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The Effect of Organic Fertilization (Pigeon and Sheep Manure) on the Productivity of Libyan Beans (Vicia faba L)

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تأثير التسميد العضوي (سماد الحمام والأغنام) على إنتاجية الفاصوليا الليبية (Vicia faba L)

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الملخص:

إنتاجية الفول البلدي **(Vicia faba L.)** في ظل ظروف شبه قاحلة في سرت، ليبيا. أُجريت تجربة حقلية خلال موسم 2025/2024 باستخدام تصميم القطاعات الكاملة العشوائية بثلاث معاملات: معاملة الشاهد (بدون سماد)، وسماد الحمام (10 أطنان للهكتار)، وسماد الأغنام (10 أطنان للهكتار)، مع تكرار كل معاملة ثلاث مرات. سُجلت خصائص النمو (ارتفاع النبات، التفرع، عدد الأوراق، مساحة الورقة) ومكونات الغلة (عدد القرون، وزن 100 بذرة، والغلة الكلية) وحللت باستخدام تحليل التباين**(ANOVA)** ، مع اعتبار الفروق ذات دلالة إحصائية عند قيمة**P ≤ 0.05**.

أظهرت النتائج أن روث الحمام تفوق بشكل ملحوظ على المعالجات الأخرى، حيث أنتج أطول النباتات (92 سم)، وأعلى عدد قرون (16 قرنة لكل نبتة)، وأعلى إنتاجية للبذور (2.10 طن للهكتار)، مما يمثل زيادة بنسبة 42% مقارنةً بالمجموعة الضابطة و16% مقارنةً بروث الأغنام. وعلى الرغم من أن روث الأغنام أقل فعالية في إنتاج المحصول الفوري، إلا أنه عزز تراكم الكتلة الحيوية النباتية، مما يشير إلى فوائده في خصوبة التربة ومرونتها على المدى الطويل.

بشكل عام، تؤكد هذه النتائج أن روث الحمام هو الخيار الأكثر فعالية لتحسين المحصول على المدى القصير، بينما يلعب روث الأغنام دورًا حاسمًا في استدامة المادة العضوية في التربة. من المنظورين الاقتصادي والبيئي، يوفر دمج روث الحمام والأغنام استراتيجية فعالة من حيث التكلفة لتحسين إنتاجية الفول مع تقليل الاعتماد على الأسمدة الصناعية والحد من المخاطر البيئية المرتبطة بها.

الكلمات الدالة: الفول، التسميد العضوي، روث الحمام، روث الأغنام، المحصول، الزراعة المستدامة.

Abstract

Faba bean (Vicia faba L.) productivity. in Sirte, Libya, in semi-arid conditions. Using a randomized complete block design, a field experiment was carried out in the 2024–2025 season with three replicates of each treatment: sheep manure (10 t ha^{-1}), pigeon manure (10 t ha^{-1}), and control (no manure). Differences were deemed statistically significant at $P \leq 0.05$. Growth traits (plant height, branching, leaf number, leaf area) and yield components (pod number, 100-seed weight, and total yield) were measured and examined using ANOVA. Pigeon manure produced the tallest plants (92 cm), the most pods (16 pods per plant), and the highest seed yield (2.10 t ha^{-1}), outperforming the other treatments by a significant margin. This was a

42 percent increase over the control and a 16 percent increase over sheep manure, according to the results. Sheep manure increased vegetative biomass accumulation, indicating advantages for long-term soil fertility and regrowth, despite being less effective for immediate yield.

Keywords*:* Faba bean, Organic fertilization, Pigeon manure, Sheep manure, Yield, Sustainable agriculture.

Introduction

One of the most important legume crops cultivated across the Mediterranean basin is Faba bean (Vicia faba L.), which serves as a major source of plant protein, essential amino acids, and minerals for human nutrition as well as a valuable feed for livestock [1]. Despite its significance, faba bean is highly valued for its agronomic benefits, particularly its ability to fix atmospheric nitrogen, thereby reducing reliance on costly and environmentally detrimental chemical fertilizers [2]. The average yield of faba bean in North African countries varies considerably. In Libya, productivity is generally lower compared to neighboring countries, with yields often below 1.5 t ha^{-1}, while in Egypt and Tunisia average yields can exceed 2.5–3.0 t ha^{-1} [3]. The main causes of this productivity gap are declining soil fertility, limited use of organic soil amendments, and Libyan farmers' heavy reliance on synthetic fertilizers. Chemical fertilizers can temporarily increase yields, but their continuous use leads to groundwater pollution, greenhouse gas emissions, and soil degradation [4]. These challenges highlight how urgently sustainable alternatives that can simultaneously improve crop yields and maintain soil health are needed.

