

TOWARDS SUSTAINABLE AGRICULTURE: THE ROLE OF RECYCLED CAT WASTE AND ORGANIC ACIDS IN IMPROVING GARLIC PRODUCTIVITY AND QUALITY

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Abstract. *In recent years, the number of Iraqi families keeping pets, particularly cats, has increased, leading to a significant rise in cat waste. Therefore, it is crucial to focus on treating and disposing of this waste in an environmentally safe manner, utilizing it as organic fertilizer to reduce environmental pollution. A field experiment was conducted in one of the agricultural fields in Ramadi, where garlic cloves were planted in mid-October in loam sandy soil using a completely randomized block design. The garlic was planted in rows with a spacing of 50cm and a plant spacing of 10cm. Fully decomposed cat waste was added at 0, 1, 2, 3, and 4 megagrams per hectare and placed 5cm beneath the planting line. Organic acids were sprayed at 0 and 1ml.L⁻¹ concentrations in three applications throughout the garlic growing season at monthly intervals. Growth traits were measured, including plant height, the number of leaves, the number of cloves per head, head weight, and total yield per hectare. After harvest, the cloves' nitrogen, phosphorus, potassium content, and allicin compounds were measured. The study results showed a significant increase in growth traits, yield, and qualitative traits of garlic cloves with application of cat waste at 4Mg.h⁻¹ compared to the control (no application). The statistical analysis results indicated a significant increase in the studied traits of garlic plant when spraying with organic acids at 1ml.L⁻¹ compared to spraying with distilled water alone. Except for plant height, number of leaves, and cloves per head, where organic acid spraying had no significant impact. The interaction between cat waste and spraying with organic acids(C4B1) had a significant effect on the studied traits compared to the other treatments.*

Keywords: *sustainable agriculture, recycling cat waste, organic acid, garlic, productivity.*

1. INTRODUCTION

Fertilizers are a crucial factor and a fundamental pillar in agricultural development processes, as fertilizers generally improve soil fertility and increase agricultural production both in quantity and quality. the excessive and improper use of chemical fertilizers poses risks that negatively impact the biological balance, the environment, and human health. They are a primary factor in soil surface and groundwater pollution. food produced using chemical fertilizers tends to be of lower quality than food produced using natural fertilizers. Organic fertilization is considered a more sustainable and healthier option for the environment and plants than chemical fertilization. It plays a crucial role in improving the soil's chemical, physical, and fertility properties, thereby promoting healthy plant growth. Organic fertilizers provide essential nutrients that enhance soil fertility, such as nitrogen, phosphorus, potassium, and trace elements, vital for plant growth. Moreover, they support sustainable agricultural practices that benefit the environment and reduce environmental pollution resulting from the overuse of mineral (chemical) fertilizers. Therefore, recycling organic waste is a key factor in providing sufficient quantities of organic fertilizers to meet the needs of agricultural lands.

Given the current environmental conditions, it is observed that a significant number of cats leave their waste around us. This raises the question: Is there an environmentally friendly way to use this waste? In recent years, the number of Iraqi families keeping pets, especially cats and dogs, has increased, leading to a significant rise in their waste. Therefore, it is essential to focus on treating and disposing of this waste in an environmentally safe manner, and to utilize it as organic fertilizer to reduce environmental pollution. Leaving cat waste untreated causes environmental pollution in general, and heavy metal pollution in particular, which affects both the environment and human health. Bentonite is utilized in cat production due to its unique properties, such as moisture and heavy metal absorption, where the latter is commonly found in cat feces (26). Table 1 shows the maximum allowable limits for heavy metals in organic-based fertilizers in accordance with European Union standards [1] and the Compost Quality Standards and Guidelines [2]. Bentonite is known as an adsorptive surface for the removal of heavy metals [3]. Also, it is utilized for wastewater treatment by removing lead and copper ions, which various studies have proved due to its ability to ion exchange efficiently [4]. due to its properties, such as high surface area and exchange capacity, bentonite can efficiently remove various heavy metals such as arsenic, cadmium, chromium, iron, lead, and zinc from aqueous solutions [5, 6]. Organic-based fertilizers induced by the fermentation process of various animal feces, such as sheep, cattle, and poultry, are utilized to enhance soil nutrients and fertility properties [7]. Several studies have highlighted that around 1.2 million tons of cat waste are disposed of to preserve the environment in the United States [8]. Due to its unique properties, such as high nutrient capacity, specifically nitrogen, disease- and bacteria-free (such as *Toxoplasma*) [9], and a limited amount of heavy metals [10], cat waste stood up as a valuable fertilizer for crop production. Additionally, sterilized medical-grade bentonite with cat waste can help eliminate diseases and significantly remove heavy metals. Martínez-Sabater et al. [11] investigated the impact of utilizing cat waste with ground coffee on the spinach plant. The results revealed that the combination significantly increased the plant yield; meanwhile, the heavy metal accumulation was kept limited compared to

