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RESEARCH ARTICLE

Harmonizing Growth: Unleashing the Potential of Fish Waste as a Natural Liquid Elixir for Soil Health and Bountiful Tomato Harvests in Open Fields

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ABSTRACT

In this study, the impact of foliar spray treatments with fish amino acid (FAA) and urea on the growth parameters of *Solanum lycopersicum* was investigated. The results revealed significant influences on plant height, number of leaves per plant, and Leaf Area Index (LAI). Notably, the foliar application of 2% urea stimulated cell division and metabolic activity, resulting in taller plants and increased leaf count. Conversely, 1% FAA exhibited a notable increase in plant height, leaf count, and chlorophyll content, showcasing the potential of FAA to enhance metabolic activity and cell division. However, higher concentrations of FAA negatively impacted growth parameters. The study further explored the field growth differences, highlighting the substantial increase in fresh and dry weights under the foliar spray of 2% urea. Additionally, the yield of green leafy vegetables, particularly amaranthus, was significantly influenced by urea and FAA, with 2% urea contributing to a remarkable increase in yield. The research underscores the potential benefits of FAA and urea in enhancing soil fertility, nutrient content, and overall crop yield, providing insights into sustainable agricultural practices. Finally, the study introduces the benefits of fish protein fertilizer, emphasizing its role in soil enrichment, microbial biomass maintenance, root and leaf growth stimulation, and overall plant health. The environmentally friendly nature of fish protein fertilizer and its positive impact on *Solanum lycopersicum* make it a promising alternative for sustainable and robust agricultural practices.

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Introduction

Fertilizers play a crucial role in enhancing crop productivity by providing essential nutrients to plants. Farmers regularly utilize these chemical substances to boost crop yields. There are two main categories of fertilizers: mineral and organic. These substances deliver vital nutrients such as nitrogen, potassium, and phosphorus, contributing to improved soil fertility and increased water retention capacity (Hati and Bandyoopadhay, 2011). Overall, fertilizers are instrumental in supporting plant growth and enhancing agricultural output. Fertilizers play a vital role in enhancing crop productivity, and they can be broadly categorized into two types: inorganic and organic (Kakar et al., 2020).

Inorganic Fertilizers

Nitrogen Fertilizers

Inorganic fertilizers, synthesized chemically, include nitrogen fertilizers crucial for crop development. Nitrogen, a key component of chlorophyll, supports photosynthesis and is integral to amino acids and protein formation. These fertilizers contribute to improved agricultural production and product quality (Anas et al., 2020).

Phosphorus Fertilizers

Another type of inorganic fertilizer focuses on phosphorus as the main nutrient. Effective phosphorus content, soil properties, fertilization methods, and crop strains collectively influence fertilizer efficiency. Phosphorus plays a crucial role in cell growth, particularly in the protoplasm, and benefits root development in plants (Khan et al., 2023).

Organic Fertilizers

Organic fertilizers, derived from animal manures (livestock feces and urine, poultry droppings), plant residues, municipal effluents, bio-solids, and organic by-products, are natural alternatives. These fertilizers enrich the soil with essential carbon compounds, fostering plant growth. They increase soil organic matter, promote microorganism reproduction, and alter soil's physical and chemical properties (Babcock-Jackson et al., 2023).

Organic fertilizers can be sourced from various products, including agricultural waste, livestock manure, industrial waste, and municipal sludge. Historically, organic manures, combined with leguminous nitrogen fixation, were primary nutrient sources, contributing significantly to agricultural productivity and soil quality. However, the advent of the Haber–Bosch process in the twentieth century led to a surge in mineral fertilizer usage, coinciding with population growth and agricultural advancements like the Green Revolution. Mineral fertilizer use skyrocketed from 14 million nutrient tons in 1950 to 142 million nutrient tons in 2002, correlating with an increase in world cereal production (Harris and Ratnieks, 2022).

In tropical regions, maintaining fruit tree yields without fallow periods or fertilizer application is challenging. While acceptable yields can be achieved by inter planting crop trees with N-fixing legumes, fertilizers play a crucial role in sustaining productivity. The current emphasis on organic fertilizer inputs stems from their environmental benefits over chemical fertilizers. Practices such as anaerobic digestion of organic matter, including animal manure, sewage sludge, and food wastes, contribute to environmental sustainability (Chatzistathis et al., 2021; Gopalakrishnan et al., 2015).

