúcar

D. D. Cruz Nieto[a*], L. A. A. Montes[b], I. R. Lirión Rodríguez[b], V. M. Z. Chauca[c], J. M. More López[c], J. Yovera Saldarriaga[c], J. U. Romero Menacho[a], H. E. Chanducas Tantaleán[c], J. E. Sotelo Montes[c], M. A. Jamanca Ramirez[c], C. M. Caira Mamani[d], M. N. M. Alberto[e], A. E. Carbonel Neciosup[c] and Y. J. Vélez Chang[a]

[a] Universidad Nacional José Faustino Sánchez Carrión, Huacho, Peru
[b] Universidad Privada César Vallejo, Huaraz, Peru
[c] Universidad Nacional Santiago Antúnez De Mayolo, Huaraz, Peru
[d] Universidad Nacional de Jaén, Jaén, Peru
[e] Universidad Nacional de Cañete, Cañete, Peru

Abstract

The pandemic and the geopolitical conflict between Russia and Ukraine are events that have caused economic instability in Peru. Reason that was investigated on the analysis of the biological and chemical characteristics of cabbage fed with compost based on sugarcane residues. The objective was to analyze the physical, chemical and biological characteristics of cabbage from the adequate dose of compost based on sugarcane residues and distance between plants. It is based on the methodology applied with an experimental approach, for which the Completely Random Block Design with a 4x 2 factorial arrangement was used, which consisted of 3 blocks and 8 treatments that were the combination: F1 with 0, F2 with 8, T3 with 10 and F4 with 12 t/ha and spacing (D1) with 0.30 m between plants and 0.60 m between rows and (D2) with 0.35 m between plants and 0.60 m between rows. The physical characteristics of cabbage were evaluated and processed by analysis of variance, nutrient concentrations in leaves and stomatal density were analyzed. The results determined that T7 stood out in plant height with 41.88 cm, yield with 26.76 tn/ha and T6 in root length with 20.22 cm. In chemical analysis of leaves T1 stood out in nitrogen, phosphorus, potassium and T4 in calcium, magnesium and sulfur. In T7 stomata density with 977 stomata/mm2. It concludes that at an adequate dose and greater distance that T7 stands out in the concentration of nutrients that are within normal values and high density of stomata; Therefore, these characteristics influenced the optimal biochemical reactions, which obtained good development and yield that differed at 51.39% and 32.17% with respect to the controls T1 and T5.

Keywords: sugarcane residues, compost, nutrients, stomata and yield.

Resumo

A pandemia e o conflito geopolítico entre a Rússia e a Ucrânia são eventos que têm causado instabilidade econômica no Peru. Motivo que foi investigado na análise das características biológicas e químicas do repolho alimentado com composto à base de resíduos da cana-de-açúcar. O objetivo foi analisar as características físicas, químicas e biológicas do repolho a partir da dose adequada de composto à base de resíduos da cana-de-açúcar e distância entre plantas. Baseia-se na metodologia aplicada com uma abordagem experimental, para a qual foi utilizado o Delineamento de Blocos Completamente Aleatório com arranjo fatorial 4 x 2, que consistia em 3 blocos e 8 tratamentos que eram a combinação: F1 com 0, F2 com 8, T3 com 10 e F4 com 12 toneladas/ha e espaçamento (D1) com 0,30 m entre plantas e 0,60 m entre linhas e (D2) com 0,35 m entre plantas e 0,60 m entre linhas. As características físicas do repolho foram avaliadas e processadas por análise de variância, as concentrações de nutrientes nas folhas e a densidade estomática foram analisadas. Os resultados determinaram que T7 se destacou em altura de planta com 41,88 cm, produtividade com 26,76 tn/ha e T6 em comprimento de raiz com 20,22 cm. Na análise química das folhas T1 se destacou em nitrogênio, fósforo, potássio e T4 em cálcio, magnésio e enxofre. Em densidade de estômatos T7 com 977 estômatos/mm2. Conclui que em dose adequada e maior distância que T7 se destaca na concentração de nutrientes que estão dentro dos valores normais e alta densidade de estômatos; Portanto, essas características influenciaram nas reações bioquímicas ótimas, que obtiveram bom desenvolvimento e rendimentos que diferiram em 51,39% e 32,17% em relação aos controles T1 e T5.