poultry waste utilization. According to the Nova Scotia Environment, an explicit composting facility in Nova Scotia province, Colchester, is authorized to accept cat waste and dog feces (CLDF) for its residential composting program. Nova Scotia generates about 9,400 to 11,200 tons of CLDF annually, where most of it are sent to regional landfills. Furthermore, the province plans to convert this waste to composite, which has a future benefits in sustainable agriculture. Cat urine consists of 0.05% of ammonia, 0.6% of Chloride, 0.12% of phosphate, 0.18% of sulphate, 0.1% of Creatinine, 0.1% of sodium, 2% of urea, 0.003% of Uric Acid, and 95% of water, as well as nitrogen, which the latter considered an essential nutrient in fertilizer. Since 1992, cat waste and dog feces have been included in the Residential Green Cart Compost Program, Atlantic Canada (Heather Myers, Island Waste Management Corporation). The Cumberland-Colchester East Hants region is collecting and converting CLDF into compost. the cat waste component contributes beneficially to plant nutrients while also enhancing water retention capacity. [12] investigated the impact of applying poultry manure, cow dung, and sheep manure in different fertilizer combinations with a 2% rate of the dry soil weight. The results showed that increasing the fertilizer has significantly improved the growth traits and the yield of the garlic plant. Furthermore, applying poultry manure has significantly improved the gloves' growth traits, yield, and protein level, particularly when applying it at 7 tons per hectare.

Sources of organic fertilizers vary, including plant or animal waste. In recent years, the number of soluble organic fertilizers has increased, containing some organic acids such as humic acids, fulvic acids, amino acids, and other materials. These fertilizers are characterized by their low cost, ease of use, minimal environmental pollution, and contribution to improving the soil's physical, chemical, and biological properties, positively impacting the growth and production of various plants. The utilization of organic acids has become more rapid due to their properties in improving plant growth and productivity, as well as making the plant more durable for environmental conditions and diseases. Furthermore, they can increase seed germination by 2 to 3 days, productivity by 15 to 30%, and reduce the vegetable nitrate content by 25 to 40% [13,14]. [15] found a significant increase in growth characteristics, yield, and qualitative characteristics of fennel plants after applying rabbit manure at a rate of 60 m³/fed compared to control treatment. [16] concluded that applying nutrients as fertilizers in high levels with organic nutrients has significantly increased garlic's growth and yield characteristics. [17,18] found that applying sheep waste, along with organic acids, is critical in improving the plant's growth, yield, and qualitative characteristics. Garlic (*Allium sativum* L.), a winter crop belonging to the *Allium* family, is an essential and rich crop due to its gloves' nutritional value, vitamins, carbohydrates, niacin, and protein. Additionally, garlic extracts help eliminate heavy metals like lead, mercury, and cadmium in the body by binding with them. This study aims to explore a new pilot fertilizer project based on recycling pet waste, particularly cat waste, as organic fertilizer, thereby contributing to environmental protection and reducing diseases associated with this waste. Furthermore, the project aims to improve local sustainable environmental practices by supporting farmers and providing them with environmentally friendly fertilizer.

