

Foliar Amino Acids Promote Elongated, Well-Filled Fruits and High Yield in Hot Pepper (*Capsicum annuum* L. cv. Demir F1)

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Abstract: Free amino acids supplied through the leaves act as building blocks and signals: they cut the metabolic cost of protein synthesis and steer assimilates towards the fruits. A randomized complete block experiment with six replicates was conducted in the 2024–2025 season in the glasshouse of the Faculty of Agricultural Engineering, University of Idlib, to compare weekly foliar sprays of a free amino-acid concentrate (1 g L^{-1}) with a water control on hot pepper cv. Demir F1. Amino-acid-treated plants were taller (72.67 vs. 62.00 cm) and carried almost twice the leaf area of the control (28.64 vs. 15.63 cm^2). The treatment excelled in fruit size and shape: fruit length increased from 13.30 to 15.43 cm, volume from 5.85 to 8.75 cm^3 , diameter from 1.08 to 1.28 cm, peduncle length from 2.63 to 3.58 cm, and average fruit weight from 4.17 to 6.19 g. Yield responded strongly: fruit number rose from 16 to 30 per plant and total yield from 66.72 to 185.65 g plant^{-1} (+178%). The amino-acid programme produced the longest, most voluminous fruits of the trial while also supporting an exceptional fruit load. Foliar amino acids at this rate are recommended to improve both fruit morphology and overall productivity of greenhouse pepper.

Keywords: *Capsicum annuum*, amino acids, biostimulant, fruit length, fruit volume, yield, greenhouse, hot pepper.

1. Introduction

Free amino acids are much more than the bricks of proteins. In the plant they act as synthesis precursors, osmoregulators, stress protectants and signal molecules, and a foliar supply of ready-made amino acids saves the plant the energy it would otherwise spend building them from scratch [1],[2]. This saving can be redirected to growth and, above all, to the fruits.

Some amino acids have specific regulatory roles: tryptophan is the precursor of auxin, proline protects cells under stress, and glutamine feeds the nitrogen metabolism of growing organs [3],[4]. Applied on the leaf, amino acids are absorbed quickly and used where they are needed, which makes them a popular biostimulant in vegetable production [5]. On pepper, foliar amino acids have been shown to stimulate vegetative growth and productivity by improving photosynthesis and nutrient uptake [6],[7].

This study isolated the amino-acid effect under controlled greenhouse conditions: hot pepper cv. Demir F1 received weekly foliar amino acids (1 g L^{-1}) or plain water, and the differences in vegetative growth, fruit morphology and yield were measured directly.

a) Objectives of the study

1. To evaluate the effect of weekly foliar amino acids (1 g L^{-1}) on the vegetative growth of hot pepper cv. Demir F1;
2. To measure the response of fruit length, volume, diameter, peduncle and weight to amino acids;
3. To quantify changes in fruit number and total yield per plant.

2. Materials and Methods

a) Site and plant material

The work was done in the 2024–2025 season at the Faculty of Agricultural Engineering, University of Idlib. The house is a

gable glasshouse of 8 × 5 m with a 4 m ridge. It takes direct sun from mid-morning until the end of the day, keeps out wind, rain and insects, and takes the edge off the winter cold. Hot pepper cv. Demir F1 was grown throughout [8]. This is a Dutch hybrid. Its fruits are long and thin, they are strongly pungent, and they turn deep red at full maturity.

b) Experimental design and treatments

Seeds were sown in cork propagation trays filled with sphagnum peat. The trays were covered with black polyethylene for four days to bring the seed up faster, then watered every second day until the seedlings were ready to move. Seedlings of even size were picked and transplanted into 5.0-L plastic pots filled with clean growing medium. Each pot counted as one replicate and six pots made up a treatment, laid out in randomized complete blocks. With the control that comes to twelve plants. The spray was made up on the morning it was used, by dissolving 1 g of a free amino-acid concentrate in one litre of distilled water. Where yeast was involved, the suspension stood for an hour with the sugar so the cells woke up before it went on the plant. Control plants received distilled water and nothing else. Agral was added to every solution, the control included, so that the droplets would sit on the leaf instead of rolling off. Spraying was done early in the morning to the point of run-off, about one litre for six plants, and it was repeated every week for the length of the season [9].

One point should be stated plainly. The treatment reported in this paper was one of several foliar products grown side by side in the same glasshouse during the same season, against one shared water control. Each product raises a separate question and is reported separately. The consequence is that the control figures quoted here, and the description of the site and the design, are common to the companion papers from this trial.

c) Measured traits

Plant height was taken with a graduated ruler and the main branches were counted by hand. Leaf area was computed in Image-J from five fully expanded leaves per replicate. The fruit measurements were made at harvest. Fruits were counted, then weighed on a balance reading to 0.001 g, from which mean fruit weight follows. Volume was read by displacement in a 500-mL graduated cylinder. Fruit length and peduncle length were measured against a ruler, and diameter with a digital vernier caliper. Yield per plant is the weight of all the fruit that plant carried.

d) Statistical analysis

Analysis of variance for the randomized complete block design was run in SigmaStat 10.0. Means were separated by Fisher's protected least significant difference at the 5% level, which is the usual threshold for field measurements of this kind.



