

Impact of Non-Traditional Organic Nitrogen Sources on the Growth and Productivity of Cucumber

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ABSTRACT

This study evaluated the effects of unconventional organic nitrogen fertilizers, such as hoof powder, crushed hooves and ripe crushed horns on the growth, yield and related characteristics of cucumber (*Cucumis sativus* L.) compared to traditional mineral nitrogen fertilization. Results of field experiments across two growing years demonstrated that hoof-based fertilizers significantly enhanced cucumber productivity. Applying hoof powder at a rate of 10 g per plant produced the highest total yield, the greatest fruit number, and the shortest time to the first harvest. Excessive application of hoof powder (15 g) caused a decrease in yield during the first year, likely due to temporary nitrogen immobilization and potential osmotic effects. The findings suggest that hoof-based fertilizers, when applied at optimal rates, offer a sustainable alternatives or partial solutions to synthetic fertilizers. They improve crop performance while promoting environmentally friendly waste recycling. These fertilizers can partially replace mineral nitrogen sources by releasing nutrients slowly for improving soil health.

KEYWORDS: cucumber – hoof powder- crushed hooves -ripe crushed horns.

1. INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the most widely cultivated vegetable crops due to its nutritional value and economic importance. It thrives particularly in tropical and subtropical regions, such as those in Africa and Asia, where it represents an essential dietary component and a source of income for both small-scale and commercial farmers (Ali *et al.*, 2021). Its popularity stems from a short growth

cycle, high yield potential, and adaptability to diverse environmental conditions (Chowdhury *et al.*, 2022). Cucumber is mainly cultivated for its immature fruits, which are commonly consumed fresh in salads or processed into pickles. The fruits are containing about 90 – 95 % water and valuable nutrients, including potassium, magnesium, calcium, iron, thiamine, riboflavin, and vitamins A, C, and K. Additionally, cucumbers provide dietary fiber and antioxidants that contribute to hydration, aid

digestion, and potentially reducing the risk of cardiovascular disorders and certain types of cancer (Mallick, 2022).

The application of chemical fertilizers has historically played a significant role in enhancing agricultural productivity. However, despite their effectiveness, increasing awareness since the 1990s has emphasized the necessity of reducing their use due to associated environmental and health concerns. Excessive reliance on chemical fertilizers has been linked to adverse effects on soil microbial populations, degradation of soil properties, and contamination of groundwater resources (Al-Redhaiman, 2003). Organic farming practices aim, in part, to minimize these risks by producing crops free from harmful chemical residues (Al-Redhaiman, 2004; Al-Redhaiman and Al-Shenawy, 2005). Moreover, while prolonged application of chemical fertilizers can increase soil acidity, the incorporation of organic amendments has been shown to enhance soil pH, improve organic carbon content, and reducing acidification (Liu *et al.*, 2021).

Soil organic matter plays a crucial role in maintaining and improving soil quality as it enhances its physical properties, including structure, water-holding capacity, and aeration. Additionally, it is protecting the soil from erosion. It serves as a reservoir of essential plant nutrients, particularly nitrogen (N), phosphorus (P), and sulfur (S), and acts as an energy source for beneficial soil organisms like nitrogen-fixing bacteria and earthworms. Ideally, fertile soils should contain at least 2.5% organic matter; however, in Bangladesh, most soils contain less than 1.5%, and in certain cases, the content drops below 1% according to Bangladesh Agricultural Research Council (BARC, 2008).

The application of organic fertilizers (OrgFs) is a widely adopted practice to increase both nutrient levels and organic matter content in soils (Luo *et al.*, 2018). These fertilizers contribute to combating soil degradation issues such as desertification and erosion by improving the physical, chemical, and biological characteristics of depleted soils through the addition of organic matter (Carbonell *et al.*, 2011). Moreover, they help reduce the environmental impacts associated with chemical fertilizers, whose production and misuse raise ecological and health concerns (Zhang *et al.*,

2019; Sharma *et al.*, 2019). Additionally, incorporating OrgFs into agricultural practices provides an effective way to recycle organic waste materials that would otherwise be disposed of in landfills or incinerated, both of which pose potential environmental risks (Sharma *et al.*, 2019).

