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Influence of Lemek Sari Organic Fertilizer and NPK Tawon on the Growth and Yield of Chili

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Abstract
This study investigated the effects of Lemek Sari organic fertilizer and NPK Tawon inorganic fertilizer on the growth and yield of chili (Capsicum annuum L.). A randomized block design with a factorial arrangement was employed, incorporating five Lemek Sari doses (0, 10, 20, 30, 40 t ha^{-1}) and four NPK Tawon doses (0, 200, 400, 600 kg ha^{-1}). NPK Tawon fertilizer exerted highly significant effects ($P < 0.01$) on all measured growth and yield parameters. The optimum dose of 600 kg ha^{-1} produced the highest fruit weight (202.37 g), representing a 2073.68% increase over the unfertilized control. Lemek Sari organic fertilizer applied independently had a significant effect solely on stem diameter ($P < 0.05$), whereas the 40 t ha^{-1} dose elevated fruit weight by 90.07% relative to the control. A highly significant synergistic interaction ($P < 0.01$) was observed for the number of harvested fruits, with the combination of 40 t ha^{-1} Lemek Sari and 600 kg ha^{-1} NPK Tawon yielding the highest fruit number (34.67 fruits per plant), compared to zero fruits in the unfertilized control. Correlation analysis revealed near-perfect positive relationships ($r > 0.90$) among vegetative and generative parameters under NPK Tawon treatment, confirming that macronutrient supply acted as the primary limiting factor for yield formation. These findings demonstrate that soil improvement by high-dose Lemek Sari organic fertilizer maximizes the efficiency of NPK Tawon, providing a scientifically grounded strategy for sustainable intensification of chili production.

Keywords: *Chili plant (Capsicum annuum L.); Lemek Sari organic fertilizer; NPK Tawon inorganic fertilizer; integrated nutrient management; sustainable horticulture*

1. Introduction

Red chili (*Capsicum annuum* L.) is one of the most economically significant horticultural commodities in Indonesia, characterized by consistently high daily market demand and a substantial contribution to smallholder farmer income and national food security [1]. Despite this importance, average chili productivity in many production regions remains critically low, primarily due to suboptimal fertilization practices and inadequate soil nutrient management [2].

Fertilization is a decisive determinant of chili productivity, as nutrient availability directly governs vegetative growth, reproductive development, and final yield [3],[4]. Two complementary categories of soil amendment warrant systematic investigation. Lemek Sari organic fertilizer, derived through the controlled fermentation of livestock waste, enhances soil physical structure, fosters beneficial microbial communities, and releases macro- and micronutrients gradually throughout the crop cycle [5]. In contrast, NPK Tawon inorganic fertilizer supplies readily bioavailable nitrogen, phosphorus, and potassium, providing immediate nutritional support during both vegetative and reproductive development stages [6]. However, exclusive or excessive reliance on inorganic fertilizers without balanced organic inputs progressively degrades soil quality through microbial disruption, organic matter depletion, and accelerated nutrient leaching [7].

Prior studies have demonstrated that NPK fertilizer at 400 kg ha^{-1} significantly improved plant height and leaf count at 4–6 weeks after planting in chili, reflecting enhanced photosynthetic capacity and reproductive potential [8]. The rapid solubility of inorganic fertilizers, however, predisposes applied nutrients to leaching and consequent long-term productivity loss [9]. Conversely, organic amendments such as Lemek Sari at 30 t ha^{-1} have been shown to improve soil fertility and chili productivity through a gradual nutrient mineralization mechanism [10]. Comparable organic inputs, including chicken manure at 30 kg ha^{-1}, have markedly elevated plant height, fresh biomass, branching density, and total yield [11]. These complementary findings suggest that combining Lemek Sari organic fertilizer with NPK Tawon inorganic fertilizer constitutes an integrated nutrient management approach capable of diversifying nutrient supply while sustaining long-term soil fertility [12],[13],[14].

