

VEGETATIVE GROWTH RESPONSE OF CURLY CHILI (*CAPSICUM ANNUUM* L.) TO THE APPLICATION OF TWO MICROORGANISM-BASED LIQUID ORGANIC FERTILIZERS

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ABSTRACT

Chili pepper (*Capsicum annuum* L.) is a strategically important horticultural commodity in Indonesia whose vegetative phase strongly determines subsequent productivity. Microorganism-based liquid organic fertilizers represent a sustainable alternative to synthetic inputs, yet comparative efficacy data under local conditions remain limited. This study evaluated the vegetative growth response of curly chili treated with two commercially available microorganism-based liquid organic fertilizers (Fertilizer A and Fertilizer B) at the Experimental Field of Universitas Boyolali, Central Java, Indonesia. A comparative design with five replications per treatment was employed; observations were carried out at 7, 14, 21, and 28 days after transplanting (DAT). Growth parameters included plant height, number of leaves, and stem diameter. Fertilizer A consistently outperformed Fertilizer B from 14 DAT onward. At 28 DAT, Fertilizer A produced higher mean plant height (34.31cm vs. 30.88cm) and greater leaf number (24.89 vs. 22.87). Stem diameter was equivalent between treatments at 28 DAT (3.86mm). These findings suggest that Fertilizer A more effectively supports vegetative development of curly chili, likely through enhanced biological nitrogen availability and plant growth-promoting substance production. Results support use of microorganism-based organic fertilizers as a viable approach for sustainable chili cultivation in Boyolali.

Keywords: biofertilizer; chili pepper; microorganism; organic agriculture; vegetative growth; *Capsicum annuum* L.

INTRODUCTION

Chili pepper (*Capsicum annuum* L.) is one of the most economically important horticultural commodities in Indonesia, consumed as a fresh spice and as a processed food ingredient. Indonesia is among the world's largest producers of chili, with national production exceeding 2.5 million tonnes per year (Badan Pusat Statistik [BPS], 2022). In Boyolali Regency, Central Java, chili — particularly the curly variety — is the dominant horticultural crop; in 2015, it accounted for approximately 35.7% of the total vegetable harvest area (2,753 ha) and yielded 340,369 quintals (BPS Kabupaten Boyolali, 2015).

The vegetative phase is a critical determinant of final chili productivity. Plant height, stem diameter, and leaf number during this phase reflect the plant's capacity for photosynthesis, nutrient assimilation, and structural support for subsequent flowering and fruit production (Marcelis et al., 1998). Inadequate vegetative development arising from suboptimal nutrient management frequently leads to reduced flowering intensity and lower fruit yield (Golcz et al., 2012).

Conventional chili cultivation in Indonesia has relied heavily on synthetic nitrogen–phosphorus–potassium (NPK) fertilizers. While effective in the short term, excessive synthetic fertilizer use contributes to soil acidification, reduction of soil microbial diversity, and

accumulation of chemical residues that diminish long-term soil productivity (Sutanto, 2002). Growing public awareness of these risks has driven demand for organic and biologically based crop production systems, particularly in areas such as Boyolali where highland conditions are conducive to organic horticulture.

Microorganism-based liquid organic fertilizers — commonly referred to as biofertilizers or liquid bio stimulants — represent a promising sustainable alternative. These products harness the metabolic activity of beneficial microorganisms, including nitrogen-fixing bacteria (*Rhizobium*, *Azotobacter*, *Azospirillum*), phosphate-solubilizing bacteria, and decomposer organisms such as Effective Microorganisms (EM), to improve soil nutrient availability and stimulate plant growth (Nurhayati & Darwati, 2014; Rahmawati, 2006). Several studies have demonstrated that biofertilizer application can increase crop yields while reducing dependence on synthetic inputs (Bhattacharyya & Jha, 2012; Vessey, 2003).

Despite growing commercial availability of microorganism-based liquid fertilizers in Indonesia, comparative performance data for specific products under local agroecological conditions remain scarce. Product efficacy may vary significantly depending on microbial composition, carrier formulation, application method, and environmental conditions such as soil pH and moisture (Lugtenberg & Kamilova, 2009). Therefore, empirical evaluation of fertilizer products under representative field conditions is necessary before recommendations can be made to farmers.

The present study aimed to: (1) evaluate and compare the effects of two microorganism-based liquid organic fertilizers on vegetative growth of curly chili; (2) identify which treatment more effectively supports plant development during the vegetative phase; and (3) contribute baseline data for optimizing organic fertilizer recommendations in Boyolali and similar agricultural regions.