Organic fertilizers (OrgFs) are classified according to their source into two types: (i) animal-based fertilizers, which include blood meal, fish meal, leather meal, horn and hoof meal, slaughterhouse by-products, and manure, and (ii) plant-based fertilizers, such as crop residues and seaweed extracts. Comprehensive data on the global availability of animal by-products for OF production are limited; however, it is estimated that in the European Union and the United Kingdom alone, approximately 1.4 billion tonnes of manure are generated annually (Köninger *et al.*, 2021).

Meat and bone meal (MBM), a by-product of the rendering industry, contains approximately 8% nitrogen (N), 5% phosphorus (P), 1% potassium (K), and 10% calcium (Ca), making it a valuable nutrient source for crop production (Ylivainio *et al.*, 2007; Garcia and Rosentrater, 2008). Cascarosa *et al.* (2012) reported that applying composted and powdered bone meal improved the growth and yield of *Amaranthus cruentus*, highlighting its potential as an effective soil amendment. It is particularly rich in calcium, and its phosphorus becomes more plant-available in acidic soils (pH < 7.0).

Horn-based fertilizers have also been shown to improve soil fertility. Juknevičienė *et al.* (2019) observed that applying horn-manure significantly increased soil nitrogen, phosphorus, and potassium levels while boosting enzymatic activities such as urease and saccharase. Similarly, Žibutis *et al.* (2013) found that incorporating horn shavings and horn cores into winter wheat fields increased soil nitrogen content and improved crop yields, particularly in warm and humid conditions, demonstrating their role in enhancing nutrient uptake. Another non-conventional organic fertilizer, horn and hoof meal (HHM), is characterized by its slow nutrient release, attributable to its keratin-rich composition, which includes sulfur-containing amino acids such as methionine, cystine, and cysteine as described by Cayuela *et al.* (2009).

Although these findings on the use of unconventional organic fertilizers highlight promising prospects, limited research exists on the use of such non-traditional organic fertilizers - including horn and hoof powders - on cucumber (*Cucumis sativus* L.). Given their nutrient composition and potential to positively influence soil-plant-microbe interactions, the present study aims to assess the effects of horn and hoof meals as soil amendments on cucumber growth, yield, and associated yield components.

2. Materials and Methods:

2.1. Experimental site

This study was carried out at El-Sabaheya Horticulture Research Station

(SHRS), Cross-pollinated Vegetables Research Dept. Horticulture Research Institute (HRI) – Agriculture Research Center (ARC), Alexandria governorate, Egypt, during years of 2022 and 2023.

2.2. Soil Characteristics (2022–2023)

Some physical and chemical analyses of the experimental soil across two consecutive years, 2022 and 2023 are presented in Table (1). The soil maintained a clay loam texture with slight increases in pH, EC, and organic matter. Soluble cations and anions showed minor variations, indicating stable salinity conditions. Levels of available N, P, and K increased slightly in 2023, reflecting an improvement in soil fertility. These changes suggest a gradual enhancement in soil quality over time.

Table 1. Some physical properties and chemical analysis of the experimental soil during the two growing years prior to planting.

Practice size and distribution						Physical properties					
Years	Sand %	Silt %	Clay %	Texture	pH	EC dS/m	CaCO ₃ %	OM %			
2022	37.5	22.0	40.5	Clay loam	7.67	1.78	2.40	2.15			
2023	37.2	22.1	40.7	Clay loam	7.76	1.85	2.35	2.17			
Chemical analyses											
Soluble cations (meq/L)					Soluble anions (meq/L)				Available nutrients Mg/kg		
Years	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	CO ₃ ⁻	HCO ₃ ⁻	CL ⁻	SO ₄ ⁻	N	P	K
2022	5.38	4.36	9.58	0.20	--	8.26	3.26	8.12	80.0	16.9	36.2
2023	5.51	4.68	9.65	0.25	--	8.41	3.47	7.94	85.4	18.2	39.1