However, concerns exist regarding the potential contamination of crops grown in soil containing contaminated manures. Studies have highlighted variations in pathogen survival with temperature and environmental conditions during the anaerobic digestion process. Additionally, the extensive use of veterinary antibiotics in livestock manure has raised concerns about the persistence and survival of antibiotic-resistant bacteria, posing potential risks to food safety and the environment.

Organic fertilizers offer several advantages in sustainable farming practices includes, Firstly, their use contributes to the elimination of unwanted and harmful environmental contamination, such as surface water and underground water table pollution. Organic fertilizers play a crucial role in degrading natural substances present in the soil, enriching its contents (Chew et al., 2019).

Secondly, organic manure provides essential nutrients for plants but in limited quantities. This helps in maintaining an optimal Carbon to Nitrogen (C: N) ratio in the soil, subsequently enhancing soil fertility and productivity (Yohannes, 2023).

Thirdly, the use of organic fertilizers aims to provide nutrients in organic forms derived from plant and/or animal origin. Additionally, it plays a significant role in maintaining or increasing the soil's organic matter content, thereby boosting nutrient efficiency and overall organic matter in the soil (Emadodin et al., 2020).

Moreover, organic fertilizers contribute to the restoration and maintenance of soil fertility, nurturing robust plant growth. They also improve nutrient use efficiency, ensuring healthier and more vigorous crop yields. Furthermore, the slow release of nutrients from organic fertilizers aligns with the dynamic needs of plants, reducing the impact of farming and safeguarding ecosystems by minimizing leaching.

Unlike some chemical fertilizers, organic fertilizers do not burn plants. They are easy to transport, store, and apply. Their water-soluble nature allows for quick dissolution in the soil, facilitating easy absorption by plants and providing a rapid and predictable effect on crops. Ultimately, the use of organic fertilizers increases crop yield, contributing to providing enough food to sustain the needs of a growing population. The predictability and reliability of organic fertilizers make them a valuable and sustainable choice for environmentally conscious and productive agriculture.

Organic Liquid Fertilizer

Organic liquid fertilizer is crafted from naturally occurring sources, including plants and animal manure, rendering it a sustainable and eco-friendly product. Utilizing waste from animals such as cows, rabbits, fish, and chickens, this type of fertilizer offers essential nutrients to both plants and the soil. The liquid form of manure emerged in the 20th century as a viable alternative to fermented manure. Both liquid and solid manure serve as nutrient-rich fertilizers for plants, containing elevated levels of crucial elements like nitrogen, phosphorus, and potassium derived from the excretions of farm animals and the food they consume (Martínez-Alcántara et al., 2016).

The efficacy of organic liquid fertilizers extends to promoting environmental sustainability and fostering plant growth over an extended period. However, it is noteworthy that previous research has predominantly concentrated on conventional solid products like straw and manure, leaving room for further exploration into the potential benefits and applications of organic liquid fertilizers in sustainable agriculture.

Advantages of Organic Liquid Fertilizers

Natural and Non-Toxic

Organic liquid fertilizers, derived from natural materials such as recycled plant matter, are inherently non-toxic to humans, animals, and plants. This makes them a safe alternative to some inorganic fertilizers that may pose toxicity risks.

Environmental Benefits

Exclusive use of organic liquid fertilizers contributes to environmental preservation. Unlike chemical counterparts, organic fertilizers are considered entirely safe for the ecosystem, irrespective of the quantities present in the soil. In contrast, synthetic liquid fertilizers can harm surrounding plant life, insects, and contribute to soil acidity over time (Martínez-Alcántara et al., 2016).

Recycled Materials

Many organic liquid fertilizers are crafted from green waste or food waste, diverting materials from landfills or sewage plants. This environmental benefit is coupled with potential cost savings, as organic liquid fertilizers are often more affordable than their inorganic counterparts. Some countries even offer incentives for the production of organic products from recycled waste (Siddiqui et al., 2023).

Better and Healthier Produce

For those cultivating vegetables and fruits for consumption, organic liquid fertilizers are preferable due to growing concerns about the health effects of chemical fertilizers. Studies link chemical fertilizers to health issues, prompting health-conscious consumers to opt for produce grown using organic materials (Rahman et al., 2019).

