JURNAL MULTIDISIPLIN MADANI (MUDIMA)
Homepage: https://journalmudima.my.id/index.php/mudima
ISSN: 2808-5639 (Online)
Research Article

Vol. 6, No. 5 May (2026)	DOI: https://doi.org/10.55927/mudima.v6i5.53	Page: 523-527

Response of Corn (*Zea mays* L.) to Nanotechnology Liquid Organic Fertilizer Application

Alvera Prihatini Dewi Nazari[1], Eliyani[2*], David Christian Balan[3]
Mulawarman University
Corresponding Author: Eliyani eyani99@gmail.com

ARTICLEINFO

Keywords: Liquid Organic Fertilizer, Nano Technology, Pornas, *Zea Mays* L

Received : 3 March
Revised : 24 April
Accepted : 26 May

ABSTRACT

Corn productivity is heavily influenced by fertilization practices. Nanotechnology-enabled fertilizers offer controlled-release systems that enhance nutrient delivery efficiency while minimizing environmental losses, thereby reducing chemical fertilizer dependency. The research was conducted to evaluate of varying concentrations of *Pornas* nanotechnology liquid organic fertilizer on corn growth and yield. The experiment was conducted from January to November 2023 in Bangun Rejo Village, Tenggarong Seberang District, Kutai Kartanegara Regency, East Kalimantan, Indonesia, using a Randomized Complete Block Design with five replications. Treatments consisted of five *Pornas* concentrations (0.0, 0.5, 1.0, 1.5, and 2.0 mL L^{-1}. Data were analyzed using ANOVA and DMRT at a 5% significance level. Results showed that *Pornas* application significantly improved plant height, stem diameter, cob dimensions, kernel traits, and overall yield, but did not affect leaf number. The optimal concentration was 1.5 mL L^{-1}, which maximized yield at 5.07 Mg ha^{-1} without significantly different from the 2.0 mL L^{-1}, indicating superior nutrient use efficiency. These findings demonstrate the potential of nano-liquid organic fertilizers for sustainable maize production in marginal tropical soils.

INTRODUCTION

Agriculture is a crucial sector in meeting global food security demands. Corn (*Zea mays* L.) is a key agricultural commodity, widely utilized in food, animal feed, industrial flour, and oil production. Corn productivity is significantly influenced by soil properties, climatic conditions, crop varieties, and fertilization practices (Arasya & Jaelani 2019). Corn cultivation in East Kalimantan faces unique agronomic challenges, including acidic soils, low inherent fertility, and limited organic matter content, which collectively restrict nutrient availability and uptake efficiency (Agus & Subiksa 2008). These soil constraints necessitate innovative fertilizer management strategies that enhance Nutrient Use Efficiency (NUE), while maintaining ecological sustainability.

Strategies to improve corn productivity include optimized fertilization regimes and the adoption of high-yielding varieties (Duvick 2005; Prasetyo et al. 2016). Recently, liquid organic fertilizers (LOFs) have gained attention in sustainable agriculture due to their rapid nutrient availability and ease of foliar or soil application. LOFs are derived from fermented organic materials such as plant residues, animal manure, or agricultural by-products (Marschner 2012). Their efficacy, however, depends on formulation, application method, soil properties, and crop genotype.

Fertilizers with nanotechnology-enhanced have demonstrated significant potential to improve NUE. In nanofertilizers, nutrients are bound to nano-scale carriers, enabling controlled and prolonged release compared to conventional formulations (Zulfiqar et al. 2019). This technology maximizes root and foliar absorption while minimizing leaching and volatilization losses, thereby reducing environmental pollution (Shang et al. 2019). Additionally, nanofertilizers can enhance plant resilience to abiotic stress and can be synergistically combined with beneficial microbes for compounded agronomic benefits (Dimkpa & Singh 2011). Despite these advantages, field-level validation of nano-LOFs in tropical maize systems remains limited.

This study presents novel findings on the integration of nanotechnology in liquid organic fertilizers under tropical field conditions. The primary objective was to evaluate the effect of varying concentrations of *Pornas* nanotechnology liquid organic fertilizer on the growth and yield components of corn, identifying the optimal application rate for sustainable maize production.