2.3. Treatments and experimental layout

Commercial cucumber F1 hybrid El-prince known for its exceptional market quality was sown on March 29th during both growing seasons. The seeds were sown in pots measuring 28 cm in diameter and 25 cm in depth. The soil was prepared by adding farmyard manure fertilizer at a rate of 20 m³ / feddan. The soil inoculated with Microbein, a bio-fertilizer that solubilizes insoluble soil phosphate; Potassiomag, which enhances potassium availability; and Nitrobein, a non-symbiotic nitrogen bio-fertilizer. The inoculums were applied 20 days before planting. Each pot was filled with the prepared soil up to a height of 20 cm. Each pot holds 10 kg of soil. Three to four seeds were sown in each pot. The growing plants

were thinned to a single plant after the appearance of two true leaves.

The experiment was conducted using as a Randomized Complete Blocks Design (RCBD) with three replicates to assess the effects of non-traditional organic nitrogen fertilization sources on cucumber plant growth and fruits productivity. Ten nitrogen fertilization treatments were evaluated, nine of which involved non-traditional organic nitrogen sources: Crushed raw hooves (CRH), Hoof powder (HP), Ripe crushed horns (RCH), each applied in three different rates (5, 10 and 15 g / plant) during soil preparation. These non-traditional organic nitrogen fertilizers were produced by the Star Glue Works for glue manufacturing, slaughterhouse waste and

chemicals production, in Borg El-Arab City, Alexandria Governorate, Egypt. The tenth treatment was added as mineral nitrogen source in the form of ammonium sulfate (20.5% N) at a rate of 100 kg fed.⁻¹, applied in four doses One-quarter of the mineral nitrogen units was added during soil preparation, while the remainder quantity was distributed in three additional applications conducted at planting, 30, 60 and 90 days after planting.

2.4. Agricultural operations:

All experimental plots were uniformly treated with calcium super phosphate (15.5 % P₂O₅) at rate of 200 kg fed.⁻¹, potassium sulfate (48% K₂O) at a rate of 50 kg fed.⁻¹, 10 tons of compost and sulfur at a rate of 100 Kg fed.⁻¹. Compost, Phosphorus and sulfur fertilizers were applied all at once during soil preparation, whereas Potassium fertilizer was added in three

separate doses. The first application was added after germination was completed, followed by the second dose one month later, and the third a month after the second. Additional fertilizer requirements for the cucumber crop were added in accordance with the recommendation of the Horticulture Research Institute, Agriculture Research Center, Ministry of Agriculture and Land Reclamation.

2.5. Nutrient Assessment

A chemical analysis was conducted to determine the content of macro- and micronutrients present in the applied non-traditional organic nitrogen source fertilizers at the Regional Laboratory for Food and Feed, affiliated with the Agricultural Research Center, Ministry of Agriculture – Egypt, as illustrated in Table (2)

Table 2. Comparative Analysis of Nutrient Content in Crushed raw hooves (CRH), Hoof powder (HP), and ripe crushed horns (RCH)

Organic Materials	Element percentages in the used organic materials										
	Ca %	P ppm	K ppm	Mg ppm	Fe ppm	Mn ppm	Cu ppm	Zn ppm	B ppm	Mo ppm	N %
CRH	0.344%	1527.4	1876.7	336.94	67.6	2.54	3.21	136.42	>0.1µg	>0.3µg	14.4
HP	2.25%	7621.2	2692.4	1257.7	2311.5	92.65	11.76	155.02	0.6	>0.3µg	11.7
RCH	1.86%	7236.7	1227.8	465.9	1971.3	13.1	7.33	137.56	0.75	>0.3µg	13.4

The nutrient compositions of three waste materials (CRH, HP and RCH) were analyzed, specifically for macronutrients (Ca, P, K, Mg, and N) and micronutrients (Fe, Mn, Cu, Zn, B, and Mo). This analysis aimed to compare their chemical compositions and assess the potential significance of each material. As for nitrogen element (N); CRH, RCH, and HP showed high concentrations of 14.4%, 13.4%, and 11.7%, respectively. These findings suggest that all three materials could be rich nitrogen source, a vital element for plant growth, as presented in Table (2).