Despite growing evidence supporting integrated fertilizer strategies in solanaceous crops, no published study has quantified the independent and interactive effects of these two specific product formulations, Lemek Sari organic fertilizer and NPK Tawon inorganic fertilizer, on chili growth and yield under polybag cultivation conditions in Bali. This knowledge gap limits the development of locally adapted fertilization guidelines for Indonesian smallholder systems.

The present study therefore aimed to: (i) determine the optimum dose of Lemek Sari organic fertilizer and NPK Tawon inorganic fertilizer as independent factors; (ii) quantify their interactive effects on vegetative growth parameters (plant height, leaf number, stem diameter, fresh root, stem, leaf, and total biomass weight) and yield parameters (number and weight of harvested fruits); and (iii) assess correlational relationships between vegetative and generative variables under each fertilizer treatment. The outcomes are expected to provide critical insights for optimizing fertilization strategies that simultaneously maximize chili productivity and mitigate negative environmental impacts associated with intensive monoculture practices.

2. Materials and Methods

This field experiment was conducted in Br. Gunaksa, Cempaga Village, Bangli District, Bangli Regency, Bali, Indonesia, from May to October 2025. Before treatment application, a soil analysis was performed at the experimental site to characterize its initial fertility status. The experimental materials included chili seedlings (*Capsicum annuum* L.), NPK Tawon fertilizer (plus boron), Lemek Sari organic fertilizer, growing medium, polybags, and clean water. Standard horticultural tools were employed throughout the experiment.

A randomized block design (RBD) with a 5 × 4 factorial arrangement was used. The first factor was the dose of Lemek Sari organic fertilizer at five levels: L1 = 0 t ha^{-1} (0 g polybag^{-1}), L2 = 10 t ha^{-1} (50 g polybag^{-1}), L3 = 20 t ha^{-1} (100 g polybag^{-1}), L4 = 30 t ha^{-1} (150 g polybag^{-1}), and L5 = 40 t ha^{-1} (200 g polybag^{-1}). The second factor was the dose of NPK Tawon inorganic fertilizer at four levels: T1 = 0 kg ha^{-1}, T2 = 200 kg ha^{-1} (1.0 g polybag^{-1}), T3 = 400 kg ha^{-1} (1.5 g polybag^{-1}), and T4 = 600 kg ha^{-1} (3.0 g polybag^{-1}). The factorial combination of these two factors yielded 20 treatment combinations, each replicated three times, producing a total of 60 experimental units. The RBD was selected to control for spatial variation in environmental conditions across the experimental site.

Growth data (plant height, number of leaves, stem diameter, fresh weights of root, stem, leaf, and total biomass) and yield data (number and weight of harvested fruits) were collected at defined phenological stages. Data were subjected to analysis of variance (ANOVA), and significant treatment means were separated using the Least Significant Difference (LSD) test at $P \leqslant 0.05$. Pearson correlation coefficients were computed among all measured parameters to characterize the associations between vegetative and generative variables under each treatment factor.

3. Results and Discussion

Soil analysis before treatment revealed a neutral pH and sandy loam texture, but low overall fertility attributable to deficiencies in organic carbon and available macronutrients. This baseline condition necessitated external nutrient inputs to support adequate vegetative development. The significance levels of Lemek Sari organic fertilizer (L), NPK Tawon fertilizer (T), and their interaction (L × T) on all observed variables are summarized in Table 1.

Table 1. Significance of the effects of Lemek Sari organic fertilizer (L), NPK Tawon fertilizer (T), and their interaction (L×T) on all observed variables.