METHODS

The field experiment was conducted from January to November 2023 in Bangun Rejo Village, Tenggarong Seberang District, Kutai Kartanegara Regency, East Kalimantan, Indonesia. The experimental site was selected based on its representative marginal agricultural soils, characterized by acidic pH (5.17), and low natural fertility. The region exhibits a tropical climate with high humidity and bimodal rainfall patterns, suitable for maize cultivation but requiring careful nutrient management.

The materials included Bisi 321 hybrid corn seeds, dolomite lime, *Pornas* nanotechnology liquid organic fertilizer, and water.

A single-factor experiment to evaluate *Pornas* concentration was arranged in a Randomized Complete Block Design (RCBD) with five replications. *Pornas* concentrations (P) consisted of $p_0 =$ control (0.0 mL L^{-1}), p_1 = 0.5 mL L^{-1}, $p_2 =$ 1.0 mL L^{-1}, $p_3 =$ 1.5 mL L^{-1}, and $p_4 =$ 2.0 mL L^{-1}. Each plot measured 2.5 m × 4 m with 0.5 m buffer zones between blocks.

Field procedures included land preparation (three rotary tillage passes to 20 cm depth), liming (1,660 g $plot^{-1}$ to adjust pH to 6.0), planting (70 cm × 20 cm spacing), one seed $hole^{-1}$ (2–3 cm depth), and *Pornas* application. *Pornas* was applied six times at 7, 14, 21, 28, 35, and 42 DAP via foliar spraying between 07:00–10:00 or 15:00–17:00. Maintenance included irrigation, replanting, manual weeding, and pre-harvest pruning. Harvesting was conducted at ~115 DAP when husks turned light brown and a black abscission layer formed at the kernel base. Harvesting is done by hand-picking the corn and placing it in sacks.

Variables observed included plant height (cm), stem diameter (cm), number of leaves (blades), cob length (cm), cob diameter (mm), number of rows per cob (rows), number of kernels per row (kernels), kernels weight per cob (g), weight of 100 kernels (g), kernels weight per plot (g), and kernels weight per hectare (Mg ha^{-1}).

Data were analyzed using Analysis of Variance (ANOVA), if significantly different, continued with

Duncan's Multiple Range Test (DMRT) at a significance level of 5%.

RESULTS AND DISCUSSION

Results of ANOVA indicated that the effect of *Pornas* liquid organic fertilizer significantly different to all variables, except number of leaves. A recapitulation and data analysis results are presented in Table 1 below.

Table 1. Means Values Variables of Corn Growth and Yield Influenced by The Concentration of Pornas Nanotechnology Liquid Organic Fertilizer

Concentration of Pornas (P) (mL L^{-1})	Plant Height (cm)			Stem Diameter (cm)			Number of Leaves (blades)			Cob Length (cm)	Cob Diam. (mm)	Number of Rows per Cob (row)	Number of Kernels per Row (kernels)	Kernels Weight per Cob (g)	Weight of 100 Kernels (g)	Kernels Weight per Plot (g)	Kernels Weight per Hectare (Mg ha^{-1})
	15 DAP	30 DAP	45 DAP	15 DAP	30 DAP	45 DAP	15 DAP	30 DAP	45 DAP								
$p_0 = 0.0$	39.10d	72.23c	121.50c	0.53c	1.00c	1.39d	5.00	6.00	7.65	10.91bc	35.98d	22.59d	15.31c	47.53c	15.40b	3,907.24c	3.91c
$p_1 = 0.5$	40.20cd	73.45bc	131.25bc	0.54c	1.10b	1.51cd	5.20	6.48	8.10	11.23bc	37.67c	23.37c	15.45c	57.03b	16.48b	4,396.94b	4.40b
$p_2 = 1.0$	41.25abc	75.28b	143.05b	0.63b	1.10b	1.68abc	5.25	6.38	7.90	11.81b	38.25c	25.77b	16.57b	58.64ab	18.45a	4,503.66b	4.50b
$p_3 = 1.5$	42.33ab	81.78a	146.40b	0.69a	1.12b	1.73ab	5.38	6.60	7.63	12.93a	41.81b	27.36a	18.13a	63.45ab	18.90a	5,074.36a	5.07a
$p_4 = 2.0$	43.00a	82.30a	163.20a	0.71a	1.47a	1.74a	5.25	6.85	8.48	13.00a	42.65a	28.31a	18.23a	64.88a	19.63a	5,152.00a	5.15a

Note: Means followed by the same letter within a column are not significantly different according to DMRT at the 5% significance level.