2.6. Data collection

Random samples of five plants were taken from each experimental unit, 90 days after planting, for measuring plant growth parameters. The measurements included; plant height (cm), number of branches / plant, number of nodes / plant and days to first fruit harvest.

Yield characteristics were determined as follows: Total fruit yield / plant (Kg) was calculated based on the total yield for five plants within each plot area. Number of fruits per plant was determined by averaging the total count recorded for five plants within each plot area. Average fruit weight (g) was derived by dividing the total fruit yield of five plants by its corresponding number of fruits.

2.7. Experimental Design and statistical analysis

This experiment was carried out in a randomized complete blocks design (RCBD) with 3 replicates. A one-way analysis of variance (ANOVA) was performed to assess the effects of ten fertilization treatments on the cucumber plants. Duncan's multiple range test procedure was used at p = 0.05 level of probability to compare the differences in mean values among different treatments, as

illustrated by Snedecor and Cochran (1980). CoState Software (version 6.400, 2004) was used for one-way ANOVA.

3. RESULTS AND DISCUSSION

3.1. Soil Properties and Nutrients with Organic Treatments

The following Tables (3 and 4) present a comprehensive assessment of soil chemical properties and nutrient content under different organic fertilizer treatments (CRH- HP – RCH)

and its application rates. Table (3) includes measurements of electrical conductivity (EC), pH, electrical conductivity (EC), organic matter (OM), calcium carbonate (CaCO₃), as well as concentrations of soluble anions and cations. Meanwhile, Table (4) highlights macro- (N, P, K) and micro-nutrient levels (Fe, Mn, Zn), which are essential indicators of soil fertility. These data are crucial for assessing the impact of various organic sources and their application rates on soil health and nutrient availability.

Table 3. chemical analysis of the experimental soil at the end of the two growing years

samples	EC	PH	CaCO ₃	O.M	Soluble Anions (meq\L)			Soluble Cations (meq\L)			
	ds/ m		%	%	HCO ₃	Cl	SO ₄	Ca	Mg	Na	K
Control	4.10	7.76	3.40	3.54	14.90	29.80	5.10	8.10	12.80	25.10	0.87
CRH -5	2.43	7.56	2.98	2.80	9.80	14.10	3.90	6.40	4.20	13.80	0.54
CRH -10	1.65	7.98	3.11	2.90	5.80	8.80	1.09	3.80	4.70	7.98	0.43
CRH-15	2.11	7.90	4.11	4.21	7.12	13.90	2.90	8.60	5.10	9.11	0.89
HP - 5	2.11	8.10	3.24	5.43	9.10	12.00	3.80	8.30	4.10	13.80	1.98
HP- 10	1.32	7.55	3.98	1.90	5.10	6.13	1.90	4.20	3.90	7.12	0.12
HP-15	4.54	7.65	4.65	0.90	16.80	26.90	3.90	14.10	9.20	27.50	1.88
RCH – 5	2.34	8.11	2.88	1.70	5.40	13.70	2.90	5.90	8.70	11.10	0.32
RCH -10	1.87	7.76	2.98	4.12	8.65	11.90	3.11	5.80	6.90	8.54	0.65
RCH-15	1.93	8.11	3.11	4.90	6.90	10.80	2.90	6.70	3.20	11.10	0.76

CRH: Crushed raw hooves, HP: Hoof powder, RCH: Ripe crushed horns.