2. MATERIALS AND METHODS

2.1. Preparation of organic waste

Cat waste was collected from a local breed of cats that live indoors, with a healthy diet and medical care including vaccinations and deworming. In addition, bentonite, commonly used in cat waste, was applied to the waste in a 3:1 ratio. A compost pile was formed with a height of 1 meter and a width of 1.5 meters. The pile was moistened, turned regularly, and its temperature was monitored throughout the fermentation process, until the compost met the quality standards as shown in Table 1.

Table 1. Maximum allowable heavy metal concentrations in organic-based fertilizers [1,2]

Element	EU Standard (2002)	Compost Quality Standard and Guidelines (2000)
Zn (mg kg ⁻¹)	210	210
Cu (mg kg ⁻¹)	2.1	5.5
Cd (mg kg ⁻¹)	98	70
Pb (mg kg ⁻¹)	210	70

Table 2. Some soil characteristics are present before cultivation, and some characteristics of cat waste are present after fermentation

Parameter	Texture	pH	Ec	Organic Matter %	N %	P mg/kg	K mg/kg	Zn mg/kg	Cu mg/kg	Cd mg/kg	pb mg/kg
Soil	Sandy loam	7.26	2.15	0.52	0.058	8.824	86.62	1.42	1.03	-	-
Cat waste	-	7.87	3.20	88.6	10.0	1097	4489	178	2.87	5.84	2.72

2.2 Land Preparation for Cultivation

The land was prepared by plowing and dividing it into three blocks, with a 1 meter gap between each block. Each block contained ten experimental units, with each unit having an area of 1 square meter.

2.3 Fertilization Treatments

Fully decomposed cat waste was applied at the following levels:

- C0 = 0 megagrams per hectare
- C1 = 1 megagram per hectare
- C2 = 2 megagrams per hectare
- C3 = 3 megagrams per hectare
- C4 = 4 megagrams per hectare

The cat waste was placed 5 cm below the planting line. Local garlic cloves were planted in mid-October 2023 in Ramadi city, 110 km west of Baghdad) in a loam sandy soil, with the soil characteristics provided in Table 2. The experiment was designed using a

completely randomized block design with three replications, rows spaced 50 cm apart, and plants spaced 10 cm apart.

2.4 Organic acid spraying

Organic acids were sprayed at concentrations of $B0 = 0 \text{ mL.L}^{-1}$ and $B1 = 1 \text{ mL.L}^{-1}$, applied three times during the garlic growing season, with one month between each application. A 100% organic substance was used as a spreading agent. Furthermore, drip irrigation was employed as the method for irrigation in the experimental field.

2.5 Measurements

Growth traits and yield were measured, including plant height, number of leaves, number of cloves per head, head weight, and total yield per hectare. Nutrients and Allicin content in the garlic cloves were then estimated after harvest using the following methods:

1. Nitrogen: Nitrogen was determined using the Microkjeldahl method, as described in [19].
2. Phosphorus: Phosphorus was measured using the modified ammonium molybdate and ascorbic acid method [20], with detection on a spectrophotometer at a wavelength of 620 nanometers, following the procedure outlined by [21].
3. Potassium: Potassium was measured using a flame photometer, according to the method proposed by [22].
4. Allicin: The method described by [23], was followed to prepare the sample for allicin determination. 5 g of peeled garlic cloves were taken from each experimental unit and mixed with methanol and water at a ratio of 40:10 (v/v). The mixture was blended, crushed, and filtered through gauze. The filtrate was collected in opaque glass bottles and stored at -20°C . The required concentrations were prepared for analysis and separated on a reversed-phase column. Allicin was identified using the standard sample, which was injected into an HPLC device.

2.6 Statistical analysis

The study data were analyzed using analysis of variance (ANOVA) within a randomized block design. The full RCBD compares the averages of the coefficients using the Least Significant Difference (L.S.D) at a significant level of 5% using the Genestat program Twelfth Edition (V. 12.1).

3. RESULTS AND DISCUSSION

3.1. RESULTS

3.1.1 Plant height

The statistical analysis results presented in Table 3 show a significant increase in the average height of garlic plants with the increased addition of cat waste. The highest plant height was 95.50cm at the level of 4Mg.ha^{-1} , while the control treatment showed the lowest average plant height at 70.17cm, resulting in a 36.09% increase in plant height. While the results of the statistical analysis did not show any significant differences in plant height when spraying organic acids, the interaction between cat waste and spraying with organic acids

showed a significant effect in increasing the average height of the garlic plant, which reached 98.00cm when treated with C4B1 interaction compared to no addition.

