

Effects of Moringa (*Moringa oleifera* L.) Leaf Liquid Organic Fertilizer and NPK Dose on Cauliflower Growth and Curd Yield in Tomohon, Indonesia.

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Abstract. Cauliflower (*Brassica oleracea* var. botrytis) production in tropical highlands often depends on high mineral fertilizer inputs, yet integrated nutrient management using locally available organic biostimulants may improve growth and yield while supporting soil quality. This study evaluated the effects of moringa (*Moringa oleifera*) leaf liquid organic fertilizer (POC) concentration and NPK compound fertilizer dose on cauliflower grown in Kakaskasen, Tomohon City, North Sulawesi, Indonesia (May–October 2025). A 3 × 3 factorial experiment was arranged in a randomized block design with three replications (27 experimental units). POC concentrations were 0, 100, and 200 mL L⁻¹, and NPK doses were 0, 100, and 200 kg ha⁻¹; chicken manure (10 t ha⁻¹ equivalent) was applied as a basal input. Plant height, leaf number, and curd weight were assessed at harvest (~70 days after transplanting) and analyzed by ANOVA followed by LSD (5%). No interaction between POC concentration and NPK dose was detected for the reported variables. Increasing POC significantly improved plant height and leaf number, with 200 mL L⁻¹ producing the tallest plants (40.00 cm) and the highest leaf number (16.11 leaves plant⁻¹). Curd weight increased markedly with POC from 112.47 g (0 mL L⁻¹) to 192.93 g (200 mL L⁻¹). NPK significantly increased plant height and curd weight, with the highest curd weight at 200 kg ha⁻¹ (174.77 g), while the NPK effect on leaf number was not significant. Overall, 200 mL L⁻¹ moringa-leaf POC combined with adequate NPK supply is recommended for further field-scale validation under Tomohon conditions.

Keywords: *Brassica oleracea*; integrated nutrient management; liquid organic fertilizer; *Moringa oleifera*; NPK fertilizer

INTRODUCTION

Cauliflower (*Brassica oleracea* L. var. botrytis) is a high-value Brassica vegetable widely consumed because it provides vitamins and diverse health-promoting phytochemicals, including glucosinolates, phenolics, and carotenoids (Uy et al., 2024; Zhang et al., 2025). Cauliflower production in intensive vegetable systems depends strongly on adequate nutrient supply, particularly during vegetative growth and curd formation, which drives frequent reliance on mineral fertilizers (Ranjous et al., 2025). However, heavy dependence on mineral fertilizers is increasingly linked to environmental and soil-quality concerns, encouraging interest in nutrient strategies that maintain productivity while improving soil health and nutrient-use efficiency (Han et al., 2025; Xu et al., 2024).

Integrated nutrient management, which combines mineral and organic sources, is widely promoted as a practical approach to improve soil conditions and crop performance (Choudhary et al., 2025; Mustaffer & Jalani, 2025). Recent evidence in cauliflower shows that combining mineral fertilizer with organic amendments and biofertilizers can improve growth and yield compared with single-input strategies, indicating that nutrient sources may act synergistically when balanced appropriately (Aldolaimy et al., 2024; Ranjous et al., 2025). In addition, recent work on alternative amendments, including bio-based inputs, continues to expand options for sustainable fertilization in Brassica crops, including cauliflower (Alneyadi et al., 2024; Díaz-Pérez et al., 2024).

Among organic inputs, moringa (*Moringa oleifera*) leaf-based products have received increasing attention as low-

cost plant biostimulants (Daun *et al.*, 2020). Reviews and experimental studies consistently report that moringa leaf extract contains growth-promoting compounds, including cytokinins (commonly associated with zeatin), antioxidants, and macro- and micronutrients that can enhance plant physiological performance, photosynthesis-related traits, and biomass accumulation (Irshad *et al.*, 2025; Mashamaite *et al.*, 2022; Setati *et al.*, 2025). Evidence across crops and environments also suggests that moringa-based biostimulants can improve growth and yield-related traits, supporting their relevance for smallholder-friendly nutrient and crop management strategies (Yaseen *et al.*, 2023; Yuniati *et al.*, 2023).

Despite growing evidence for both integrated fertilization and moringa-derived inputs, a clear research gap remains regarding farmer-relevant combinations of moringa leaf liquid organic fertilizer and mineral NPK fertilization for cauliflower under specific local production contexts. Many studies evaluate organic inputs or NPK rates separately, and fewer studies test factorial combinations that mirror real on-farm practices where multiple inputs are often applied together (Ranjous *et al.*, 2025; Xu *et al.*, 2024). This gap is particularly important because combined inputs may produce additive or non-additive responses depending on concentration, dose, and timing, and because recommendations must be adapted to local climate and management conditions to be useful for growers.