Palavras-chave: resíduos de cana-de-açúcar, composto, nutrientes, estômatos e rendimento.

*e-mail: dcruz@unjfsc.edu.pe
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Introduction

The pandemic and the geopolitical conflict between the Russian Federation and Ukraine are events that have caused global economic instability in recent years. In Peru, this has been perceived in the increase in the prices of energy and fertilizers, which has triggered social and economic problems, such as the increase in the cost of food, medicine, basic services and other resources for comfort. All of this has led to job instability and other crises. According to Perú (2022), the war conflict between Russia and Ukraine has generated global attention due to its political and socioeconomic impact in each country, since the rise in the price of steel, energy, agricultural inputs and other materials has led to an increase in the food cost.

In response to this situation, agricultural production has been considerably affected by the increase in the price of fertilizers that were more accessible before the pandemic. The overvaluation of products such as Urea, Diammonium Phosphate, Potassium Sulfate and other inputs necessary for the physiological development of the plant, strengthening and increasing yield, make their acquisition difficult. In this regard, Diez O. (2022) mentions that the situation in Peru has been threatened by the international crisis and that it violates strategic supply management; This is due to the strong dependence on strategic food products such as urea and other fertilizers, key to maintaining agroindustrial production.

On the other hand, it is important to mention that the continuous use of synthetic fertilizers such as urea, nitrogenous compounds and others, causes damage to soil properties. This is because the residues left in the soil, such as nitrate, leach deep into the soil when watered continuously, causing contamination of groundwater; being an environmental problem and at the same time harmful to the soil due to excess of this element. According to Yepis O. et al (1999), the loss of nitrogen through leaching to the deep layers of the soil where there is no access to the roots of the plants causes nutritional deficiency, resulting in economic consequences and environmental pollution.

Due to this situation, it is necessary to innovate new nutritional alternatives in vegetable crops such as cabbage in order to reduce the cost of production, obtain higher yields and reduce environmental pollution while generating economic resources. An alternative is the use of sugarcane waste such as vinasse, which is generated in excess and does not have an adequate final disposal. For example, Cerioni et al (2019) mention that for every ton of cane, 180-280 kg of sugarcane bagasse are generated, while for every liter of ethanol produced from final honey, between 12 and 15 are obtained. liters of vinasse as residual with a chemical oxygen demand (COD) between 60 and 70 g/L. Therefore, it is advisable to make compost with this waste to reduce environmental pollution.

It is worth mentioning that the production of compost from these wastes, applied to the soil, improves the physical, chemical and biological properties of the soil. This is because it incorporates nutrients and improves their availability for optimal absorption, which favors the strengthening of the plant against environmental stress. This statement is supported by López Bravo et al. (2017), who state that compost (base of sugarcane byproducts) shows quality indicators, such as a humidity of 59%, a pH of 8.2, a carbon ratio -nitrogen of 12.5, an apparent density of 0.55 g/cm^3, a nitrogen content of 1% and a phosphorus content of 1.3%. In addition, it must be taken into account that adequate spacing between plants reduces nutritional competition and allows for better use of nutrients.

For this reason, an investigation was carried out on the analysis of the biological and chemical characteristics of cabbage nourished with compost based on sugar cane waste. The objective was to analyze the physical, chemical and biological characteristics of cabbage based on the appropriate dose of compost based on sugarcane waste and the distance between plants. Likewise, it is mentioned that the purpose of this research was to take advantage of sugarcane residues and planting space to obtain a higher yield. Therefore, the results of this experiment favor as a recommendation for farmers

2. Material and Methods

2.1. Kind of investigation

It is based on the type of applied research with an experimental approach; since through field evaluations and statistical analyzes the dose based on sugarcane residue and adequate spacing between plants for higher cabbage yield was determined.

2.2. Population

It refers to cabbage plants that were grown from 50 to 150 meters above sea level. (meters above sea level), so the data obtained was validated.