Table 3. The of cat waste and spraying with organic acids on plant height (cm)

Cat waste(Mg ha ⁻¹) effect	organic acids (ml L ⁻¹)		Mean cat waste
	B0	B1	
C0	67.67	72.67	70.17
C1	79.33	85.00	82.17
C2	91.00	70.00	80.50
C3	93.00	97.67	95.33
C4	93.00	98.00	95.50
	LSD C.B 5.82		LSD C 4.12
Mean organic acid	84.80	84.67	
	LSD B 2.604 (N.S)		

3.1.2 Leaves Number

The results indicate a significant increase in the average number of leaves per garlic plant with the increased level of fertilization with cat waste (Table 4). The highest average number of leaves was observed at the 4Mg.ha⁻¹ level of cat waste, with 9.17 leaves plant⁻¹, while the lowest number of leaves was recorded in the control treatment, with 5.17 leaves plant⁻¹, resulting in a 77.37% increase. However, no significant differences were observed in the number of leaves when spraying with organic acids, while there was a significant increase in the number of garlic leaves per plant when adding cat waste was combined with spraying with organic acids, as the C4B1 treatment was significantly superior in giving the largest number of leaves per plant, which amounted to 9.67 leaves plant⁻¹, compared to not adding.

Table 4. The effect of cat waste and spraying with organic acids on Leaves number.

Cat waste (Mg ha ⁻¹)	organic acids (ml L ⁻¹)		Mean cat waste
	B0	B1	
C0	5.00	5.33	5.17
C1	8.00	8.00	8.00
C2	7.33	5.67	6.50
C3	6.67	8.67	7.67
C4	8.67	9.67	9.17
	LSD C.B 2.096		LSD C 1.482
Mean organic acid	7.13	7.47	
	LSD B 0.937 (N.S)		

3.1.3 Number of Cloves per Garlic Head

Cat waste fertilization significantly increased clove count per garlic head (Table 5). The 4Mg.ha⁻¹ level of cat waste produced the highest average number of cloves per head, with

46.50 cloves per head, while the lowest number was observed in the control treatment, with 20.17 cloves per head. This represents a 130.54% increase in average cloves per head. The statistical analysis in Table 5 also indicated no significant effect of organic acid spraying on the average number of cloves per head. Although, the interaction treatment between cat waste and spraying with organic acids C4B0 gave the highest rate of cloves per head, which reached 47.33 cloves per head. This may be due to the role of cat waste as an organic material, a source of nutrients, and a good soil improver, which positively reflects on growth characteristics and yield.

Table 5. The effect of cat waste and spraying with organic acids on cloves per garlic head.

Cat waste (Mg ha ⁻¹)	Organic acids (ml L ⁻¹)		Mean cat waste
	B0	B1	
C0	19.67	20.67	20.17
C1	26.67	25.67	26.17
C2	32.00	33.00	32.50
C3	36.33	39.67	38.00
C4	47.33	45.67	46.50
	LSD C.B (5.27)		LSD C 3.73
Mean organic acid	32.40	32.93	
	LSD B (2.36) N.S		

3.1.4 Garlic head weight

The statistical analysis revealed a significant influence of cat waste addition on the weight of garlic heads (Table 6). The average head weight significantly increased with higher levels of cat waste fertilization, with the highest average weight at the 4Mg.ha⁻¹ level reaching 70.67gm, which represents an 84.37% improvement compared to the control treatment, where the latter recorded the lowest head weight of 38.33gm. This improvement can be attributed to the superiority induced by this treatment in terms of the number of leaves per plant and the cloves per head, affecting the head weight. These findings are aligned with those obtained by [11].

From a statistical analysis perspective, it showed that organic acid spraying has significantly increased the head weight, reaching 55.13gm, which is a 7.40% improvement compared to the spraying with distilled water, where the latter recorded an average weight of 51.33gm.

