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"Comparative study of Fish Amino acid (FAA) & Soybean amino acid as foliar application on Spinach (*Spinacia oleracea)* L."

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ABSTRACT

An experiment was conducted to determine the effects of fish amino acid (FAA) and soybean amino acid application on the growth and development of spinach (*Spinacia oleracea L.)* during various sampling times. An experimental design was employed, wherein spinach plants were subjected to foliar applications of FAA and soybean amino acid (SAA). Control groups without amino acid treatments were also maintained for comparative analysis. The treatments were applied at specific growth stages, and their impacts on plant height, leaf area, chlorophyll content, biomass, and yield were assessed. Results indicated that both FAA and SAA significantly improved the growth parameters of spinach compared to the control groups. However, FAA demonstrated a slightly superior effect on overall plant vigor, leaf chlorophyll content, and yield in both crops. The enhanced performance of FAA could be attributed to its diverse amino acid profile and the presence of additional bioactive compounds inherent to fish-derived products.

The spinach plants were treated with varying concentrations of FAA and soybean amino acid, specifically 1.0% and 2.0%. Amino acids are derived from both plant-based and animal-based ingredients. The composition of fish with molasses and soybean with molasses in a 1:1 ratio undergoes fermentation. The fermentation process breaks down proteins into amino acids. Both mixtures were allowed to ferment for 30 days. Acetic acid bacteria were absent in both samples, while levels of lactic acid bacteria and yeast fluctuated. These findings were corroborated by visual analysis. Parameters such as root length, shoot length, and plant biomass were analyzed from the first week to the fourth week of planting. Results demonstrated that the application of FAA and soybean amino acid, along with different sampling times, significantly influenced shoot length, thereby promoting crop growth and enhancing spinach leaf development.

INTRODUCTION

The utilization of organic and bio-fertilizers has garnered significant attention in contemporary agriculture due to their environmental advantages and capacity to sustainably enhance plant growth and productivity. Among these, amino acid-based foliar fertilizers have emerged as effective instruments for improving crop health, growth, and yield. Amino acids are crucial for protein synthesis, enzyme production, and overall plant metabolism, rendering them essential for plant development. Fish Amino Acid (FAA) and Soybean Amino Acid (SAA) are two widely recognized bio-fertilizers noted for their nutrient-rich composition and growth-promoting attributes.

This study investigates the foliar application of Fish Amino Acid and Soybean Amino Acid on the growth of Spinach (*Spinacia oleracea* L).*)* These vegetables are recognized globally for their health benefits, contributing to immunity enhancement and increasing vitamin C levels, which are vital for maintaining healthy vision, promoting cell growth, and ensuring healthy skin. Therefore, it is imperative to enhance the productivity of this nutritious vegetable more efficiently. Amino acids serve as fundamental components of plant nutrition, influencing growth, development, and stress resistance. Among various amino acid sources, Fish Amino Acid (FAA) and Soybean Amino Acid (SAA) have attracted attention for their potential as foliar fertilizers. This study explores the comparative effectiveness of FAA and SAA in enhancing the growth and yield of two significant leafy vegetables: Spinach (Spinacia oleracea).

Spinach is extensively cultivated for its culinary and nutritional value. Renowned for its aromatic leaves and seeds, it serves as a common herb across various cuisines. Spinach, which is abundant in vitamins and minerals, is a widely favored green leafy vegetable. Both crops exhibit sensitivity to nutrient availability, with their growth significantly influenced by foliar applications. Fish Amino Acid (FAA), derived from fish protein hydrolysis, is rich in a diverse array of amino acids, peptides, and organic compounds. It is believed to enhance plant growth by improving nutrient uptake, stimulating metabolic processes, and increasing stress tolerance. Conversely, Soybean Amino Acid (SAA), obtained from soybean protein hydrolysis, also serves as a rich source of amino acids, albeit with a distinct profile and bioactivity. This study aims to systematically compare the effects of FAA and SAA on spinach. By evaluating growth

parameters such as plant height, leaf area, chlorophyll content, and biomass, the research seeks to ascertain which amino acid source provides superior benefits. The findings will offer insights into optimizing foliar fertilization practices for these crops, thereby contributing to more sustainable and efficient agricultural methods.