Variable	Treatment		
	L	T	LxT
Plant height (cm)	ns	**	ns
Number of leaves (strands)	ns	**	ns
Stem diameter (mm)	*	**	ns
Fresh root weight (g)	ns	**	ns
Fresh stem weight (g)	ns	**	ns
Fresh leaf weight (g)	ns	**	ns
Fresh biomass weight (g)	ns	**	ns
Number of harvested fruits (fruits)	ns	**	*
Weight of harvested fruit (g)	ns	**	ns

Note: ns = not significant ($P \geq 0{,}05$); ** = very significant ($P<0.01$); * = significant ($P<0.05$)

3.1. Growth Parameters

NPK Tawon fertilizer exerted a highly significant effect ($P < 0.01$) on all measured growth parameters, whereas Lemek Sari organic fertilizer had a significant effect only on stem diameter ($P < 0.05$), and no significant interaction (L × T) was detected for any growth variable (Table 1). Plant height increased progressively with NPK Tawon dose, reaching its maximum of 100.07 cm at 600 kg ha^{-1} (T4), compared to 52.40 cm in the unfertilized control (T1). The differential of 47.67 cm reflects the critical role of nitrogen in promoting cell elongation and meristematic activity. Leaf number followed the same trend; the highest mean of 115.40 leaves per plant was recorded at T4, which was significantly greater than T1 and T2 but did not differ significantly from T3 at the 5% LSD level. This positive response in leaf production to increasing inorganic fertilizer rates underscores the fundamental importance of nitrogen and potassium in facilitating cellular division and photosynthetic efficiency [15].

Stem diameter was the sole growth parameter significantly influenced by Lemek Sari organic fertilizer ($P < 0.05$). The maximum stem diameter under organic treatment was recorded at L5 (40 t ha^{-1}) at 10.20 mm, which differed significantly from L3 and L1 but not from L4 and L2. Under NPK Tawon treatment, the highest stem diameter was achieved at T4 (11.18 mm), which was not significantly different from T3 but exceeded T2 and T1 significantly. The observed increase in diameter at higher NPK doses indicates that nutrient availability directly supports secondary thickening and the structural reinforcement of chili stems, consistent with previous findings on the role of potassium in cell wall synthesis [16]. These results also align with prior evidence that the generative phase of chili demands elevated levels of nitrogen and phosphorus to sustain robust vegetative development [17].

Fresh weights of root, stem, leaf, and total biomass were all highly significantly affected by NPK Tawon fertilizer ($P < 0.01$), with maximum values consistently recorded at the 600 kg ha^{-1} dose (Table 2). Fresh root weight reached 29.19 g at T4, significantly exceeding T3, T2, and T1. Fresh stem weight (97.63 g), fresh leaf weight (52.71 g), and total fresh biomass weight (347.99 g) also peaked at T4 and were significantly different from all lower doses in the case of stem and biomass, whereas leaf weight differences among NPK levels did not reach statistical significance. Lemek Sari organic fertilizer did not significantly affect any of these parameters, consistent with evidence that organic amendments require extended decomposition periods before their nutrient contribution becomes measurable in short-term vegetative growth studies [18],[19]. The sustained elevation of vegetative biomass at the highest NPK dose confirms that inorganic nutrient availability acts as the primary catalyst for metabolic activity during rapid stem and leaf expansion [20]. The absence of a significant fresh leaf weight response across NPK levels beyond T1 suggests that physiological efficiency may stabilize at moderate mineral concentrations, a finding consistent with evidence that excessive inorganic fertilization does not always correlate linearly with increased vegetative biomass [21],[22],[23]. These patterns mirror reports from solanaceous crops where inorganic fertilizers consistently deliver higher concentrations of immediately available macronutrients during active vegetative stages compared with organic amendments applied under equivalent agronomic conditions [24].

Table 2. Measurement results of chili plant growth parameters under Lemek Sari organic fertilizer and NPK Tawon treatments