Table 4. Macro- and micronutrient concentrations in soil experiment as affected by different organic fertilizer treatments at the end of the two growing years

samples	Macro Elements (ppm)			Micro Elements (ppm)		
	N	P	K	Fe	Mn	Zn
Control	46.90	10.90	226.00	3.90	4.80	8.76
CRH -5	45.90	15.00	232.00	3.10	3.98	6.98
CRH -10	66.80	14.40	354.00	4.80	3.87	5.40
CRH-15	76.20	18.30	374.00	6.76	2.80	7.76
HP - 5	70.20	10.80	262.00	5.87	4.64	2.21
HP- 10	63.80	11.90	265.00	3.80	2.00	4.87
HP-15	69.30	13.60	274.00	1.98	2.90	3.90
RCH – 5	55.90	14.90	209.00	3.90	3.56	6.90
RCH -10	65.80	13.60	251.40	3.96	5.65	7.66
RCH- 15	67.70	13.20	284.00	3.21	4.90	4.80

CRH: Crushed raw hooves, HP: Hoof powder, RCH: Ripe crushed horns.

Soil samples were analyzed to study the effect of different treatments (CRH, HP, RCH) applied at three levels (5, 10, 15) compared to

the control fertilization treatment (Fertilized with soluble N treatment). The analyses included the main soil chemical properties such

as electrical conductivity, pH, calcium carbonate, organic matter, macro elements and micro elements (Table, 3).

Regarding to the electrical conductivity (EC), the control sample recorded the highest salinity (4.10 dS/m), indicating a higher concentration of soluble salts than in the untreated soil. Salinity levels decreased across the treatments, especially CRH-10 (1.65 dS/m), suggesting that these treatments play a role in leaching salts or improving permeability.

The pH values ranged between 7.55 and 8.11, indicating that all samples fall within the mildly alkaline range, which is common in Egyptian soils where the highest pH value was recorded in RCH-5 and RCH-15 (8.11), while the lowest value (7.55) was occurred with HP-10.

Regarding organic matter (O.M), values varied between 0.90 and 5.43%, where HP-5 recording the highest organic content (5.43%), which may reflect the effectiveness of this treatment in enhancing organic matter.

Table (4) provides an overview of the soil composition regarding the concentrations of major elements such as nitrogen (N), phosphorus (P), and potassium (K)-and minor elements such as iron (Fe), manganese (Mn), and zinc (Zn)

The results showed a clear variation in the concentration of major elements depending on the type and quantity of treatment added. Nitrogen (N) content increased with the CRH treatment at a rate of 15 g per plant (76.20 ppm). This was followed by CRH at 10 g per plant (66.80 ppm) and MG at 15 g per plant (67.70 ppm), in contrast to the control treatment which had a nitrogen content of only 46.90 ppm. This finding indicates the effectiveness of these treatments in enhancing microbial activity or improving organic decomposition, which contributed to the release of nitrogen in the soil.

The highest concentration of phosphorus (P) was recorded with the treatment CRH applied at a rate of 15 g per plant (18.30 ppm). This finding demonstrated the ability of this treatment to improve the availability of phosphorus, which is often fixed in the soil.

Potassium (K) content showed an increase with the application of crushed raw hooves (CRH), particularly at a rate of 15 g per plant (374.00 ppm) and at 10 g per plant (354.00

ppm). This result reflected the effectiveness of the crushed raw hooves (CRH) in improving potassium availability.

These findings showed that adding crushed raw hooves (CRH) at a rate of 15 g per plant was the most effective in enhancing macro nutrients. This highlights its potential as a viable solution for improving soil fertility and increasing crop productivity.

3.2. Mean Performances for cucumber Plant Characteristics during the two study years

As for the plant height trait, the data presented in Table (5) showed that treatment CRH 15 had a significantly higher average value for plant height during the first year. The results of the second year showed that the same fertilization treatment (CRH-15) had the highest average value, without significant differences with the treatments CRH-10, HP-10, HP- 15 and RCH-15).