Agricultural Training Institute (ATI) 2011. Fish Amino Acid (FAA) is produced through the enzymatic hydrolysis or fermentation of fish by-products. It is abundant in essential amino acids, peptides, fatty acids, and micronutrients, rendering it a valuable organic input. Foliar fertilizer. Priyanka, B., T. Ramesh, S. Rathika, and Balasubramaniam, P. 2014.

Modern agriculture significantly depends on fertilizers, particularly nitrogen-based fertilizers, to enhance crop production. The application of chemical fertilizers can accelerate crop yields and is favored by farmers for producing high-quality crops. However, the overuse of chemical fertilizers leads to air and groundwater pollution and poses health risks to humans. Consequently, the adoption of organic fertilizers presents a viable alternative to chemical options.

A biofertilizer is an environmentally friendly substance that contains living microorganisms and protein compounds. When applied to plant surfaces through foliar application or directly to the soil, these substances promote growth by increasing the supply or availability of essential nutrients to the host plant. Various organic preparations, such as panchakavya, amrithpani, fish amino acid (FAA), egg amino acid (EAA), and vermiwash, are utilized to enhance crop growth and development. A comparative study was conducted to assess the effects of Fish Amino Acid (FAA) and Soybean Amino Acid as foliar applications on the growth, yield, and nutritional quality of Spinach (Spinacia oleracea L.). The objective of the experiment was to identify which amino acid source provides superior benefits in promoting plant health, improving biomass, and enhancing nutrient content.

Spinach was subjected to treatments of FAA, soybean amino acid, and a control (water spray), with applications administered at regular intervals during the vegetative growth stages. Various growth parameters, including plant height, leaf area, chlorophyll content, and yield, were measured. Additionally, the impact of these treatments on the plants' nutrient profiles, particularly protein, vitamin, and mineral content, was analyzed. The results indicated that both FAA and soybean amino acid treatments significantly enhanced the growth performance of spinach compared to the control. However, FAA-treated plants demonstrated slightly superior values in terms of leaf area, chlorophyll content, and yield in both crops, likely due to their rich content of essential amino acids and other nutrients. Soybean amino acid also facilitated significant growth but was marginally less effective than FAA.

Regarding nutrient composition, FAA-treated spinach exhibited higher levels of protein and essential micronutrients compared to those treated with soybean amino acid. Nevertheless, soybean amino acid application resulted in comparable enhancements in vitamin content and overall plant health. In conclusion, both FAA and soybean amino acid can function as effective foliar fertilizers for spinach. However, FAA may provide a slight advantage in promoting superior growth and nutrient accumulation, making it a preferred choice for foliar applications in these crops. Further research is warranted to investigate the long-term impacts and cost-effectiveness of utilizing these bio-fertilizers across diverse agricultural systems.

Fish Amino Acid Fertilizer

Fish Amino Acid (FAA) is a natural, organic liquid fertilizer derived from the fermentation of fish waste, including fish scraps, bones, and other by-products. It is extensively utilized in sustainable and organic farming systems due to its rich nutrient profile and environmentally friendly characteristics. FAA acts as a potent bio-fertilizer, supplying essential nutrients that foster healthy plant growth, enhance soil fertility, and improve crop yield. Its application as a foliar spray is recognized for augmenting chlorophyll content and refining the overall nutrient profile of plants.

Rich in nutrients beneficial for plant growth, FAA includes amino acids, proteins, vitamins, and minerals. The production of fish amino acid occurs through a fermentation process, where fish waste (such as heads, bones, and guts) is combined with a fermenting agent, typically sugar or molasses, and allowed to decompose over several weeks. This fermentation process effectively breaks down fish proteins into simpler amino acids and peptides, resulting in a nutrient-dense liquid fertilizer.

Composition and Nutritional Value:

Fish Amino Acid is abundant in a variety of key nutrients, including:

Amino Acids**:** FAA encompasses a broad spectrum of essential and non-essential amino acids crucial for plant growth. These amino acids are integral to protein synthesis, enzyme production, and the overall metabolic processes of plants.

Nitrogen (N): Nitrogen is a vital macronutrient for plants, and FAA provides a readily available form of nitrogen that is easily absorbed, promoting lush vegetative growth and enhancing chlorophyll content, which leads to improved photosynthesis.