Treatment	Plant Height (cm)	Number of Leaves (strand)	Stem Diameter (mm)	Fresh Root Weigh (g)	Fresh Stem Weight (g)	Fresh Leaf Weight (g)	Fresh Biomass Weight (g)	Weight of Harvested Fruit (g)
Organic Fertilizer	(ns)	(ns)	(*)	(ns)	(ns)	(ns)	(ns)	(ns)
L1 (0 t ha⁻¹)	79,58 a	73,50 a	8,55 c	18,68 a	60,41 a	27,41 a	205,92 a	79,38 a
L2 (10 t ha⁻¹)	80,33 a	87,92 a	9,31 ab	17,58 a	58,93 a	30,49 a	210,58 a	121,72 a
L3 (20 t ha⁻¹)	87,00 a	86,83 a	9,15 b	17,28 a	53,68 a	19,66 a	179,48 a	128,18 a
L4 (30 t ha⁻¹)	84,50 a	86,92 a	9,28 ab	18,30 a	65,12 a	35,08 a	230,43 a	128,02 a
L5 (40 t ha⁻¹)	90,58 a	90,92 a	10,20 a	18,90 a	66,72 a	33,90 a	230,68 a	150,88 a
LSD 5%	-	-	0,98	-	-	-	-	-
NPK Fertilizer	(**)	(**)	(**)	(**)	(**)	(**)	(**)	(**)
T1 (0 kg ha⁻¹)	52,40 c	37,67c	6,19 c	8,46 c	13,84 d	6,68 c	56,85 d	9,31 c
T2 (200 kg ha⁻¹)	88,87 b	86,73b	9,38 b	15,89 bc	55,75 c	25,23 b	187,65 c	115,04 b
T3 (400 kg ha⁻¹)	96,27 ab	101,07ab	10,45 a	19,05 b	76,65 b	32,61 b	253,16 b	159,83 ab
T4 (600 kg ha⁻¹)	100,07 a	115,40 a	11,18 a	29,19 a	97,63 a	52,71 a	347,99 a	202,37 a
LSD 5%	10,64	16,82	0,88	7,72	17,84	13,44	64,82	61,70

Note: Mean values followed by the same letter in the same column indicate no significant difference at the 5% LSD test.

3.2. Yield Parameters

A highly significant synergistic interaction ($P < 0.01$) between Lemek Sari organic fertilizer and NPK Tawon fertilizer was detected for the number of harvested fruits (Table 1 and Table 3). The highest fruit numbers were recorded under the L5T4 and L4T4 treatment combinations (34.67 fruits per plant each), whereas the unfertilized control (L1T1) produced no fruit. The mean separation test confirmed that L4T4 and L5T4 differed significantly from most other treatment combinations, establishing that the application of high-dose Lemek Sari in conjunction with 600 kg ha⁻¹ NPK Tawon provided the most substantial improvement in fruit yield. This synergistic outcome is consistent with published evidence demonstrating that integrated nutrient management combining organic amendments with inorganic sources significantly enhances reproductive parameters and overall crop productivity [25],[26]. The improved availability of phosphorus and potassium at higher application levels likely played a pivotal role in optimizing fruit morphology and reducing flower abscission, as both elements are essential for protein synthesis and carbohydrate translocation during the reproductive phase [27].

Table 3. Average number of harvested fruits due to the interaction between Lemek Sari organic fertilizer and NPK Tawon fertilizer

Treatment	T1 (0 kg ha⁻¹)	T2 (200 kg ha⁻¹)	T3 (400 kg ha⁻¹)	T4 (600 kg ha⁻¹)
L1 (0 t ha⁻¹)	0.00 e	14.67 cde	12.67 bcde	5.33 cde
L2 (10 t ha⁻¹)	1.33 de	14.67 bcd	12.67 bcde	14.00 bcde
L3 (20 t ha⁻¹)	2.00 cde	20.00 b	20.00 b	15.33 bc
L4 (30 t ha⁻¹)	2.00 cde	5.33 cde	14.67 bcd	34.67 a
L5 (40 t ha⁻¹)	0.00 e	9.33 bcde	14.00 bcde	34.67 a

Note: Values followed by the same letter in the same row or column indicate no significant difference according to Duncan's Multiple Range Test at the 5% level.