Improved Soil Structure

Organic fertilizers, being composed of dead or recycled plant material, enhance soil structure. They provide essential nutrients for plant growth and health while simultaneously improving soil quality. These benefits controlled planting environments by allowing the reuse of the same soil for multiple cycles without degradation (Bhunia et al., 2021).

DIY Option

Urban gardeners have the option to make their own organic liquid fertilizer using readily available materials and guides. This self-sufficiency enables individuals to repurpose dead plant and animal materials into useful fertilizers for personal gardening projects or potential commercial use.

Reduced Risk of Over-Fertilization

Unlike chemical fertilizers, overusing organic fertilizer carries minimal risk, as organic fertilizers naturally belong to the environment. A well-structured schedule ensures optimal fertilizer application without the risks associated with over-fertilization, such as plant death, acidic soil, and increased toxicity.

Faster Nutrient Absorption

Liquid fertilizers, due to their immediate penetration of the soil, provide plants with faster access to nutrients. This quality is particularly advantageous for promoting quick root growth, essential for ensuring plant establishment, especially early in the season.

Balancing Soil pH

Liquid fertilizers excel in balancing soil pH based on the chemicals they deliver, particularly nitrogen. This precision can be highly beneficial when applied correctly, avoiding potential harm to plants through over application.

Facilitating Precision Farming

Liquid fertilizers support precision farming by allowing for accurate application and targeted nutrient delivery.

Promoting Efficient Nutrient Use

Liquid fertilizers contribute to more efficient nutrient utilization, supplying plants with growth-spurring nutrients more frequently compared to slow-release granules. In the advantages of organic liquid fertilizers span environmental sustainability, health benefits, soil improvement, and user flexibility, making them a preferable choice for conscious and efficient agriculture. The current study was designed to manufacture organic fertiliser from fish waste and to test the efficacy of fish waste fertiliser on the growth of *Solanum lycopersicum*.

Materials and Methods

Collection of fish waste

A totally mixed variety of fish waste, including the head, intestines, and gills, was collected at a neighbouring fish market in Mananthavady, Wayanad, Kerala. Local stores provided the necessary ingredients for making fish waste fertiliser, which included 2 kilograms of jaggery and bananas.

Preparation of fish waste fertilizer

A clean clay pot with a capacity of 10 litres was filled with 5 litres of water. Next, 2 kg of powdered native jaggery was added and thoroughly mixed until dissolved. Following that, 2 kg of fish waste (including the skin, intestine, head, gills, and intestines) was added and thoroughly mixed. Two well-blended bananas were added to the mixture and thoroughly stirred.

To prevent flies from entering, the pot's mouth was covered with a cotton rag, and the contents were stirred once daily. After 15 days, the contents were filtered, and the resultant filtrate was used as organic liquid fertiliser. This filtrate was further diluted with water at a 1:10 ratio, yielding a 5-liter solution.

Parameters analysed

The protein and carbohydrate contents in the fish waste fertilizer were determined utilizing the A.O.A.C. (Association of Official Analytical Chemists) method from 1975. Additionally, the levels of nitrogen, phosphorus, and potassium in the fish waste fertilizer were assessed employing a flame photometer.

Efficacy of Fish Waste Fertilizer on Growth Parameters

Seed Collection

Healthy *Solanum lycopersicum* seeds were procured from the Agricultural nursery in Bathery, Wayanad. These seeds were then planted in pots and adequately watered.

Experimental Growth Setup

A triplicate experimental setup was established for both control and experimental plants. A 10 ml application of fish waste fertilizer, using the spray method, was administered to the pots at seven-day intervals. A water control group was also implemented to assess differences in plant growth. The experiment spanned a period of 35 days.

Growth Parameters

Plants with similar heights were randomly selected from both control and experimental pots to record various growths and yield parameters. The impact of the treatment was assessed in terms of overall growth and yield.

Production of Fish Amino Acid (FAA)

Fish Amino Acid (FAA) comes from ruined fish and fish byproducts such bones, heads, internal organs, and skin. The fish juice is removed and fermented after being stored for 15 days. FAA includes 90 percent nitrogen and 2.5 percent phosphorus. It is critical to employ items that are unfit for human consumption or deemed waste and are uncontaminated with chemicals, whether purchased at a low cost or obtained for free (Fig 1).

Ingredients

The primary ingredients are rotten fish and fish by-products such skin, bones, skull, and internal organs. Additionally, raw sugar or molasses can be used. A ceramic pot or plastic pail, basin, wooden ladle, cover cloth, string, marking pen, kitchen knife, chopping board, and a glass storage jar are also necessary.

