

SUSTAINABLE POTATO FARMING: THE IMPACT OF POULTRY MANURE ON GROWTH AND YIELD

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Abstract. The growing demand for sustainable agriculture has prompted the use of organic amendments like poultry manure to improve soil fertility and crop productivity. This study examines the effects of poultry manure on potato (*Solanum tuberosum* L.) growth and yield at the Eastern Regions Research Station, Marib, Yemen. Conducted from November 2022 to February 2023, the experiment used a randomized complete block design (RCBD) with four treatments. Key parameters measured included leaf area index (LAI), photosynthetic efficiency, tuber number, and yield. Plots treated with poultry manure showed faster LAI growth, peaking between 80 and 100 days post-planting, compared to urea-treated plots. Treatment E (poultry manure) recorded the highest tuber count at 10.13 per plant, significantly surpassing the control. Additionally, treatments D and F produced the highest percentages of large, market-preferred tubers (69.39% and 68.78%, respectively). These results support existing research that poultry manure enhances growth, tuber quality, and yield due to its nutrient content, including nitrogen, phosphorus, and potassium. The study highlights poultry manure's potential as a sustainable alternative to synthetic fertilizers, benefiting both productivity and environmental health.

Keywords: *poultry manure, organic fertilizers, environmental sustainability, crop yield, tuber quality*

Introduction

The increasing global demand for sustainable agricultural practices calls for organic amendments to enhance soil fertility and crop productivity. Among various organic fertilizers, poultry manure has gained significant attention due to its nutrient profile and potential benefits to soil health and crop yield. The utilization of poultry manure in potato (*Solanum tuberosum* L.) farming improves growth and yield while promoting environmental sustainability (Asefi et al., 2019; El-Goud et al., 2021). Poultry manure is known for its high nitrogen, phosphorus, and potassium content, which are essential nutrients for plant growth. Studies have demonstrated that the application of poultry manure can significantly enhance soil organic matter, microbial activity, and nutrient availability, leading to improved crop performance (Alam et al., 2020). Additionally, poultry manure contributes to better soil structure and water retention, further supporting plant growth (Usman et al., 2021).

The potato crop, a staple food in many parts of the world, requires substantial nutrient inputs for optimal growth and tuber production. Conventional farming practices often rely on synthetic fertilizers, which can lead to soil degradation and environmental pollution (Pawelzik and Möller, 2014; Rana and Jhila, 2021). In contrast, the

integration of organic fertilizers such as poultry manure offers a sustainable alternative that aligns with the principles of agroecology and circular economy (Blandón et al., 2019). Research has shown that poultry manure not only enhances the growth parameters of potato plants but also improves tuber quality and yield. For instance, a study by Dahmardeh et al. (2017) reported that the application of poultry manure resulted in significant increases in potato tuber weight, size, and overall yield compared to chemical fertilizers. Furthermore, the long-term benefits of using poultry manure, such as improved soil fertility and reduced dependence on synthetic inputs, underscore its importance in sustainable potato farming (Mekonnen et al., 2022).

Agbede and Oyewumi (2022) highlighted the benefits of biochar and poultry manure, individually and in combination, for improving soil structure, nutrient availability, and water retention in degraded tropical agricultural soils. Their study demonstrated the significant positive impact of these amendments on sweet potato yield, underscoring their role in enhancing soil fertility and supporting sustainable agricultural practices. This research aligns with broader efforts to optimize resource use and improve soil health in environmentally friendly and cost-effective ways.

Shafeeva et al. (2022) explored the use of poultry manure in potato cultivation within the southern steppe region of the Republic of Bashkortostan. Their study revealed significant enhancements in soil fertility and potato yield, further reinforcing the effectiveness of poultry manure in diverse agro-climatic zones. Their work highlights the potential of poultry manure not only as a nutrient source but also as a means of supporting sustainable farming practices.

The adoption of poultry manure in potato farming systems holds promise for enhancing crop productivity and promoting sustainable agricultural practices. This research aims to evaluate the specific effects of poultry manure on the growth and yield of potato crops, thereby contributing to the development of more resilient and eco-friendly farming practices.

Materials and methods

Plant material

The initial-generation tubers of the “Diamond” potato variety were sourced from the General Company for Potato Seed Production in the Netherlands and utilized as seed tubers. These potato tubers underwent a thorough cleaning with tap water, followed by surface sterilization through immersion in a 3% sodium hypochlorite solution for 5 min. Subsequently, they were air-dried for 45 min at ambient temperature and then stored in a dark environment at 4°C until the commencement of the experiments. For pre-planting germination, the tubers were placed in sealed plastic bags to maintain humidity and incubated at 22°C in darkness for nine days until the sprouting seedlings reached approximately 1 cm in length.