Among organic fertilizers, pigeon manure is known for its high nitrogen and phosphorus content, which accelerates vegetative growth and enhances pod formation [5]. Sheep manure, particularly when co-applied with organic fertilizer, significantly increases soil organic matter and enhances microbial community structure and function, thereby improving long-term soil fertility and plant productivity in alpine mining areas [6,7]. Both manures are available in abundance in Libyan farming systems due to widespread backyard poultry production and sheep husbandry. However, to date, no comparative field studies have been conducted in Libya to evaluate their relative effects on faba bean productivity under semi-arid conditions.

For Libyan farmers, who frequently deal with the high price of chemical fertilizers and restricted access to imported agricultural inputs, this research gap is practically significant. Finding out if locally accessible pigeon or sheep manure can be used as economical and sustainable substitutes would offer quick, doable suggestions for raising output and encouraging sustainable nutrient management. Thus, the current study intends to assess the relative impacts of sheep and pigeon manures on the yield, growth, and yield components of faba beans in Sirte, Libya, under semi-arid conditions. It is anticipated that the results will support the incorporation of organic fertilization into sustainable agricultural practices, offer farmers practical advice, and help close the productivity gap with neighbouring nations.

Research Hypotheses

This study was designed to test the following hypotheses in light of the identified research gap and the need for useful, farmer-oriented recommendations in Libya:

• H1: Pigeon manure application significantly improves faba bean growth and yield performance when compared to sheep manure and the unfertilized control because of its higher nitrogen and phosphorus content, which supports rapid vegetative growth and reproductive development.

• H2: Although its immediate effect on seed yield is less noticeable, applying sheep manure improves biomass accumulation and soil organic matter in comparison to the unfertilized control, thereby promoting long-term soil fertility and sustainability.

• H3: Sheep and pigeon manures offer economical and sustainable substitutes for chemical fertilizers, potentially lowering input costs for farmers and lowering environmental hazards related to synthetic fertilizers.

Significance of the Study

This study is the first to comparatively evaluate the effects of pigeon manure and sheep manure on the productivity of faba bean (Vicia faba L.) under the semi-arid conditions of Libya. While previous research has separately highlighted the benefits of different organic amendments, no field-based evidence has been available for Libyan soils regarding the relative advantages of these two locally abundant manures. By systematically assessing their impact on growth, yield components, and soil fertility, this research provides:

1. **Novel empirical data** on how pigeon manure accelerates reproductive development and enhances yield performance compared with sheep manure.
2. **Clear evidence** of sheep manure's long-term role in improving soil organic matter and biomass accumulation, which are crucial for soil sustainability.
3. **Practical recommendations** tailored to Libyan farmers, offering low-cost and eco-friendly alternatives to chemical fertilizers.
4. **A dual perspective** that integrates short term yield gains with long term soil fertility improvement, supporting sustainable agricultural practices in semi-arid regions. This contribution narrows a critical knowledge gap in Libyan agriculture and offers a replicable model for other semi-arid farming systems facing similar soil fertility and productivity challenges.

2. Materials and Methods

2.1 Experimental Site and Climatic Conditions

The experiment was conducted at the Agricultural Nursery in Sirte City, Libya (31°12′N, 16°36′E) during the 2024/2025 cropping season. Sowing took place on 15 November 2024, and harvesting was completed on 20 February 2025, covering a growth period of approximately 97 days. The region is characterized by a semi-arid Mediterranean climate, with an average annual rainfall of 180–220 mm concentrated in winter and mean daily temperatures ranging from 10 °C (January) to 26 °C (November).

2.2 Plant Material

Seeds of the Libyan sweet faba bean (Vicia faba L.), a locally adapted landrace widely cultivated in Sirte, were used. Seeds were washed and soaked in clean water for 6 hours prior to sowing to enhance germination.

2.3 Experimental Design and Layout

A Randomized Complete Block Design (RCBD) was adopted with three treatments and three replicates (nine plots in total) Figure 1:

- T_1 (Control): No manure.
- T_2 (Pigeon manure): 10 t ha^{-1} equivalent.
- T_3 (Sheep manure): 10 t ha^{-1} equivalent.