METHODS

Study Site and Experimental Period

The experiment was conducted in January–March 2023 at the Experimental Field of Universitas Boyolali, Boyolali Regency, Central Java, Indonesia (7°31'S, 110°36'E; altitude approximately 300 m a.s.l.). Mean annual temperature at the site ranges from 20–25°C with average annual rainfall of 600–1,250 mm, conditions considered suitable for chili cultivation (Sutrisna & Yanto, 2014).

Plant Material

Capsicum annuum L. curly chili seedlings were germinated in small polybags and grown in a shaded nursery for four weeks until reaching the 3–5 true-leaf stage before transplanting.

Fertilizer Treatments

Two commercially available microorganism-based liquid organic fertilizers were evaluated: Fertilizer A and Fertilizer B. Both were applied at 100 mL plant⁻¹ week⁻¹. Prior to transplanting, all beds received a uniform base dressing of manure at 20 tonnes ha⁻¹, in accordance with standard organic chili cultivation practice (Ariani, 2009).

Experimental Design

A comparative experimental design was employed with two treatments, each replicated five times. Each replication consisted of one raised bed (1 m × 13 m) planted at 50 × 60 cm spacing (~50 plants bed⁻¹), yielding ten beds and ~500 plants in total. Beds were arranged in an alternating pattern to minimise positional bias.

Land Preparation and Planting

Soil was tilled to 25 cm depth. Raised beds (1 m wide, 30 cm high, 60 cm inter-bed spacing) received manure and agricultural lime, then were rested for one week. Beds were subsequently sprayed with the assigned liquid fertilizer and covered with silver-black plastic mulch; planting holes (10 cm diameter, 50 × 60 cm spacing) were made after a further week of resting. Four-week-old seedlings were transplanted individually; bamboo stakes were installed at 7 DAT.

Plant Maintenance

Irrigation was performed daily or as required. Pest and disease control was conducted mechanically. Pruning, staking, and weekly fertilizer application (100 mL plant⁻¹ week⁻¹ by hand-held sprayer) were carried out throughout the observation period.

Growth Observations

Observations were conducted at 7, 14, 21, and 28 DAT. Parameters recorded were:

Plant height (cm) – measured from root collar to shoot apex.

Number of leaves – all fully intact leaves or those retaining ≥30% of leaf area.

Stem diameter (mm) – measured at mid-stem using a digital calliper.

Time of first branch formation and first flower opening were also recorded (days after transplanting).

Statistical Analysis

Data were analysed using an independent-samples significance test ($\alpha = 0.05$) to evaluate whether differences between the two fertilizer treatments were statistically meaningful. All calculations were performed in Microsoft Excel.

RESULTS AND DISCUSSION

Number of Leaves

The mean number of leaves per plant increased progressively throughout the vegetative phase in both treatments (Table 1). At 7 DAT, Fertilizer B produced a marginally higher mean leaf number (8.76) than Fertilizer A (8.63), suggesting comparable early establishment. From 14 DAT onward, Fertilizer A consistently produced more leaves: 11.99 vs. 11.93 at 14 DAT, 19.61 vs. 15.63 at 21 DAT, and 24.89 vs. 22.87 at 28 DAT.

The divergence between treatments was most pronounced at 21 DAT (~25.4% advantage for Fertilizer A). Leaf number is directly related to photosynthetic capacity and is strongly influenced by nitrogen availability (Marschner, 2012). The superior leaf production under Fertilizer A may reflect more effective nitrogen mineralisation by its microbial consortia. Nitrogen-fixing microorganisms such as *Azotobacter* and *Azospirillum* convert atmospheric N₂ into ammonium, thereby supporting leaf primordia initiation and expansion (Bashan & Bashan, 2010; Rahmawati, 2006). Figure 1 demonstrates that the application of Fertilizer A produced a consistently greater positive effect than Fertilizer B, with the superiority becoming evident at 14 days after transplanting (DAT) and remaining observable through the final assessment period.

Table 1. Mean number of leaves per plant at each observation period.