Agronomic practices and study procedures

The following agronomic practices were applied during the study: Land preparation involved plowing and harrowing the soil to achieve a fine tilth, facilitating root and tuber growth. Planting was done using certified and disease-free seed potatoes, spaced 75 cm between rows and 30 cm between plants within rows to allow room for tuber expansion and air circulation. Hilling was performed twice during the growing season,

at 3 and 6 weeks after planting, to cover emerging tubers and prevent greening and solanine production. Weed management was carried out manually at regular intervals to minimize competition for nutrients and water. Pest and disease management employed integrated pest management practices, including routine monitoring for pests like aphids and diseases such as late blight, with organic and synthetic measures applied judiciously when needed. Harvesting took place after foliage senescence, indicating tuber maturity, with care taken to minimize mechanical damage and preserve tuber quality.

Irrigation practices and water management techniques

In our experiment, the following irrigation practices were applied: The crop was irrigated using surface irrigation. The total irrigation quantity during the season ranged from 7400 to 7800 m³, with 8 to 10 irrigations performed throughout the growing period. The water quantity per irrigation ranged from 750 to 800 m³.

Experiment conditions

This research was carried out at the Agricultural Research and Experiments Station located in Eastern Regions Research Station, Marib, (15°23'N, 45°17'E) Republic of Yemen. The experimental phase spanned from November 2022 to February 2023 within the agricultural season, employing a randomized complete block design (RCBD) with four treatments (*Table 1*). An analysis was conducted on the soil in which the experiment will be carried out (*Table 2*). Each individual block measured 17 m². Harvesting took place following complete senescence.

After irrigating the land and adding fertilizers, the seed tubers were planted at a depth of 15 cm, with a spacing of 0.85 m between rows and 0.40 m between plants. The crop was irrigated using the furrow irrigation method, receiving fourteen irrigations throughout the season. Fertilizers were applied to the experimental plots by broadcasting them uniformly before planting, in accordance with the specified treatments, followed by incorporation into the soil through plowing, creating rows, and direct sowing.

Table 1. Fertilizers content

Fertilizer	pH	Ca	Mg	N	P	K	EC	C/N ratio
Poultry manure	7.77	7.6	2.58	2.41	1.25	1.57	5.4	14

Table 2. Results of soil tests of cultivation location

pH	Saturated soil (%)	EC mmhos per cm	Organic matter (%)	Mechanical analysis (%)			Mineral elements (ppm)				
				Silt	Sand	Clay	N	P	K	Ca	Mg
8.36	37	0.126	1.18	29	31	40	11.4	8.13	374	17.12	2.21

The poultry manure used was derived from air-dried chicken waste with a straw base, containing 2.41% total nitrogen, 1.25% total phosphorus, 1.57% total potassium, and a carbon to nitrogen (C/N) ratio of 14. In comparison, commercial urea fertilizer contained 46% nitrogen. Consequently, the nitrogen amount added to the soil as per the

treatments is detailed in *Table 3*. To prevent blight, the crop was sprayed three times with VACOMIL-MZ 72% WP, which comprises 64% MANCOZEB and 8% METALAXYL. Herbicides Paraquat and monolaurin were applied to enhance weed control. The crop was harvested 120 days after planting, following the collection of necessary data and measurements.

Table 3. *The treatments applied in this study*

Fertilizer	Treatment (kg/m ²)		Nitrogen content (g/m ²)
Poultry manure	D	0.5	12.05
	E	1.0	24.1
	F	1.5	36.15
Urea fertilizer	G	0.035	16.1
Control (without any fertilizer additives)	H		

Data and measurements

Emphasis was placed on the leaf area index and photosynthesis efficiency due to the strong correlation between them and productivity and response to fertilizer.

Leaf area index

The leaf area index (LAI) represents the total one-sided leaf surface area per unit of ground area and is a crucial parameter in ecophysiological studies and plant growth analysis. Leaf area measurements of the harvested material were conducted using a LI 3000 A area meter (LiCor, Lincoln, NE, USA).

Leaf area index (LAI) serves as a critical parameter for evaluating the instantaneous crop growth rate at any given time (t) and acts as a straightforward indicator of agricultural productivity. During the growing season, LAI was assessed at three specific intervals: the first measurement was taken 60 days after planting, followed by the second measurement at 80 days, and the third measurement at 120 days after planting. These assessments were conducted at 20-day intervals, beginning 60 days post-planting.