This study addresses the gap by evaluating the effects of moringa leaf liquid

organic fertilizer (POC) concentrations and NPK fertilizer doses on cauliflower growth and yield under Tomohon conditions. The novelty of this work lies in applying a factorial approach using farmer-relevant input combinations to determine whether moringa-based POC can enhance cauliflower performance alongside NPK fertilization, thereby supporting locally grounded recommendations for integrated nutrient management.

MATERIALS AND METHODS

Study area and study period

The experiment was conducted in Kakaskasen, Tomohon City, North Sulawesi, Indonesia, over five months from May to October 2025.

Experimental design and treatment structure

A two-factor factorial experiment was arranged in a randomized block design with three replications, resulting in 27 experimental units. The first factor was moringa leaf liquid organic fertilizer (POC) concentration, and the second factor was NPK compound fertilizer dose. To clarify the factorial structure and the treatment combinations evaluated, the factor levels are summarized in Table 1 and treatments are summarized in Table 2.

Table 1 shows that the study tested three levels of moringa leaf POC concentration combined with three NPK doses.

Table 1. Data structure and measurement plan

Factor	Code	Level description
Moringa leaf POC concentration	A0	0 mL POC L ⁻¹ water (no POC)
	A1	100 mL POC L ⁻¹ water
	A2	200 mL POC L ⁻¹ water
NPK compound fertilizer dose	B0	0 kg ha ⁻¹ (no NPK)
	B1	100 kg ha ⁻¹
	B2	200 kg ha ⁻¹

Table 2. Treatment combinations of moringa leaf POC concentration and NPK dose applied to cauliflower

Treatment combination	Description
A0B0	No POC, no NPK
A0B1	No POC, 100 kg ha ⁻¹ NPK
A0B2	No POC, 200 kg ha ⁻¹ NPK
A1B0	100 mL L ⁻¹ POC, no NPK
A1B1	100 mL L ⁻¹ POC, 100 kg ha ⁻¹ NPK
A1B2	100 mL L ⁻¹ POC, 200 kg ha ⁻¹ NPK
A2B0	200 mL L ⁻¹ POC, no NPK
A2B1	200 mL L ⁻¹ POC, 100 kg ha ⁻¹ NPK
A2B2	200 mL L ⁻¹ POC, 200 kg ha ⁻¹ NPK

Table 2 shows nine treatment combinations in a full factorial arrangement. The factorial layout allowed estimation of the main effects of POC concentration and NPK dose, as well as their interaction, which is essential because plant-based liquid fertilizers may complement or modify crop responses to mineral nutrient inputs. Replication across three blocks enabled the effects of each factor and their interaction to be evaluated under the experimental conditions.

Preparation of moringa leaf liquid organic fertilizer

Moringa leaves were crushed and mixed with rice washing water, coconut water, and liquid palm sugar using a 5:2:2 proportion, then a fruit based local microorganism solution (MOL) was added as a decomposer. The mixture was stirred until homogeneous, placed in a container, sealed, and fermented for 10 to 14 days, with periodic checking of the fermentation temperature. The resulting liquid was used as POC for application treatments.

Growing medium preparation, nursery, and transplanting

Soil used as planting medium was collected, air dried, crushed, and sieved. The prepared soil was filled into polybags or pots at 20 kg of air dried soil per container. Cauliflower seeds were sown in a nursery, and seedlings were transplanted to polybags after 21 days.

Fertilizer application and crop maintenance

Chicken manure was applied as a basal fertilizer at an equivalent rate of 10 t ha⁻¹, three days before transplanting. NPK fertilizer was applied according to the assigned treatment dose and split into staged applications, with fertilization starting one week after transplanting and continuing at one month after transplanting to meet the planned dose. Moringa leaf POC was applied once per week starting at one week after transplanting and continuing until six weeks after transplanting. Crop maintenance included replanting of dead seedlings, weed control, and pest and disease control during the growing period.

Data collection and harvest

Observed variables included plant height, number of leaves, curd diameter, whole plant fresh weight, and curd weight. Data collection was conducted at harvest. Harvest was performed at approximately 70 days after transplanting, adjusted to harvest readiness criteria.

Statistical analysis

Data were analyzed using analysis of variance (ANOVA). When significant treatment effects were detected, mean separation was performed using the least significant difference test (BNT) at the 5% level.

RESULTS AND DISCUSSION

Effects of moringa leaf POC concentration and NPK dose (plant height and leaf number)

The factorial ANOVA indicated no interaction between moringa leaf POC

concentration and NPK dose for plant height and leaf number. Both variables were therefore interpreted using the main effects (single-factor effects) of POC concentration and NPK dose.

To make the response pattern clear, Table 3 summarizes the mean plant height and leaf number under each POC level and each NPK dose, including the LSD (BNT) at 5% where reported.