Each experimental plot measured 1.5 m × 1.5 m (2.25 m^2) and contained 15 plants at a spacing of 30 cm between rows and 15 cm between plants. Buffer zones of 0.5 m were maintained between replicates, and a 1 m border strip surrounded the experimental field, resulting in a total area of 81 m^2.

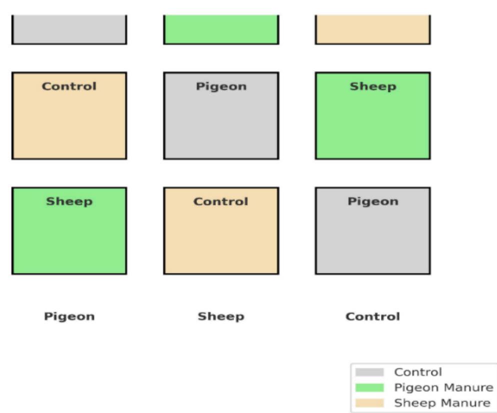

Figure 1 experimental layout: randomized complete block design (RCBD)

2.4 Soil Preparation and Manure Application

Before the manure was added, the soil was leveled and ploughed twice. The top 20 cm of soil was mixed with pigeon and sheep manures that were gathered from nearby farms, air-dried, and mixed three days prior to planting. Irrigation water and manures were combined to speed up nutrient release and decomposition.

2.5 Soil and Manure Analysis

To ascertain the effect of treatments on soil properties, composite soil samples (0–30 cm depth) were taken both prior to planting and right after harvest. pH, electrical conductivity (EC), organic matter (OM), total nitrogen (N), available phosphorus (P), and available potassium (K) were measured after the samples were air-dried and sieved (2 mm). Prior to application, the chemical composition of manure samples was also examined.

2.6 Crop Management

Seeds were sown at a depth of 7 cm on 15 November 2024. Flood irrigation using groundwater (EC 1.2 dS m^{-1}, pH 7.4) was applied every 4–5 days, with approximately 25–30 liters per plot per irrigation. Weed control was carried out manually, and insect pests were managed with Dursban 48 (chlorpyrifos) applied once during the early vegetative stage. No synthetic fertilizers were applied in order to preserve the organic integrity of the experiment.

2.7 Data Collection

Data collection began 7 days after sowing (22 November 2024) and continued weekly until harvest. Parameters measured included:

- Vegetative traits: plant height (cm), branch number, leaf number, leaf area (cm^2).
- Reproductive traits: days to flowering, number of flowers, number of pods per plant, pod length (cm).
- Yield components: fresh and dry pod weight (g), 100-seed weight (g), and total seed yield (t ha^{-1}).
- Biomass traits: fresh and dry shoot and root weights (g).

Leaf area was estimated using the formula:

$$LA = L * W * 0.75$$

where L = leaf length and W = leaf width. Dry biomass was measured by oven-drying samples at 70 °C until constant weight.

Calculation of Seed Yield (t ha^{-1}):

Seed yield per plot was first recorded in grams. This value was converted to tones per hectare using the following formula:

$$Yield(tha^{-1}) = \frac{plotyield(g)}{plot\ area\ (m^2)} * 10000 * 10^{-6}(\frac{m^2}{ha})$$

This ensured that yield estimates were standardized to a hectare basis for comparison across treatments.

2.8 Statistical Analysis

All data were subjected to ANOVA for RCBD using SPSS v25 and R software v4.2. Treatment means were separated by Fisher's LSD test at $P \leq 0.05$. Graphs and visualizations were prepared with Microsoft Excel and Matplotlib (Python).

2.9 Soil and Manure Analysis)

To assess the direct impact of manure application on soil fertility, composite soil samples (0–30 cm depth) were analyzed before sowing and after harvest. The results are summarized in Table 2 and figure 2.

Table 1. Physicochemical properties of soil before sowing and after harvest under different treatments

Parameter	Units	Initial Soil Before sowing)	Control (After harvest)	Pigeon Manure (After harvest)	heep Manure (After harvest)
pH	–	7.6	7.5	7.2	7.3
EC	dS m^{-1}	1.2	1.3	1.8	1.6
Organic Matter	%	0.84	0.80	1.25	1.65
Total Nitrogen	mg kg^{-1}	48	46	72	65
Available Phosphorus	mg kg^{-1}	12	11	18	15
Available Potassium	mg kg^{-1}	210	205	245	238

