# PRODUCTIVITY OF FERTIGATED CORIANDER AS A FUNCTION OF NITROGEN RATES AND BIOSTIMULANT APPLICATION

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**Thaíse Santos França[1], Fabio Vasconcelos Santos Luz[2], Lisley Pimentel Caetano[3], Lucilene Gomes Texeira[4], Evio Alves Galindo[5] and Antônio Lucrécio dos Santos Neto[6]**

## Abstract

Coriander (*Coriandrum sativum L.*) is widely used as a culinary seasoning and is an important income-generating crop, particularly for small-scale farmers. However, its cultivation requires appropriate management and the rational use of fertilizers, together with the adoption of technologies such as biofertilizers. Accordingly, this study evaluated the yield of coriander subjected to different nitrogen rates applied through fertigation and to foliar biofertilizers. The experiment was conducted under field conditions in the experimental area of the Federal University of Alagoas (UFAL), Arapiraca Campus, between August and October 2022. A randomized block design was used in a factorial arrangement with split plots, comprising four blocks and 16 treatments consisting of four nitrogen rates (0, 40, 80, and 120 kg ha$^{-1}$) and four biofertilizer treatments (control, Arbolin, Bioative, and Organo Top Grap). Six fertigation applications and three foliar applications were performed. The variables analyzed were chlorophyll B, yield per hectare, total fresh weight, root fresh weight, stem dry weight, root length, and

[1] Agronomist
Universidade Federal de Alagoas (UFAL) – Campus Arapiraca
E-mail: thaysefranca00@gmail.com
[2] Agronomist
Universidade Federal de Alagoas (UFAL) – Campus Arapiraca
E-mail: fluz59582@gmail.com
[3] Master's Student in Plant Production
Universidade Estadual do Norte Fluminense Darcy Ribeiro (UENF)
E-mail: eng.agronomalisleycaetano@gmail.com
[4] Undergraduate Student in Agronomic Engineering
Instituto Federal de Alagoas (IFAL) – Campus Piranhas
E-mail: lucileneleticia15@gmail.com
[5] Professor (IFAL)
Instituto Federal de Alagoas (IFAL) – Campus Piranhas
E-mail: evio.galindo@ifal.edu.br
[6] Professor (UFAL)
Universidade Federal de Alagoas (UFAL) – Campus Arapiraca
E-mail: lucrecio@arapiraca.ufal.br

number of plants per linear meter. The data were subjected to analysis of variance, with means compared using Tukey's test at the 5% significance level and regression analysis performed for the nitrogen rates. Chlorophyll B, total fresh weight, and stem dry weight reached their highest values at the nitrogen rate of 120 kg ha$^{-1}$. Maximum yield was obtained at a rate of 89.07 kg ha$^{-1}$, at approximately 17,000 kg ha$^{-1}$. The biofertilizers did not affect the agronomic characteristics evaluated.

***Keywords:*** *Coriandrum sativum* L., Fertigation, Leafy vegetable, Nitrogen fertilization.

## INTRODUCTION

Coriander (*Coriandrum sativum L.*) is an annual leafy vegetable belonging to the Apiaceae family (Msaada, 2007). It is adapted to warm-climate conditions and has low tolerance to cool temperatures. It is also highly tolerant of soil acidity and has relatively low fertility requirements, which facilitates its cultivation under different soil and climatic conditions (Oliveira, 2018).

In Brazil, coriander is grown predominantly by small- and medium-scale farmers, primarily for the production of fresh biomass, which is widely used as a seasoning in dishes, sauces, and salads. In addition to its culinary importance, the crop is notable for its medicinal properties, including anticancer, anti-inflammatory, antidiabetic, and analgesic effects attributed to the presence of phytochemical compounds such as polyphenols, vitamins, and phytosterols (Mahleyuddin et al., 2021).

Regarding its regional distribution, much of the coriander grown in Northeastern Brazil is cultivated in household gardens using family labor. In this context, the city of Arapiraca, formerly known for tobacco production, underwent a process of agricultural restructuring following the decline of that crop. Consequently, greenbelts gained prominence and stimulated vegetable production, with coriander emerging as a crop of considerable economic importance (Oliveira, 2018).

Given the crop's growing importance, appropriate management is essential, particularly concerning fertilization. The soil's natural fertility is not always sufficient to meet coriander's nutritional requirements, making supplemental nutrient application necessary. Among these nutrients, nitrogen (N) is one of the elements most required by leafy vegetables. It plays a fundamental role in plant growth and development and influences the source-sink relationship and the distribution of assimilates within the plant (Filgueira, 2008).

