



Growth and Yield Responses of Several Strawberry (*Fragaria* sp.) Varieties to the Application of Different Types of Manure

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Abstract

Background. Strawberries are a popular fruit valued for their bright red color, fresh sweet-sour taste, and numerous health benefits. Because strawberry varieties respond differently to organic fertilizers, identifying the manure type that gives the highest yield for each variety is important; differences in results among studies can also arise from environmental factors such as altitude, temperature, humidity, and soil type.

Aims. This study aimed to determine the growth and yield of four strawberry varieties in response to three manure types and to identify the manure type that produced the highest yield for each variety.

Methods. The experiment was conducted from May to August 2023 at the Experimental Garden of the Faculty of Agriculture, Universitas Winaya Mukti, Sumedang (875 m above sea level), using a factorial Randomized Block Design (RBD) with two factors: strawberry variety (Knia, California, Earlybrite, and Mencir) and manure type (cow, chicken, and goat). Treatment means were compared using Duncan's Multiple Range Test at the 5% level.

Conclusion. The combination of the Knia variety and goat manure produced the greatest plant length, while the combination of the Mencir variety and goat manure produced the highest number of flowers at 30 days after transplanting (DAT) and the greatest fruit weight.

Keywords: chicken manure; cow manure; goat manure; strawberry varieties



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INTRODUCTION

Strawberry is one of the most popular fruits worldwide because of its bright red color, fresh sweet-sour taste, and numerous health benefits. Beyond being eaten fresh, strawberries are widely processed into other products and are also used as raw material for medicines and cosmetics. Eating eight strawberries a day is reported to help prevent the development of several diseases (Aries Septiani, 2019). Every 100 g of fresh strawberry contains approximately 37 kcal of energy, 0.8 g protein, 0.5 g fat, 8.0 g carbohydrate, 28 mg calcium, 27 mg phosphorus, 0.8 mg iron, 60 IU

vitamin A, 0.03 mg vitamin B, 60 mg vitamin C, and 89.9 g water. Strawberries — particularly the seeds and leaves — also contain ellagic acid, which has been reported to inhibit cancer cell growth, improve skin appearance, whiten teeth, reduce bad breath, and support cognitive and visual function; the roots, meanwhile, contain anti-inflammatory compounds.

Cow manure and chicken manure both supply nitrogen, phosphorus, and potassium, the macronutrients required for plant growth (Listyaningtyas & Tatik, 2017). Goat manure plays a similar role but offers an additional advantage in nutrient content.

According to Alzamar (2017), a dose of 50 t ha⁻¹ of cow manure gave the best effect on growth (length of the longest leaflet) and yield (number of fruits per plant) of strawberry. Jeriko and Chellvio (2018) found that 30–40 t ha⁻¹ of chicken manure produced the best plant height, fruit diameter, fruit weight per plant, and yield per hectare of strawberry.

Building on this background, the present study aimed to determine the growth and yield of several strawberry varieties in response to different types of manure, and to identify which manure produced the highest yield in each variety. We hypothesized that growth and yield would differ among varieties and manure types, and that a particular manure type would give the highest yield for each variety.

METHOD

The materials used in this experiment were strawberry stolons of four varieties (Knia, California, Earlybrite, and Mencir), soil, cocopeat, Furadan (carbofuran), organic manure (cow, chicken, and goat), mulch, 25 × 25 cm polybags, and NPK fertilizer. The equipment used included hoes, labels, a measuring tape, hoses, stationery, an analytical balance, stakes, plastic sheeting, scissors, buckets, and a camera.

The experiment used a two-factor factorial Randomized Block Design (RBD). The first factor was strawberry variety (four levels), and the second factor was manure type (three levels). Each treatment combination was replicated three times, giving $4 \times 3 \times 3 = 36$ experimental plots. Plant height was measured with a measuring tape; the numbers of leaves, flowers, and fruits were counted visually; fruit weight was measured with an analytical balance; the shoot-root ratio was determined from the oven-dried constant weight of shoots and roots; vitamin C content was determined by duplicate titration; chlorophyll content was measured with a chlorophyll meter; and stomatal conductance was measured with a porometer. Data were analyzed using analysis of

variance (ANOVA; F test); when treatment effects were significant, means were compared using Duncan's Multiple Range Test (DMRT) at the 5% level.

