



## **Effects of Different Organic Fertilizers on the Growth and Yield Performance of Cabbage (*Brassica oleracea* var. *capitata*) Cultivated in a Closed Production System in Somalia**

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### **Abstract**

Organic fertilizers offer smallholder farmers in Somalia a locally accessible alternative to costly synthetic inputs, yet little comparative evidence exists on how different organic amendments perform under the controlled, closed-system conditions increasingly used for vegetable production in the country. This study evaluated the effects of four organic fertilizers, camel manure, poultry manure, bat guano, and sesame by-products, together with an unfertilized control, on the growth and yield of cabbage (*Brassica oleracea* var. *capitata*, hybrid F1 Vizir) grown in a shade-net greenhouse in Kahda District, Mogadishu, Somalia. A randomized complete block design with five treatments and three replications was used, and plant height, shoot and root fresh and dry weights, shoot and root length, and marketable and non-marketable fresh weight were recorded at 70 days after transplanting and analyzed by analysis of variance with mean separation by least significant difference at the 5 percent level. Poultry manure and bat guano consistently produced the strongest growth and yield responses, with bat guano recording the highest plant fresh weight (1.66 kg) and shoot dry weight (161.00 g), and poultry manure producing the highest marketable fresh weight (0.97 kg), significantly exceeding camel manure and the control in most parameters. Sesame by-products performed moderately, notably producing the highest root fresh weight (64.00 g), while camel manure recorded the weakest overall performance. No significant treatment differences were found in non-marketable fresh weight. These findings indicate that poultry manure and bat guano are the most effective organic fertilizers for closed-system cabbage production under Somali conditions and support their promotion as sustainable, locally sourced alternatives to synthetic fertilizers for smallholder greenhouse horticulture.

**Keywords:** *Organic fertilizer; Cabbage; Poultry manure; Bat guano; Closed production system; Somalia*

### **1. Introduction**

Agriculture remains the backbone of the Somali economy, engaging more than 70 percent of the population either directly or indirectly and underpinning national food security, rural livelihoods, and household income (World Bank, 2019). Within this predominantly rural and agrarian economy, vegetable production occupies a growing niche, offering shorter production cycles and higher per-hectare returns than many staple cereals, and thereby providing smallholder farmers with an important pathway to improved income and dietary diversity. Yet Somali agriculture continues to contend with degraded arable land, prolonged

drought, and unsustainable input use, conditions that have progressively undermined soil fertility and constrained productivity across much of the country's farming systems.

Among vegetable crops, cabbage (*Brassica oleracea* var. *capitata*) is one of the most widely grown and economically important, valued for its relatively short growing cycle, broad climatic adaptability, and strong market demand. It is a major source of dietary vitamin C, vitamin K, folate, and fiber for Somali households, and its nutritional and functional properties, including its antioxidant and cancer-preventive glucosinolate content, have made it an increasingly prominent focus of both nutrition and agronomic research (Wu et al., 2021). Because of this combined economic and nutritional value, improving cabbage productivity carries direct benefits for both producers and consumers in fragile food systems such as Somalia's.

The global rise of organic farming, driven by consumer demand for chemical-free produce and growing environmental concern over synthetic input use, has drawn increasing research attention to organic fertilizers as a sustainable alternative to conventional agrochemicals. Derived from plant, animal, or mineral sources, organic fertilizers improve soil physical structure, stimulate microbial activity, enhance water retention, and release nutrients gradually, producing benefits for soil health and crop productivity that extend well beyond a single growing season (Diacono & Montemurro, 2010). These properties make organic fertilizers particularly well suited to the kind of degraded, moisture-limited soils common across much of Somalia's agricultural land.

Closed production systems, such as greenhouses and shade-net structures, provide a valuable platform for evaluating organic inputs under controlled conditions, since they regulate light, humidity, temperature, and irrigation and thereby allow the effects of a specific fertilizer to be isolated from the confounding influence of variable weather. This approach is especially relevant in fragile agroecological settings such as Somalia's, where open-field cultivation remains vulnerable to erratic rainfall, extreme temperatures, and poor soil structure, and where controlled-environment vegetable production is expanding as a climate-resilient alternative (Nordey et al., 2017).