During the first year the fertilization treatment HP-5 recorded the highest mean value for number of branches per plant trait without any significant differences with each of the treatments HP-10, HP-15, RCH-10 and RCH-15 (Table, 5). In the second year, the obtained results showed that the fertilization treatment HP 15 achieved the highest mean performance for number of branches per plant characteristic without significant differences with each of the treatments HP-5, HP-10 and RCH-15.

Data shown in Table (5) illustrated that the fertilization treatment CRH-15 exhibited the highest mean average for number of nodes per plant characteristic during the first study season. However, no significant differences were observed between this fertilization treatment and the treatments CRH-10, HP-10 and HP-15. Similarly, CRH-15 possessed the highest mean value during the second year of the study. Also, there were no significant differences were observed between this fertilization treatment and the treatments HP-5, HP-15 and RCH-15 (Table, 5).

The results of Table (5) showed that the highest mean value for days to first fruit harvest characteristic was detected with the treatment HP-15 without significant differences with CRH-15 and CRH-5 treatments, across first year. The results of the second year appeared

that HP-15 and RCH-15 applications possessed the highest mean values in this regard.

In terms of the number of fruits per plant trait, fertilization treatment RCH5 exhibited the highest mean average. However, no significant differences were observed between this fertilization treatment (RCH-15) and each of the treatment CRH-15, HP-5, HP-10 and HP-15, this results are true during the first study season. The results of the second year showed that the fertilization treatment HP-15 gave the highest mean value without significant differences compared to HP-10 and RCH-15, as shown in Table (5).

In relation to the average fruit weight trait, data shown in Table (5) illustrated that the fertilization treatment CRH-10 gave the highest

mean value. However, there were no significant differences between CRH 10 and the treatments CRH-15, HP-5, HP-10, RCH-5, and RCH-10. As for the second year, the obtained results cleared that there were no significant differences existed among the evaluated fertilization treatments.

The analysis revealed that total yield character increased by 63.33%, 48.56%, and 30.94% with fertilization using substances HP, RCH, and CRH respectively, compared to fertilization with mineral N. In the second season, the trend remained consistent, as the best yields once again obtained with fertilization using substance HP, followed by substances RCH and CRH resulting in increasing of 44.62%, 32.76% and 24.73%, respectively.

Table 5. Mean Performances for cucumber Characteristics during the two study years of 2022 and 2023.

Fertilization treatments	Plant length (cm)	Number of branches / plant	Number of Nodes / plant	Days to first fruit harvest	Number of fruits / plant	Average fruit weight (g)	Total yield / plant (Kg)
2022							
Control	206.33 f	5.16c	30.36e	22.33ab	35.66d	75.23 bc	2.68d
CRH-5	256.66cd	5.02c	44.30cd	17.02def	36.00d	75.74bc	2.72d
CRH-10	290.01b	6.33bc	49.31abc	18.01cde	38.66d	88.75a	3.43cd
CRH-15	320.02a	7.01b	54.35a	15.66ef	54.33ab	80.63abc	4.38ab
HP-5	218.33 ef	8.66a	44.71cd	20.02bc	57.66ab	77.92abc	4.49ab
HP-10	273.33bc	7.66ab	49.02abc	19.03cd	55.66ab	85.65ab	4.76a
HP-15	286.66 b	7.33ab	53.11ab	14.66f	55.66ab	69.79c	3.88bc
RCH-5	197.66f	6.33bc	40.31d	23.33a	45.66c	81.11abc	3.70bc
RCH-10	238.02de	7.33ab	40.65d	22.66a	51.00bc	78.47abc	4.00abc
RCH-15	287.66b	7.66ab	47.68bc	22.01ab	59.00a	72.04bc	4.25abc
2023							
Control	208.33 b	4.50e	27.66d	25.66a	39.00d	76.38a	2.98d
CRH-5	232.33b	5.02de	40.66bc	21.00bc	46.00c	74.91a	3.44cd
CRH-10	286.16a	6.66c	44.33bc	21.33b	45.66c	75.86a	3.46 cd
CRH-15	301.33a	7.01bc	52.00a	16.00d	54.00b	78.52a	4.24ab
HP-5	229.16b	8.33ab	45.33abc	19.33c	52.66b	78.19a	4.12ab
HP-10	280.16a	7.66abc	38.00c	22.00b	58.00a	78.07a	4.53a
HP-15	274.66a	8.83a	45.00abc	15.33de	61.33a	69.89a	4.27ab
RCH-5	215.00b	6.33cd	38.66c	24.00a	47.33c	74.77a	3.53cd
RCH-10	228.33b	7.16bc	41.33bc	21.33b	52.33b	71.99a	3.76bc
RCH-15	280.83a	8.16ab	46.33ab	14.00e	61.00a	74.75a	4.57a