2.3. Sample

For the evaluations, samples of 16 plants were taken, which are equivalent to more than 40% of plants from each plot of the central part of the furrow. These were marked with a tape and the physical characteristics of cabbage were evaluated and samples of cabbage leaves were taken for chemical and stomatal analysis.

2.4. Study factor

2.4.1. Fertilization for larger plant population

Compost fertilization was established taking into account soil analysis, the dose used by farmers in the area, which is 8 to 10 tons/ha for vegetables such as cabbage, and the recommendation of Hirzel and Salazar (2016), who mention that 6 to 12 t/ha of compost based on bird guano, sawdust, vegetable residues and other high C/N organic residues are needed for cabbage cultivation. (See Table 1).

2.4.2. Fertilization for lower plant population

Regarding fertilization for a smaller population, the doses were established taking into account the amount of compost used by farmers in the area, which is 8 to 10 t/ha and control (F1). The application doses for each cabbage plant are detailed below in Table 2.

2.5. Planting densities

Planting densities were established according to the measures used by farmers in the area for growing cabbage. Being these distances between plants of 0.30 m. at 0.35 m and between furrows 0.60 m. Table 3 details the distance measurements and the population per hectare below.

2.6. Treatments

To establish the treatments, the fertilization and distancing doses were combined in an orderly manner, thus obtaining the pairs or interactions which were used in the experiment (See Table 4).

2.7. Specify the amount of nitrogen in soil

To calculate the weight of soil per hectare, the Formula 1 will be applied

Para calcular el peso de suelo por hectárea se aplicará la fórmula (Ipanaqué, 2023)

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

Where:
Weight. ha : Weight of arable layer per hectare
Soil Depth : Soil depth (0.25m)
D.Ap : Apparent density (1.4 g/cm3)
Ha : hectare = 10,000 m2
Weight. ha : 3500 tons of land/ha

2.8. Calculation of organic carbon

The Van Bemmelen Formula 2 was applied, which is [Organic C.]= (M.O.x 0.58) (Vela et al., 2012)

$$\left[Organic\ C.\right] = \left(M.O.\ \times\ 0.58\right) = \left(1.60 * 0.58\right) = 0.928\% \quad (2)$$

Where:
C. organic: Organic carbon
M.O. : Organic matter with 1.60% (Table 6) (INIA, 2021a)

2.9. Calculation of the carbon/nitrogen ratio (C/N)

The values are replaced (Formula 3)

$$C / N = \left(1.60 \times 0.58\right) / 0.08 = 0.928 / 0.08 = 11.60 \quad (3)$$

Where:
C: Organic carbon
N: 0.08% of N (nitrogen) (Table 6) (INIA (2021a)
C/N: Carbon/Nitrogen ratio 11.60

Once the C/N ratio was obtained, which is 11.60, it was compared with the values of Table 5 (Kass, 1998), which is within the C/N range of 10 to 12. This result is equivalent to 140 ppm of Nitrogen in ppm (See Table 5) (Kass (1998).

As indicated in Table 5 (Kass, 1998), that the C/N ratio, which is 11.60, is within the values of 10 to 12, which obtained 140 ppm of nitrogen. Next, the nitrogen from the soil analysis was taken, which is 0.08 (Table 6) (INIA (2021a) and the operation of Available Nitrogen (N.D.) = 140 ppm * 0.08 was carried out, obtaining 11.2 ppm of N.D. From there, the Weight of the arable layer per hectare (Weight.

Table 1. Compost fertilization for less distance.

Symbol	kg/ha	g./plant
F_1	0	0
F_2	8000	144
F_3	10 000	180
F_4	12 000	216

Note: Doses that were applied for distance 0,30 m between plant and 0,60 m between furrow

Table 2. Compost fertilization for greater distance.

Symbol	kg/ha	g./plant
F_1	0	0
F_2	8000	168
F_3	10 000	210
F_4	12 000	252

Note: Doses that were applied for distance 0,35 m between plant and 0,60 m between furrow

Table 3. Planting densities and plant population.