For this reason, nitrogen fertilization has been extensively studied in coriander because it promotes vegetative development and increases leaf biomass, directly contributing to higher yields and improved final product quality (Cerqueira et al., 2016; Pinto et al., 2018). Furthermore, strategies such as fertigation, particularly when combined with localized drip irrigation systems, contribute to more efficient nutrient use (Cunha et al., 2023). When coupled with appropriate cultivar selection and proper plant spatial arrangement, these practices enhance crop productivity (Martins et al., 2018).

Consistent with this approach, experimental studies have demonstrated coriander's positive response to nitrogen application. Silva (2022) observed linear increases in yield per square meter, number of bunches, and plant height as N rates increased from 30 to 60, 90, and 120 kg $ha^{-1}$. Similarly, Oliveira (2003) found a positive linear response in plant height and fresh biomass yield at N rates ranging from 0 to 80 kg $ha^{-1}$, with the highest values obtained at the highest rate.

In addition to mineral fertilization, other technologies have been incorporated into crop management to optimize production. These include biostimulants, substances capable of promoting plant development through different physiological mechanisms (Du Jardin, 2015). More recently, advances in nanotechnology have enabled the development of nanoparticle-based biostimulants that are more efficient than conventional formulations. These products may enhance nutrient uptake, improve plant tolerance to stress, and increase photosynthetic rates, resulting in greater growth and productivity (Lemos, 2021).

Therefore, considering the importance of nutrient management and the potential of emerging technologies, this study evaluated coriander yield as a function of different nitrogen rates associated with biostimulant sources.

## METHODOLOGY

### RESEARCH TYPE

This was a quantitative experimental field study conducted under actual cultivation conditions to evaluate the yield of coriander subjected to different nitrogen rates applied through fertigation in combination with foliar biostimulants. The study sought to identify the crop's agronomic response by comparing previously established treatments.

### STUDY SITE AND PERIOD

The experiment was conducted in the experimental area of the Federal University of Alagoas (UFAL), Arapiraca Campus, located in the Agreste region of Alagoas State (9°45′09″ S, 36°39′40″ W, at an elevation of 325 m), from August 31 to October 2, 2022.

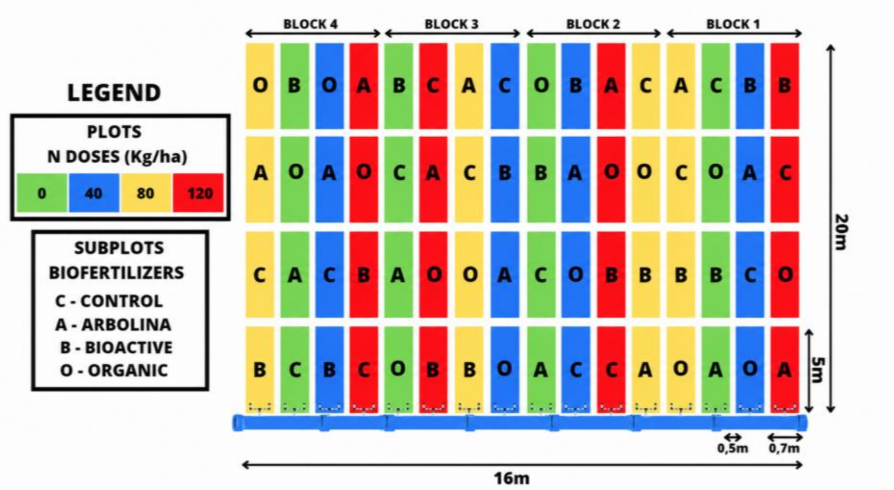
The soil in the region is classified as a nonsaline and nonsodic dystrophic Red-Yellow Latosol, with a medium-to-clayey texture and bulk density (Ds) of 1.48 g $cm^{-3}$. The local climate is classified as tropical "As," with a characteristically dry, hot summer season extending from September to March. December is the driest and hottest month of the year, with an average temperature of approximately 25 °C, although the location has a considerable temperature range. According to Xavier and Dornellas (2012), the region's rainy season generally extends from April to early August, with an average annual precipitation of approximately 854.27 mm $year^{-1}$.