Despite this growing interest, the adoption of organic fertilization practices in Somalia remains slow, constrained, as elsewhere in sub-Saharan Africa, by limited technical support and training for farmers (Nordey et al., 2017) and by a near-total absence of localized comparative research on how different organic materials perform under Somali growing conditions. Organic materials such as camel manure, poultry droppings, bat guano, and sesame processing by-products are all locally available to Somali farmers, yet their relative effectiveness for vegetable production has not been systematically compared, leaving farmers to rely on trial-and-error practices rather than evidence-based recommendations.

Cabbage is also an internationally significant crop against which any local production gains can be benchmarked. Global cabbage cultivation spans a wide range of agro-climatic zones, from intensive mechanised systems in East Asia to smallholder plots across sub-Saharan Africa, and the crop's short growth cycle of roughly 75 to 90 days allows for multiple harvests within a single year wherever growing conditions and infrastructure permit. In many developing regions, including parts of East Africa, cabbage is an economically important and profitable smallholder vegetable (Daniel et al., 2023; Ayalew & Girma, 2025), underscoring why even modest, evidence-based improvements in local production practice can have an outsized effect on farmer welfare.

Fertilizer choice is one of the most consequential of these practices, since cabbage is a comparatively heavy feeder whose growth and head formation depend on a steady and well-timed supply of nitrogen, phosphorus, and potassium. Nitrogen is particularly critical during the early vegetative phase, supporting leaf expansion and canopy development, while potassium and calcium become more important during head formation, contributing to head

firmness and resistance to physiological disorders. Because organic fertilizers differ substantially from one another, and from synthetic fertilizers, in how quickly they release these nutrients into the soil, the specific organic material selected can materially affect how well a given amendment matches cabbage's changing nutrient demand across the growing cycle, which is precisely the kind of comparative question this study was designed to address.

This study was therefore designed to evaluate the effects of four locally available organic fertilizers, camel manure, poultry manure, bat guano, and sesame by-products, on the growth and yield performance of cabbage cultivated in a closed production system in Mogadishu, Somalia. The specific objectives were to determine the effect of each organic fertilizer on cabbage growth and yield components, including marketable fresh weight, and to identify the organic fertilizer or fertilizers best suited to promoting optimal cabbage performance under closed-system conditions. The findings are intended to provide Somali farmers, extension services, and researchers with a locally grounded evidence base for selecting organic fertilizers that can improve productivity while reducing dependence on costly synthetic inputs.

## **2. Materials and Methods**

### ***2.1 Study Site and Experimental Design***

The study was conducted in a shade-net greenhouse at Dr. Omar's Greenhouses, Kahda District, Mogadishu, Somalia, a controlled cultivation environment designed to minimize exposure to wind, heavy rainfall, extreme temperature fluctuations, and pest pressure. The trial used the hybrid cabbage variety F1 Vizir and was laid out in a randomized complete block design with five treatments and three replications to minimize experimental error and ensure robust statistical inference. Each experimental plot measured 3 m by 0.5 m and accommodated three cabbage plants, giving nine plants per treatment across the three replications, with plant spacing maintained at 60 cm between rows and 50 cm between plants; a 10 cm border gap was left within each plot to avoid edge effects, and replications and treatment plots were separated by 50 cm and 60 cm gaps respectively to facilitate irrigation, weeding, and monitoring. A total of 45 cabbage plants were established across the five treatments and three replications (Figure 1).



*Figure 1. Young cabbage seedling established under drip irrigation at the trial site, Kahda District, Mogadishu, Somalia.*

A uniform soil mixture, a sandy loam base amended with well-rotted compost and adjusted to a pH of 6.5 to 7.0, was prepared for all plots to eliminate baseline variability in soil fertility, with soil organic matter content, nutrient levels, pH, and electrical conductivity tested prior to treatment application. No synthetic agrochemicals were used at any stage of the experiment, and organic inputs were properly composted before application to avoid introducing pathogens, in keeping with standard ethical and environmental protocols for organic field research.