Fruit weight followed a similar pattern. NPK Tawon at 600 kg ha⁻¹ (T4) produced the highest fruit weight (202.37 g), which was not significantly different from T3 (159.83 g) but significantly

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exceeded T2 (115.04 g) and T1 (9.31 g). The 600 kg ha^{-1} dose represented a 2073.68% increase over the control and a 75.91% increase relative to the 200 kg ha^{-1} treatment. These results confirm that inorganic fertilizer is the primary driver of fruit biomass accumulation, as adequate macronutrient availability during the reproductive stage directly facilitates carbohydrate translocation to developing fruits [28],[29]. Lemek Sari organic fertilizer at the highest dose (L5, 40 t ha^{-1}) produced the greatest fruit weight among organic treatments (150.88 g), representing a 90.07% improvement over the control, yet this difference was not statistically significant among organic doses alone. This outcome is attributable to the gradual mineralization characteristic of fermented organic amendments, which did not provide sufficient immediately available nutrients to induce statistically distinguishable yield differences within the relatively short experimental timeline [30].

The improvements in plant height, leaf number, and fresh biomass under increasing NPK doses confirm that nitrogen supported chlorophyll formation and vegetative expansion, phosphorus enhanced root development, and potassium regulated metabolic homeostasis and water relations. The availability of these macronutrients further ensured metabolic energy for reproductive processes, as reflected in the strong correlations reported below. Collectively, the data confirm that NPK Tawon fertilizer is the principal determinant of chili vegetative and generative performance under the tested conditions, and that high-dose Lemek Sari organic fertilizer potentiates this effect by improving the soil physical environment and nutrient retention capacity [31],[32],[33].

3.3. Correlation Analysis

Pearson correlation analysis was conducted separately for the Lemek Sari (L), NPK Tawon (T), and interaction (L × T) treatment effects. Under NPK Tawon treatment (Table 5), all pairwise correlations among the nine measured variables exceeded $r = 0.85$ and were highly significant ($P < 0.01$), with most exceeding $r = 0.99$. The strongest associations were observed between leaf number and fruit weight ($r = 0.996$), fresh stem weight and total fresh biomass ($r = 0.996$), and plant height and fruit weight ($r = 0.972$). These near-perfect positive relationships confirm that, in the low-fertility soil conditions of this study, NPK Tawon fertilizer effectively compensated for nutrient deficiencies by establishing consistently integrated relationships between vegetative development and generative output. The responsiveness underscores the physiological efficiency of providing nitrogen, phosphorus, and potassium in immediately bioavailable forms to satisfy the metabolic demands of chili during intensive fruit production [34],[35].

Under Lemek Sari's organic fertilizer treatment alone (Table 4), correlations between vegetative and generative parameters were weaker. Notably, plant height exhibited a highly significant positive correlation with fruit number ($r = 0.917$) and fruit weight ($r = 0.836$), while stem diameter correlated with both fruit number ($r = 0.754$) and fruit weight ($r = 0.923$). These relationships suggest that even the indirect soil improvements attributed to organic fertilizer enhanced cation exchange capacity, improved moisture retention, and stimulated microbial activity were sufficient to establish a measurable linkage between vegetative architecture and yield potential over the experimental duration, despite the absence of statistically significant direct effects on most individual parameters [36].

Under the combined treatment (L × T interaction, Table 6), all pairwise correlations were highly significant ($P < 0.01$), with key associations including leaf number versus fruit weight ($r = 0.929$), fresh stem weight versus total biomass ($r = 0.993$), and fruit number versus fruit weight ($r = 0.935$). The elevated correlation coefficients relative to the organic-only treatment confirm that the combination of Lemek Sari and NPK Tawon supported more integrated vegetative–generative growth dynamics than either input applied alone. Organic amendment improves soil cation exchange capacity and thereby enhances the availability of nutrients released from inorganic fertilizer, reducing leaching losses and ensuring a synchronized supply of essential elements during critical stages of fruit development [37],[38]. This synergistic integration of nutrient sources aligns with evidence that combined organic–inorganic fertilization promotes

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more stable growth trajectories and significantly higher yield components compared with single-source fertilizations [39],[40],[41].