Rep.	A 7 DAT	B 7 DAT	A 14 DAT	B 14 DAT	A 21 DAT	B 21 DAT	A 28 DAT	B 28 DAT
1	8.87	8.47	13.40	14.20	14.20	15.87	23.80	23.87
2	8.00	8.67	12.77	11.80	16.46	15.40	23.46	21.87
3	8.93	9.20	12.60	11.80	26.40	16.27	25.07	25.60
4	8.73	9.53	10.47	11.80	24.93	16.93	20.73	23.93
5	8.60	7.93	10.73	10.07	16.07	13.67	31.40	19.07
Mean	8.63	8.76	11.99	11.93	19.61	15.63	24.89	22.87

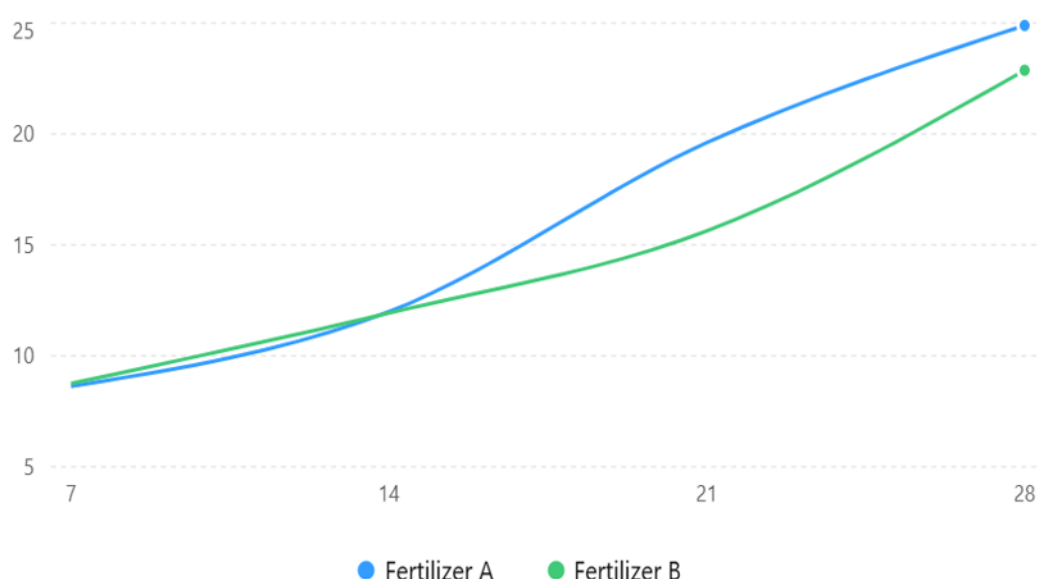


Figure 1. Number of leaves response to microorganism-based liquid fertilizers

Plant Height

Plant height data followed a similar pattern (Table 2). At 7 DAT, Fertilizer B plants were marginally taller (14.27 cm vs. 13.34 cm). From 14 DAT onward, Fertilizer A plants were consistently taller: 18.54 vs. 17.17 cm at 14 DAT, 26.32 vs. 22.43 cm at 21 DAT, and 34.31 vs. 30.88 cm at 28 DAT.

The 11.2% height advantage for Fertilizer A at 28 DAT is agronomically meaningful, as taller plants with well-developed stems are better positioned to support fruiting branches. Stem elongation during the vegetative phase depends on adequate nitrogen, phosphorus, and plant growth hormones such as auxins and cytokinins (Taiz et al., 2015). Biofertilizers containing phosphate-solubilising bacteria and growth-promoting microorganisms stimulate root development and increase auxin production, thereby enhancing shoot elongation (Glick, 2012; Vessey, 2003).

Hapsoh et al. (2017) reported chili plant heights of up to 60.3 cm at the end of the vegetative phase under compost combined with reduced-dose NPK, indicating that balanced organic-inorganic nutrition supports vigorous growth. The heights recorded here (34.31 cm at 28 DAT) are consistent with vegetative-phase benchmarks for curly chili under organic management in similar highland conditions. Although Fertilizer B resulted in a slightly greater

plant height at 7 days after transplanting (DAT), Fertilizer A promoted a faster and more consistent increase in plant height up to 28 DAT (figure 2).

Table 2. Mean plant height (cm) at each observation period.