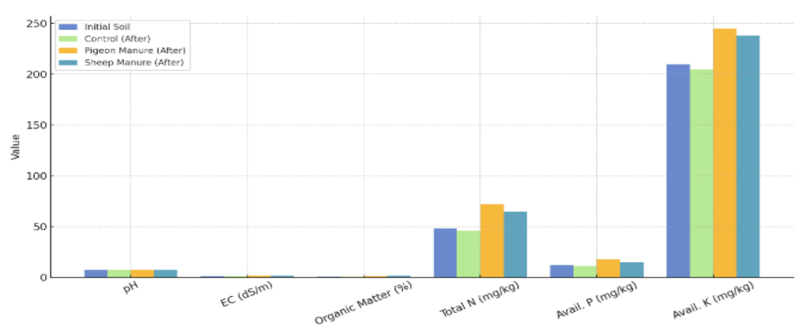

Figure 2 soil properties before and after manure application

3.1 literature review

The faba bean is regarded as a valuable legume crop that offers significant ecological and nutritional advantages. Its ability to fix nitrogen biologically, especially in semi-arid and arid environments, can drastically cut down on the need for synthetic fertilizers, making it a crucial part of sustainable farming systems [2]. However, Libya's yields have lagged behind the world average due to low soil fertility and a lack of organic amendment adoption [4]. Because organic amendments improve soil fertility and ecosystem functions, they are increasingly popular as an eco-friendly alternative to chemical fertilizers. Such inputs enhance soil biological activity, aeration, water retention, and essential nutrient provision. Furthermore, the slow release of nutrients from organic sources helps decrease leaching and gaseous losses, while enhancing soil organic carbon and soil structure stability [8]. Because of their comparatively high levels of nitrogen and phosphorus, which are necessary for promoting pod initiation and speeding up vegetative growth, poultry manures especially pigeon manure are valued [3]. Applying poultry manure greatly increases plant stature, increases leaf area, and improves the production of biomass from both shoots and roots, according to evidence from recent studies [9].

In contrast, sheep manure, although typically lower in readily available nutrients, has been shown to effectively improve long-term soil quality in challenging environments. It enhances soil organic matter, structure, and nutrient retention when applied alone or alongside commercial organic fertilizers, significantly boosting soil total nitrogen, phosphorus, and organic carbon levels [10]. Additionally, in semi-arid environments like the Loess Plateau, sheep manure application maintains soil moisture during critical growth stages, thereby promoting more stable seed filling and higher grain yield [11]. Its slower decomposition rate also reduces nutrient losses and supports soil fertility across multiple cropping cycles.

Comparative studies generally show that poultry manure results in stronger initial crop responses than ruminant manure, due to faster nutrient release [12, 13].

In Libya and elsewhere, integrating organic manures with inorganic fertilizers or bio-based amendments has proven effective in enhancing faba bean productivity and soil health [14, 15]. However, outcomes vary depending on application rates, soil characteristics, and climatic conditions, underlining the importance of locally adapted trials.

Consequently, assessing the relative effectiveness of pigeon and sheep manures under Libyan semi-arid conditions is essential for developing cost-effective and sustainable fertilization strategies.

4. Results and Discussion

4.1 Vegetative Growth

There were notable variations ($P \leq 0.05$) in plant height between treatments (Table 2; Figure 3). Pigeon manure fertilized plants had the highest mean height (92 cm), followed by sheep manure (69 cm). The plants in the control treatment were the shortest (55 cm). Higher levels of phosphorus (18 mg kg^{-1}) and nitrogen (72 mg kg^{-1}) in pigeon manure plots (Table 2) most likely promoted photosynthetic activity and chlorophyll synthesis, which in turn led to improved vegetative growth. Baghlani et al. are in agreement with these findings. (2024), who noted significant increases in legume growth in sandy soils following the application of poultry manure.

4.2 Branching and Leaf Development

The application of organic manure also had a positive effect on the number of branches and leaves. Pigeon manure-treated plants yielded an average of nine branches and 105 leaves, while sheep manure-treated plants produced five branches and 65 leaves, while the control group produced only three branches and 41 leaves. Pigeon manure plots' enhanced canopy structure indicates more photosynthetic surface area, which promotes higher assimilate production. Prado and associates in a similar vein, 2022 discovered that poultry manure increased the broad bean's leaf area index more than ruminant manure.