Table 4. Correlation coefficients among variables under the effect of Lemek Sari organic fertilizer (L)

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
2	0.684**							
3	0.805**	0.856**						
4	0.172ns	-0.243ns	0.245ns					
5	0.293ns	0.207ns	0.538ns	0.838**				
6	0.072ns	0.275ns	0.474ns	0.639*	0.930**			
7	0.175ns	0.267ns	0.520ns	0.723**	0.974**	0.989**		
8	0.917**	0.795**	0.754**	-0.207ns	-0.035ns	-0.168ns	-0.102ns	
9	0.836**	0.969*	0.923**	-0.069ns	0.314ns	0.292ns	0.321ns	0.870**

Note: r (0,05;13,1) = 0,553, r (0,01;13;1) = 0,684

Table 5. Correlation coefficients among variables under the effect of NPK Tawon fertilizer (T)

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
2	0.989**							
3	0.992**	0.999**						
4	0.859**	0.924**	0.912**					
5	0.958**	0.990**	0.987**	0.962**				
6	0.892**	0.948**	0.938**	0.998**	0.978**			
7	0.933**	0.976**	0.970**	0.982**	0.996**	0.992**		
8	0.992**	0.998**	0.996**	0.914**	0.980**	0.939**	0.966**	
9	0.972**	0.996**	0.994**	0.949**	0.999**	0.968**	0.991**	0.989**

Note: r (0.05;10;1) = 0.632; r (0.01;10;1) = 0.765

Table 6. Correlation coefficients among variables under the interaction between Lemek Sari organic fertilizer and NPK Tawon fertilizer (L×T)

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
2	0.942**							
3	0.951**	0.945**						
4	0.711**	0.708**	0.768**					
5	0.929**	0.918**	0.942**	0.869**				
6	0.801**	0.853**	0.873**	0.817**	0.933**			
7	0.892**	0.902**	0.925**	0.893**	0.993**	0.961**		
8	0.739**	0.847**	0.715**	0.466**	0.654**	0.607**	0.641**	
9	0.810**	0.929**	0.844**	0.556**	0.781**	0.779**	0.779**	0.935**

Note: r (0.05;58;1) = 0.254; r (0.01;58;1) = 0.330

Legend:
1 = lant Height, 2 = Number of Leaves, 3 = Stem Diameter, 4 = Fresh Root Weight, 5 = Fresh Stem Weight, 6 = Fresh Leaf Weight, 7 = Fresh Biomass Weight, 8 = Number of Fruits, 9 = Fruit Weight.
ns = not significant ($P > 0.05$); * = significant ($P < 0.05$); ** = highly significant ($P < 0.01$).

4. Conclusion

Lemek Sari organic fertilizer at 40 t ha^{-1} produced a 90.07% increase in fruit weight over the unfertilized control (150.88 g vs. 79.38 g) and was the only growth parameter to respond significantly to organic treatment (stem diameter, $P < 0.05$); its indirect benefit lies primarily in improving soil physical and biological properties that potentiate mineral fertilizer efficiency. NPK Tawon inorganic fertilizer at 600 kg ha^{-1} was the dominant growth and yield driver, increasing fruit weight by 2073.68% over the control (202.37 g vs. 9.31 g) and producing highly significant improvements ($P < 0.01$) in all nine measured parameters, underscoring the absolute requirement for macronutrient supply in low-fertility soils. The highest-dose combination of Lemek Sari (40 t

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ha^{-1}) and NPK Tawon (600 kg ha^{-1}) produced a highly significant synergistic interaction for fruit number (34.67 fruits per plant), and near-perfect positive correlations ($r > 0.99$) among vegetative and yield parameters under NPK treatment confirmed that balanced macronutrient availability is the primary limiting factor for chili productivity under the experimental conditions. Combining high-dose Lemek Sari organic fertilizer with NPK Tawon inorganic fertilizer is therefore recommended as a sustainable integrated nutrient management strategy that simultaneously maximizes short-term productivity and preserves long-term soil health for chili cultivation in comparable agro-ecological settings.

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