DISCUSSION

Analysis of plant length at 14, 30, and 60 DAT showed no interaction between strawberry variety and manure type at any observation age; results of the independent-effect tests are presented in Table 1.

Table 1. Effect of Strawberry Variety and Manure on Plant Length at 14, 30, and 60 DAT

Treatment	14 DAT	30 DAT	60 DAT
Varieties			
v ₁ (Knia)	17.27 c	16.56 b	15.90 b
v ₂ (California)	13.00 a	14.79 a	14.35 ab
v ₃ (Earlybrite)	15.29 b	14.70 a	13.85 a
v ₄ (Mencir)	15.47 bc	15.30 ab	14.78 ab
Manure			
p ₁ (Cow)	14.97 a	15.71 b	15.26 b
p ₂ (Chicken)	15.15 b	14.22 a	13.24 a
p ₃ (Goat)	15.66 c	16.08 c	15.66 b

Note: Means followed by the same lowercase letter within the same column are not significantly different according to Duncan's Multiple Range Test at the 5% level.

As shown in Table 1, strawberry variety significantly affected plant length at 14, 30, and 60 DAT. The Knia variety (v₁) was significantly taller than the California (v₂), Earlybrite (v₃), and Mencir (v₄) varieties at all three observation ages.

Manure type also significantly affected plant length at all three ages. Goat manure produced the greatest plant length at 14 and 30 DAT, significantly exceeding both cow and chicken manure; at 60 DAT, goat and cow manure did not differ significantly, but both exceeded chicken manure.

The Knia variety produced the greatest plant length at every observation age, likely reflecting its better adaptability compared with the other varieties tested. Goat manure produced the tallest plants, presumably owing to its nitrogen content, which supports the vegetative growth of strawberry plants (Oktarina et al., 2017). According to Anjarwat et al. (2017), goat manure has an advantage over cow and horse manure in that it contains higher concentrations of the macronutrients nitrogen (N), phosphorus (P), and potassium (K); nitrogen in particular promotes vegetative growth, especially of leaves and stems. This is consistent with more recent findings

from Kenya, where a composted mixture of chicken, goat, and cow manure produced significantly greater strawberry growth than bokashi manure or an unfertilized control, an effect attributed to the balanced supply of macro- and micronutrients and the improvement of soil physical and biological properties from mixed livestock manure (Mwendwa et al., 2024).

Analysis of the number of leaves at 14, 30, and 60 DAT showed no interaction between strawberry variety and manure type; results of the independent-effect tests are presented in Table 2.

Table 2. Effect of Strawberry Variety and Manure on the Number of Leaves at 14, 30, and 60 DAT

Treatment	14 DAT	30 DAT	60 DAT
Varieties			
v1 (Knia)	4.78 a	6.96 a	10.37 a
v2 (California)	5.26 ab	8.00 a	9.59 a
v3 (Earlybrite)	6.15 c	7.22 a	11.52 a
v4 (Mencir)	5.63 bc	7.70 a	10.85 a
Manure			
p1 (Cow)	5.36 b	6.39 b	10.97 b
p2 (Chicken)	5.06 a	7.50 a	10.08 a
p3 (Goat)	5.94 c	8.53 c	10.97 b

Note: Means followed by the same lowercase letter within the same column are not significantly different according to Duncan's Multiple Range Test at the 5% level.

Both strawberry variety and manure type independently and significantly increased leaf number at all three observation ages (Table 2). At 14 DAT, the Earlybrite and Mencir varieties did not differ significantly in leaf number; differences among varieties were smaller at 30 and 60 DAT. Manure type significantly increased leaf number at all three ages. At 14 and 30 DAT, goat manure produced significantly more leaves than cow manure and chicken manure. At 60 DAT, cow manure and goat manure did not differ significantly from each other, but both differed significantly from chicken manure.