Randomisation of treatment to plot within each of the three replications was carried out independently, a standard precaution that allows any underlying gradient in greenhouse microclimate or soil fertility to be statistically separated from the treatment effect of fertilizer type. Irrigation and general crop husbandry, including transplanting, staking, and pest monitoring, followed a uniform schedule across all plots regardless of treatment, so that observed differences in growth and yield could be attributed to fertilizer type rather than to unintended differences in water availability or general crop management.

## **2.2 Experimental Treatments**

Five treatments were evaluated: camel manure, poultry manure, bat guano, sesame by-products, and an unfertilized control, as summarized in Table 1. All organic fertilizers were sourced locally and incorporated into the soil two weeks before transplanting, with application rates based on nutrient equivalence to standard nitrogen recommendations for cabbage, approximately 120 to 150 kg N per hectare, adjusted for the specific nutrient content and decomposition rate of each material. Watering, weeding, and other cultural practices were

carried out uniformly across all treatments to avoid confounding effects unrelated to fertilizer type.

**Table 1. Experimental Treatments**

| <b>Treatment Code</b> | <b>Description</b>      |
|-----------------------|-------------------------|
| T1                    | Camel Manure            |
| T2                    | Poultry Manure          |
| T3                    | Bat Guano               |
| T4                    | Sesame By-Products      |
| T5                    | Control (No Fertilizer) |

### **2.3 Data Collection and Statistical Analysis**

Data were collected at 70 days after transplanting from all three plants in each plot, giving nine plants per treatment. Growth parameters recorded included plant height, plant fresh weight, shoot fresh weight, root fresh weight, and shoot length, while yield parameters included root length, marketable fresh weight, non-marketable fresh weight, root dry weight, and shoot dry weight. Marketable fresh weight was defined as the fresh mass of firm, well-formed heads suitable for sale, while non-marketable fresh weight comprised heads affected by splitting, poor compactness, or visible defects.

Data were analyzed using analysis of variance for a randomized complete block design in Statistix 8.1 to determine the significance of treatment effects, with means separated using the least significant difference test at the 5 percent probability level where significant differences occurred. Assumptions of normality and homogeneity of variance were checked prior to analysis, and summary tables and graphical representations were prepared using Microsoft Excel. Coefficients of variation were calculated for each measured parameter to assess the precision of the experiment, and treatment means sharing the same letter within a column were considered not significantly different at the stated probability level.

### **3. Results**

Table 2 presents the effect of the four organic fertilizer treatments and the control on plant height, plant fresh weight, shoot fresh weight, root fresh weight, and shoot length. The tallest plants were recorded under poultry manure (27.83 cm), significantly taller than those under camel manure (23.46 cm) and the control (23.00 cm), while bat guano (27.00 cm) and sesame by-products (23.96 cm) were intermediate and did not differ significantly from either group. Bat guano produced the highest plant fresh weight (1.66 kg), significantly exceeding all other treatments, while poultry manure (1.42 kg) and sesame by-products (1.34 kg) also significantly outperformed camel manure (0.79 kg) and the control (0.89 kg). A broadly similar pattern was observed for shoot fresh weight, where poultry manure (657.67 g), bat guano (646.00 g), and sesame by-products (594.00 g) all significantly exceeded camel manure (464.00 g) and the control (502.33 g). Root fresh weight was highest under sesame by-products (64.00 g), significantly greater than under camel manure (49.00 g) and the control (47.00 g), with bat guano and poultry manure (57.33 g each) intermediate and not significantly different from either group. For shoot length, bat guano produced the longest shoots (13.33 cm), significantly longer than those under camel manure (10.83 cm) and the control (10.46 cm), with poultry manure and sesame by-products (12.00 cm each) intermediate.

**Table 2. Effect of Different Organic Fertilizers on Plant Height, Plant Fresh Weight, Shoot Fresh Weight, Root Fresh Weight, and Shoot Length of Cabbage**

| Treatment          | Plant Height (cm) | Plant Fresh Weight (kg) | Shoot Fresh Weight (g) | Root Fresh Weight (g) | Shoot Length (cm) |
|--------------------|-------------------|-------------------------|------------------------|-----------------------|-------------------|
| Sesame By-Products | 23.96 AB          | 1.34 B                  | 594.00 A               | 64.00 A               | 12.00 AB          |
| Camel Manure       | 23.46 B           | 0.79 C                  | 464.00 B               | 49.00 B               | 10.83 B           |
| Poultry Manure     | 27.83 A           | 1.42 B                  | 657.67 A               | 57.33 AB              | 12.00 AB          |
| Bat Guano          | 27.00 AB          | 1.66 A                  | 646.00 A               | 57.33 AB              | 13.33 A           |
| Control            | 23.00 B           | 0.89 C                  | 502.33 B               | 47.00 B               | 10.46 B           |
| Significance       | *                 | *                       | *                      | *                     | *                 |
| CV (%)             | 8.52              | 8.91                    | 8.23                   | 17.05                 | 8.26              |