Table 3. Main effects of moringa leaf POC concentration and NPK dose on cauliflower plant

Factor	Level	Plant height (cm)	Leaf number
POC concentration	A0 (0 mL L ⁻¹)	29.93 (a)	11.67 (a)
	A1 (100 mL L ⁻¹)	36.88 (b)	12.00 (a)
	A2 (200 mL L ⁻¹)	40.00 (b)	16.11 (b)
LSD 5% (POC)		3.38	1.61
NPK dose	B0 (0 kg ha ⁻¹)	30.38 (a)	12.56
	B1 (100 kg ha ⁻¹)	37.29 (b)	13.78
	B2 (200 kg ha ⁻¹)	39.14 (b)	14.11
LSD 5% (NPK)		3.38	- (ns)

Table 3 indicates that applying moringa leaf POC increased plant height relative to no POC, with the 100- and 200-mL L⁻¹ treatments producing significantly taller plants than the control. Leaf number showed the strongest response at 200 mL L⁻¹, which produced the highest leaf number (16.11 leaves), while 0- and 100-mL L⁻¹ were statistically similar. For NPK, plant height increased from 30.38 cm (no NPK) to 37.29–39.14 cm (100–200 kg ha⁻¹), with both fertilized treatments significantly taller than the unfertilized control. Leaf number also increased numerically with NPK dose (12.56 to 14.11), although the manuscript does not report an LSD value for this variable under the NPK factor, so significance for NPK effects on leaf number cannot be confirmed from the presented table.

From a physiological perspective, these patterns are consistent with the role of moringa-based inputs as biostimulants containing nutrients and growth-related compounds (including cytokinins/zeatin) that can support vegetative development, and with the expected response of Brassica crops to improved mineral nutrient

availability (Mashamaite *et al.*, 2022; Ranjous *et al.*, 2025; Setati *et al.*, 2025).

Effects of moringa leaf POC concentration and NPK dose on curd weight

Curd weight is a primary yield indicator in cauliflower. The analysis reported no interaction between moringa leaf POC concentration and NPK dose for curd weight, while each factor had a significant main effect. Table 4 presents the main effects of moringa leaf POC concentration and NPK dose on curd weight (g), including the least significant difference (LSD; BNT) at the 5% level.

Table 4 shows that increasing moringa leaf POC concentration produced a clear yield improvement, with curd weight rising from 112.47 g (no POC) to 157.46 g at 100 mL L⁻¹ and reaching 192.93 g at 200 mL L⁻¹. This indicates a strong positive response of cauliflower curd development to the higher POC concentration under the study conditions. For NPK, curd weight increased from 133.83 g (no NPK) to 174.77 g at 200 kg ha⁻¹. The 100 kg ha⁻¹ treatment was intermediate (154.26 g) and was not statistically different from either the

control or the higher dose based on the letter grouping.

Overall, the absence of interaction suggests that moringa leaf POC improved cauliflower performance consistently across NPK doses rather than only under a specific NPK level. This supports the

concept of integrated nutrient management, where organic and mineral inputs can both contribute to improved crop growth and yield, and their combined effects may appear mainly as additive main effects depending on rates and local conditions.

Table 4. Main effects of moringa leaf POC concentration and NPK dose on cauliflower curd weight at harvest

Factor	Level	Curd weight (g)
POC concentration	A0 (0 mL L ⁻¹)	112.47 (a)
	A1 (100 mL L ⁻¹)	157.46 (b)
	A2 (200 mL L ⁻¹)	192.93 (c)
	LSD 5% (POC)	32.33
NPK dose	B0 (0 kg ha ⁻¹)	133.83 (a)
	B1 (100 kg ha ⁻¹)	154.26 (ab)
	B2 (200 kg ha ⁻¹)	174.77 (b)
	LSD 5% (NPK)	32.33

CONCLUSION

Under the experimental conditions in Kakaskasen, Tomohon (May-October 2025), cauliflower growth and yield responded to moringa leaf liquid organic fertilizer (POC) concentration and NPK compound fertilizer dose primarily through main effects, with no interaction detected between the two factors for plant height, leaf number, or curd weight. Increasing POC concentration improved vegetative growth and yield, with 200 mL L⁻¹ producing the highest mean leaf number (16.11 leaves plant⁻¹) and the greatest curd weight (192.93 g plant⁻¹) compared with the non-POC control. NPK fertilization increased plant height and curd weight, with the highest mean curd weight observed at 200 kg ha⁻¹ (174.77 g plant⁻¹). Within the tested ranges, 200 mL L⁻¹ moringa-leaf POC and 200 kg ha⁻¹ NPK are the most promising levels for subsequent field validation under local production conditions. Leaf number increased numerically with NPK dose, but the manuscript does not report the LSD/mean-separation result for this comparison, so statistical confirmation of the NPK effect on

leaf number cannot be verified from the current table presentation.

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