Symbol	Entre planta y entre surco	Plantas/ha	Population/ ha
D_1	0.30 m y 0.60 m	55556	Mayor
D_2	0.35 m y 0.60 m	47620	Menor

Table 4. Interaction of compost dose and spacing by treatment.

Treatment	Fertilization	Distancing	Interaction
T_1	F_1	D_1	$F_1 * D_1$
T_2	F_2	D_1	$F_2 * D_1$
T_3	F_3	D_1	$F_3 * D_1$
T_4	F_4	D_1	$F_4 * D_1$
T_5	F_1	D_2	$F_1 * D_2$
T_6	F_2	D_2	$F_2 * D_2$
T_7	F_3	D_2	$F_3 * D_2$
T_8	F_4	D_2	$F_4 * D_2$

Note: (*) Interaction

Table 5. 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
Older than 12	11.2
From 10 to 12	140
Under 12	225

Note: The C/N ratio = 11.6 obtained is within the range of C/N ratio 10 -12 of the conversion factor that is equivalent to 140 ppm of nitrogen
Source: Kass (1998).

Table 6. Soil analysis of the cabbage planting area

N° Lab.	E.C. 1:2:5 mS/cm	pH 1:2:5	O.M. %	N %	P ppm	K ppm	$CaCO_{3\%}$	Cation exchange (mEq/100 g soil)				C.E.C.
								Ca	Mg	Na	K	
246	1.57	7.12	1.60	0.08	5	262	0.88	12.2	0.51	0.17	0.67	13.55

Note: Results of the concentration of elements and other conditions of the experimental area
Source: INIA (2021a) Soil analysis
C.E.C.: cation exchange capacity. O.M.: organic matter. E.C.: electrical conductivity

Ha) was projected, which is 3500 tons/ha of land, obtaining 39.2 kg/ha of N.D.S. (Available Soil Nitrogen)

2.10. Calculation of the standard dose of compost in relation to nitrogen

To establish the standard doses of compost based on sugarcane residues, the following was done.

The nitrogen value of the recommendation in Table 7(INIA (2021b) , which is 220 N kg/ha, was subtracted with 39.2 kg/ha of N.D.S. Obtaining 180.08 kg/ha of N.D.A. (Available Nitrogen Applied)

Afterwards, the nitrogen value of the chemical analysis of compost (See Table 8) (INIA (2021c) was taken, which is 3.64% of N and it was projected at 8 and 10 tn/ha of compost, which is equivalent to 291.2 and 364 kg/ha of N.

Obtained the two results it can be seen that the nitrogen of the recommendation subtracted with the nitrogen of the soil that is 180.08 kg/ha of (N.D.A.) is compared with the nitrogen of the compost that at a dose of 8 to 10 tn/ha for its equivalence to 291.2 and 364 kg/ha of (N.D.A.) Obtaining the margins of the doses of 180.08 to 364 kg/ha of (N.D.A.) for the treatments.

2.11. Statistic analysis

2.11.1. Variance analysis

Evaluated the physical characteristics of the cabbage crop, the data of each plot was obtained, these were averaged by the number of plants and processed through the analysis of variance, then compared with the data from the Fisher table at 5% error. This statistical procedure determined the significance in the interaction (Fcal > Ftab 5%); that is, if the application of compost and distance influenced the performance, height and other characteristics.

2.11.2. Duncan's test

Following the analysis of variance, the data was processed with Duncan's Multiple Test at 5% error. This operation determined the homogeneity or differentiation of the treatment averages qualified by letter of the alphabet and specified which interaction stood out in relation to the others.

2.11.3. Data collection technique

To collect the data from the experiment, observation and measurement techniques were taken into account, which consisted of quantifying the measurements of the physical characteristics of the cabbage and to specify the amount of nitrogen nutrients in the soil, laboratory precision instruments were used.

Table 7. Nutrition recommendation for cabbage cultivation.

	Cabbage		
	N	P_2O_5	K_2O
Kg/ha	220	160	120

Note: INIA – Huaral recommendation of macronutrient measurements for cabbage cultivation per hectare
Source: INIA (2021b) Analysis of soil"

2.11.4. Procedures

The compost was made with amounts of 25% bagasse, 25% vinasse, 25% guinea pig guano and 25% dry grass. Every week it was removed with a lamp and covered with a plastic blanket for up to 4 months, during which time the granules and darkness were appreciated.