Table 3 presents the effect of treatment on root length, marketable and non-marketable fresh weight, and root and shoot dry weight. Bat guano produced the longest roots (16.00 cm), significantly exceeding camel manure (12.80 cm) and the control (12.16 cm), with poultry manure also promoting considerable root length (15.50 cm) and sesame by-products intermediate (13.50 cm). Poultry manure produced the highest marketable fresh weight (0.97 kg), significantly greater than sesame by-products (0.69 kg) and bat guano (0.68 kg), and markedly higher than camel manure and the control (0.33 kg each). No significant differences were found among treatments in non-marketable fresh weight, which ranged narrowly from 9.33 g to 10.00 g. Poultry manure and bat guano produced the highest root dry weights (9.33 g each), significantly exceeding camel manure (6.33 g), while bat guano produced the highest shoot dry weight (161.00 g), significantly outperforming camel manure (105.67 g) and the control (114.33 g), with sesame by-products (150.67 g) and poultry manure (135.33 g) also contributing substantial shoot dry matter.

**Table 3. Effect of Different Organic Fertilizers on Root Length, Marketable Fresh Weight, Non-Marketable Fresh Weight, Root Dry Weight, and Shoot Dry Weight of Cabbage**

| Treatment          | Root Length (cm) | Marketable Fresh Weight (kg) | Non-Marketable Fresh Weight (g) | Root Dry Weight (g) | Shoot Dry Weight (g) |
|--------------------|------------------|------------------------------|---------------------------------|---------------------|----------------------|
| Sesame By-Products | 13.50 BC         | 0.69 B                       | 9.33 A                          | 8.33 AB             | 150.67 AB            |
| Camel Manure       | 12.80 C          | 0.33 C                       | 9.66 A                          | 6.33 B              | 105.67 C             |
| Poultry Manure     | 15.50 AB         | 0.97 A                       | 10.00 A                         | 9.33 A              | 135.33 ABC           |
| Bat Guano          | 16.00 A          | 0.68 B                       | 10.00 A                         | 9.33 A              | 161.00 A             |
| Control            | 12.16 C          | 0.33 C                       | 10.00 A                         | 6.66 AB             | 114.33 BC            |
| Significance       | *                | *                            | NS                              | *                   | **                   |
| CV (%)             | 8.15             | 11.96                        | 14.09                           | 19.63               | 14.52                |

Considered together, Tables 2 and 3 show a consistent pattern across the ten growth and yield parameters measured, with poultry manure and bat guano occupying the top statistical grouping in most cases, sesame by-products performing moderately but excelling specifically in root fresh weight, and camel manure and the unfertilized control forming the weakest

statistical grouping throughout, often without a significant difference between them. Coefficients of variation across the measured parameters ranged from 8.15 to 19.63 percent, values consistent with the level of precision typically expected in replicated greenhouse pot and plot trials, lending confidence to the reliability of the treatment differences reported here. The single exception to this pattern was non-marketable fresh weight, where no significant treatment effect was detected, indicating that fertilizer type influenced the quantity of high-quality marketable heads produced without correspondingly increasing the amount of unmarketable plant material.