### EXPERIMENTAL DESIGN

The experiment was established using a randomized block design (RBD) in a factorial split-plot arrangement with four blocks, distributed over an area of 320 m². It consisted of 16 beds measuring 0.7 × 5 m in width and length, respectively. Each bed represented one plot and was divided into four subplots. Each bed consisted of two sets of paired rows, totaling four plant rows. The spacing used was 10 cm between individual rows and 20 cm between paired rows (Figure 1). The usable area of each subplot consisted of the plants in the central paired rows, corresponding to 50 cm of each central individual row, with the plants at the ends excluded to avoid possible border effects.

**Figure 1**

*Layout of the experimental area.*




Source: Authors, 2023.

The treatments consisted of four nitrogen rates (0, 40, 80, and 120 kg ha$^{-1}$), using urea as the source and applying it as topdressing. According to the recommendation manual of the Agronomic Institute of Pernambuco (Instituto Agronômico de Pernambuco—IPA), the recommended N rate for the crop is 40 kg ha$^{-1}$. Three foliar biofertilizers, Arbolin, Bioative, and Organo Top Grap, as well as a control treatment, were also used, totaling 16 treatments.

EXPERIMENTAL TECHNIQUES AND PROCEDURES

The area was cleared and demarcated, after which the beds were prepared using string, wooden stakes, measuring tapes, hoes, and rakes.

Localized drip irrigation was used. The system consisted of an 18-m-long, 32-mm mainline supplying 16 lateral lines spaced 0.70 m apart. Each lateral line was subdivided into two 20-m-long drip tapes spaced 0.30 m apart, with 0.20 m between emitters and an average flow rate of 2.1 L h$^{-1}$. A distribution uniformity coefficient (DUC) test was performed, yielding a value of 92.27%, which was considered excellent. Irrigation was performed daily, and the net irrigation depth was determined according to crop evapotranspiration (ETc), calculated using Equation 1:

$$Etc = Eto \times Kc \quad (1)$$

Where:

ETc = crop evapotranspiration;

ETo = reference evapotranspiration;

Kc = crop coefficient.

Reference evapotranspiration was estimated using the Hargreaves-Samani method. A Kc value of 1 was used because no specific value had been established for coriander; therefore, the tabulated value for lettuce, another leafy vegetable, was adopted. The climatic data used to determine the daily net irrigation depth were obtained from a small weather station installed beside the experimental area.

Soil fertility in the experimental area was analyzed to guide the fertilization recommendation. The results are presented in Table 1.

**Table 1**

*Soil fertility analysis results for the experimental area, Arapiraca, Alagoas, 2023.*

| | Parameters | | | | | | |
|---|---|---|---|---|---|---|---|
| | pH | P | K | Sum of bases (SB) | H+Al | Cation-exchange capacity (CEC) | Base saturation (V) |
| | $H_2O$ | ppm | ppm | mmol/dm³ | meq/100mL | mmol/dm³ | % |
| **Results** | 6.7 | 53 | 167 | 4.75 | 1.87 | 4.87 | 73.6 |

Source: Authors, 2023.

Basal fertilization consisted of an N-P-K formulation in the proportions 20-00-20 plus 19% single superphosphate. Accordingly, 150 kg ha$^{-1}$ of urea, 150 kg ha$^{-1}$ of KCl, and 315.78 kg ha$^{-1}$ of single superphosphate were applied in accordance with the IPA fertilization recommendation for coriander. The fertilizer was manually distributed per linear meter of bed and then incorporated and mixed into the soil using rakes.

For sowing, two planting furrows 4 cm deep were opened 5 cm from each drip tape, totaling four furrows per bed and thereby forming paired rows. Seeds of the Verdão cultivar were manually distributed in the furrows. Planting density was determined according to the weight of the diachenes, corresponding to 1.5 g $m^{-1}$, which were distributed uniformly across the plots.

Nitrogen was applied as topdressing through fertigation, using urea containing 46% N and a Venturi injector. Applications began 12 days after sowing. For each application, the urea was dissolved in 5 L of water according to the following fertigation quantities: control, 0 kg $ha^{-1}$ N; 118.3 g, 40 kg $ha^{-1}$ N; 236 g, 80 kg $ha^{-1}$ N; and 355 g, 120 kg $ha^{-1}$ N. Six applications were performed during the crop cycle, with each quantity applied twice weekly until harvest at 32 days after sowing (DAS).