Steps in Making FAA

Collect supplies from the market, fish processing facility, or fish port. The frequency of collecting is determined by the manufacturing volume.Cut the materials into little pieces to aid in juice extraction. Place 3 kg of chopped materials in a basin, then add 1 kg of crude sugar or molasses and stir thoroughly with a wooden ladle. Pour the mixture into a glass jar or plastic pail, then cover with a towel and tie with a string.

Collect the fermented extract and store it in a colourful glass jar. Cover the jar with paper and keep it in a cool, dark area. Cover the pot or pail with cloth or paper and secure it with a string. On the cover, write the date of processing and the predicted harvest date. Store the container containing the mixture in a cool, dry, shady location for four weeks, making sure it is not pest-infested. After one month, the fermented extract is ready.

Uses and Rates of Application of FAA

FAA can be used as a nitrogen source via foliar spray during the vegetative stage at a rate of 1 tsp/liter of water, or straight to the soil to boost microbial activity. It can also be added to the compost heap to provide energy for soil microorganisms and speed up the decomposition process.

Advantages of Producing FAA

Raw resources are easily available, making manufacture cost-effective. Complete control over both the quality and quantity of the product. Simple and straightforward step-by-step instructions.

Fig 1. FAA production.

Advantages of Using FAA

FAA is safe to use and provides no health hazards, even if unintentionally consumed. An inexpensive source of nitrogen for plants and soil microbes. Provides plants with a steady, slow-release nutrition source.

Result and Discussion

Growth Parameters

Solanum lycopersicum growth characteristics, such as plant height and leaf count, were significantly influenced by foliar spray treatments with fish amino acid and urea. Notably, the 2% urea foliar spray resulted in considerably taller plants (9.5 and 11.4 cm), more leaves per plant (10.7 and 11.7 cm), and a larger Leaf Area Index (LAI) (1.37 and 2.51) at 7 and 14 days after the spray, respectively, compared to the control. This result shows that foliar application of urea may have encouraged cell division and metabolic activity, resulting in increased plant height and chlorophyll content (Figure 1). Nitrogen, which is essential for plant growth, increases vegetative growth, including plant height and LAI.

In contrast, the foliar spray of Fish Amino Acid (FAA) had no significant effect on growth metrics at 7 days following application, although significant differences were found at 14 days (Table 1). The foliar spray of 1% FAA produced equivalent growth characteristics to the 2% urea spray. Among the FAA doses, 1% FAA resulted in considerably taller plants (11.3 cm), more leaves per plant (11.6 cm), and a higher LAI (2.46) at 14 days after spraying than the higher levels (3% and 4%). However, it was comparable to the 0.5% FAA in all growth aspects (Fig 2).

Foliar application of 1% FAA increased plant height, leaf number per plant, and chlorophyll content by 16.5%, 12.6%, and 8.1%, respectively, compared to the control group. This enhancement could be attributable to the rapid absorption and assimilation of macro and micronutrients found in FAA, which improves metabolic activity and cell division, resulting in higher plant height, leaf count, and chlorophyll content. These findings are consistent with previous studies by Vasmathi (2001) and Sanjuthi et al., (2008), which found that spraying organic preparations such as fish amino acid increased plant height, owing primarily to the growth enzymes present in fish amino acid, which promote rapid cell division and multiplication.

Interestingly, the foliar spray of 4% FAA produced lower growth parameter values than the 2% urea and 1% FAA sprays. Higher concentrations of FAA (3% and 4%) in foliar sprays reduced plant growth compared to lower dosages, indicating a potential inhibitory action at higher concentrations.