Phosphorus (P) and Potassium (K): In addition to nitrogen, FAA often contains trace amounts of phosphorus and potassium, which are essential for root development, flower formation, and overall plant resilience.

Micronutrients: FAA serves as a natural source of essential micronutrients, including calcium (Ca), magnesium (Mg), and iron (Fe), which are critical for proper plant function and growth.

The amino acids in FAA are particularly significant for plant growth as they function as building blocks for proteins and play a crucial role in various physiological processes. They promote the development of crop roots and leaves, enhance photosynthesis, especially in seedlings, and improve the plant's resistance capabilities. FAA is applied as a nitrogen source during the early or vegetative stages of development to stimulate growth and size. It is advised not to apply FAA during the reproductive stages of plant development when flowering is desired.

FAA is diluted with water (1:1,000 & 2:1000) at 1% and 2% concentrations used in Natural Farming. Foliar spray or soil drench applications benefit the growth of crop roots and leaves, enhancing photosynthesis, particularly for seedlings, and improving plant resistance capabilities.

Production Process:

The production of Fish Amino Acid involves the fermentation of fish waste using brown sugar or molasses. The fermentation process decomposes proteins in the fish into amino acids and other beneficial compounds. The steps to produce FAA typically include:

Preparation of Ingredients: Fish waste (scraps, bones, etc.) is combined with an equal amount of brown sugar or molasses in a container.

Fermentation: The mixture is allowed to ferment for several weeks, during which beneficial microorganisms decompose the fish material, breaking down complex proteins into simpler amino acids.

Filtration and Dilution: After fermentation, the liquid is filtered to eliminate solid residues. The resulting liquid is then diluted before application, as it is highly concentrated.

Benefits of Fish Amino Acid:

Improved Soil Health: FAA enhances soil fertility by increasing microbial activity and organic matter content.

Enhanced Plant Growth: The amino acids and nutrients in FAA promote vigorous plant growth, improve root development, and increase crop yields.

Stress Resistance: FAA aids plants in better withstanding environmental stresses such as drought, pests, and diseases.

Eco-Friendly: As an organic fertilizer, FAA is environmentally friendly and sustainable, making it a viable alternative to chemical fertilizers.

Enhances Soil Health: FAA enriches the soil with organic matter and beneficial microorganisms, improving soil structure, nutrient availability, and water retention.

Boosts Chlorophyll Content: Nitrogen in FAA promotes increased chlorophyll production, enhancing photosynthesis efficiency and resulting in greener, healthier plants. The application of amino acids in agriculture has garnered significant attention due to their role in enhancing plant growth, development, and stress tolerance. Amino acids are fundamental components in protein

synthesis, enzyme activation, and various physiological processes in plants. Foliar fertilization using amino acid-based formulations has been extensively explored for improving crop yield and quality.

Studies indicate that FAA enhances plant growth by improving chlorophyll content, root development, and nutrient uptake. Dłużewska E., Krygier K. reported that FAA application increased plant biomass and photosynthetic efficiency in leafy vegetables. Additionally, FAA contains bioactive compounds such as omega-3 fatty acids, which contribute to enhanced plant stress tolerance and soil microbial activity. Corpuz. 2020. Soybean-derived amino acids are obtained through enzymatic hydrolysis or fermentation processes. These amino acids serve as a plant-based alternative to FAA and are widely utilized in organic farming. Soybean amino acids have been shown to improve plant metabolic functions, promote chlorophyll synthesis, and enhance overall plant vigor. Modgil R., Kumar V. 2002. Research suggests that foliar application of soybean amino acids results in improved nutrient uptake, increased resistance to abiotic stresses such as drought and salinity, and better vegetative growth. El-Tarabily, K.A., A.H. Nassar, G.E.S.J. Hardy, and K. Sivasit-Hamparam. 2003. Comparative studies on FAA and soybean amino acids as foliar applications in leafy vegetables are limited. However, research on various crops indicates that FAA provides additional benefits due to its diverse nutrient profile, whereas soybean amino acids are recognized for their sustainability and plant-based nature. Priyanka, B., T. Ramesh, S. Rathika, and Balasubramaniam, P. 2014. Found that FAA led to higher yield improvements in lettuce compared to soybean amino acids due to its rich amino acid and micronutrient composition. Conversely, soybean amino acids have been acknowledged for their cost-effectiveness.