Furthermore, the interaction between cat waste and organic acid spraying has significantly impacted head weight, where the treatment of C4B1 has recorded the highest head weight of 73.33gm, which is a 124.46% to C0B0 treatment, where the latter recorded 32.67gm. This improvement can be attributed to organic matter and organic acids enhancing growth and yield, which is also confirmed by [11] in the spinach plant.

Table 6. The effect of cat waste and spraying with organic acids on Garlic head weight (gm)

Cat waste (Mg ha ⁻¹)	Organic acids (ml L ⁻¹)		Mean cat waste
	B0	B1	
C0	32.67	44.00	38.33
C1	45.00	49.67	47.33
C2	53.67	48.33	51.00
C3	57.33	60.33	58.83
C4	68.00	73.33	70.67
	LSD C.B 5.14		LSD C 3.63
Mean organic acid	51.33	55.13	
	LSD B 2.30		

3.1.5 Garlic yield (Mg.ha⁻¹)

Cat waste can effectively increase garlic yield as the addition level increases, as shown in Table 7, where a 4 Mg ha⁻¹ level recorded the highest garlic yield at 10.83Mg.ha⁻¹, which is a 103.19% improvement compared to those without fertilizers, where the latter recorded a 5.33Mg.ha⁻¹.

The statistical analysis also indicated a significant effect of organic acid spraying on garlic yield, which reached 9.93Mg.ha⁻¹ compared to spraying with distilled water, where the yield was 7.73Mg.ha⁻¹, representing a 28.46% increase in yield, Whereas the interaction treatment between cat waste and spraying with organic acids C4B1 gave the highest garlic yield of 12.00Mg.ha⁻¹ compared to no addition treatment.

This increase could be attributed to the role of organic matter in improving soil properties, enhancing nutrient absorption availability, and being a source of those nutrients. This, in turn, increases biological activities and the activity of growth hormones, leading to an increase in growth indicators and yield. These results are consistent with [23, 24, 25].

Table 7. The effect of cat waste and spraying with organic acids on Garlic yield (Mg ha-1)

Cat waste (Mg ha ⁻¹)	Organic acids (ml L ⁻¹)		Mean cat waste
	B0	B1	
C0	4.67	6.00	5.33
C1	7.33	9.67	8.50
C2	7.67	10.67	9.17
C3	9.33	11.33	10.33
C4	9.67	12.00	10.83
	LSD C.B 2.080		LSD C 1.47
Mean organic acid	7.73	9.93	
	LSD B 0.93		

3.1.6 Nitrogen content of garlic cloves (g.kg^{-1})

Table 8 shows that cat waste fertilizer significantly impacts the nitrogen content of garlic gloves, recording the highest concentration of 40.48g.kg^{-1} at the C4 level compared to the control treatment, which recorded a concentration of 26.74g.kg^{-1} . Moreover, spraying with organic acids has significantly increased the nitrogen content of the garlic cloves, recording a 35.11g.kg^{-1} compared to the control treatment, which recorded a 33.17g.kg^{-1} . Furthermore, the interaction between cat waste and organic acid spraying treatments significantly impacts the cloves' nitrogen content, recording the highest content of 41.72g.kg^{-1} in the C4B1 combination due to their role as a source of nitrogen supply. Given the role of organic matter and organic acids in increasing the nitrogen content of garlic cloves as a source of this element, in addition to improving the properties of the soil, which increases the readiness of nitrogen absorption by the plant, this is consistent with what was reached by each of [15, 24].

Table 8. The effect of cat waste and spraying with organic acids on the nitrogen content of garlic cloves (g kg^{-1}).

