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Research article

Increasing growth of monobulb garlic through the application of corona glow discharge plasma radiation and organic fertilizers

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Abstract: Monobulb garlic, distinguished by its elevated allic.in content, has garnered heightened consumer interest due to its perceived health benefits. However, the challenge lies in scaling up production to meet this demand. This study investigates the potential enhancement of monobulb garlic growth by employing a novel approach that combines corona glow discharge plasma radiation technology and organic fertilizers. By employing a factorial complete randomized design with nine treatments and three repetitions, the research evaluates the impact of varying durations of plasma radiation (0, 15, and 30 minutes) and levels of organic fertilizers (0, 31.25, and 62.5 grams). Key growth parameters, including plant height, leaf count, root length, and root quantity, were measured. Results indicate that the optimal combination for growth enhancement involves 30 minutes of radiation coupled with 31.25 grams of organic fertilization. In conclusion, the integration of corona glow discharge plasma radiation technology and organic fertilization proves effective in promoting the growth of monobulb garlic plants.

Keywords: allicin; corona glow discharge; organic fertilizers; root development; agricultural technology

1. Introduction

The utilization of medicinal plants has been deeply rooted in historical traditions, contributing not only to culinary practices but also to holistic well-being. Among these botanical treasures, garlic (*Allium sativum* L.) has garnered widespread attention for its multifaceted health benefits, spanning anti-atherosclerotic, antibacterial, anticarcinogenic, antidiabetic, antifungal, antihypertensive, and antioxidant properties [1]. As the global demand for medicinal plants escalates, understanding and enhancing the cultivation of valuable varieties such as garlic becomes paramount. The monobulb or single garlic stands out in Indonesia's diverse landscape of garlic. Distinguished by its capacity to produce a solitary clove under specific conditions [2], monobulb garlic boasts heightened allicin content—a compound renowned for its potent antimicrobial properties against bacteria, fungi, and viruses [3,4]. The significant elevation of allicin content in monobulb garlic, surpassing that of regular garlic, has spurred public interest in its consumption. However, despite the increasing demand, the production of monobulb garlic has not met market needs, presenting a unique challenge to the agricultural sector.

Allicin (diallylthiosulfinate) is a major compound in garlic, derived from the enzymatic conversion of the non-proteinogenic amino acid alliin (S-allyl cysteine sulfoxide) following tissue damage [5,6]. Monobulb garlic, with its superior allicin content, containing approximately 5 mg of allicin [7], has become a focal point for consumers seeking enhanced medicinal benefits. The growing demand for monobulb garlic, juxtaposed with its suboptimal production, is evident in Indonesia's reliance on garlic imports despite a reported production of 88,816 tons [8]. This paradox underscores the urgent need for innovative and efficient production methods to meet the escalating demand for garlic.

This study addresses this critical gap by exploring the application of corona glow discharge plasma radiation technology—an established growth catalyst in various crops [9]. Paired with this technological intervention is the judicious incorporation of organic fertilizers strategically chosen to fortify soil fertility and supply essential nutrients [10−12]. The amalgamation of these two approaches aims to unravel their synergistic impact on the growth of monobulb garlic, focusing on pivotal parameters such as plant height, leaf count, root length, and the abundance of roots.

The corona glow discharge plasma radiation technology, recognized for its ability to generate crucial nitrogen ions essential for plant growth, is examined in conjunction with organic fertilizers known for their contributions to soil fertility and nutrient supply. Our study endeavors to comprehensively analyze growth parameters, elucidating the synergistic impact of these combined treatments on monobulb garlic plants. By positioning this research at the forefront of agricultural innovation, the integration of plasma technology and organic fertilizers offers a transformative avenue for monobulb garlic cultivation [11,12].

The significance of plasma technology lies in its unique ability to introduce nitrogen ions crucial for plant growth, sourced directly from air infiltration—a process indispensable for forming new tissue [13]. Additionally, in alignment with Kakar et al.'s insights, organic matter emerges as a key player, enriching soil nutrition and serving as a pivotal plant growth regulator [14]. The primary objective of this investigation is to discern whether the synergistic augmentation of nitrogen elements, facilitated by the tandem use of corona glow discharge plasma radiation and organic fertilizers, translates into tangible improvements in crucial growth metrics for monobulb garlic plants. Against the backdrop of burgeoning global demand for medicinal plants, the investigation's outcomes hold the promise of revolutionizing monobulb garlic cultivation, addressing production challenges, and contributing to the sustainable supply of this invaluable botanical resource.