Plant Growth Response

The application of *Pornas* nanotechnology liquid organic fertilizer showed a significant positive effect on the growth of corn plants. Statistical analysis showed significantly different in plant height and stem diameter at 15, 30, and 45 DAP, but not significant in the number of leaves.

Plant height and stem diameter increased consistently with higher *Pornas* concentrations. At 45 DAP, plant height increased by 34.32% in the 2.0 mL L^{-1} compared to the control. This response is attributed to enhanced uptake of nitrogen and phosphorus, which are critical for cell division, elongation, and metabolic processes such as photosynthesis, protein synthesis, and respiration (Taiz et al. 2015). The nano-sized particles in *Pornas* facilitate rapid cuticular penetration, enhancing nutrient translocation to meristematic tissues. Nitrogen and potassium, in particular, promote turgor maintenance, lignin deposition, and vascular development, resulting in thicker, more resilient stems (Hawkesford & Zhao 2022).

The number of leaves did not significantly different among *Pornas* concentrations. This aligns with established plant physiology principles, as leaf number in maize is primarily genetically determined and less responsive to short-term nutrient variations during the vegetative phase (Bouchabke et al. 2008; Tian et al. 2019). Environmental factors primarily influence leaf expansion rate and senescence timing rather than phytomer initiation.

Yield Components and Productivity

The effect of *Pornas* nanotechnology liquid organic fertilizer showed significantly different in all components of corn yield.

Pornas significantly improved length and diameter of cob, number of rows per cob, number of kernels per row, kernels wight per cob, 100-kernels weight, and yield of corn. The 2.0 mL L^{-1} treatment yielded the longest cobs (13.00 cm) and largest diameters (42.65 mm), representing increases of 19.16% and 18.54% over the control, respectively. Phosphorus plays a pivotal role in reproductive development, including inflorescence differentiation and seed set (Vance et al. 2003). The controlled-release nature of nano-fertilizers aligns nutrient supply with the crop's reproductive demand curve, minimizing deficiency-induced yield losses.

Kernels weight per cob peaked at *Pornas* 2.0 mL L^{-1} (64.88 g), not significantly different from 1.5 mL L^{-1} (64.45 g). Similarly, 100-kernels weight increased from 15.40 g (control) to 19.63 g (*Pornas* 2.0 mL L^{-1}). These improvements reflect enhanced source-sink relationships, where adequate macro- and micronutrient availability sustains photosynthate production and remobilization to developing kernels (Broadley et al. 2012). Nano-carriers reduce nutrient fixation in acidic tropical soils, ensuring prolonged bioavailability during grain filling.

Yield increased from 3.91 Mg ha^{-1} (control) to 5.15 Mg ha^{-1} (*Pornas* 2.0 mL L^{-1}). However, the 1.5 mL L^{-1} (5.07 Mg ha^{-1}) did not significantly different from 2.0 mL L^{-1}, indicating diminishing returns at higher concentrations. Thus, 1.5 mL L^{-1} is agronomically and economically optimal. The observed yields remain below the Bisi 321 genetic potential (11.65–14.75 Mg ha^{-1}), likely due to suboptimal basal fertilization, limited organic matter, and compacted soil structure that restricted root exploration despite liming (Prasetyo et al. 2016). Future studies should integrate nano-LOFs with basal NPK and organic amendments to unlock full yield potential.

CONCLUSION

Based on the results of the study on "Response of Corn (*Zea mays* L.) to Nanotechnology Liquid Organic Fertilizer Application", it can be concluded as follows:

1. Application of *Pornas* nanotechnology liquid organic fertilizer significantly improved plant height, stem diameter, cob length, cob diameter, number of rows per cob, number of kernels per row, kernels weight per cob, weight of 100 kernels, yield of corn, but did not significantly affect leaf number.
2. The optimal concentration of *Pornas* to maximize maize growth and yield was 1.5 mL L^{-1}, producing 5.07 Mg ha^{-1} without significantly different in yield compared to 2.0 mL L^{-1} indicating higher nutrient use efficiency at lower concentrations.

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