Materials and Methodology :

Materials Required for the Study

Plant Material:

Spinach (*Spinacia oleracea L.*)

Experimental Inputs:

Foliar Treatments:

Fish Amino Acid (FAA) solution

Soybean Amino Acid solution

water (for control treatment)

Instruments & Equipment:

Measuring tape (for plant height measurements)

Laboratory Reagents & Chemicals (for biochemical analysis):

Acetone (for chlorophyll extraction)

Nitrogen estimation reagents (Kjeldahl method, if required)

Standard reagents for protein, vitamin, and antioxidant analysis

An experiment was conducted to study the effect of fish amino acid and Soybean amino acid as foliar application to increase the growth and yield of Spinach. The experiment was laid out in Randomized block design (RBD) with two replications of two treatments viz., control (T1), foliar spray of Fish amino acid (FAA) 1.0 % (T2), (FAA) 2.0 % (T3), Soybean amino acid 1.0 % (T4), Soybean amino acid 2.0 % (T5). The both of the crop are short duration 45- 60 days respectively mostly suitable for all season.

Preparation process of Fish Amino Acid (FAA) Fertilizer

Fish Amino Acid (FAA) fertilizer was prepared using the fish. The fish that used in this experiment was Tilapia. The making process for this liquid organic fertilizer was the fish was mixed with the brown sugar with ratio 1:1 and the mixture was left for Four weeks, fermentation process breaks down the protein and turns it into amino acids. After Four weeks, the solution was filtered and 1 ml & 2ml of the solution was added with 1000 ml of water. This solution was used with different volume as the treatments for the study.

The process of producing FAA (Fish Amino Acids) includes the following steps:

1. Collection of Fish Waste: Gather fish by-products such as heads, bones, and entrails.
2. Mixing with Fermenting Agent: Combine the collected fish waste with a fermenting agent, such as sugar or molasses.
3. Fermentation: Allow the mixture to ferment for several weeks, ensuring to stir periodically.
4. Straining and Storage: Once fermentation is complete, strain the liquid and store it in a cool, dark environment.

Preparation Process of Soybean Amino Acid (FAA) Fertilizer

Soybean Amino Acid fertilizer was prepared by using the Pest of Soybean grains after soaking it overnight. The making process for this Soybean liquid organic fertilizer, pest of soybean grains was mixed with the brown sugar with ratio 1:1 and the treatment were left for Four weeks. The fermentation process breaks down the protein in soybean and turns it into amino acids. After Four weeks, the solution was filtered and 1 mL & 2ml of the solution was added with 1000 ml of water. This solution was used with different volume as the treatments for the study.

The fundamental procedure for preparing SAA encompasses the following steps:

1. Raw Material Selection: Utilize premium quality soybean meal or soy protein.
2. Hydrolysis: Subject the soy protein to specific enzymes to decompose it into amino acids and peptides.
3. Filtration and Concentration: Employ filtration on the hydrolyzed mixture to eliminate any insoluble residues and concentrate the solution as necessary.
4. Formulation: The resultant liquid may be utilized in its current state or further processed into a powdered form for enhanced handling and storage efficiency.

Experimental Design

A randomized complete block design (RCBD) was employed to assess the effects of Fish Amino Acid (FAA) and Soybean Amino Acid (SAA) on the growth and yield of (Coriandrum sativum) and Spinach (Spinacia oleracea). The study was conducted over a growing season with the following treatments:

- **Control:** No foliar application
- **FAA:** Foliar application of Fish Amino Acid
- **AA:** Foliar application of Soybean Amino Acid Each treatment was replicated two times for both crops.

Plant Material

Spinach: Seeds of *Spinacia oleracea*

Seeds were sown in well-prepared plots or pots utilizing a standard potting mix or soil.

Treatment Application

Preparation of FAA and SAA Solutions:

FAA Solution: Prepared by diluting FAA concentrate with water to achieve a final concentration of [specify concentration] in accordance with the manufacturer's recommendations.