2. Materials and methods

2.1. Time and places of research

The study was conducted from December 27, 2018, to February 22, 2019, at the Center for Plasma Research Laboratory, BSF Plant Laboratory (Faculty of Science and Mathematics, University of Diponegoro), and an experimental garden in Kalisidi Village, Ungaran, Central Java (7°07'51.4"S, 110°22'04.4"E).

2.2. Materials and study design

Monobulb garlic seeds, soil, burned husks (1: 1 ratio), and cow dung organic fertilizer constituted the materials. Employing a factorial completely randomized design (FCRD) with nine treatments and three repetitions, the study assessed the impact of corona glow discharge plasma radiation durations (0, 15, and 30 minutes) and organic fertilizer dosages (0 g, 31.25 g, and 62.5 g).

2.3. Bulbs selection and bulbs irradiation

Selected disease-free bulbs underwent corona glow discharge plasma radiation using a device with a voltage of 14 kV and a current of 1 mA. Radiation durations varied (0, 15, and 30 minutes).

2.4. Planting medium

A planting medium comprising soil and burned husks (1: 1 ratio) was placed in polybags (20 x 15 cm) and supplemented with organic fertilizer doses (0, 31.25, and 62.5 g).

2.5. Planting

Sliced monobulb garlic bulbs were planted in polybags (approximately 15 cm depth) after being sliced to expedite sprouting.

2.6. Observation

Plant height and leaf count were observed one week post-planting (dap) and subsequently on a weekly basis. After 63 dap, the length and number of roots were also examined. The research encompassed nine treatments, consisting of a control group (R_0P_0) without radiation and fertilization, plants not irradiated and provided with 31.25 g of organic fertilizers (R_0P_1), plants not irradiated and given 62.5 g of organic fertilizers (R_0P_2), plants irradiated for 15 minutes without fertilization (R_1P_0), plants irradiated for 15 minutes and given 31.25 g of organic fertilizers (R_1P_1), plants irradiated for 15 minutes and given 62.5 g of organic fertilizers (P_2R_1), plants irradiated for 30 minutes without fertilization (R_2P_0), plants irradiated for 30 minutes and given 31.25 g of organic fertilizers (R_2P_1), and plants irradiated for 30 minutes and given 62.5 g of organic fertilizers (P_2R_2). Measurements of plant height were taken from the ground to the highest leaf tip using a ruler, while root length was determined from the end of the longest root, also utilizing a ruler. The duration of radiation was determined based on prior research [15], and the methodology for parameter measurement was adapted from the study conducted by Yani et al. [16].

2.7. Analysis statistics

Data underwent ANOVA (Analysis of Variance) at a 95% significance level, with DMRT (Duncan's Multiple Range Test) for further analysis.