To measure LAI, leaf surface area was determined for five randomly selected plants from each experimental plot. For each plant, all leaves were collected, and a single leaf was randomly chosen for measurement to ensure consistency and accuracy in data collection.

Photosynthesis efficiency

Gas exchange measurements (photosynthesis rate, transpiration rate, stomatal conductance, and intercellular CO₂ concentration) were taken from three uniform plants between 9:00 am to 11:00 am at 3, 4, 5, 6, 8, 10, and 12 weeks after planting from three selected sample areas within each plot using a Li-6400XT Portable Photosynthesis System (Li-Cor Inc., Lincoln, NE, USA). The chamber was adjusted to 25°C (temperature), 360 µM/mol (CO₂), and 800 µM/m²/s (photosynthetic photon-flux density).

Photosynthesis efficiency

Leaf water use efficiency (LWUE), leaf area duration (LAD), and net assimilation rate (NAR) were calculated by the following formula:

$$\text{LWUE } (\mu\text{molCO}_2/\text{mmolH}_2\text{O}) = \text{Pn}/\text{Tr}$$

where LWUE is the water use efficiency at the leaf level, Pn is the photosynthesis ratio of the ear leaf at the R3 stage, and Tr is the transpiration ratio of the ear leaf at the R3 stage.

$$\text{LAD } [(\text{m}^2 \cdot \text{d})/\text{hm}^2] = [(\text{L}_1 + \text{L}_2)/2] \times (\text{t}_2 - \text{t}_1)$$

$$\text{NAR } [\text{g}/(\text{m}^2 \cdot \text{d})] = [(\ln \text{L}_2 - \ln \text{L}_1) \times (\text{W}_2 - \text{W}_1)] / [(\text{L}_2 - \text{L}_1) \times (\text{t}_2 - \text{t}_1)]$$

where L1 and L2 are the leaf area at time t1 and t2, respectively; W1 and W2 are the dry matter weight at time t1 and t2, respectively.

Productivity

Yield in grams per plant and number of tubers:

Five plants were randomly selected from each experimental plot at harvest and the tubers were counted and weighed for each plant.

Productivity in tons per hectare

Two rows were randomly selected and harvested from each trial plot. The weight of their production was measured and with knowledge of the area occupied by the two rows, the productivity was attributed to tons per hectare.

Quality of production

The focus has been on consumers' acceptance of the product in terms of condition, shape, and size of tubers. The tubers were collected and divided into two categories according to their condition, shape and size according to (Hassan, 2003) as follows:

- Non-marketable: infected, deformed (not identical to the variety) and small tubers (whose diameter is lower than 3.5 cm).
- Marketable: the rest of the tubers; which in turn, graded according to their size:
 - Small tubers: diameter is between 3.5-5.5 cm
 - Medium tubers: diameter is between 5.5-6.5 cm
 - Large tubers: diameter is greater than 6.5 cm

Each category was weighted separately and calculated as a percentage of the total tubers weight for each plant.

Experiment design and statistical analysis

A randomized complete block design (RCBD) with three replications was employed, and data analysis was performed using GenStat version 18. A one-way ANOVA (in randomized blocks) was utilized, and standard errors were calculated to determine the least significant range (L.S.R.) for comparing averages, using the Duncan polynomial method at a 0.05 confidence level. The coefficient of variation for the analyzed variables was also computed. The mathematical relationship between nitrogen levels and production was derived, and the coefficient of determination was assessed.

Collected data encompassed various metrics including tuber emergence time, number of germinated seeds, percentage of small-sized potato tubers (<50 mm), percentage of plants with secondary stems, total yield, and net yield (t/ha). Total yield was calculated by summing all categories, while market yield excluded small-sized tubers (<50 mm) and rotten tubers from the total.

Results

Table 4 clearly shows that the leaf area index (LAI) increases over time, peaking between 80 and 100 days after planting, after which it begins to decline until harvest. Notably, the LAI rises more rapidly in plots treated with poultry manure. Conversely, the increase in LAI is slower with urea treatment due to the immediate availability of nitrogen from urea fertilizer.