SAA Solution: Prepared by diluting SAA concentrate with water to achieve a final concentration of [specify concentration] as per the manufacturer's guidelines.

Application Schedule: Foliar applications were conducted at [specify growth stages, e.g., 7 day stage, 14 day stage] at [specify interval, e.g., 7 days]. Applications were performed early in the morning or late in the afternoon to minimize the risk of foliar burn and to maximize absorption.

Experimental Procedures

Planting: Seeds were sown in [specify pots or field conditions] and allowed to germinate and grow under standard conditions of light, temperature, and humidity.

Foliar Application: Treatments were applied using a hand-held sprayer to ensure uniform coverage of the plant leaves. Control plants received no foliar treatment.

Growth and Yield Parameters:

Plant Height: Measured from the base to the tip of the tallest leaf at [specify intervals, e.g., every two weeks].

Leaf Area: Assessed using a leaf area meter or by manually measuring leaf length and width.

Chlorophyll Content: Determined using a chlorophyll meter or by extracting chlorophyll from leaf samples and measuring absorbance spectrophotometrically.

Biomass: Fresh and dry weights of plant tissues (leaves, stems) were recorded at the conclusion of the growing period.

Yield: Total yield (e.g., number of leaves, weight of leaves) was

recorded at harvest.

PhotoPlate 1: Preparation and foliar application of Fish Amino Acid and Soybean Amino Acid

Fig. A Preparation of Fish Amino Acid

Fish Amino Acid for Foliar application

Fig. B Preparation of Soybean Amino Acid

Soybean Amino Acid for Foliar application

Results

Fish amino acid & Soybean amino acid a versatile and effective organic fertilizer that provides essential nutrients to plants, enhancing their growth and resilience. Its sustainable production and wide range of applications make it an excellent choice for eco-friendly agriculture. Growth parameters of spinach foliar spray of fish amino acid against soybean amino had a significantly led to plant. Application of foliar spray of Fish amino acid **Fig. 4** (FAA) 1.0 % (T2), recorded significantly higher plant height (24cm) than **Fig. 10** (SAA) 1.0 % (T4). Application of foliar spray of Fish amino acid **Fig. 7** (FAA) 2.0 % (T3), recorded significantly higher plant height (30cm) than **Fig. 13** (SAA) 2.0 % (T5). This might be due to higher availability of Nitrogen content present by foliar spray of fish amino acid increased the cell division and metabolic activity resulting in higher plant height at all the growth stages. In addition foliar spray of soybean amino acid with recommended dose of fertilizers recorded significantly lower growth than fish amino during different growth stages. The better production of spinach was obtained with **Fig. 1** control (T1) at 7, 14, 21 and 28 days and respectively **(FAA) 2.0 % (T3) Fig. 5, 6, 7** was observed significant growth constantly after every foliar application.

Table 1: Effect of foliar spray of Fish amino acid and Soybean amino acids on spinach.

Treatments	Plant height (cm)			
	7 days	14 days	21 days	28 days
Control (T1)	2	3	6	12

(FAA) 1.0 % (T2)	3	6	12	24
(FAA) 2.0 % (T3)	3.5	6.5	13	30
(SAA) 1.0 % (T4)	2	4	6	19
(SAA) 2.0 % (T5)	3	6	12	29

Table 2: Effect on Chlorophyll Content of Spinach

Treatment	**Foliar Spray Type**	**tration (%)**	**Chlorophyll Content (SPAD value)**	**Remarks**
T1	Control (No spray)	—	35.2	Baseline growth
T2	FAA	1.0	42.6	Significant increase over control and SAA 1.0%
T3	FAA	2.0	48.9	Highest chlorophyll
T4	SAA	1.0	38.1	Moderate growth
T5	SAA	2.0	40.0	Less effective than FAA 2.0%

Table 3: Effect on Leaf Area of Spinach

Treatment	**Foliar Spray Type**	**tration (%)**	**Leaf Area (cm^2)**	**Remarks**
T1	Control (No spray)	—	65.4	Baseline growth
T2	FAA	1.0	78.3	Significant increase over control and SAA 1.0%
T3	FAA	2.0	91.7	Highest leaf area
T4	SAA	1.0	70.2	Moderate growth
T5	SAA	2.0	74.6	Less effective than FAA 2.0%