Cat waste (Mg ha^{-1})	Organic acids (ml L^{-1})		Mean cat waste
	B0	B1	
C0	25.85	27.63	26.74
C1	27.83	29.77	28.8
C2	35.91	35.15	35.53
C3	37.05	41.29	39.17
C4	39.23	41.72	40.48
	LSD C.B 1.914		LSD C 1.354
Mean organic acid	33.17	35.11	
	LSD B 0.856		

3.1.7 Phosphorus content of garlic cloves (g.kg^{-1})

Many studies have demonstrated the role of organic fertilizers and humic acids in increasing plants' nutrient content, as shown in Table 9. The addition of cat waste significantly increased the phosphorus content in garlic cloves as the addition level increased. Treatment C4 was significantly superior in providing the highest phosphorus content in garlic cloves, which reached 2.634g.kg^{-1} , compared to control treatment. As a result of the role of organic acids in enhancing the nutrient content of plants by serving as a source of these nutrients, foliar application of organic acids significantly increased the phosphorus content of garlic cloves, reaching 1.923g.kg^{-1} compared to the unsprayed treatment. However, the interaction between cat waste treatment and organic acid spraying resulted in a significant increase in the phosphorus content of garlic cloves. The interaction treatment, C4B1, produced the highest phosphorus content in garlic cloves, reaching 2.933g.kg^{-1} , which significantly exceeded the control treatment, C0B0.

This effect can be attributed to the role of cat waste and humic acids in enhancing nutrient availability, particularly phosphorus, as well as in improving the physical, chemical, and biological properties of the soil. This leads to the release of phosphorus in a readily available form for plant uptake [26, 27].

Table 9. The effect of cat waste and spraying with organic acids on the phosphorus content of garlic cloves(g kg⁻¹)

Cat waste (Mg ha ⁻¹)	Organic acids (ml L ⁻¹)		Mean cat waste
	B0	B1	
C0	1.008	1.276	1.142
C1	1.397	1.69	1.544
C2	1.654	1.591	1.622
C3	1.853	2.123	1.988
C4	2.335	2.933	2.634
	LSD C.B 0.4282		LSD C 0.303
Mean organic acid	1.649	1.923	
	LSD B 0.191		

3.1.8 Potassium content of garlic cloves (g.kg⁻¹)

The study results in Table 10 indicate that adding cat waste and spraying with humic acids significantly increases the potassium content in garlic cloves as the addition levels increase. Treatment C4 was significantly superior in providing the highest Potassium content of garlic cloves, which reached 16.662g.kg⁻¹, compared to no addition. A significant differences were also observed in the potassium content of garlic cloves when spraying with organic acids, as the treatment of spraying with organic acids B1 gave the highest potassium content in garlic cloves, reaching 17.323g.kg⁻¹ compared to not spraying.

However, the interaction between cat waste treatment and organic acid spraying resulted in a significant increase in the Potassium content of garlic cloves. The interaction treatment, C4B1, produced the highest Potassium content in garlic cloves, reaching 17.323g.kg⁻¹, which significantly exceeded the control treatment, C0B0.

Table 10. The effect of cat waste and spraying with organic acids on the Potassium content of garlic cloves(g kg⁻¹)

Cat waste (Mg ha ⁻¹)	Organic acids (ml L ⁻¹)		Mean cat waste
	B0	B1	
C0	11.129	11.785	11.457
C1	12.800	13.673	13.237
C2	13.332	14.092	13.712
C3	14.792	15.730	15.261
C4	16.000	17.323	16.662
	LSD C.B 0.6191		LSD C 0.438
Mean organic acid	13.611	14.520	
	LSD B 0.277		

3.1.9 Allicin content in garlic cloves.

Fertilization with cat waste had a significant effect on increasing the allicin content of garlic cloves. The allicin content in the cloves increased with higher levels of cat waste fertilization,

with the 4Mg.ha⁻¹ level providing the highest Allicin content at 0.2739gm 100gm⁻¹, while the lowest allicin content was observed in the control treatment at 0.1156gm 100gm⁻¹ (Table 11). The statistical analysis results in Table 11 also showed a significant effect of organic acid spraying on increasing the Allicin content in garlic cloves, with a content of 0.2361gm 100gm⁻¹, compared to spraying with distilled water, which resulted in an allicin content of 0.1963gm 100gm⁻¹.

The C4B1 interaction treatment was significantly superior in giving the highest content of allicin, which reached 0.2925gm 100gm⁻¹, compared to the treatment without adding C0B0. This may be due to the overlapping effect of the role of organic waste and organic acids in stimulating and increasing growth and production indicators, and consequently increasing the plant's content of nutrients and active compounds, including allicin. This was confirmed by [10, 11, 28].