Table 4. Effect of treatments on the index of leaf area and photosynthesis efficiency

Treatments	Leaf area index at first measurement cm ²	Leaf area index at the second measurement cm ²	Leaf area index at third measurement cm ²	Photosynthesis efficiency for the first period m ² days/m	Photosynthesis efficiency for the second period m ² days/m
D	3.58 a	4.09 c	2.12 e	76.7 c	62.1 c
E	3.61 a	4.55 d	2.95 d	81.6 cd	75.0 b
F	3.62 a	4.68 d	3.32 d	82.9 d	80.0 b
G	3.22 b	3.38 b	1.28 b	66.1 b	46.6 a
H	1.99 d	1.94 a	0.50 a	39.3 e	24.4 d
CV %	6.7	5.7	17.7	4.6	7.6

Means followed by a common letter are not significantly different by the Duncan-test at the 95% level of significance

Table 5 illustrates that all treatments exceeded the control H in tuber numbers. No significant differences were observed between urea manure G and the treatments involving poultry manure. Overall, poultry manure treatments surpassed the other fertilizers, with treatment E achieving the highest value of 10.13 tubers per plant, significantly outperforming control H.

Table 5. The effect of treatments on productivity indicators

Treatments	Number of tubers/lants	Productivity tonne/ha	Productivity gm/plant
D	7.56 def	35.33 b	1163.40 b
E	10.13 bdf	42.10 d	1383.51 d
F	8.40 de	51.78 e	1808.60 e
G	7.42 de	25.94 a	856.90 a
H	4.67 cg	11.67 f	397.73 f
CV %	34.2	10.7	11.5

Means followed by a common letter are not significantly different by the Duncan-test at the 95% level of significance

Production quality

Production quality indicates that there are no significant differences in tuber marketability across treatments. Treatment D yielded the highest marketable tuber

percentage at 96.99%, while the control treatment H had the lowest at 79.30%. Similarly, *Figure 1* reveals no significant differences in the proportion of small tubers among treatments. However, for medium-sized tubers, significant differences were observed between the control and the other treatments. Regarding the proportion of large tubers, all treatments surpassed the control, with treatments D and F achieving the highest percentages at 69.39% and 68.78%, respectively. It is apparent that poultry manure produced larger potato tubers preferred by consumers, as it is rich in phosphorus and potassium, making it an ideal fertilizer for high-quality tuber production (*Fig. 2*).

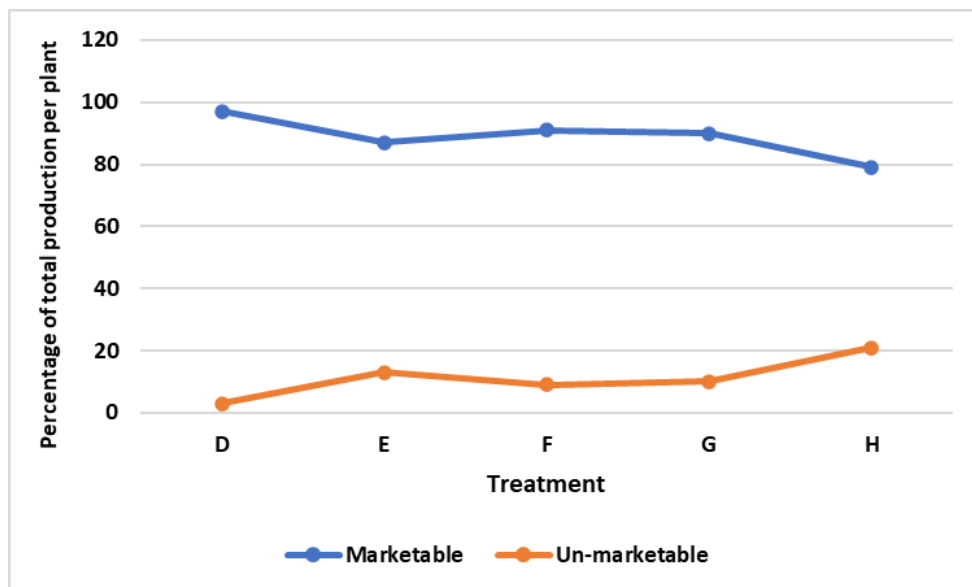


Figure 1. The effect of treatments on the percentage of marketable and Un-marketable tubers