(a) the gable glasshouse used for the trial



(b) seedlings raised in cork trays



(c) plants after transplanting into 5-L pots



(d) plants at the fruiting stage

Figure 1: The experimental site and the successive stages of the hot pepper crop (*Capsicum annuum* L. cv. Demir F1)



(a) plant height



(b) leaf area



(c) fruit length on millimetre paper



(d) fruit diameter with a vernier caliper

Figure 2: Measurement of the vegetative and fruit traits recorded in the trial

3. Results and Discussion

a) Vegetative growth

Table 1: Effect of Free amino acids foliar spray on the vegetative growth of hot pepper cv. Demir F1

Trait	Control	Free amino acids	Change (%)	LSD	Significance
Plant height (cm)	62.00 ± 1.09	72.67 ± 1.09	+17.2	3.11	Significant
Number of main branches/plant	4.00 ± 0.02	4.00 ± 0.02	+0.0	0.050	n.s.
Leaf area (cm ²)	15.63 ± 1.00	28.64 ± 1.00	+83.2	2.87	Significant

Vegetative growth: Free amino acids vs control

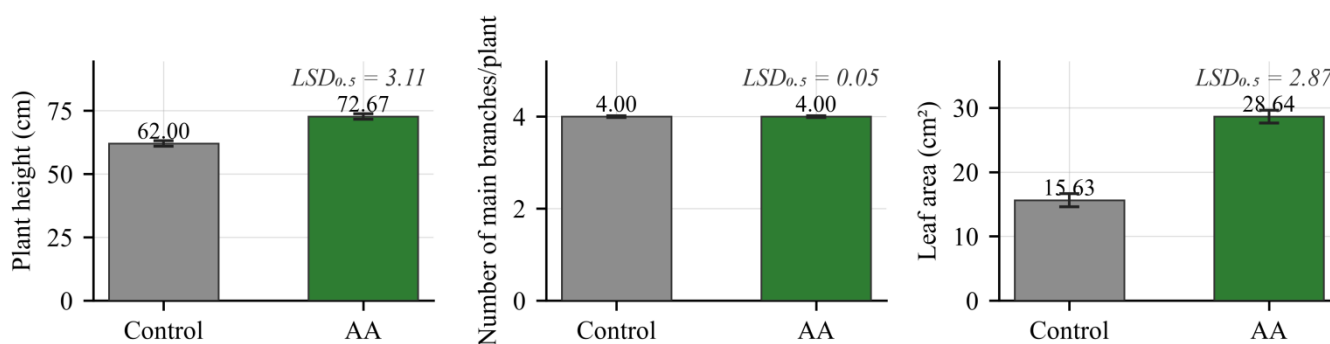


Figure 3: Effect of Free amino acids foliar spray on the vegetative growth of hot pepper

The amino-acid programme produced vigorous, balanced growth. Height rose from 62.00 to 72.67 cm and leaf area nearly doubled, from 15.63 to 28.64 cm², with branching unchanged at four (Fig. 2, Table 1). Because amino acids provide readily usable nitrogen and building blocks, the plant invests less energy in nitrogen assimilation and more in growth, exactly as described in the biostimulant literature [2],[5].

b) Fruit morphological traits

Table 2: Effect of Free amino acids foliar spray on the morphological traits of hot pepper fruits

Trait	Control	Free amino acids	Change (%)	LSD	Significance
Average fruit weight (g)	4.17 ± 0.05	6.19 ± 0.05	+48.4	0.15	Significant
Fruit volume (cm ³)	5.85 ± 0.10	8.75 ± 0.10	+49.6	0.30	Significant
Fruit length (cm)	13.30 ± 0.10	15.43 ± 0.10	+16.0	0.30	Significant
Fruit diameter (cm)	1.08 ± 0.02	1.28 ± 0.02	+18.5	0.050	Significant
Peduncle length (cm)	2.63 ± 0.03	3.58 ± 0.03	+36.1	0.10	Significant