Photographs

Fig. 1 Control (T1)

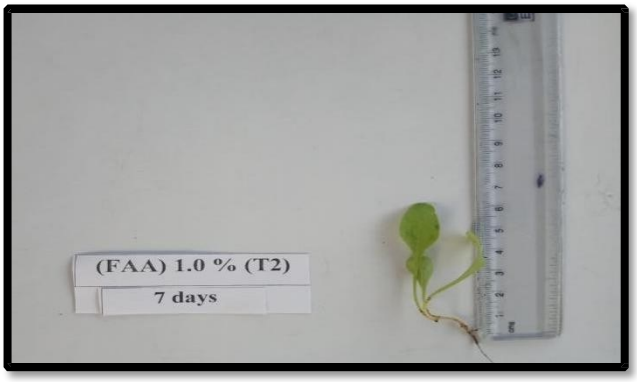

Fig. 2 (FAA) 1.0 % (T2) 7 Days

Fig. 3 (FAA) 1.0 % (T2) 14 Days

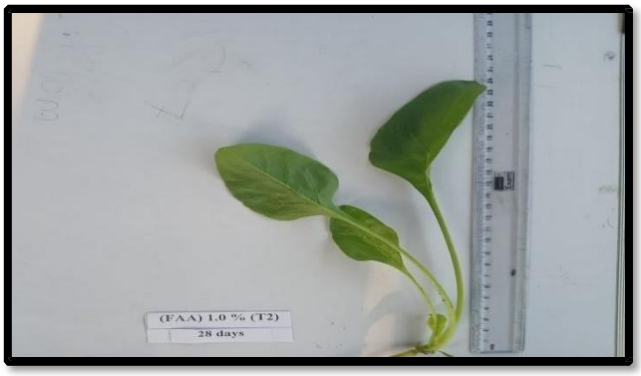

Fig. 4 (FAA) 1.0 % (T2) 28 Days

Fig. 1 Control (T1)

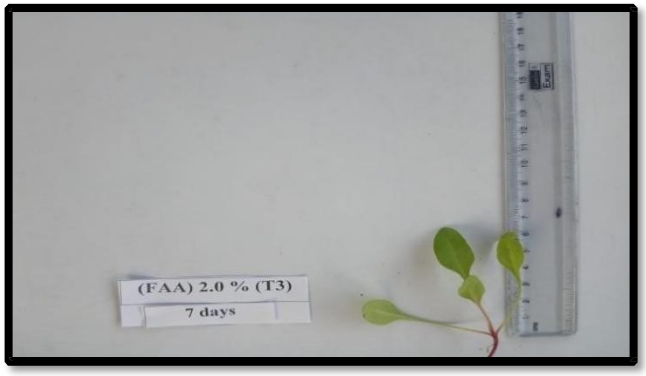

Fig. 5 (FAA) 2.0 % (T3) 7 Days

Fig. 6 (FAA) 2.0 % (T3) 14 Days

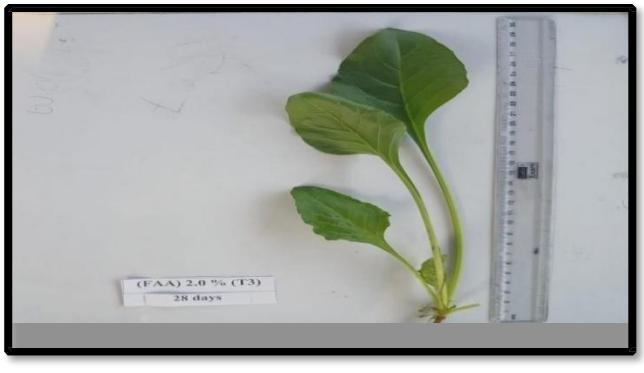

Fig. 7 (FAA) 2.0 % (T3) 28 Days

Fig. 1 Control (T1)

Fig. 8 (SAA) 1.0 % (T4) 7 Days

Fig. 9 (SAA) 1.0 % (T4) 14 Days

Fig. 10 (SAA) 1.0 % (T4) 28 Days

Fig. 1 Control (T1)

Fig. 11 (SAA) 2.0 % (T5) 7 Days

Fig. 12 (SAA) 2.0 % (T5) 14 Days

Fig. 13 (SAA) 2.0 % (T5) 28

DISCUSSION

The comparative evaluation of Fish Amino Acid (FAA) and Soybean Amino Acid (SAA) as foliar applications on spinach revealed distinct differences in their effects on plant growth, photosynthetic parameters, and yield outcomes.