Foliar products were applied one day after the first weekly fertigation application. A manual sprayer with a flow rate of 2.67 mL $s^{-1}$ and a capacity of up to 12 L was used. However, only 2 L of spray solution was used to treat 80 $m^2$. The respective rate of each product was added separately in accordance with its label instructions, resulting in the following quantities per application: 0.82 mL of Arbolin, 2 mL of Bioative, and 4 mL of Organo Top Grap.

Weeds were controlled manually whenever necessary to prevent competition for water, light, and nutrients, which could impair the development of the main crop, coriander.

## DATA-COLLECTION TECHNIQUES AND INSTRUMENTS

The crop was harvested at 32 DAS, when the plants had visibly reached their maximum vegetative development and exhibited desirable commercial characteristics, such as appropriate height and intense color.

After harvesting, the plants selected for evaluation were placed in polyethylene trays and taken for agronomic assessment. Evaluations were performed immediately after harvest, always following chronological order within the blocks and plots. The variables evaluated were chlorophyll B (CLOB), yield per hectare (YIELDha), total fresh weight (TFW), root fresh weight (RFW), stem dry weight (SDW), root length (RL), and number of plants per linear meter (NPLANT). A precision balance accurate to 0.001 g was used for all variables requiring the weighing of fresh or dry matter.

The variables were measured as follows:

- CLOB: Measured using a ClorofiLOG electronic chlorophyll content meter. The mean was calculated from 20 measurements taken in each subplot.
- YIELDha: Estimated from the weight of all whole fresh plants, including leaves, roots, and stems, harvested from one linear meter.
- TFW: From all plants harvested within one linear meter, 20 plants were randomly selected and weighed fresh and whole, including leaves, stems, and roots, using a digital balance accurate to two decimal places.
- RFW: The roots of the 20 selected plants were detached and weighed fresh using a digital balance accurate to two decimal places.
- SDW: The stems of the 20 selected plants were separated from the leaflets and roots, weighed, oven-dried at 62 °C for 48 hours, and weighed again using a digital balance.
- RL: After the roots had been detached from the 20 selected plants, the length of each root was measured with a measuring tape positioned from the root tip to the root collar.
- NPLANT: All plants within the harvested linear meter were counted.

## STATISTICAL DATA ANALYSIS

The data were subjected to analysis of variance, and significance was assessed using the F-test. For significant variables, means were compared using Tukey's test at the 5% probability level, while the quantitative factor was subjected to regression analysis using Sisvar software.

During the preparation of this study, ChatGPT was used as an auxiliary tool to support the translation of passages and identify possible spelling errors. Its use was limited to linguistic matters and did not interfere with data analysis, interpretation of the results, or the study's conclusions. The authors assume full responsibility for all scientific content.

## RESULTS AND DISCUSSION

There was no significant interaction between nitrogen rates and foliar biofertilizers for the variables analyzed. Nitrogen rates had a significant effect at the 1% probability level on chlorophyll B, yield per hectare, and total fresh weight, and at the 5% level on stem dry weight. Root fresh weight, root length, and number of plants per linear meter did not differ significantly. The isolated application of foliar biofertilizers did not significantly affect any of the variables analyzed in the experiment (Table 2).

**Table 2**

*Analysis of variance for chlorophyll B (CLOB), yield per hectare (YIELDha⁻¹), total fresh weight (TFW), root fresh weight (RFW), stem dry weight (SDW), root length (RL), and number of plants per linear meter (NPLANT) in coriander grown under different nitrogen rates and foliar biofertilizer treatments.*

| **Source of variation** | **df** | **MS** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | CLOB | YIELDha⁻¹ | TFW | RFW | SDW | RL | NPLANT |
| Nitrogen (N) | 3 | 12,323$^{**}$ | 238686666,6$^{**}$ | 21,866** | 0,068$^{ns}$ | 0,02$^{*}$ | 4,622$^{ns}$ | 2014,43$^{ns}$ |
| Block | 3 | 0,018$^{ns}$ | 27866666,6$^{ns}$ | 2,233$^{ns}$ | 0,039$^{ns}$ | 0,002$^{ns}$ | 6,615$^{ns}$ | 912,68$^{ns}$ |
| Residual 1 | 9 | 0,28 | 10011111,1 | 2,541 | 0,021 | 0,004 | 1,363 | 1434,62 |
| Foliar biofertilizers (F) | 3 | 0,281$^{ns}$ | 7653333,3$^{ns}$ | 0,886$^{ns}$ | 0,004$^{ns}$ | 0,001$^{ns}$ | 1,644$^{ns}$ | 197,93$^{ns}$ |
| N x F | 9 | 0,193$^{ns}$ | 6722222,2$^{ns}$ | 0,268$^{ns}$ | 0,003$^{ns}$ | 0,0006$^{ns}$ | 0,698$^{ns}$ | 472,87$^{ns}$ |
| Residual 2 | 36 | 0,181 | 5837222,2 | 0,613 | 0,003 | 0,001 | 0,837 | 705,68 |
| CV 1 (%) | | 8,15 | 22,44 | 43,3 | 50,02 | 43,58 | 12,43 | 35,27 |
| CV 2 (%) | | 6,56 | 17,13 | 21,14 | 20,31 | 23,77 | 9,74 | 24,74 |