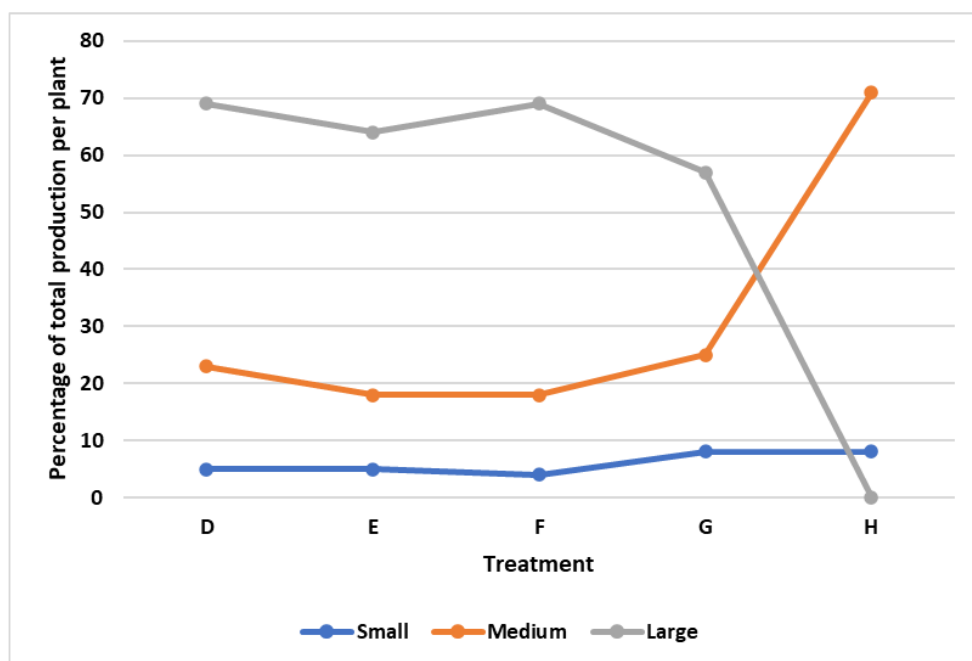


Figure 2. Effect of treatments on percentage scaling of marketable tubers

Discussion

The study's findings reveal that the leaf area index (LAI) increased steadily over time, reaching a peak between 80- and 100-days post-planting, before declining until harvest. This trend was more pronounced in plots treated with poultry manure compared to those treated with urea. This aligns with the findings of Alam et al. (2020), who reported that organic fertilizers, including poultry manure, significantly enhance leaf area and plant growth due to the gradual release of nutrients, particularly nitrogen, phosphorus, and potassium, which are crucial for photosynthesis and vegetative growth.

The research indicated no significant differences in the marketability of tubers across different treatments, with treatment D achieving the highest marketable tuber percentage (96.99%), and the control treatment H obtaining the lowest (79.30%). This is consistent with the study by Usman et al. (2021), which demonstrated that organic amendments like poultry manure can improve the overall quality and marketability of crops due to enhanced soil fertility and better nutrient availability.

Regarding the proportion of small tubers, the results showed no significant differences among treatments, but significant differences were observed for medium-sized tubers between the control and other treatments. For large tubers, all treatments outperformed the control, with treatments D and F showing the highest percentages (69.39% and 68.78%, respectively). This finding is supported by Mekonnen et al. (2022), who found that organic fertilizers such as poultry manure contribute to larger tuber sizes due to their high phosphorus and potassium content, which are essential for tuber development and enlargement. For medium-sized tubers, significant differences were observed between the control and other treatments, while all treatments outperformed the control in the proportion of large tubers, with treatments D and F achieving the highest percentages. This is corroborated by Dikinya and Mufwanzala (2010), who reported that poultry manure applications lead to increased tuber size and yield due to higher nutrient content, particularly phosphorus and potassium, which are crucial for tuber development.

The study's observation that poultry manure resulted in larger potato tubers aligns with previous research indicating that the slow release of nutrients from organic fertilizers provides a more sustained nutrient supply compared to synthetic fertilizers like urea, which offer an immediate but short-lived nitrogen boost. Dahmardeh et al. (2017) highlighted that the gradual nutrient release from poultry manure enhances root development and nutrient uptake efficiency, leading to better growth performance and higher yields. The observation that poultry manure resulted in larger potato tubers is consistent with findings by Albuquerque et al. (2014), who noted that the slow-release nature of nutrients from organic fertilizers like poultry manure supports sustained growth and higher yields compared to synthetic fertilizers. The study also found that poultry manure significantly improves soil physical properties, further supporting plant health and productivity.

Conclusion

The results of this study corroborate the findings of several other studies, emphasizing the benefits of using poultry manure in potato farming. The gradual release of essential nutrients from poultry manure not only improves the leaf area index and overall plant growth but also enhances the marketability and size of potato tubers. These

findings underscore the potential of poultry manure as a sustainable alternative to synthetic fertilizers, promoting both agricultural productivity and environmental health.

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Data availability statement. Data may be made available upon valid request.

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