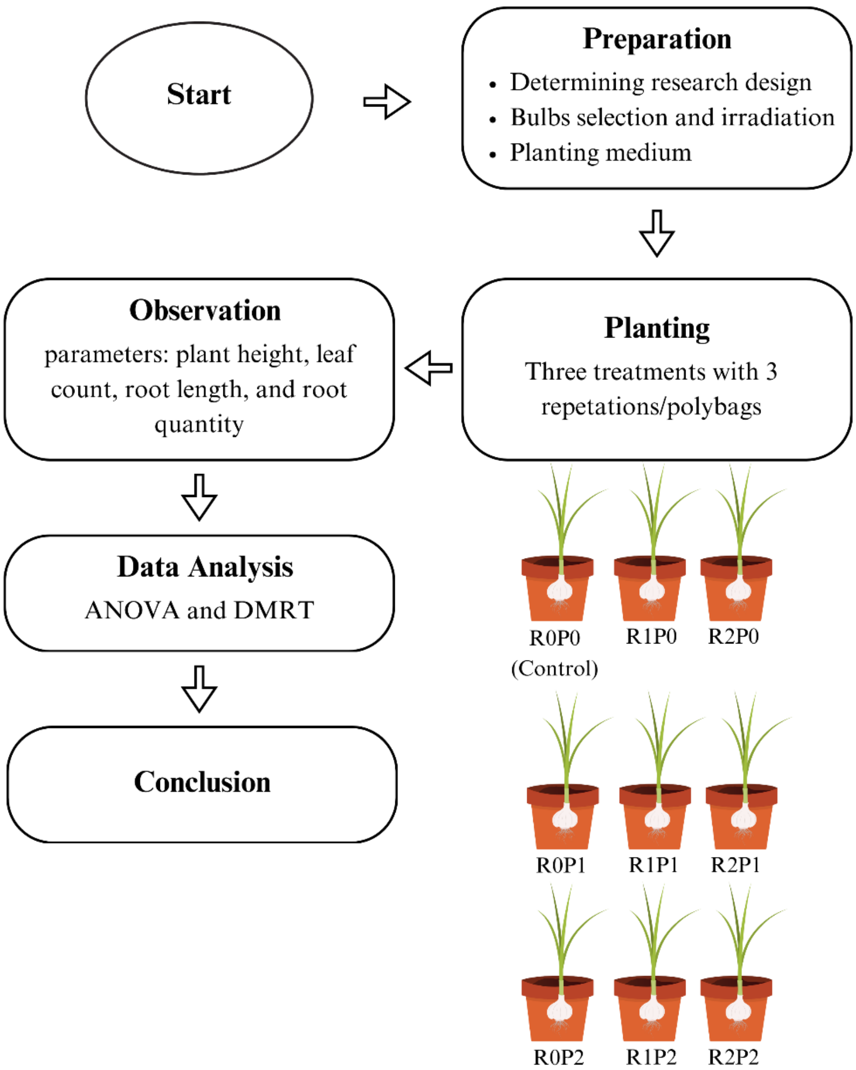

Figure 1. Experimental plan.

3. Results

Results are depicted in Figures 2 and 3, showing the visual impact of different treatments on monobulb garlic plants.