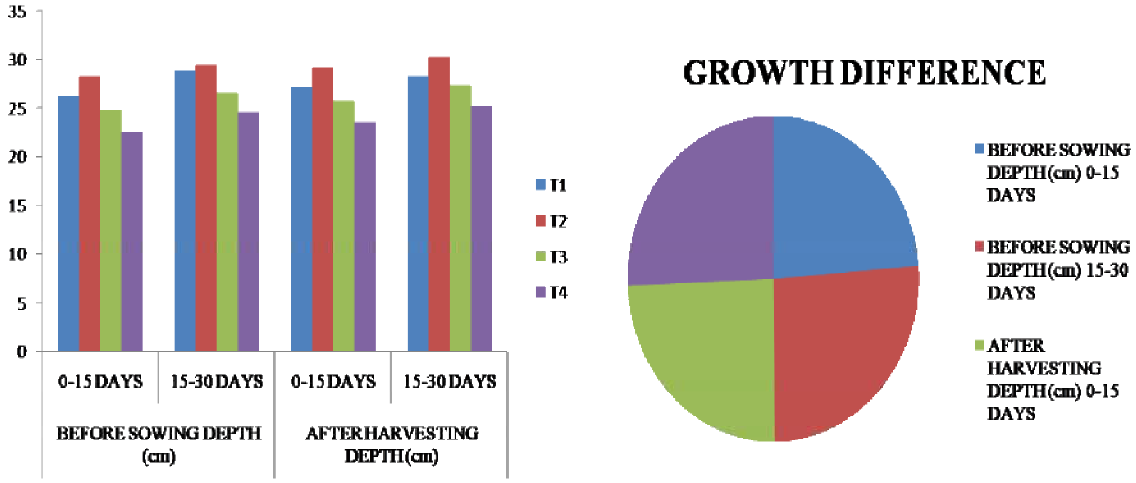

Fig 2. Growth difference of Harvesting.

Table 1. Difference of field growth.

Field Growth	Before Sowing Depth (Cm)		After Harvesting Depth (Cm)	
Treatments	**0-15 Days**	**15-30 Days**	**0-15 Days**	**15-30 Days**
T1	26.27	28.85	27.17	28.34
T2	28.32	29.43	29.18	30.27
T3	24.82	26.57	25.81	27.3
T4	22.54	24.59	23.54	25.16

Difference of field growth

The foliar application of Fish Amino Acid (FAA) and Urea had a significant effect on the fresh and dry weights of *Solanum lycopersicum*. The foliar spray of 2% urea resulted in a considerable increase in fresh weights (4.6 g/plant) and dry weights (0.7 g/plant) when compared to the FAA and control groups. Following that, a foliar spray of 1% FAA yielded a fresh weight of 3.7 g/plant and a dry weight of 0.6 g. The foliar spray of 4% FAA resulted in the lowest fresh and dry weights, measuring 2.8 g/plant and 0.05 g/plant, respectively (Fig 3).

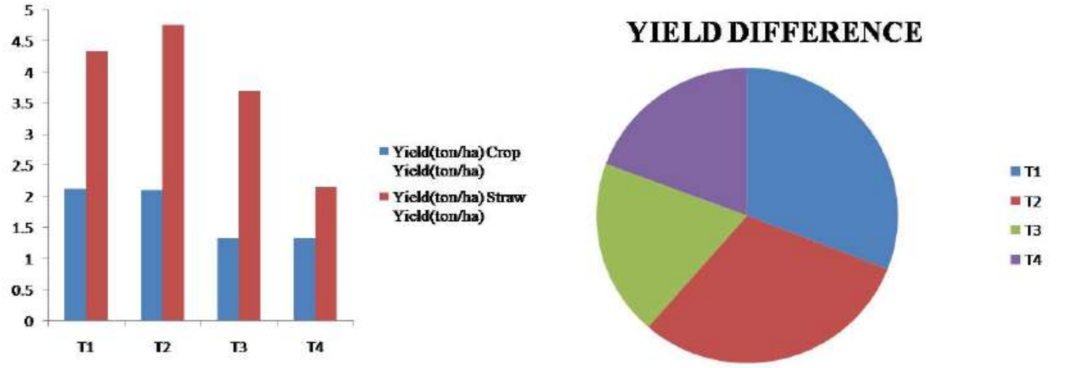

Fig 3. Yield Difference.

The foliar spray of urea and FAA considerably increased the output of green leafy vegetables, particularly amaranthus. The foliar application of 2% urea produced a significantly larger yield of green leaves (1.52 t/ha) than the FAA foliar spray and the control group. This was followed by a foliar application of 1% FAA (1.22 t/ha) and 0.5% FAA (1.21 t/ha) (Table 2).

Table 2. Difference of field yield.

	Yield (ton/ha)	
Treatments	**Crop Yield (ton/ha)**	**Straw Yield (ton/ha)**
T1	2.13	4.33
T2	2.1	4.76
T3	1.33	3.7
T4	1.33	2.16

The foliar application of 2% urea increased green leaf vegetable yield by 47.5% over the control. This rise was ascribed to the delivery of nitrogen in the form of urea, which, as a foliar spray, encouraged vegetative development, resulting in increased chlorophyll content, Leaf Area Index (LAI), and photosynthetic activity, thus enhancing leafy vegetable yield (Gulser, 2005).