4.3 Flowering and Pod Formation

Flowering was initiated earlier in pigeon-manure plots (week 5) compared with sheep manure (week 6) and the control (week 7). Moreover, pigeon manure significantly increased the number of flowers and pods per plant, averaging 16.3 pods/plant, while sheep manure produced 5.5 pods/plant and the control only 3 pods/plant (Table 2; Figure 4). When expressed as total pod counts across all plants per treatment (45 plants), pigeon manure plots yielded 735 pods, sheep manure 248 pods, and the control 135 pods. The rapid nutrient availability, particularly phosphorus, likely promoted early flowering and pod set, aligning with Bai et al. (2023), who demonstrated the role of organic P in reproductive development of legumes [16].

4.4 Yield Components and Biomass Production

Yield components reflected the advantage of pigeon manure. Seed yield reached 2.10 t ha^{-1}, compared to 1.81 t ha^{-1} under sheep manure and 1.48 t ha^{-1} in the control (Table 2; Figure 5). Fresh pod weight showed a similar trend: 745 g per plot under pigeon manure, 526 g under sheep manure, and 380 g in the control.

Interestingly, sheep manure recorded the highest dry shoot weight (449 g $plant^{-1}$) compared to pigeon manure (267 g $plant^{-1}$) and the control (110 g $plant^{-1}$). This indicates that while pigeon manure enhances reproductive traits and seed yield, sheep manure promotes greater vegetative biomass, supporting soil organic matter accumulation. These results agree with Haddad et al. (2021), who found that sheep manure increased biomass but was slower to translate into grain yield improvements.

4.5 Soil Fertility Response

The differing effects of the two manures were validated by soil analysis conducted both before and after the experiment (Table 2). The strong reproductive response can be explained by the significant increases in available nitrogen (to 72 mg kg^{-1}) and phosphorus (to 18 mg kg^{-1}) caused by pigeon manure. In contrast, sheep manure had the biggest effect on soil organic matter (1.65%), which is indicative of its longer-term fertility benefits and slower rate of decomposition. Nutrient depletion in the absence of fertilization was indicated by control plots that displayed decreases in both organic matter (0–80%) and available nutrients. These results demonstrate the need for organic amendments in Libyan soils, which are naturally low in fertility and semi-arid.

4.6 Comparative Impact of Manures

Overall, the findings show how the two types of manure play complementary roles:

• Pigeon manure, for example, provides easily accessible nutrients that promote early flowering, rapid vegetative growth, and increased seed yields.

• Sheep manure: supports long-term sustainability by enhancing soil structure, increasing vegetative biomass, and enriching organic matter.

• Control: continuously showed the lowest values, highlighting the necessity of external nutrient inputs to maintain productivity in sandy soils with low nutrient levels.

4.7 Comparison with Previous Studies

These results are consistent with evidence from previous studies conducted in semi-arid and Mediterranean environments. Ghosh and associates. (2004) found that in tropical dryland soils, poultry manure was superior to cattle manure in terms of increasing crop growth and yield. In the same way, Sant'Anna et al. (2024) showed that by improving soil physical characteristics and nutrient cycling, the application of organic amendments can raise soil fertility and crop performance. Furthermore, a number of studies have highlighted the value of sheep manure as an organic matter source, pointing out that it improves soil aggregation, increases nutrient retention, and increases system resilience in farming systems with limited water resources [12, 13].

4.8 Implications for Sustainable Agriculture

Pigeon manure is the best choice for improving yields in the short term, according to the combined data from plant performance and soil fertility, while sheep manure is essential for gradually increasing soil fertility. Combining the two types of manure provides Libyan farmers with an economical and practical approach that simultaneously increases output, lessens dependency on artificial fertilizers, and protects soil health. Thus, this integrated approach offers a sustainable way to improve faba bean cultivation in the Mediterranean's semi-arid climate.

4.9 Correlation Analysis

To further clarify the relationships between key agronomic traits and yield performance, correlation and regression analyses were conducted.

• Pod number vs. yield:

A strong positive correlation was found between pod number per plant and seed yield ($r = 0.93$, $R^2 = 0.86$). However, the regression was not statistically significant ($P > 0.05$) due to the limited number of treatments. Therefore, this result should be interpreted as a directional trend rather than conclusive evidence. The pattern nevertheless indicates that pod number is likely a major determinant of yield in faba bean (Figure 7). Pigeon manure, which produced the highest pod number (16.3 pods/plant), also yielded the greatest seed output (2.10 t ha^{-1}).