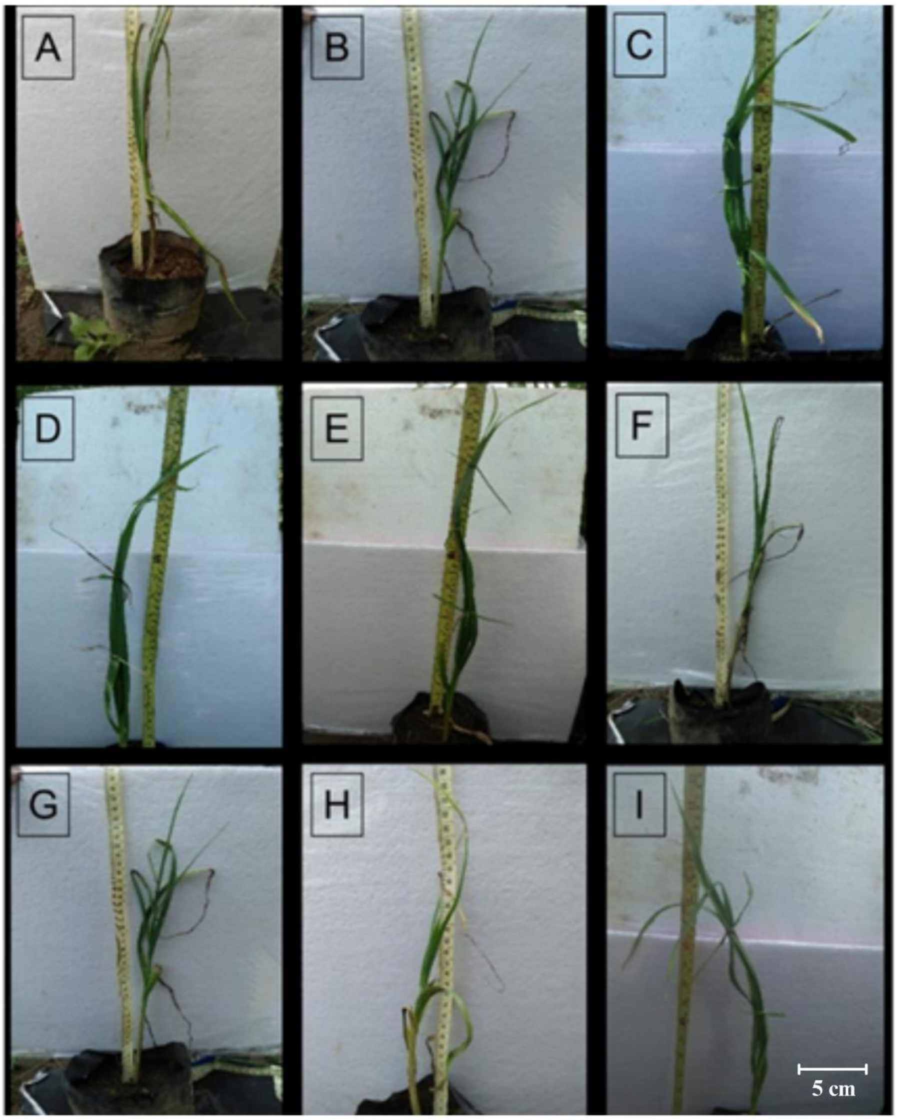

Figure 2. Different treatments of monobulb garlic plants on plant height. (A) P_0R_0, (B) P_0R_1, (C) P_0R_2, (D) P_1R_0, (E) P_1R_1, (F) P_1R_2, (G) P_2R_0, (H) P_2R_1, (I) P_2R_2.

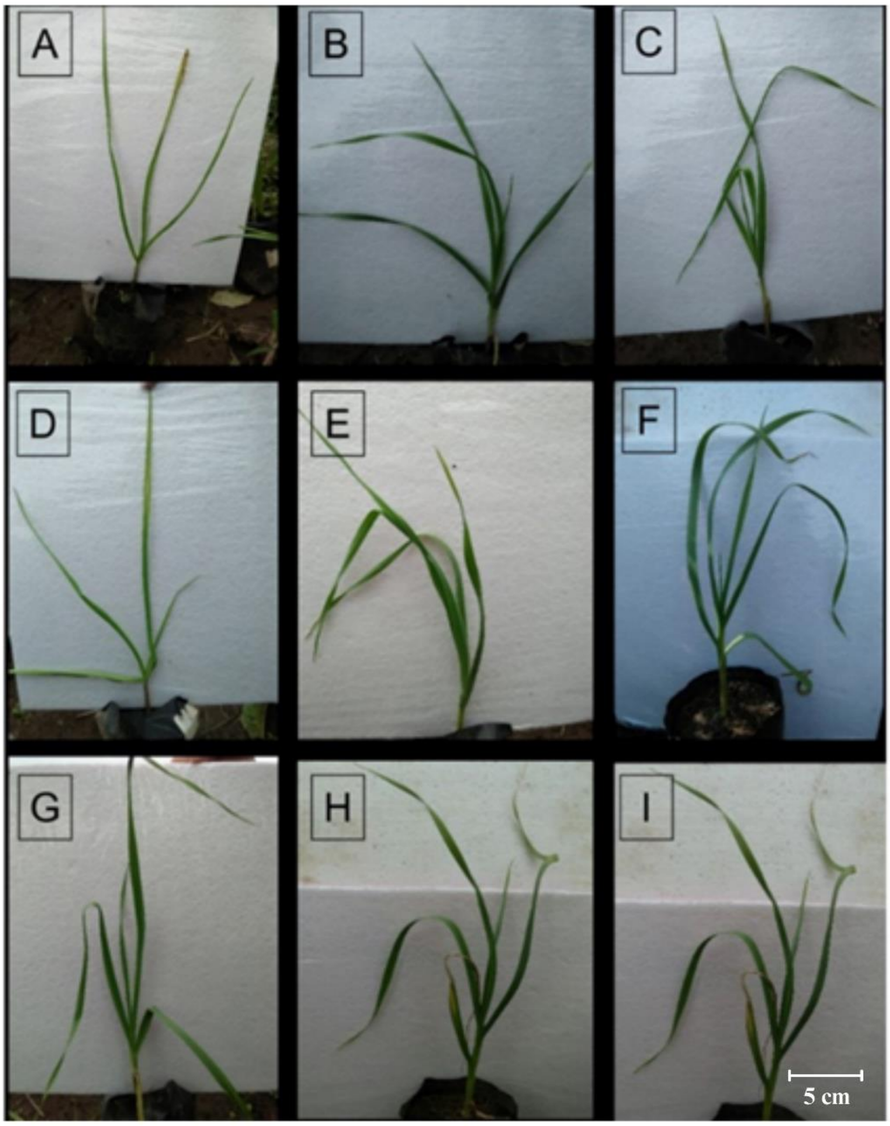

Figure 3. Different treatments of monobulb garlic plants on leaf count (A) P_0R_0, (B) P_0R_1, (C) P_0R_2, (D) P_1R_0, (E) P_1R_1, (F) P_1R_2, (G) P_2R_0, (H) P_2R_1, (I) P_2R_2.

3.1. Height of plants

Table 1. Height of plants (cm).