Furthermore, foliar application of 1% FAA resulted in an 18.4% increase in green leaf vegetable yield compared to the control. This rise could be ascribed to FAA's delivery of macro and micronutrients, as well as growth hormones, which improve growth characteristics such as plant height, leaf count, and chlorophyll content, hence enhancing green leafy food yields. These findings are consistent with the findings of Abbasi et al., (2003), who found that spraying fish emulsion on tomato and pepper plants enhanced total production. Similarly, foliar treatment of 1% FAA improved rice yield by 15.5% compared to the control (Priyanka et al., 2019). Higher FAA doses, on the other hand, were linked to a decrease in *Solanum lycopersicum*'s green leafy output.

Benefits

Enhancing soil fertility and nutrient content, fish protein fertilizer contributes to soil loosening, maintains microbial biomass, and fosters a healthy soil environment. It stimulates root and leaf growth, particularly beneficial for seedlings, and promotes robust photosynthesis. The use of fish protein aids in root development, improved photosynthesis, overall plant growth, early maturation, and heightened quality, especially in *Solanum lycopersicum*. When applied to fruit trees, it imparts a vibrant green hue to leaves, reduces diseases, and augments the quality and yield of fruits and vegetables. As a pollution-free, environmentally friendly, green fertilizer, fish protein fertilizer proves highly beneficial for *Solanum lycopersicum*, ensuring robust growth and abundant fruiting.

Liquid fertilizer, including fish waste extract, offers time-saving benefits for farmers. It minimizes equipment downtime, allows faster application, and permits fertilizer application even during light rain. Liquid equipment calibration is straightforward, more precise than granular alternatives, and can be executed promptly.

This study aimed to assess the impact of fish waste extract on the growth, yield, and quality of tomatoes. Results indicated that applying 20 ml of fish waste extract significantly increased vine length, leaf number, flower count, fruit number, and individual fruit weight compared to other treatments and the control group. The study concluded that 20 ml of fish waste extract was the optimal treatment for enhancing the growth, yield, and quality of tomatoes.

Tomatoes, crucial vegetables in organic agricultural production, are grown with a focus on delivering top-quality food, respecting the environment, and maintaining soil fertility. Fish waste, abundant in nitrogen, potassium, phosphorus, and trace minerals, serves as valuable raw material for producing various nutritive and non-nutritive products. Fish waste extract, derived from head, scale, intestine, gall bladder, etc., was applied to cucumber plants in an experiment, revealing positive effects on growth, yield, and quality under polybag conditions.

The experiment involved the collection of well-blended fish waste from a local market, preparation of fish waste extract, and application on coco peat. Measurements of leaf area and flower count per plant were recorded to assess the impact of different concentrations of fish waste extract. Overall, the experiment demonstrated the potential of fish waste extract as an effective organic liquid fertilizer for promoting plant growth and enhancing yield.

Conclusion

The utilization of liquid organic fertilizers, such as Fish Amino Acid (FAA), emerges as a promising alternative to chemical counterparts. Organic amendments play a crucial role in enhancing soil fertility and sustainability by promoting biological activity, facilitating nutrient mineralization, and aiding in nutrient immobilization. However, there were no noteworthy distinctions observed in root length and plant biomass due to the addition of FAA fertilizer. The introduction of FAA did not yield significant changes in the parameters of root length and plant biomass.

Conversely, the findings indicated a notable impact on shoot length, which was significantly influenced by both the number of weeks and the volume of FAA as individual factors. Furthermore, soil pH, considered as a single factor, exhibited a significant correlation with the volume of FAA, while soil moisture content, also considered independently, displayed a noteworthy connection with the number of weeks. In the evaluation of the effects of biological nutrient supplements on crop performance within the complexities of an integrated production system, isolating key variables, such as the impact of individual nutrients and specific bio stimulant compounds, can prove challenging. Additional research is therefore imperative to deepen our understanding of the physiological mechanisms underlying the action of organic supplements, ultimately enhancing soil biological activity and promoting overall crop growth.

Conflict of interest

All authors declare that there is no conflict of interest in this work.

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