#### 4. Discussion

The results demonstrate that organic fertilizer type exerted a strong and consistent influence on cabbage growth and yield performance under closed-system conditions in Somalia, with poultry manure and bat guano emerging as the two most effective amendments across nearly every parameter measured. Both fertilizers are characterized by relatively high concentrations of readily available nitrogen and a broad spectrum of macro- and micronutrients, properties that plausibly explain their advantage in biomass accumulation, shoot and root development, and, for poultry manure, plant height. This finding is consistent with Moyin-Jesu (2015), who reported that poultry manure gave the greatest improvement in soil fertility, growth, and head yield of cabbage among several organic fertilizers, outperforming NPK fertilizer, an effect attributed to its balanced nutrient composition and low carbon-to-nitrogen ratio. The performance of bat guano observed here likewise agrees with Palita et al. (2021), who found that guano-amended soils increased the biomass and photosynthetic rates of finger millet and black gram, and with Dimande et al. (2023), who showed that bat guano, owing to its low carbon-to-nitrogen ratio, mineralises almost completely within a single tropical growing season and behaves more like a mineral fertilizer than a conventional farmyard manure.

The particularly strong marketable yield response to poultry manure, which produced nearly three times the marketable fresh weight of camel manure or the unfertilized control, carries direct practical significance, since marketable yield rather than total biomass ultimately determines a farmer's return from cabbage production. That non-marketable fresh weight did not differ significantly among treatments suggests that the yield gains associated with poultry manure and bat guano arose from an increase in the proportion of well-formed, saleable heads rather than from a general increase in unmarketable plant material, a distinction that strengthens the economic case for these two amendments over camel manure or no fertilization at all.

Sesame by-products occupied an intermediate position overall, but notably produced the highest root fresh weight of any treatment, exceeding even poultry manure and bat guano. Oilseed processing residues such as sesame cake and husk supply organic carbon alongside nitrogen, and organic amendments of this kind are known to improve soil structure, water retention, and biological activity in the root zone (Diacono & Montemurro, 2010), which may explain the stronger root response observed here. The comparatively strong root performance of sesame by-products, despite their more moderate effect on above-ground biomass, suggests that this locally available material may be particularly well suited to improving soil structure and root-zone conditions even where its overall nutrient concentration is lower than that of poultry manure or bat guano.

It is worth noting that camel manure, despite ranking lowest among the organic amendments, did not differ significantly from the unfertilized control in any of the ten parameters measured. Its means were marginally higher than those of the control for plant height, root fresh weight, shoot length, and root length, marginally lower for plant fresh weight, shoot fresh weight, and root and shoot dry weight, and identical for marketable fresh weight. At the application rate and degree of decomposition used in this trial, camel manure therefore

provided no measurable benefit to cabbage over growing without amendment, although it was not detrimental either. For resource-constrained smallholders whose access to poultry manure or bat guano may be limited by local supply, camel manure is therefore best regarded as a soil-conditioning material to be further composted or combined with a higher-nutrient organic input, rather than as a stand-alone fertilizer for cabbage.

Camel manure consistently recorded the weakest performance among the four organic amendments, differing little from the unfertilized control across most parameters. This is consistent with recent evidence that raw camel manure is characterized by slower mineralization and lower short-term nutrient release than conventional livestock manures, and that further processing through composting or vermicomposting substantially enhances its nutrient value (Mupambwa et al., 2026), and with the wider observation that manures differ markedly in carbon-to-nitrogen ratio, phosphorus content, and decomposition rate according to animal species (Rayne & Aula, 2020). Such properties make camel manure less suited to crops with the relatively high, concentrated nutrient demand of cabbage during its vegetative and heading stages. Together, these findings suggest that camel manure's weak performance in the present study reflects a mismatch between its nutrient release profile and cabbage's demands, rather than an inherent lack of agronomic value, and support the recommendation that camel manure be more thoroughly composted, vermicomposted, or blended with a higher-nutrient organic material before use on cabbage.

The closed-system setting of this trial also merits discussion in its own right. Growing cabbage in a shade-net greenhouse removed much of the environmental variability, such as erratic rainfall, wind damage, and extreme temperature swings, that would otherwise complicate a comparison of organic fertilizers under open-field conditions in Somalia. This controlled setting strengthens confidence that the differences observed among treatments reflect genuine fertilizer effects rather than uncontrolled site variation, but it also means the results are most directly applicable to the growing number of Somali producers adopting greenhouse or shade-net cultivation rather than to open-field cabbage growers, whose crops remain exposed to rainfall variability, pest pressure, and temperature extremes that could interact differently with organic fertilizer type. Extending this comparison to open-field conditions would help establish whether the clear advantage of poultry manure and bat guano observed here persists once these additional sources of environmental variability are reintroduced.