Fertilization (P)	**Plasma Radiation (R)**			**Average**
	R_0	**R_1**	**R_2**	
P_0	32.47	36.44	35.09	34.66^b
P_1	31.49	33.80	35.47	33.58^{ab}
P_2	36.30	35.14	37.01	36.15^a
Average	33.42^b	35.12^a	35.85^a	(-)

Notes: The numbers in the row and column followed by the same letter showed no difference at the significant level (α) of 5% according to the DMRT test. (-) = There was no interaction between factors.

The interaction between plasma radiation and fertilization did not significantly affect plant height (Table 1). However, plasma radiation alone exhibited a significant impact, with 30 minutes of radiation yielding the highest plant height at 35.85 cm.

3.2. Number of leaves

The interaction between plasma radiation and fertilization did not affect the number of leaves (Table 2).

Table 2. Number of leaves (strands).

Fertilization (P)	Plasma Radiation (R)			Average
	R_0	R_1	R_2	
P_0	3.33	4.29	4.55	4.05^b
P_1	4.03	4.62	4.77	4.47^{ab}
P_2	4.29	4.55	4.55	4.46^a
Average	3.88^b	4.48^a	4.62^a	(−)

Notes: The numbers in the row and column followed by the same letter showed no difference at the significant level (α) of 5% according to the DMRT test. (−) = There was no interaction between factors.

3.3. Length of roots

The interaction between plasma radiation and fertilization significantly influenced the length of roots (Table 3). The optimum treatment was 30 minutes of radiation with 31.25 g fertilization (R_2P_1), resulting in a root length of 17.16 cm. Factors of plasma radiation and fertilization each significantly affected the length of roots. The longest length of roots was found in 30 min of radiation (R_2), which was 14.14 cm. Fertilization of 31.25 g (P_1) showed the highest length of roots of 14.58 cm.

Table 3. Length of roots (cm).

Fertilization (P)	Plasma Radiation (R)			Average
	R_0	R_1	R_2	
P_0	8.33^d	15.16^{ab}	10.53^{cd}	11.34^b
P_1	13.16^{bc}	13.43^{bc}	17.16^a	14.58^a
P_2	8.06^d	8.30^d	14.73^{ab}	10.36^b
Average	9.85^c	12.29^b	14.14^a	

Notes: The numbers in the row and column followed by the same letter showed no difference at the significant level (α) of 5% according to the DMRT test. (+) = There was an interaction between factors.

3.4. Number of roots

The interaction between plasma radiation and fertilization significantly impacted the number of roots. The most favorable combination was observed with 30 minutes of radiation and 31.25 g fertilization, producing 62.66 roots (Table 4).

Table 4. Number of roots (strands/clumps).

Fertilization (P)	Plasma Radiation (R)			Average
	R_0	R_1	R_2	
P_0	3.70^{d}	51.00^{c}	60.00^{ab}	49.33^{b}
P_1	57.66^{b}	49.66^{c}	62.66^{a}	56.66^{a}
P_2	49.66^{c}	49.00^{c}	46.66^{c}	48.44^{b}
Average	48.1^{b}	49.88^{b}	56.44^{a}	

Notes: The numbers in the row and column followed by the same letter showed no difference at the significant level (α) of 5% according to the DMRT test. (+) = There was an interaction between factors.

4. Discussion

The observed significant influence of nitrogen content on plant height corroborates the critical role of nitrogen in vegetative growth, encompassing cell division, elongation, and differentiation [17,18]. Consistent with existing literature, the positive correlation between plasma radiation duration and plant height emphasizes the growth-promoting effects of the corona glow discharge plasma system, generating nitrogen ions that aid bulb penetration [19]. Notably, organic fertilizers support essential nutrients, particularly amino acids and proteins, further enhancing garlic growth [20].

While the interaction between plasma radiation and fertilization did not yield a significant response in the number of leaves, the treatment with 30 minutes of radiation and 62.5 g fertilization (R2) resulted in the highest leaf count at 5 strands. Interestingly, the delayed positive effect of organic fertilizers on leaf development, attributed to their slow nutrient release, underscores the prioritization of root development before leaf expansion [21]. Cow manure application, known to provide nutrients for leaf formation, did not exhibit a similar effect in this study, possibly due to the gradual nutrient release pattern prioritizing root over leaf development [11−14,17−20].

The contribution of nitrogen in fertilizers to plant growth and development, as highlighted by Sitompul, Zulfati, Royani, and Prihastanti, involves its role in synthesizing amino acids and proteins and stimulating vegetative growth, mainly leaves [22−24]. The nitrogen element's stimulation of leaf formation and chlorophyll production are crucial factors, as an increase in chlorophyll positively correlates with carbohydrate formation and subsequent storage in garlic bulbs [23].