Then the land was prepared and soil samples were taken in stages, from there 1 kg of soil was removed and taken to the laboratory of the National Institute of Agrarian Innovation (INIA) - Huaral.

Next, the experimental area was implemented, for which the statistical model of the Completely Random Block Design was used with a 4 x 2 factorial arrangement that consisted of 3 blocks, 8 treatments and the plot measurements were 6.30 m long and 1.20 wide. m.

Transplantation was done when the seedlings reached 12 cm on average or one month in seedbed at distances of 0.30 m between plants and 0.60 m between furrows; 0.35 m between plants and 0.60 m between rows and one row per row.

After 15 days of transplanting cabbage, the doses of compost were applied as indicated in Table 4 and hilling was done with a lamp in order to give it support and aeration.

Then the physical characteristics of cabbage of each treatment, the concentrations of nutrients that influenced performance were evaluated.

Finally, stomatal evaluations were carried out, for which representative leaf samples of each treatment were taken to the laboratory where they were observed in the Scanning Electron Microscope. This result allowed to determine the stomatal index for which the Formula 4 was applied.

$$I = \frac{N.e.}{N.c.} * 100 \quad (4)$$

Where:
I = stomatal index
N.e. = Number of stomata
N.C. = number of cells

Table 8. Macronutrient analysis of organic fertilizer.

No. Laboratory	ID Sample	pH	C.E. mS/cm	Humidity (%)	O.M. (%)	N (%)	P_2O_5 (%)	K_2O (%)	CaO (%)	MgO (%)	C/N
AO-003	compost	8.13	5.21	67.45	22.70	3.64	0.92	0.80	2.29|	2.66	6.24

Note: Results of concentrations of macronutrients, micronutrients and conditions of compost based on sugarcane waste
Source: INIA (2021c) "Analysis of compost".

Table 9. Physical characteristics of cabbage according to treatments.

Treatment	Plant height (cm)	Treatment	Yield (kg/plot)	Treatment	Root length (cm)
T_7	41.88 a	T_7	26.761 a	T_6	20.22 a
T_6	41.03 ab	T_6	23.142 ab	T_7	19.69 a
T_8	40.11 ab	T_8	21.863 ab	T_4	19.31 a
T_5	39.21 ab	T_4	20.011 ab	T_3	19.02 a
T_4	38.19 ab	T_3	19.486 ab	T_2	18.91 a
T_3	37.39 ab	T_5	18.152 ab	T_5	18.84 a
T_2	35.68 ab	T_2	15.941 b	T_1	18.46 a
T_1	34.68 b	T_1	13.006 b	T_8	17.99 a
significance	N.S.		N.S.		**
C. V.	8.44%		27.27%		10.09%

Note: (S) significant and (N.S.) not significant, C.V.: Coefficient of variation and (a, ab and b) results obtained through the Duncan Test, which indicates equal letters are statistically homogeneous.

3. Results

3.1. Soil analysis and nutritional recommendation

According to the soil analysis carried out at INIA-Huaral, it was determined that the pH is within the neutral value, but low concentration of organic matter, nitrogen, phosphorus and high potassium, these measurements are supported by the margins of Prialé (2016). Regarding the interchangeable elements, it is high in calcium, but potassium, magnesium are within the normal value and low in sodium and electrical conductivity (ECC), these amounts are supported by McKean (1993). Therefore, it is interpreted that this soil is suitable for planting; however it is necessary to incorporate compost to improve the properties of the soil (See Table 6) (INIA (2021a).

The appropriate recommendation for the application of macronutrients (N, P2O5 and K2O) was also determined for cabbage cultivation, which will be taken into account for the establishment of treatments (See Table 7) (INIA (2021b)

3.2. Compost analysis

Obtained the data from the compost analysis indicated in Table 8 (INIA (2021c), it is specified that there is a low percentage of organic matter that is 22.70%, low percentages of nitrogen with 3.64%, phosphorus with 0.92% and potassium with 0.80%. Therefore, it is analyzed that the compost has a low percentage of macronutrients and micronutrients; However, when applying 10 to 20 tons/ha, depending on the crop, it improves the properties of the soil and improves the nutrition of the plant, which in comparison with other fertilizers is beneficial for the development of the plant.