Means followed by a similar letter within a column for each parameter are not significantly different at the 0.05 level of probability using Duncan's multiple range test procedure.

4. DISCUSSION

Crushed hooves, hoof powder and ripe crushed horns were evaluated under field

conditions for study their effects on the growth and yield of cucumber (*Cucumis sativus* L.) compared with conventional mineral nitrogen

fertilizers. The investigation demonstrated that organic fertilizers derived from hooves - particularly hoof powder and crushed hooves significantly improved cucumber growth, fruit yield, and vegetative development compared to traditional mineral nitrogen fertilization. Among the tested organic fertilizers, hoof powder applied at a rate of 10 g resulted in the highest yields, the greatest number of fruits, and the shortest period to first harvest across both growing seasons. These findings are consistent with reach by Ouattara *et al.* (2025), who reported that compost enriched with hoof, horn, and bone powder significantly enhanced soil nitrogen levels, organic carbon, and crop yields under organic tomato production systems.

Hoof powder functions as a slow-release nitrogen source, ensuring steady nutrient availability, improving soil structure, and enhancing water-holding capacity, which support sustained vegetative growth and higher fruit set. This can be attributed to the keratin-rich materials which release nitrogen gradually into the soil, as demonstrated by Owen *et al.*, (1953a-1953b) who documented nitrogen mineralization over a prolonged incubation period dependent on particle size and soil microbial activity. The slow release of nitrogen inherent to keratinous materials (hoof/horn) provides a steady supply throughout the crop lifecycle, enabling consistent vegetative activity rather than a rapid pulse common to synthetic N fertilizers (Chen *et al.*, 2022). Furthermore, Jang *et al.* (2019) observed enhanced soil water retention and nutrient levels following horn meal application in vegetable and rice cultivation, supporting the premise of improved soil structure and sustained nutrient release. Additionally, Almeida *et al.* (2021) showed that hoof and horn powder bio-fertilizers had significantly higher nitrogen content and phosphorus availability than bone meal, reinforcing its role as a superior organic nitrogen sources.

Crushed hooves applied at a rate of 10–15 g produced taller plants and greater vegetative vigor compared to all other treatments. The Enhanced plant length and branching observed may be attributed to high keratin content in hooves, which decomposes gradually, providing a consistent nitrogen release and stimulating root development.

Additional experimental evidence from keratin hydrolysates molecular derivatives obtained from hoof, horn, feathers, or wool demonstrated notable stimulation of root elongation and shoot growth in leafy vegetables like lettuce, spinach, and radish, driven by slow mineralization of keratin and enrichment of microbial activity in the rhizosphere (Sobucki *et al.*, 2019 and Sahin *et al.*, 2025). Further field studies (Barbarán and Hernández, 2025) revealed that horn and hoof meal enhanced leaf chlorophyll content and root biomass in cacao, performing comparably to urea-evidence of effective slow-release nitrogen supply. These results are consistent with the findings of Abd-El-Shafy *et al.* (2024), who reported that applying animal-based organic amendments combined with bio-fertilizers significantly improved cucumber canopy growth and nutrient uptake under sandy soil conditions.