Root length, influenced by nitrogen from organic fertilizers and nitrogen ions produced by corona glow discharge plasma technology, reflects the plant's capacity to access deeper soil layers for nutrient absorption [25]. The facilitating effect of the combination treatment on soil penetration by roots enhances the plant's ability to extract essential nutrients, in line with the observations of Frona et al. [26]. The interaction that produced the highest number of roots was identified in the R2P1 treatment (30 min radiation and 31.25 g fertilization), underscoring the significance of both plasma radiation and fertilization. The highest number of roots was associated with 30 minutes of radiation (R2), emphasizing the positive impact of extended plasma exposure. The length of plant roots can indicate that the plant can meet the needs of nutrients and minerals in the soil [27]. Supplemented with 31.25 g fertilization (P1), this combination achieved the most robust root development, possibly due to the interplay of nitrogen from organic fertilizers and nitrogen ions produced by plasma radiation [28]. The successful absorption of nutrients by roots, indicated by an increased number of roots, aligns with studies highlighting the correlation between the number of roots and nutrient levels in the soil [29,30].

The length of the roots formed was caused by the presence of N provided by organic fertilizers and the presence of N ions produced by the corona glow discharge plasma technology. Root length describes the plant's ability to obtain water supply including nutrients in deeper soil layers [25]. The roots cannot penetrate the soil or hard planting media, so that this combination treatment makes the soil easy to penetrate by the roots to find nutrient supplies. Frona et al. stated that in general, nitrogen is needed to form or grow vegetative parts of plants such as leaves, stems and roots [26].

The interaction that produced the highest number of roots was found in the R2P1 treatment (30 min radiation and 31.25 g fertilization), which was 62.66 strands. Factors of plasma radiation and fertilization each significantly affected the number of roots. The highest number of roots was found in 30 min of radiation (R2), of 56.44 strands/clumps. Fertilization of 31.25 g (P1) showed the highest number of roots of 56.66 strands/clumps. The large composition of nitrogen in free air, causes the release of plasma in the free air to produce N + ions [19]. which can be used as nutrients or regulatory signals for metabolism and plant growth, especially in roots [28]. Supposed, the more fertilizer is applied, the more N can increase growth. However, the highest number of roots parameter was in P1 fertilization, this was possible because root growth was also affected by food reserves in the bulb.

The number of roots plays a pivotal role in nutrient absorption, directly proportional to the increasing levels of macro and micronutrients in the soil [29]. Enhanced nutrient absorption, facilitated by a higher number of roots, positively impacts the availability of materials for photosynthesis [30]. An efficient photosynthesis process stimulates the accumulation of carbohydrates and proteins in plant organs, contributing to the overall formation of monobulb garlic. The symbiotic combination of burned husks and cow manure as a plant medium further enhances nutrient absorption, with burned husks effectively binding water and nutrients and preventing nutrient loss [31].

5. Conclusions

In summary, the synergistic application of corona glow discharge plasma radiation technology and organic fertilization has proven effective in enhancing monobulb garlic plants' growth. The most favorable outcomes were observed when employing a 30-minute radiation duration coupled with 31.25 g of fertilization, underscoring the collaborative benefits of these technologies. This study provides valuable insights for optimizing monobulb garlic production through innovative agricultural approaches. Further research optimization is recommended to explore additional combinations of corona glow discharge plasma radiation technology and organic fertilization to fully exploit their potential in enhancing monobulb garlic growth. Notably, the study found no interaction between radiation factors and organic fertilization concerning plant height and the number of leaves in garlic plants. However, there was an evident interaction between these two factors when considering the length and number of roots. The treatment combination that yielded optimal results, with 62.66 roots and 17.16 cm root length, was identified as P1R2 (31.25 g of organic fertilization and 30 minutes of irradiation), further emphasizing the effectiveness of this specific combination.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Compliance with ethical standards

This article does not contain any studies with human participants performed by any of the authors.

Conflict of interest

The authors declare no conflict of interest.

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article.

Author contributions

Erma Prihastanti: Conceptualization, Methodology, Investigation, Writing- Original draft preparation. Sumariyah: Data curation, Writing- Original draft preparation. Febiasasti Trias Nugraheni: Validation, Investigation, Writing-Reviewing and Editing.

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