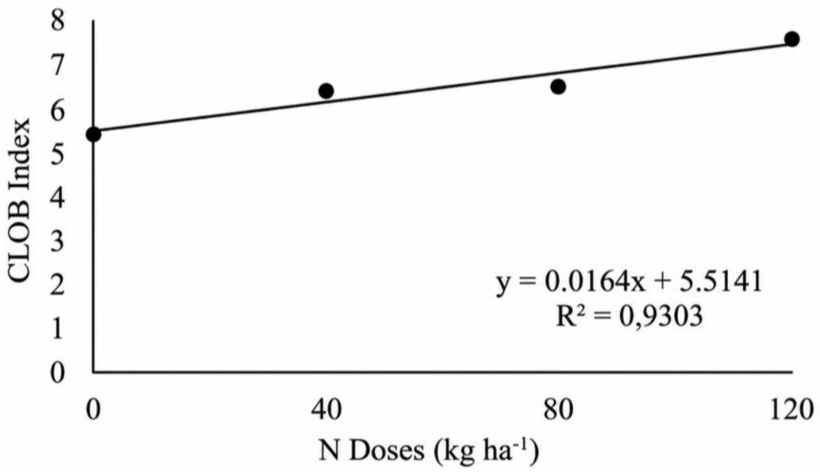
Note: ** Significant at 1%; * significant at 5%; ns, not significant. Source: Authors, 2023.

Chlorophyll B content increased as N rates increased. Consequently, chlorophyll B indices increased linearly up to the rate of 120 kg ha⁻¹ N (Figure 2). The index increased by 0.0163 for each kilogram of nitrogen added to the soil and reached 7.5 at the maximum application rate, representing an increase of 26.1% relative to the control treatment without topdressing, which had a value of 5.53.

The effect of nitrogen fertilization on chlorophyll content can be explained by the fact that, under soil N deficiency, plants degrade chlorophyll molecules to translocate N to areas of active growth (Furlani Júnior et al., 1996). Nitrogen is one of the elements used in chlorophyll synthesis. Chlorophyll content is positively correlated with plant N content and crop yield. This relationship is primarily attributed to the fact that 50% to 70% of total leaf N is found in enzymes associated with chloroplasts (Singh et al., 2010; Reinbothe et al., 2010).

**Figure 2**

*Chlorophyll B indices as a function of different nitrogen rates.*




Source: Authors, 2023.

In contrast to the present findings, Silva (2022), when evaluating coriander performance under different nitrogen rates, found no significant effect on chlorophyll content. That study evaluated total chlorophyll using a Delta Vista portable spectrophotometer, whereas the present study used the ClorofiLOG instrument, which can measure chlorophyll A and B contents separately.

According to Muhammad (2022), nitrogen is a structural component of the chlorophyll molecule. An adequate supply of this nutrient therefore significantly increases the crop's chlorophyll index, enhancing its photosynthetic capacity and, consequently, its productivity.

In support of the present findings, Palavicini et al. (2021) evaluated another leafy vegetable, lettuce, under different N rates of 0, 50, 100, 150, and 200 kg ha$^{-1}$, using urea as the source under greenhouse conditions. For the Mimosa cultivar, the authors observed an increase up to 150 kg ha$^{-1}$, at which total chlorophyll content reached approximately 16.3 and remained constant at higher rates.