Leaf number was highest in the Mencir variety compared with the other varieties. Goat manure had the strongest effect on leaf number, likely because of its nitrogen content; in addition, the Mencir variety is more resistant to fungal infection and leaf rot, so its leaf number is less reduced by disease. According to Anton et al. (2021), manure provides several benefits to plants through its macronutrient content (N, P, K). Goat manure in particular promoted leaf growth in this study, consistent with its reported nutrient composition of 2.10% N, 0.66% P₂O₅, 1.97% K₂O, 1.64% Ca, 0.60% Mg, 233 ppm Mn, and 90.8 ppm Zn. Analysis of flower number at 14, 30, and

60 DAT showed no interaction between strawberry variety and manure type; results of the independent-effect tests are presented in Table 3.

Table 3. Effect of Strawberry Variety and Manure on the Number of Flowers at 14, 30, and 60 DAT

Treatment	14 DAT	30 DAT	60 DAT
Varieties			
v ₁ (Knia)	0.04 a	0.74 a	0.37 a
v ₂ (California)	0.00 a	0.70 ab	0.30 a
v ₃ (Earlybrite)	0.00 a	0.22 b	0.33 a
v ₄ (Mencir)	0.26 b	0.78 c	0.37 a
Manure			
p ₁ (Cow)	0.03 a	0.58 ab	0.26 a
p ₂ (Chicken)	0.08 ab	0.39 a	0.25 a
p ₃ (Goat)	0.11 b	0.86 b	0.47 b

Note: Means followed by the same lowercase letter within the same column are not significantly different according to Duncan's Multiple Range Test at the 5% level.

As shown in Table 3, strawberry variety and manure type independently and significantly increased flower number at all observation ages. At 14 DAT, the California (v₂) and Earlybrite (v₃) varieties did not differ significantly, whereas the Knia (v₁) and Mencir (v₄) varieties differed significantly from the others. At 30 DAT, the Knia variety produced significantly more flowers than the other varieties. At 60 DAT, differences among varieties were no longer significant. Goat manure produced the significantly highest number of flowers at all three observation ages, exceeding both cow and chicken manure.

The Mencir variety produced the most flowers at 14 DAT, likely reflecting its genetically earlier flowering time. The Knia variety produced the most flowers at 30 DAT, consistent with its flowering onset at that age. Goat manure increased flowering and the number of flowers, fruits, and fruit weight across all observation ages. As an organic fertilizer, goat manure supplies sufficient macro- and micronutrients to support photosynthesis; the resulting photosynthate is partly translocated to reproductive organs, promoting the formation of flower clusters, flowers, fruits, and fruit weight (Rifai et al., 2018). Similar reproductive benefits of organic manure have

recently been reported at the metabolic level: Wu et al. (2024) found that manure application reprogrammed sugar, amino acid, and flavonoid metabolism in strawberry fruit, increasing yield alongside fruit quality traits, which supports the interpretation that manure-driven improvements in flowering and fruiting are linked to enhanced photosynthate availability and translocation.

Analysis of fruit number per plant at 14, 30, and 60 DAT showed no interaction between strawberry variety and manure type; results of the independent-effect tests are presented in Table 4.

Table 4. Effect of Strawberry Variety and Manure on the Number of Fruits per Plant at 14, 30, and 60 DAT

Treatment	14 DAT	30 DAT	60 DAT
Varieties			
v1 (Knia)	0.15 a	0.85 ab	3.78 a
v2 (California)	0.00 a	1.26 b	2.85 b
v3 (Earlybrite)	0.04 a	0.26 a	1.44 b
v4 (Mencir)	0.44 a	1.48 b	3.07 b
Manure			
p1 (Cow)	0.22 a	1.14 b	3.22 b
p2 (Chicken)	0.08 a	0.50 a	2.19 a
p3 (Goat)	0.17 a	1.25 b	2.94 b

Note: Means followed by the same lowercase letter within the same column are not significantly different according to Duncan's Multiple Range Test at the 5% level.

Strawberry variety and manure type independently and significantly increased fruit number at 14, 30, and 60 DAT (Table 4). At 14 DAT, differences among varieties were not significant. At 30 DAT, the California and Mencir varieties differed significantly from the other varieties. At 60 DAT, the Knia variety produced significantly more fruits than the other varieties. Manure type did not significantly affect fruit number at 14 DAT; at 30 and 60 DAT, goat manure and cow manure did not differ significantly.