3.4. Cabbage physical characteristics

Regarding the analysis of variance that can be seen in Table 9, it can be seen that there was no significance in the physical characteristics of cabbage; so it means that the doses of compost and distancing did not influence. It can also be seen that the T7 stands out in plant height and yield in relation to the other treatments and are related in qualification (a and ab) according to the processing of the Duncan test at 5% error: by which it means that they are statistically homogeneous.

3.5. Chemical characteristic of cabbage

Concerning the analysis of the concentration of nutrients in cabbage leaves by treatment indicated in Table 10 (AGQ Perú SAC, 2022), it is specified that the T7 has the elements of nitrogen, calcium, sulfur, manganese, zinc and boron within the normal values but in excess of iron. Therefore, it is evident that these measurements of these elements within the normal margins influenced the development, strengthening and therefore higher yield of cabbage.

3.6. Total nitrogen consumption

In the total nitrogen consumption in relation to cabbage yield per treatment indicated in Table 10 (AGQ Perú SAC, 2022), it was determined that T4 and T8 consumed 476 kg/ha of nitrogen each; however, this amount did not influence performance; since at an adequate dose of compost and greater distance that is T7 with 403.2 kg/ha of nitrogen, it excelled in yield with 26,761 tn/ha of cabbage, which differs from 51.39% and 32.17% of the controls T1 and T5 respectively.

Table 10. Concentration of nutrients in cabbage leaves by treatment

Macronutrients (%)	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Normal values
Potassium	3.13	2.24	2.33	2.34	2.65	2.45	2.54	2.62	3.00 – 5.00
Nitrogen	4.64	3.61	3.67	3.36	3.91	3.28	3.66	4.28	3.60 – 5.00
Match	0.326	0.238	0.213	0.216	0.252	0.210	0.236	0.308	0.330 – 0.750
Calcium	2.11	2.43	2.26	2.66	2.54	2.46	2.33	1.59	1.10 – 3.00
Magnesium	0.328	0.328	0.287	0.363	0.329	0.296	0.327	0.254	0.400 – 0.750
Sulfur	1.09	0.79	0.76	0.97	0.74	0.66	0.75	0.77	0.30 – 0.75
Micronutrients (mg/Kg)									
Iron	234	255	250	217	298	211	225	134	30.0 - 200
Manganese	113	222	208	159	195	186	154	82.6	25.0 – 200
Copper	3.36	3.28	3.58	2.70	3.07	2.79	2.38	2.85	5.00 – 15.0
Zinc	32.9	43.8	43.2	37.3	39.0	38.0	35.1	28.9	20.0 – 200
Boron	29.4	29.5	30.5	32.9	26.4	21.9	28.6	28.3	25.0 – 75.0
Molybdenum	< 0.10	< 0.10	< 0.10	0,20	0.30	< 0.10	< 0.10	< 0.10	
Phytotoxic Elements (mg/Kg)									
Chlorides	8872	10465	9853	11128	9926	9265	10718	7773	
Sodiums	4723	5768	7702	5614	5313	3515	4160	2685	

Source: AGQ Perú SAC (2022) Test Report-Plant Material

3.7. Evaluation of stomata in cabbage leaves

As for the evaluation of the density of stomata in cabbage leaves by treatment that is observed in Table 12 and Figure 1, it is indicated that at an adequate dose of compost and greater distance that is T7 with 977 stomata/mm2 stood out in relation to to others. Therefore, this number of stomata is established as an indicator; since it influenced the good development, protection against environmental stress and higher performance.