Rep.	A 7 DAT	B 7 DAT	A 14 DAT	B 14 DAT	A 21 DAT	B 21 DAT	A 28 DAT	B 28 DAT
1	13.07	13.67	16.23	16.67	24.17	22.60	30.87	32.77
2	13.30	15.63	17.30	18.80	42.34	22.80	32.50	31.00
3	14.67	14.30	17.73	16.77	24.47	22.83	32.67	33.35
4	12.50	14.27	15.83	18.13	19.63	24.20	46.40	30.89
5	13.14	13.50	25.63	15.50	21.00	19.72	29.10	26.37
Mean	13.34	14.27	18.54	17.17	26.32	22.43	34.31	30.88

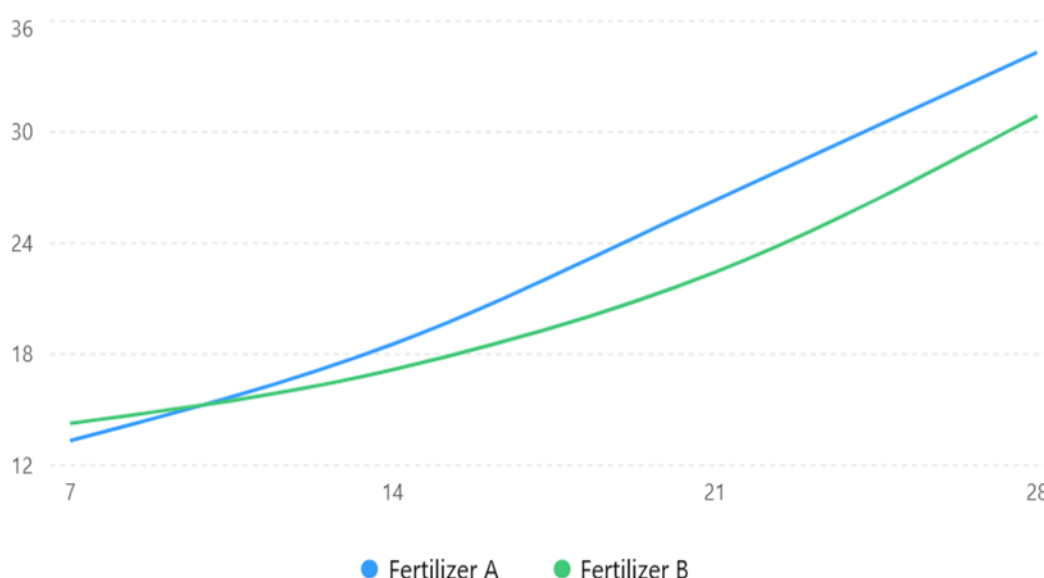


Figure 2. Plant height reponse to microorganism-based liquid fertilizers

Stem Diameter

Stem diameter increased gradually in both treatments (Table 3). Fertilizer B showed marginally larger stem diameters at observations 1 and 3. At 28 DAT, however, both treatments converged to identical mean stem diameters of 3.86 mm.

The equivalent final stem diameter suggests that both fertilizers supported structural development to the same degree. Stem diameter reflects vascular bundle development and the plant's capacity for water and nutrient transport (Widyanti & Susila, 2015). Convergence at 28 DAT may indicate that while Fertilizer A drove faster shoot elongation and leaf area expansion, both products delivered sufficient potassium and phosphorus to sustain equivalent stem thickening. Potassium plays an important role in cell wall strengthening and yield quality in pepper crops, and adequate K supply from both fertilizers likely explains this parity (Ortas, 2013).

As illustrated in Figure 3, the two treatments produced comparable stem diameters during the experimental period. By the final observation at 28 days after transplanting (DAT), both treatments attained an identical stem diameter of 3.86 mm.

Table 3. Mean stem diameter (mm) at each observation period.

Rep.	A 7 DAT	B 7 DAT	A 14 DAT	B 14 DAT	A 21 DAT	B 21 DAT	A 28 DAT	B 28 DAT
1	2.45	2.44	2.76	2.77	3.05	3.26	3.85	4.06
2	2.37	2.21	2.80	2.47	3.02	2.90	4.10	3.78
3	2.12	2.41	2.50	2.64	3.00	3.17	4.14	4.21
4	2.09	2.30	2.38	2.52	2.69	2.93	3.64	3.88
5	1.81	1.66	2.28	2.27	2.75	2.60	3.57	3.37
Mean	2.17	2.20	2.54	2.53	2.90	2.97	3.86	3.86