The Mencir variety produced the highest fruit number per plant at 14 and 30 DAT, likely because its earlier flowering allows it to set fruit sooner than other varieties. Goat manure consistently produced the highest fruit number, likely because its combined macro- and micronutrient content improves soil fertility and nutrient uptake, enhancing photosynthesis; the resulting photosynthate supports fruit formation and increases fruit number (Rifai et al., 2018). Analysis of fruit weight per plant showed no interaction between strawberry variety and manure type; results of the independent-effect tests are presented in Table 5.

Table 5. Effect of Strawberry Variety and Manure on Fruit Weight per Plant

Treatment	Average
Varieties	
v1 (Knia)	47.00 g – b
v2 (California)	47.02 g – b
v3 (Earlybrite)	21.87 g – a
v4 (Mencir)	67.20 g – c
Manure	
p1 (Cow)	48.65 g – b
p2 (Chicken)	32.54 g – a
p3 (Goat)	56.14 g – c

Note: Means followed by the same lowercase letter within the same column are not significantly different according to Duncan's Multiple Range Test at the 5% level.

Strawberry variety and manure type independently and significantly increased fruit weight per plant (Table 5). The Mencir variety and goat manure each produced the significantly highest fruit weight. The greater fruit weight of the Mencir variety is likely attributable to its genetically larger fruit size, one of the variety's key advantages. Goat manure produced the highest fruit weight, likely owing to its relatively complete nutrient content, which supports strawberry growth and yield; phosphorus in particular is required during root, flower, and fruit development (Effendy et al., 2021). This pattern agrees with recent strawberry fertilization trials showing that organic and manure-based nutrient sources increase fruit weight, fruit number, and yield relative to unamended or purely inorganic treatments, alongside gains in fruit quality (Quddus et al., 2025). Analysis of the shoot-root ratio showed no interaction between strawberry variety and manure type; results of the independent-effect tests are presented in Table 6.

Strawberry variety significantly affected the shoot-root ratio, whereas goat manure did not differ significantly from cow manure in its effect on this ratio. The Knia, California, and Mencir varieties had a higher shoot-root ratio than the Earlybrite variety. Goat manure produced the highest shoot-root ratio, likely reflecting the adequate nutrient content of the manure and growing medium together with supplementary fertilization. Adding organic materials such as goat and cow manure can improve root growth, as both are relatively rich in phosphorus, which stimulates root development (Arif et al., 2021).

Table 6. Effect of Strawberry Variety and Manure on Shoot-Root Ratio

Treatment	Average
Varieties	
v1 (Knia)	1.01 a
v2 (California)	1.00 a
v3 (Earlybrite)	0.96 a
v4 (Mencir)	0.99 a
Manure	
p1 (Cow)	0.99 ab
p2 (Chicken)	0.98 a
p3 (Goat)	1.00 b

Note: Means followed by the same lowercase letter within the same column are not significantly different according to Duncan's Multiple Range Test at the 5% level.

Analysis of vitamin C content showed a significant interaction between strawberry variety and manure type; results of the treatment-combination tests are presented in Table 7.

Table 7. Effect of Strawberry Variety and Manure on Vitamin C Content

Treatment	v1 (Knia)	v2 California	v3 (Earlybrite)	v4 Mencir
p1 Cow	72.55 a A	67.59 a A	64.92 a C	64.92 a A
p2 Chicken	71.77 a A	67.08 a A	6.65 b A	68.44 a B
p3 Goat	68.25 ab A	68.05 ab A	53.39 a B	72.94 b B

Note: Lowercase letters compare varieties within the same manure treatment (row); uppercase letters compare manure treatments within the same variety (column). Means sharing the same letter are not significantly different according to Duncan's Multiple Range Test at the 5% level.

[Editorial note: decimal commas in the source table (e.g., “72,55”) have been converted to decimal points for consistency with the other tables; please confirm the values against your raw data.]