4. Discussion

4.1. Cabbage physical characteristics

According to the statistical analysis that can be seen in Table 9, it was determined that there is no significance between the treatments; that is, there is no effect of compost dose and distance on the physical characteristics of the cabbage. Likewise, it is highlighted that the T7 with 26,761 tn/ha of cabbage differs at 51.39% and 32.17% with respect to the controls T1 and T5. This result is analyzed that by adding the amount of 10 tn/ha of compost and a greater distance between plants, nutrients were incorporated into the soil, which resulted in greater availability and less competition of elements, which resulted in greater absorption for the plant. Therefore, it obtained good development, greater resistance to environmental stress and therefore greater yield. This analysis is supported by Pérez et. al. (2017) who applied 15 tn/ha of compost that increased the organic matter of the soil, with a value of 2.81%, significantly higher than the control. Evidenced the increased nutrients such as phosphorus, calcium and magnesium in all treatments in relation to the control. At harvest, the yield increased significantly, with values of 18.82; 23.37 and 20.68 tn/ha of cane with respect to the control. Likewise, Cancino (2022) mentions that planting spacing influences the physical characteristics of leaf cabbage, the Portuguese Tronchuda variety; since T4 (0.50 m x 0.30 m) obtained better results in higher leaf weight yield/ha, with 43.48 t/ha and showed its adaptation to the edaphoclimatic characteristics of the place.

4.2. Chemical characteristic of cabbage leaves

Regarding the evaluation of the concentration of nutrients in cabbage leaves indicated in Table 10 (AGQ Perú SAC, 2022), it can be seen that T8 stood out in most of the concentration of elements; however, the T7 obtained measurements of nitrogen, calcium, sulfur, manganese, zinc and boron within normal values. Therefore, it is analyzed that this measure of elements influenced many biochemical reactions such as good development, strengthening against environmental stress and therefore greater performance. This analysis is supported by Gálvez et al. (2021) who determined that the highest dose of compost based on sugarcane residues applied to beetroot obtained the highest concentration of elements such as oxygen, potassium, magnesium, sodium and chlorine, which favored in development and performance. Likewise, Mejía (2021) determined the quality of the organic compost produced in composting piles using organic agricultural residues: sugar cane bagasse, vacaza, chicken manure and cuyaza. He obtained excellent results in the composition of macro and micro minerals such as N, P, K, Co, Ca Mg, Fe and other nutrients.

4.3. Total nitrogen consumption

Regarding the total nitrogen consumption per treatment indicated in Table 11, it can be seen that T4 and

Table 11. Nitrogen consumption in relation to cabbage yield per treatment.

Treatment	Interaction	Dose (kg/ha)	Nitrogen concentration in compost (kg/ha)	Nitrogen in the soil (kg/ha)	Total nitrogen used (kg/ha)	Performance (tons/ha.)
T_1	$F_1 D_1$	0	0	39.2	39.2	13.006
T_2	$F_2 D_1$	8000	291.2	39.2	330.4	15.941
T_3	$F_3 D_1$	10000	364.0	39.2	403.2	19.486
T_4	$F_4 D_1$	12 000	436.8	39.2	476.0	20.011
T_5	$F_1 D_2$	0	0	39.2	39.2	18.152
T_6	$F_2 D_2$	8000	291.2	39.2	330.4	23.142
T_7	$F_3 D_2$	10000	364.0	39.2	403.2	26.761
T_8	$F_4 D_2$	12 000	436.8	39.2	476.0	21.863

Note: Result of the compost analysis is 3.64% Nitrogen, which is equal to 364 Kg of nitrogen/10,000 Kg of compost (See Table 8). INIA (2021c)

Table 12. Evaluation of the stomatal index by treatment in cabbage leaves.

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Number of stomata (0.133 mm^2, lens area)	48	50	120	100	95	120	130	107
Stomatal density (number of stomas/0.133 mm^2)	361	376	902	752	714	902	977	805
Stomatal index %	30.97	60.98	89.55	90.91	76.61	93.02	86.67	104.90
Number of cells (0.133 mm^2)	155	82	134	110	124	129	150	102