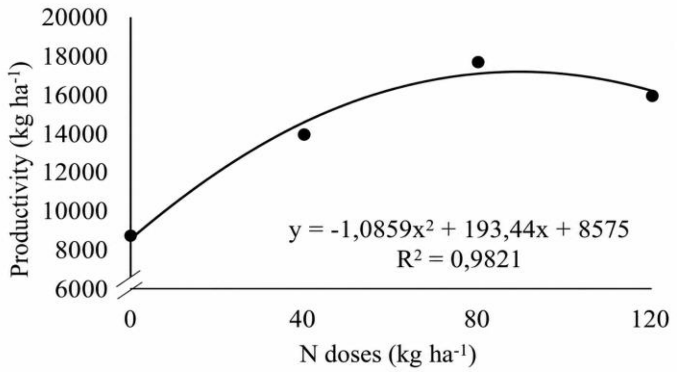
Silva (2016) also evaluated coriander under different N rates of 0, 60, 120, and 180 kg ha$^{-1}$, with and without thinning, and observed a linear response in the total chlorophyll index. The highest value, 34.4, occurred at the highest rate evaluated, 180 kg ha$^{-1}$, without thinning. This response was similar to that found in the present study.

Coriander yield per hectare was significantly affected by changes in N rates and exhibited a quadratic response. The highest yield, 17,189.75 kg ha$^{-1}$, or approximately 17 metric tons, was obtained with the application of 89.07 kg ha$^{-1}$ N. This indicates that higher rates do not produce additional yield gains, as demonstrated by the rate of 120 kg ha$^{-1}$ evaluated in this study, which produced a yield of 16,150.84 kg ha$^{-1}$. This represented a 1.72% decrease relative to the maximum point, corresponding to 33.59 kg ha$^{-1}$ of coriander for each kilogram of nitrogen applied to the soil (Figure 3).

Thus, coriander yield increased by 94.5 kg ha$^{-1}$ for each kilogram of N added to the soil until the rate of 89.07 kg ha$^{-1}$ was reached. This rate produced the maximum yield and represented a 49% increase compared with the control treatment without topdressing, which yielded 8,767.35 kg ha$^{-1}$.

**Figure 3**

*Coriander yield in kg ha$^{-1}$ as a function of different nitrogen rates.*




Source: Authors, 2023.

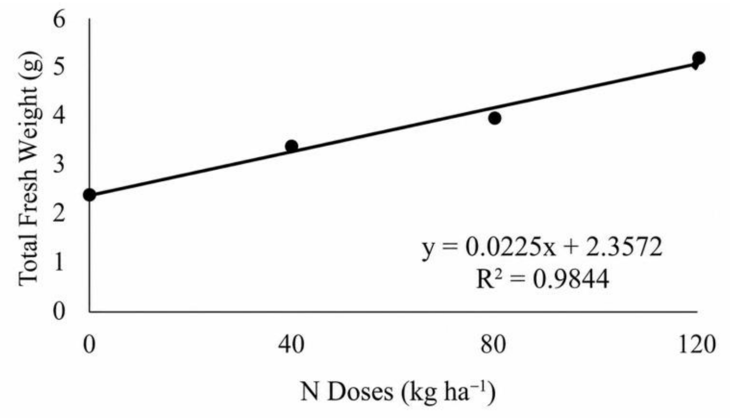
Oliveira et al. (2003), when evaluating coriander yield under increasing N rates, obtained a similar result. Coriander showed its best response at 80 kg ha$^{-1}$, with a yield of approximately 40,500 kg ha$^{-1}$, which exceeded the yield obtained in the present study. However, 80 kg ha$^{-1}$ was the highest rate evaluated by Oliveira et al. (2003); single rows were used, the spacing was wider at 0.25 m between furrows, and cattle manure was the nitrogen source.

Alves et al. (2020) obtained a contrasting result when evaluating different N rates of 0, 75, 150, 225, and 300 kg ha$^{-1}$ and two N sources, urea and ammonium sulfate, in coriander cultivation. With urea as the source, the maximum response occurred at 166 kg ha$^{-1}$ N, producing a fresh biomass yield of 9,800 kg ha$^{-1}$ with 0.25 m between furrows.

Total fresh weight increased as N rates rose. The values therefore increased linearly up to 120 kg ha$^{-1}$ N, the highest rate evaluated, a response that differed from that of the preceding variable. Fresh weight increased by 0.0223 g for each kilogram of nitrogen added to the soil and reached 5.06 g at the highest rate. This represented a 53% increase compared with the control treatment without topdressing and indicates that rates higher than those evaluated in this study might produce even greater fresh-weight values (Figure 4).

**Figure 4**

*Total fresh weight per plant as a function of different nitrogen rates.*




Source: Authors, 2023.