• Soil organic matter vs. biomass:

A positive correlation was also observed between soil organic matter after harvest and shoot biomass. Sheep manure enhanced both organic matter (1.65%) and dry shoot weight (449 g $plant^{-1}$), highlighting its role in supporting vegetative growth and soil fertility. Pigeon manure improved organic matter less markedly (1.25%), while the control showed the lowest values (0.80% OM and 110 g $plant^{-1}$ biomass). Although this correlation was not statistically significant, it provides a directional indication that soil organic matter enrichment contributes to vegetative productivity and long-term sustainability (Figure 8).

Together, these analyses illustrate the complementary benefits of pigeon and sheep manures:

• pigeon manure enhances pod formation and yield, while sheep manure contributes to soil fertility and biomass accumulation.

• Integrating both types of manure could therefore maximize short-term productivity and long-term sustainability in Libyan faba bean production systems.

Table 2. Growth, yield, soil fertility, and statistical significance of faba bean under different treatments

Indicator	Control	Sheep Manure	Pigeon Manure	F-value	P-value
Avg. Plant Height (cm)	55	69	92	15.2	0.003
Pod Number (per plant)	3.0	5.5	16.3	22.7	0.001
Total Pod Count (45 plants)	135	248	735	24.5	0.001
Fresh Pod Weight (g/plot)	380	526	745	10.8	0.007
Dry Shoot Weight (g/plant)	110	449	267	13.6	0.004
Dry Root Weight (g/plant)	10	18	14	5.9	0.028
Yield (t ha^{-1})	1.48	1.81	2.10	18.3	0.002
Soil Organic Matter (%)	0.80	1.65	1.25	12.4	0.005
Available N (mg kg^{-1})	46	65	72	14.9	0.004
Available P (mg kg^{-1})	11	15	18	11.6	0.006
Available K (mg kg^{-1})	205	238	245	7.8	0.019

Table 3. Weekly average plant height (cm) of faba bean under different treatments

الأسبوع	Control	Sheep Manure	Pigeon Manure
1	2–4	4–6	7–15
2	4–6	8–9	14–22
3	6–8	12	21–29
4	9–12	16–18	28–36
5	12–15	20–22	35–43
6	15–18	24–28	42–50
7	18–22	28–34	49–57
8	22–26	31–36	56–64
9	26–30	34–41	63–71
10	30–35	37–48	70–78
11	35–40	40–51	77–85
12	40–45	47–54	81–92

Table 4. Pod count per replicate under different treatments

Treatment	Replicate	Pod count (range, pods/plant)	Replicate mean (pods/plant)	Replicate total pods (15 plants/plot)
Control	R1	2 – 4	3.0	45
	R2	2 – 5	3.5	53
	R3	3 – 4	3.0	45
Control Total	—	—	3.2 (grand mean)	143
Sheep manure	R1	3 – 7	5.0	75
	R2	5 – 7	6.0	90
	R3	5 – 6	5.5	83
Sheep Total	—	—	5.5 (grand mean)	248
Pigeon manure	R1	15 – 19	17.0	255
	R2	14 – 20	17.0	255
	R3	12 – 18	15.0	225
Pigeon Total	—	—	16.3 (grand mean)	735

Table 5. Weekly flower development under pigeon manure

Week	Flower Number
1–4	0
5	9
6	24
7	65
8	107
9	145
10	169
11	216
12	254

Table 6. Weekly flower development under sheep manure

Week	Flower Number
1–3	0
4	5
5	12
6	34
7	58
8	66
9	87
10	114
11	120
12	132

Table 7. Reproductive traits of faba bean under different treatments

Indicator	Control	Sheep Manure	Pigeon Manure
Shoot Length (cm)	42	58	78
Root Length (cm)	15	20	18
Branch Number	3	5	9
Leaf Count	41	65	105
Flower Count	3	6	45
Pod Count	3	5	16

Table 8. Biomass and weight parameters of faba bean

Indicator	Control	Sheep Manure	Pigeon Manure
Fresh Shoot Weight (g)	45–120	59–162	318–1025
Fresh Root Weight (g)	5–40	7–84	18–260
Dry Shoot Weight (g)	6–50	9–49	36–449
Dry Root Weight (g)	2–8	3–14	8–54
Fresh Pod Weight (g)	380	526	745

Table 9. Comparative weekly flower development under different manures

Week	Pigeon Manure	Sheep Manure
1–3	0	0
4	0	5
5	9	12
6	24	34
7	65	58
8	107	66
9	145	87
10	169	114
11	216	120
12	254	132