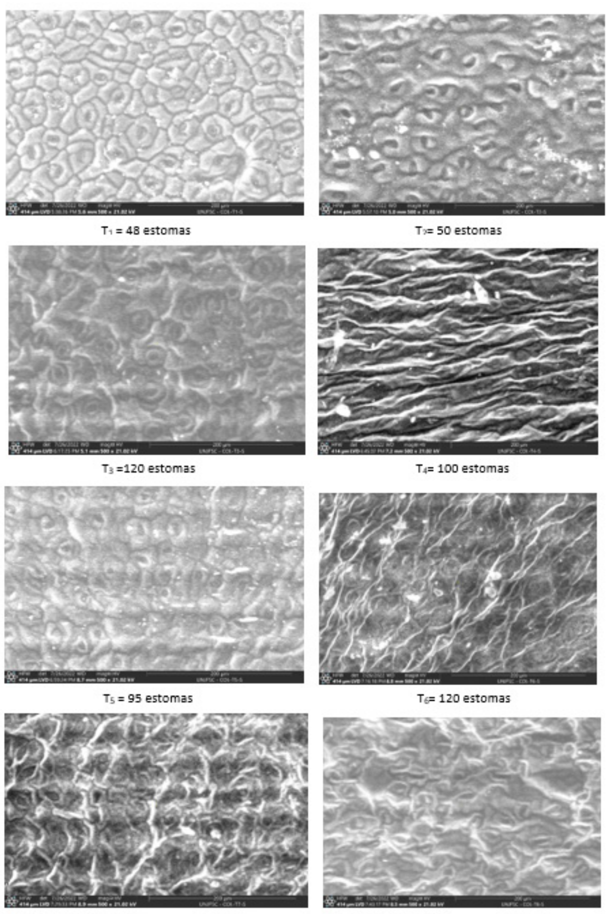

Figure 1. Micrograph of stomata on cabbage leaves by treatment.

T8 obtained the highest total nitrogen consumption; however, the T7 with 330.4 kg/ha of nitrogen obtained a higher yield with 26,761 tn/ha of cabbage. Therefore, it is analyzed that at 10 tn/ha of compost and greater distance there was greater availability of nitrogen, which influenced good development, protection against adverse factors and good yield. Likewise, there was a difference in yield at 51.39% and 32.17% with respect to the controls T1 and T5. The analysis is based on Cruz et al. (2022) determined that as the doses of compost increased, the total nitrogen in the soil increased, which is T5 with 200.40 kg/ha; Therefore, in this concentration its availability increased, this increased the absorption that optimized the biochemical reactions that influenced the lettuce yield.

4.4. Stoma evaluation

Regarding the evaluation of stomata that is observed in Table 12, it can be seen that at an adequate dose of compost and a greater distance, which is T7, it obtained 977 stomata/mm2, which stood out in relation to the others. Therefore, it is highlighted that this number of stomata is an indicator for the highest performance. This is because the greater number of stomata can be related to optimal evapotranspiration, which influences biochemical reactions for the formation of carbohydrates and greater translocation. This analysis is supported by Li et al. (2022) who consider that stomata play an important role in gas and water exchange. Promotes the absorption of nutrients in the different biochemical reactions. Also Larriva (2006) and Fernández et al. (2015) argue that the efficiency of biochemical reactions such as biosynthesis and evapotranspiration is related to high densities of stomata that are on the leaves, where the control of gas exchange and transpiration is carried out, which it allows the assimilation of CO2 and the output of O2 and maintains a good ratio of water in the plant.

5. Conclusions

It was determined that at an adequate dose that is 10 tn/ha and a distance of 0.35 m between plants and 0.60 m between furrows that is T7, it stood out in plant height and yield. Therefore, at this dose and distance there was a response in development, strengthening against environmental stress, which obtained a higher yield.

It is also highlighted that T7 obtained most of the concentrations of nutrients in cabbage leaves such as nitrogen, calcium, sulfur, manganese, zinc and boron within normal values. Also these amounts of these elements influenced the optimal formation of carbohydrates and therefore higher performance.

Finally, it is concluded that in the density of stomas, T7 stood out with 977 stomas/mm2, which differed at 63.05% and 26.92% in relation to the controls T1 and T5 respectively. Therefore, this number of stomata is established as an indicator; since it influenced the optimal biochemical reactions, which had good development of the plant, protection against adverse factors and higher yield.

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