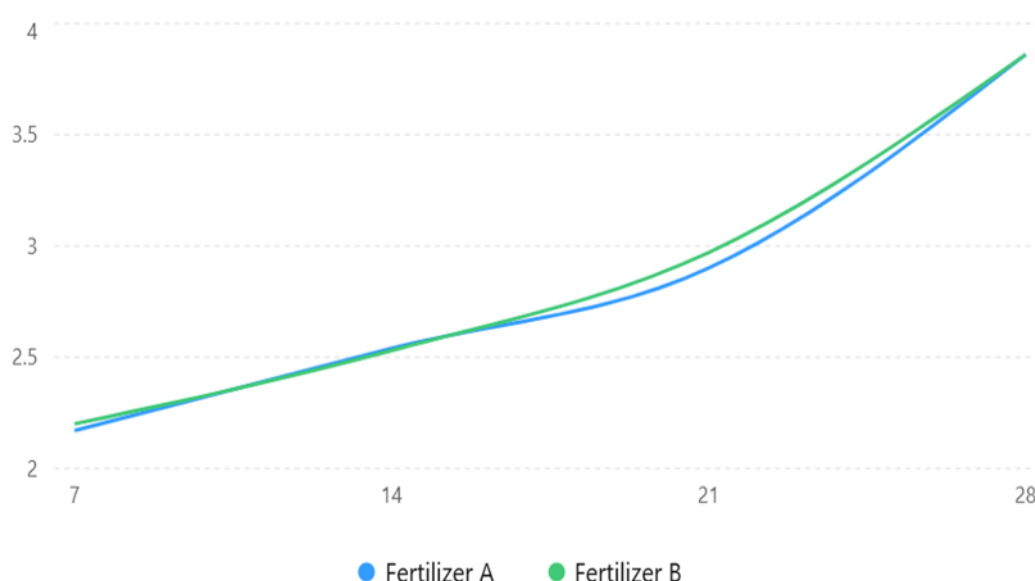


Figure 3. Stem diameter response to microorganism-based liquid fertilizers

Overall Growth Performance and Mechanism of Action

Across all measured parameters, Fertilizer A demonstrated superior or equivalent performance compared to Fertilizer B from 14 DAT onward. The initial advantage of Fertilizer B at 7 DAT may reflect a faster release of soluble nutrients early in the application cycle, while Fertilizer A's benefits became more apparent as microbial rhizosphere colonisation intensified over time.

The general mechanism by which microorganism-based fertilizers improve plant growth encompasses: (1) biological nitrogen fixation by free-living bacteria (*Azotobacter*, *Azospirillum*); (2) phosphate solubilisation by bacteria and fungi; (3) production of plant growth-promoting substances including indole-3-acetic acid (IAA), gibberellins, and cytokinin; and (4) acceleration of organic matter decomposition by EM, releasing macro- and micronutrients in plant-available forms (Bhattacharyya & Jha, 2012; Nurhayati & Darwati, 2014; Rahmawati, 2006). Fertilizer A appears to have delivered these functions more effectively under the prevailing field conditions.

These findings are consistent with Rahmawati (2006), who demonstrated that biofertilizers enhance nutrient availability and support vegetative development in organic cropping systems, and with Nurhayati and Darwati (2014), who reported that agricultural microorganisms act as bio decomposers and produce growth regulators that stimulate vegetative development. The results also align with Margolang et al. (2015), who showed that

high soil organic matter content — maintained by microbial activity — improves soil physical and chemical properties that benefit plant growth.

It should be noted that the microbial composition of both products was not disclosed by manufacturers and therefore could not be verified in this study. Future research should include microbiological characterisation of fertilizer products and soil microbial community analysis to elucidate the specific mechanisms driving differential growth responses.

CONCLUSIONS

Application of microorganism-based liquid organic Fertilizer A produced superior vegetative growth performance in curly chili compared to Fertilizer B, as evidenced by consistently higher plant height and greater leaf number from 14 to 28 DAT. At 28 DAT, Fertilizer A resulted in mean plant height of 34.31 cm and 24.89 leaves per plant, compared to 30.88 cm and 22.87 leaves per plant under Fertilizer B. Stem diameter was equivalent between treatments at 28 DAT (3.86 mm). These results indicate that Fertilizer A more effectively supports vegetative development of curly chili under the conditions studied, likely through enhanced biological nitrogen fixation, phosphate solubilisation, and plant growth-promoting substance production.

These findings support the potential of microorganism-based organic fertilizers as viable, sustainable inputs for organic chili cultivation in Boyolali and similar highland regions. Future studies should extend the observation period to include the generative phase and final yield, characterise the microbial composition of both products, and evaluate performance across different soil types and seasons.

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