Although hoof powder and crushed hooves improved cucumber productivity when applied at moderate rates, however, applying the highest dose of hoof powder (15 g) led to a notable yield decline during first year. This decline can be attributed to two soil-related mechanisms. Firstly, when large amounts of high-carbon organic amendments like keratin-based hoof meal are applied, soil microbes may temporarily immobilize available mineral nitrogen as they decompose the material. This microbial demand can outpace supply, reducing nitrogen availability to plants during critical early growth stages. This phenomenon is supported by Geisseler *et al.*, (2021), who revealed through meta-analysis that certain organic materials may delay nitrogen release and even cause net immobilization unless mineral nitrogen is sufficiently present. Secondly, excessive organic amendments can result in salt buildup or changes in soil osmotic potential, especially in sandy or low-organic soils. Such effects may impair root water uptake and suppress yield. Reviews by Liu *et al.*, (2024) and Albano *et al.*, (2023) illustrates how organic fertilizer can reduce osmotic stress and improve soil physical properties at proper doses, but over-application may reverse these benefits, limiting plant growth due to temporary imbalance and reduced nutrient assimilation. Both mechanisms help explain why the 15 g rate- though nutrient-rich- yielded less than the

10 g treatment. The microbial immobilization reduced plant-available nitrogen during early growth, while potential osmotic stress impaired root function, delaying development and reducing fruit set.

5. CONCLUSION

The study demonstrated that organic fertilizers derived from hooves can substantially improve cucumber (*Cucumis sativus* L.) growth and productivity when applied at appropriate rates, outperforming traditional nitrogen chemical fertilizers. The keratin-rich composition of hoof powder provides slow-release organic nitrogen, supporting prolonged vegetative growth. These fertilizers, when applied at appropriate rates, can serve as sustainable alternatives or partial replacements for mineral nitrogen fertilizers due to their gradual nutrient release and potential to enhance soil health. However, further researches are required across diverse climates and soil types to identify optimal application strategies.

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الملخص العربي

تأثير مصادر النيتروجين العضوي غير التقليدية على نمو و إنتاجية الخيار

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تناولت هذه الدراسة تقييم تأثير بعض مصادر النيتروجين العضوية غير التقليدية مثل مسحوق الحوافر ، و الحوافر المطحونة، والقرون المطحونة على النمو و المحصول و خصائصه في الخيار (*Cucumis sativus* L.) مقارنة بالتسميد النيتروجيني المعدني التقليدي. أظهرت نتائج التجارب الحقلية خلال عامين متتاليين أن الأسمدة المشتقة من الحوافر حسّنت بشكل ملحوظ إنتاجية الخيار؛ حيث أعطى مسحوق الحوافر بمعدل ١٠ جم/نبات أعلى محصول كلي للنبات وأكبر عدد من الثمار للنبات وأقصر فترة للوصول إلى أول حصاد، بينما ساهمت الحوافر المطحونة بمعدل ١٥، ١٠ جم /نبات في تحقيق أفضل نمو خضري وزيادة طول النباتات. في المقابل ، أدى التسميد بمعدل مرتفع (١٥ جم/نبات) من مسحوق الحوافر الى حدوث انخفاض في المحصول خلال العام الأول، ويُعزى ذلك على الأرجح إلى حدوث تثبيت مؤقت للنيتروجين بواسطة الكائنات الدقيقة وإلى تأثيرات أسموزية محتملة. تشير النتائج الى أن الأسمدة المشتقة من الحوافر، عند استخدامها بمعدلات مناسبة، يمكن أن تمثل بدائل مستدامة أو مكملات للأسمدة المعدنية، مما يحسن أداء المحصول ويسهم في إعادة تدوير مخلفات المجازر بطرق صديقة للبيئة. و يمكن لهذه الأسمدة أن تحل جزئياً محل مصادر النيتروجين المعدني عن طريق إطلاق العناصر الغذائية ببطء لتحسين صحة التربة.

الكلمات المفتاحية: الخيار، مسحوق الحوافر ، و الحوافر المطحونة، والقرون المطحونة