In support of this result, Santos (2021) also found a linear increase in total fresh weight as the nitrogen rate increased. At 120 kg $ha^{-1}$, total fresh weight reached 2.53 g per plant, representing a 28% increase over the lowest value of 1.81 g per plant. In that study, however, the lowest nitrogen rate evaluated was 30 kg $ha^{-1}$.

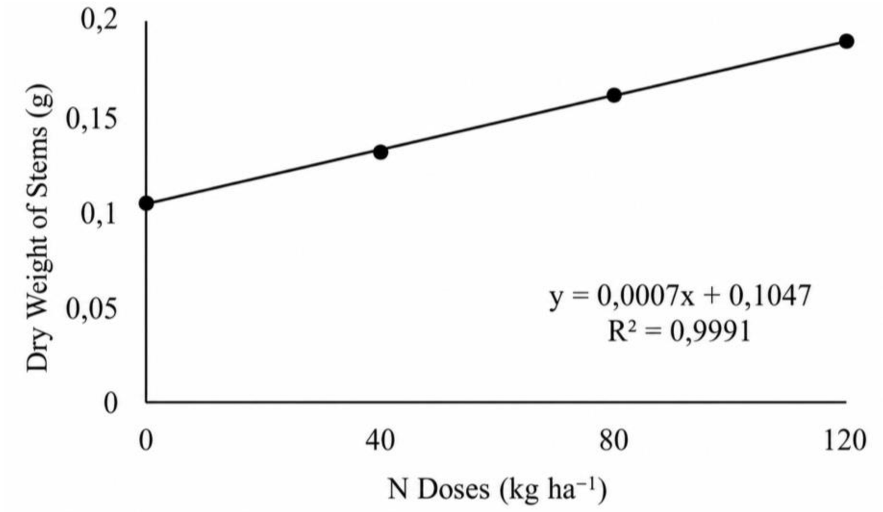
Alves et al. (2020) stated that nitrogen alters the source-sink relationship in plants. In other words, it influences crop growth and development processes and thereby favors the distribution of assimilates between vegetative and reproductive organs. In coriander specifically, nitrogen fertilization has a direct positive effect on leaf volume. Yield potential therefore increases, improving product quality, adding value, and raising the market price.

Silva (2016), when evaluating coriander productivity under N rates of 0, 60, 120, and 180 kg $ha^{-1}$, with and without thinning, observed that the treatment without thinning and with an optimal N rate of 69.5 kg $ha^{-1}$ produced a maximum fresh biomass weight of 800 g within the usable experimental area.

Like the preceding variable, stem dry weight increased as N rates rose. Its values increased linearly up to 120 kg $ha^{-1}$ N, the highest rate evaluated. Stem dry weight increased by 0.00067 g for each kilogram of nitrogen added to the soil and reached 0.19 g at the highest rate. This represented a 42.2% increase compared with the control treatment without topdressing, which produced 0.11 g, indicating that rates higher than those evaluated in this study might produce even higher stem dry-weight values (Figure 5).

**Figure 5**

*Stem dry weight per coriander plant as a function of different nitrogen rates.*




Source: Authors, 2023.

Silva (2016) also observed a linear response in stem dry weight when evaluating coriander under N rates of 0, 60, 120, and 180 kg ha$^{-1}$, with and without thinning. At the highest rate analyzed, 180 kg ha$^{-1}$ N, the maximum observed value was 9.22 g for 20 plants.

Ferro (2016), when evaluating coriander under different nitrogen fertilization and seeding levels, found the highest stem dry-weight value, 6.6541 g, at the highest fertilizer rate evaluated, 80 kg ha$^{-1}$, using urea as the N source. This finding supports the results obtained in the present study. Coriander remains severely underexplored in scientific studies and research, making comparisons with a larger body of data difficult.

## CONCLUSION

Nitrogen fertilization increases coriander yield. For chlorophyll B, total fresh weight, and stem dry weight, the best-performing N rate was 120 kg ha$^{-1}$. A topdressing rate of 89.07 kg ha$^{-1}$ N is the most strongly recommended rate for fertigated coriander because it produces a satisfactory increase in yield per hectare. The use of biostimulants did not affect the agronomic characteristics studied under the soil and climatic conditions in which the experiment was conducted. The results therefore contribute to nitrogen fertilization management in fertigated coriander by providing information that may support future management recommendations and further research on interactions between nitrogen rates and biostimulants.

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