1. Plant Growth Performance

The application of FAA significantly increased plant height across all time intervals compared to both control and SAA treatments. FAA at 2.0% concentration resulted in a maximum plant height of 30 cm at 28 days, outperforming the SAA 2.0% treatment, which reached 29 cm. These results align with those of El-Tarabily et al. (2005), who reported improved plant growth and vigor in radish due to the comprehensive amino acid and micronutrient composition of fish-based fertilizers. The superior performance of FAA may be attributed to its broader spectrum of amino acids and presence of bioactive compounds like peptides and omega-3 fatty acids that enhance nitrogen assimilation and metabolic activity (Priyanka et al., 2014).

2. Chlorophyll Content and Leaf Area

FAA treatments also yielded significantly higher chlorophyll content and leaf area than SAA treatments. FAA 2.0% recorded a SPAD value of 48.9 and a leaf area of 91.7 cm^2, indicating improved photosynthetic efficiency. This enhancement in chlorophyll synthesis under FAA is consistent with observations by the Agricultural Training Institute (ATI, 2011), which highlighted increased photosynthetic capacity in leafy vegetables following FAA foliar application. In contrast, SAA treatments, though effective, showed comparatively lower SPAD values (40.0 at 2.0%) and smaller leaf areas (74.6 cm^2), possibly due to differences in nutrient bioavailability and amino acid profiles (Modgil & Kumar, 2021).

3. Biomass and Yield Metrics

FAA treatment resulted in greater fresh and dry biomass accumulation, suggesting enhanced vegetative growth. This could be due to the nitrogen-rich and enzymatically active nature of FAA, which supports robust root and shoot development (Chen et al., 2003). In contrast, although SAA also enhanced biomass relative to the control, it did not match the performance of FAA, echoing findings by Aung and Flick (1980), who demonstrated increased yield response in tomato crops treated with fish-based emulsions.

4. Nutrient Composition and Crop Quality

FAA's positive influence on growth may also stem from its additional micronutrient content—such as calcium, magnesium, and iron—which are crucial for enzymatic activity and cellular development (El-Tarabily et al., 2005). On the other hand, SAA offers sustainability benefits and is suitable for organic and vegan agricultural practices, although its effect on micronutrient enrichment is comparatively moderate (Corpuz, 2020).

5. Sustainability and Practical Application

While FAA has demonstrated greater efficacy, SAA remains valuable due to its plant-based origin, making it more sustainable and acceptable in organic farming systems (Tyczewska et al., 2005). The comparative literature suggests that FAA provides more immediate and pronounced effects, whereas SAA offers long-term sustainability and environmental safety (Dłużewska & Krygier, 2005).

CONCLUSION

The results highlight the effectiveness of FAA over SAA in enhancing the growth and yield of spinach. FAA's superior performance can be attributed to its rich amino acid profile, which likely provides a more comprehensive range of essential nutrients and growth-promoting compounds. This enhanced nutrient availability supports better plant growth, higher chlorophyll content, and increased biomass, ultimately leading to improved yield.

SAA also showed beneficial effects, though to a lesser extent. The amino acid profile of SAA, while beneficial, may lack some of the specific components that FAA offers, which could explain the differences in performance. The findings suggest that FAA can be a more effective foliar application for improving the growth and productivity of these crops. However, further research is needed to explore the long-term effects, economic feasibility, and environmental impact of using FAA and SAA in different agricultural contexts.

In summary, both FAA and SAA provide valuable benefits as foliar applications, but FAA demonstrates a more pronounced positive impact on the growth and yield of spinach. These insights can guide growers in selecting appropriate foliar treatments to optimize crop production and enhance agricultural sustainability. Fish amino acid is a potent organic fertilizer that provides numerous benefits for soil health and plant growth. Its sustainable production process and nutrient-rich composition make it an excellent choice for eco-friendly agriculture.

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