Figure 3 effect of organic manures on plant height of Faba Bean

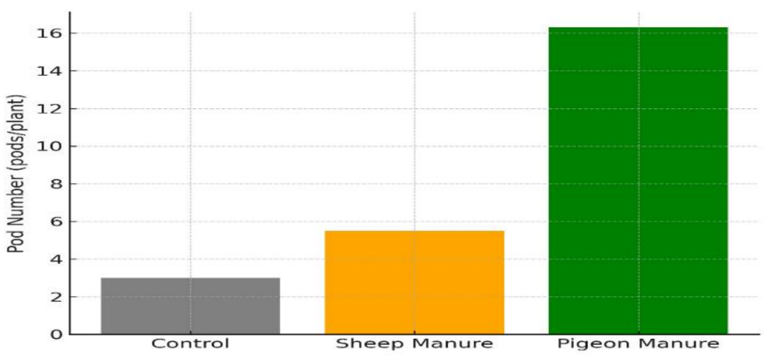

Figure 4 effect of organic manures on pod number of Faba Bean

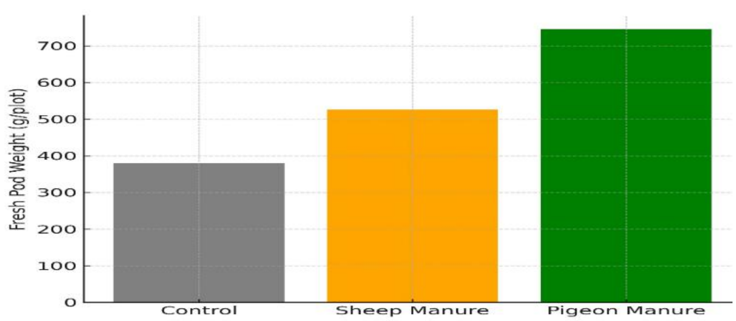

Figure 5 effect of organic manures on fresh pod weight of Faba Bean

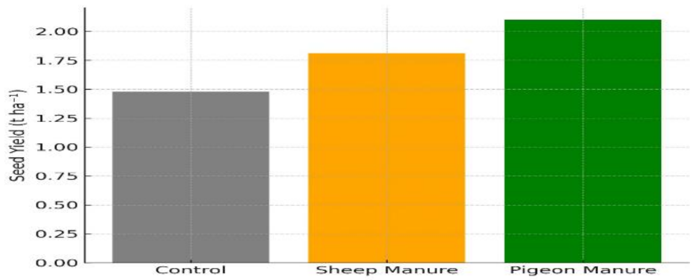

Figure 6 effect of organic manures on seed yield of Faba Bean

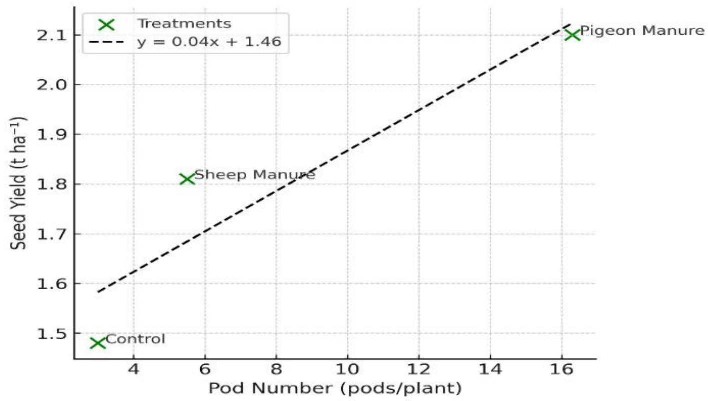

Figure 7 correlation between pod number and yield of faba bean

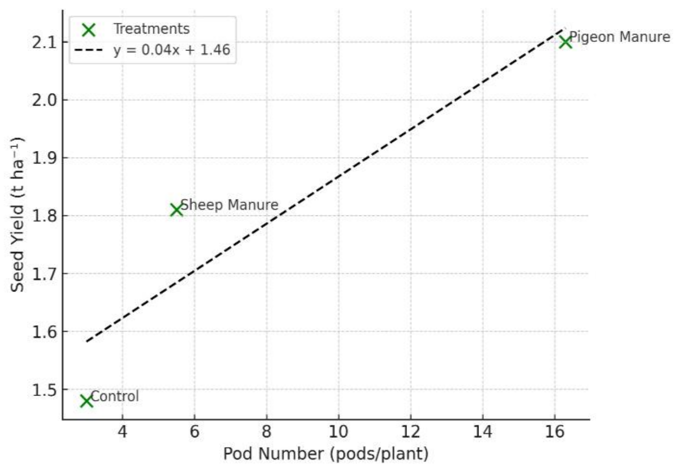

Figure 8 Correlation between pod number and seed yield

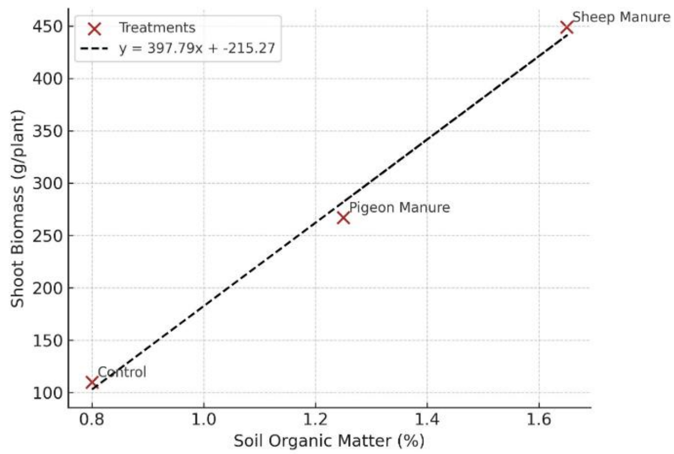

Figure 9 Correlation between soil organic matter and shoot biomass

5. Conclusion and Practical Implications

This study demonstrated that organic fertilization with pigeon and sheep manures significantly influenced the growth, yield, and soil fertility of faba bean (Vicia faba L.) under semi-arid conditions in Sirte, Libya. Pigeon manure consistently outperformed other treatments in terms of plant height, leaf production, pod number, and seed yield (2.10 t ha^{-1}), representing a 42% increase over the control and a 16% increase over sheep manure. These results are primarily attributed to its higher nitrogen and phosphorus contents, which promoted vigorous vegetative growth, early flowering, and pod development. Sheep manure, while less effective in terms of immediate seed yield, contributed significantly to soil fertility improvement, particularly by increasing soil organic matter from 0.84% to 1.65%. This was reflected in greater dry shoot biomass (449 g $plant^{-1}$), demonstrating its role in sustaining soil health and long-term productivity. Correlation analyses confirmed these complementary roles: pod number per plant was strongly correlated with yield ($R^2 = 0.86$), while soil organic matter was positively correlated with shoot biomass.

From a practical standpoint, the findings indicate:

• **Short-term yield improvement**: Farmers aiming to maximize immediate productivity should apply pigeon manure at a rate of 10 t ha^{-1}, which provides readily available nutrients for rapid growth and higher yields.