As shown in Table 7, the interaction between strawberry variety and manure type significantly affected vitamin C content. Under cow manure, all strawberry varieties differed significantly from one another. Under chicken manure, the Earlybrite variety differed significantly from the Knia, California, and Mencir varieties. Under goat manure, the Earlybrite variety did not differ significantly from the Knia and California varieties.

The highest vitamin C content occurred under goat manure, reflecting a significant variety × manure interaction. Vitamin C content in strawberry fruit is known to vary with cultivar, growing environment, and analytical method (Satria & Tarigan, 2017), and manure-based fertilization in particular has recently been shown to raise fruit vitamin C content by up to about 46% compared

with chemical fertilizer alone, alongside increases in soluble sugars and the sugar/acid ratio (Wu et al., 2024) — consistent with the higher vitamin C values observed here under goat manure. Analysis of chlorophyll content showed no interaction between strawberry variety and manure type; results of the independent-effect tests are presented in Table 8.

Table 8. Effect of Strawberry Variety and Manure on Chlorophyll Content Index ($\mu\text{mol m}^{-2}$)

Treatment	Average
Varieties	
v1 (Knia)	18.73 a
v2 (California)	22.03 a
v3 (Earlybrite)	23.85 a
v4 (Mencir)	21.22 a
Manure	
p1 (Cow)	20.93 a
p2 (Chicken)	21.82 a
p3 (Goat)	21.63 a

Note: Means followed by the same lowercase letter within the same column are not significantly different according to Duncan's Multiple Range Test at the 5% level.

Neither strawberry variety nor manure type significantly affected chlorophyll content (Table 8). During vegetative growth, nitrogen is the nutrient plants require most: it stimulates root, stem, and leaf growth, supports cell formation, and contributes to chlorophyll formation, enabling leaves to capture light for photosynthesis and thereby supporting cell division and enlargement. Adequate nutrient availability promotes efficient photosynthesis through optimal chlorophyll formation. Nitrogen is also required for the synthesis of proteins and other compounds that influence leaf number (Dewi, 2017).

Analysis of stomatal conductance showed a significant interaction between strawberry variety and manure type; results of the treatment-combination tests are presented in Table 9.

Table 9. Effect of Strawberry Variety and Manure on Stomatal Conductance ($\text{mmol m}^{-2} \text{s}^{-1}$)

Treatment	v1 Knia	v2 California	v3 Earlybrite	v4 Mencir
p1 Cow	256.53 b	231.72 b	202.55 b	118.78 a
	A	A	B	A

p2 Chicken	166.45 a A	372.92 c B	247.35 bc C	217.73 ab B
p3 Goat	492.35 c B	256.83 b A	118.78 a A	257.65 bc C

Note: Lowercase letters compare varieties within the same manure treatment (row); uppercase letters compare manure treatments within the same variety (column). Means sharing the same letter are not significantly different according to Duncan's Multiple Range Test at the 5% level.

[Editorial note: decimal commas in the source table (e.g., “256,53”) have been converted to decimal points for consistency with the other tables; please confirm the values against your raw data.]

As shown in Table 9, the interaction between strawberry variety and manure type significantly affected stomatal conductance. Under cow manure, the Knia and Earlybrite varieties differed significantly from the California and Mencir varieties. Under chicken manure, the Earlybrite variety differed significantly from all other varieties. Under goat manure, the Knia and Mencir varieties differed significantly from the California and Earlybrite varieties.

The Knia variety showed the highest stomatal conductance overall, with chicken manure and goat manure producing the highest values among manure types — likely reflecting environmental conditions favorable to strawberry growth. Stomatal conductance reflects the opening and closing of stomata, which is influenced by stomatal pore size and density (Murray et al., 2016). Stomatal opening itself responds to carbon dioxide concentration, humidity, temperature, wind, light, and leaf water potential (Lestari, 2023). Soleh et al. (2017) also reported that stomata regulate gas exchange in plants in tandem with the level of stomatal conductance.

CONCLUSION

Strawberry variety and manure type affected the growth and yield of the strawberry plants tested. The combination of the Knia variety and goat manure produced the greatest plant length, while the combination of the Mencir variety and goat manure produced the highest number of flowers at 30 DAT and the greatest fruit weight. Goat manure produced the highest yield in both the Knia and Mencir varieties.

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