Table 11. The effect of cat waste and spraying with organic acids on Allicin content in garlic cloves (g100g-1)

Cat waste (Mg ha ⁻¹)	Organic acids (ml L ⁻¹)		Mean cat waste
	B0	B1	
C0	0.1080	0.1231	0.1156
C1	0.1391	0.1927	0.1659
C2	0.2192	0.2874	0.2533
C3	0.2601	0.2847	0.2724
C4	0.2552	0.2925	0.2739
	LSD C.B 0.0306		LSD C 0.0216
Mean organic acid	0.1963	0.2361	
	LSD B 0.0137		

3.2. DISCUSSION

The results of the field experiment showed that using cat waste at the level of 4Mg.ha⁻¹ as a source of organic fertilizer played an effective role in improving the vegetative and yield characteristics of garlic plants grown in sandy loam soil. It was evident that increasing application rates led to significant improvements in parameters such as plant height, number of leaves, number of cloves per bulb, and bulb weight, which positively impacted the total yield per hectare. Additionally, the application contributed to improving the chemical composition of cloves in terms of their nitrogen, phosphorus, and potassium content, as well as enhancing the concentration of allicin compound of great medicinal and nutritional importance. This may be due to the role of cat waste as an organic material, a source of nutrients, and a good soil improver, which positively reflects on growth characteristics and yield. This improvement can be attributed to the superiority induced by this treatment in terms of the number of leaves per plant and the cloves per head, affecting the head weight. These findings are aligned with those obtained by [11]. This increase could be attributed to the role of organic matter in improving soil properties, enhancing nutrient absorption availability, and

being a source of those nutrients. This, in turn, increases biological activities and the activity of growth hormones, leading to an increase in growth indicators and yield. These results are consistent with [23, 24, 25].

Foliar spraying of organic acid at a concentration of 1 ml.L^{-1} had significant effects on most of the studied characteristics, with the exception of plant height, number of leaves, and number of cloves per bulb. This suggests that organic acid spraying can be a supportive tool for enhancing productivity when applied in a balanced manner. The interaction coefficients between the use of cat waste and organic acid spraying (C4B1) were statistically significant for most characteristics. This may be due to the overlapping effect of the role of organic waste and organic acids in stimulating and increasing growth and production indicators, and consequently increasing the plant's content of nutrients and active compounds, including allicin. This was confirmed by [10, 11, 28]. The concept of sustainable agriculture has been applied in several studies using different environmentally friendly strategies and on various plant species [29, 30, 31, 32, 33, 34, 35].

4. CONCLUSIONS

The results of the field experiment showed that using cat waste as a source of organic fertilizer played an effective role in improving the vegetative and yield characteristics of garlic plants grown in sandy loam soil. It was evident that increasing application rates led to significant improvements in parameters such as plant height, number of leaves, number of cloves per bulb, and bulb weight, which positively impacted the total yield per hectare. Additionally, the application contributed to improving the chemical composition of cloves in terms of their nitrogen, phosphorus, and potassium content, as well as enhancing the concentration of allicin compound of great medicinal and nutritional importance.

Furthermore, foliar spraying of organic acid at a concentration of 1 ml/L^1 had significant effects on most of the studied characteristics, with the exception of plant height, number of leaves, and number of cloves per bulb. This suggests that organic acid spraying can be a supportive tool for enhancing productivity when applied in a balanced manner. The interaction coefficients between the use of cat waste and organic acid spraying were statistically significant for most characteristics. Furthermore, each factor independently contributed to improved plant performance. Based on these results, the study recommends using cat waste as an environmentally friendly, decomposing organic fertilizer, which helps recycle household waste and reduce environmental damage, while improving garlic yield and quality. It also recommends incorporating organic acids as natural growth promoters into integrated nutrient management programs. In addition, household waste and cat waste can be effectively recycled into environmentally friendly organic fertilizers, which can be used to increase both the quantity and quality of plant yields.

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DECLARATION OF COMPETING INTEREST

None

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