Fruit morphology: Free amino acids vs control

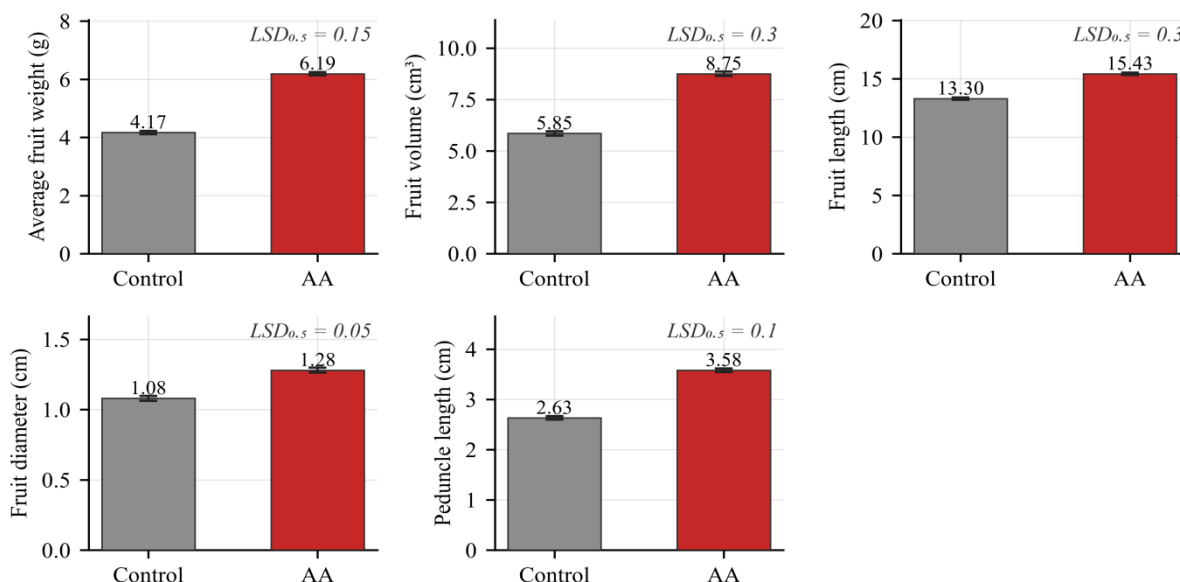


Figure 4: Effect of Free amino acids foliar spray on the morphology of hot pepper fruits

Fruit morphology was where amino acids truly shone. Fruits were longer (15.43 vs. 13.30 cm), wider (1.28 vs. 1.08 cm), heavier (6.19 vs. 4.17 g) and much more voluminous (8.75 vs. 5.85 cm³), with a longer peduncle (3.58 vs. 2.63 cm) (Table 2, Fig. 3). Amino acids stimulate cell division and expansion by feeding the protein machinery of growth and by boosting the synthesis of natural growth hormones, particularly auxin, which drives longitudinal cell elongation [6],[1]. The result was the longest, best-filled fruits of the entire study.

c) Yield components

Table 3: Effect of Free amino acids foliar spray on the yield components of hot pepper

Trait	Control	Free amino acids	Change (%)	LSD	Significance
Number of fruits/plant	16.00 ± 0.88	30.00 ± 0.88	+87.5	2.50	Significant
Total fruit yield/plant (g)	66.72 ± 2.10	185.65 ± 2.10	+178.3	6.00	Significant

Yield components: Free amino acids vs control

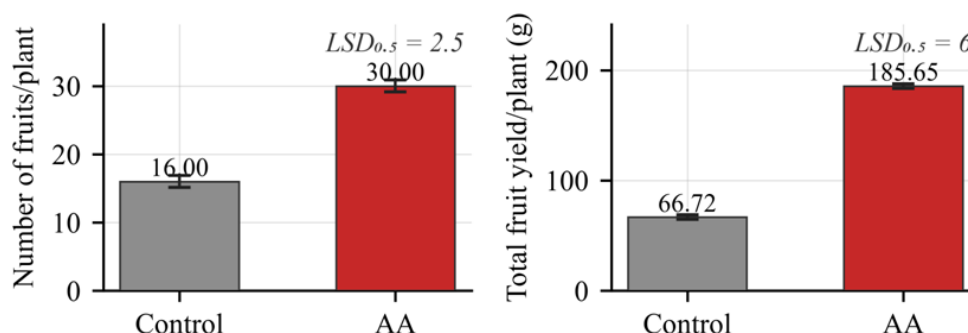


Figure 5: Effect of Free amino acids foliar spray on the yield components of hot pepper

The harvest kept pace with the fruit. Number rose from 16 to 30 per plant and yield from 66.72 to 185.65 g, up 178% (Table 3, Fig. 5). A plant that is handed its amino acids ready-made does not have to spend energy assimilating nitrogen and building them, and that saving went into carrying a heavy flower load and expanding each fruit at the same time [7],[2]. Those two things usually pull against each other. More fruits on a plant normally means smaller fruits, because they share one pool of carbon. Here both rose together, which suggests the treatment lifted the size of the pool rather than dividing it differently. Earlier work on foliar amino acids in pepper reports the same direction [6],[7].

4. Conclusion

Weekly foliar amino acids at 1 g L⁻¹ gave the best combination of fruit size and fruit load in this trial. Fruits reached 15.43 cm in length, 8.75 cm³ in volume and 6.19 g in weight, and yield came to 185.65 g per plant, 178% above the control.

Supplying the amino acids ready-made spares the plant the energy of building them, and the tryptophan among them feeds auxin production, which is what lengthened the fruit. The result is long, well-filled fruit of the shape the fresh market prefers, on plants carrying almost twice the normal load. For greenhouse pepper this is among the treatments most worth its cost.

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