• **Long-term soil fertility**: Sheep manure should be integrated into crop management plans to enhance soil organic matter, improve structure, and sustain fertility across multiple seasons.

• **Integrated application strategy**: A combined use of pigeon and sheep manures balances rapid nutrient availability with long- term soil fertility improvement. This reduces reliance on synthetic fertilizers, lowering costs and environmental risks.

• **Policy and extension relevance**: Agricultural programs should promote the use of locally available organic manures as substitutes for costly imported fertilizers, supporting food security and climate-resilient farming.

Together, these results provide actionable recommendations for Libyan farmers, extension agents, and policy makers. Integrating both manure types offers a cost-effective and environmentally sustainable strategy that enhances productivity while safeguarding soil health.

6. Limitations of the Study

This study provides useful insights into the role of pigeon and sheep manures in faba bean production under semi-arid conditions; however, some limitations should be noted:

• **Single season and site**: Conducted only in Sirte during one growing season, so results may not fully represent other regions or climatic variations in Libya. The outcomes of a single season can also be strongly influenced by seasonal weather fluctuations, which may limit broader generalization.

• **Limited scope**: Focused mainly on agronomic traits; soil biology, microbial activity, and long-term fertility effects were not assessed.

• **Organic manure accumulation**: The study did not evaluate the cumulative effects of repeated manure applications across multiple years, which are essential for understanding the true long-term impact on soil fertility and productivity.

• **Economic analysis**: Costs and benefits of manure application at farm scale were not evaluated.

• **Manure variability**: Results are based on a single batch of pigeon and sheep manure, while nutrient content may vary depending on animal diet and management.

Future research should therefore include multi-location, multi-season trials that integrate agronomic, soil health, and economic assessments to better guide sustainable fertilization strategies.

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