These results should be interpreted with reference to the study's scope. The trial was conducted over a single growing season in one greenhouse facility, and the experiment did not include a chemical fertilizer comparison group that would allow the organic treatments to be benchmarked directly against conventional practice. Organic fertilizer nutrient release rates can also vary with source and decomposition conditions that were not standardized beyond baseline application rates, introducing a source of variability that a multi-season trial with tighter material characterization could help resolve. The gradual nutrient release characteristic of organic amendments, which continues to support crop nutrition beyond the season of application (Diacono & Montemurro, 2010), is broadly consistent with the sustained growth advantage of poultry manure and bat guano observed in this trial, and future work incorporating repeated seasonal trials would help confirm the stability of this advantage under Somalia's variable greenhouse operating conditions.

The consistency of the poultry manure and bat guano advantage across such a broad set of growth and yield indicators, spanning above-ground biomass, root development, and marketable head formation, suggests that the mechanism at work is a genuine improvement in overall nutrient supply rather than a treatment effect confined to a single physiological process. This distinction matters for how the results should be applied: rather than treating poultry manure or bat guano as a targeted remedy for one specific growth constraint, farmers and

extension agents can reasonably expect these two amendments to lift cabbage performance broadly, across the vegetative, root, and yield-formation stages of the crop, which simplifies the practical guidance that can be offered to growers with limited capacity for fine-tuned, stage-specific fertilization.

Beyond the immediate agronomic findings, the results carry practical relevance for Somalia's smallholder horticulture sector, where closed-system cabbage production is expanding as a response to land degradation and climatic unpredictability in open-field systems. Because poultry droppings and bat guano are both locally available through existing livestock and cave-harvesting networks, their demonstrated effectiveness offers Somali greenhouse farmers a realistic, low-cost route to higher marketable yields without reliance on imported synthetic fertilizers, a consideration of particular importance given the foreign-exchange and supply-chain constraints that make synthetic fertilizer access unreliable in much of the country. Studies from Kenya and Ethiopia similarly show that cabbage is an economically important and profitable enterprise for smallholder farmers in East Africa (Daniel et al., 2023; Ayalew & Girma, 2025), reinforcing the case for extension programmes that specifically promote the organic fertilizer combinations shown here to perform best.

## **5. Conclusion**

This study evaluated the effects of camel manure, poultry manure, bat guano, and sesame by-products on the growth and yield performance of cabbage grown in a closed shade-net greenhouse system in Mogadishu, Somalia, and found clear and statistically significant differences among treatments across most growth and yield parameters measured. Poultry manure and bat guano consistently produced the strongest results, with bat guano recording the highest plant fresh weight and shoot dry weight and poultry manure producing the highest marketable fresh weight, while sesame by-products showed a distinct advantage in promoting root biomass and camel manure recorded the weakest overall performance. Translating these findings into practical benefit for Somali greenhouse farmers will depend on coordinated follow-through: extension services and agricultural training programmes prioritising poultry manure and bat guano as the recommended organic amendments for closed-system cabbage production, guidance encouraging farmers to compost or blend camel manure with a higher-nutrient organic material before use rather than discarding it as ineffective, continued research exploring sesame by-products as a complementary amendment for improving root development and soil structure, community-based systems for collecting, processing, and distributing quality organic fertilizers to support consistent farmer access, and further multi-season trials that incorporate a chemical fertilizer benchmark and assess the cumulative effects of repeated organic fertilizer use on soil health and farm profitability. Pursued together, these steps would allow the yield advantages demonstrated here to translate into a meaningful and sustainable improvement in cabbage productivity, farmer income, and food security within Somalia's expanding closed-system horticulture sector.

## **Author Contributions**

Liban Mohamed Muse: data curation, formal analysis, writing, original draft. Abdiwahab Abdulkadir Ali: investigation, data curation. Abas Ali Mohamed: investigation, methodology. Farhan Elmi Ibrahim: investigation, resources. Mohamed Abdulkadir Mukhtar: investigation, writing, review and editing. Yusuf Ali Arif: conceptualisation, supervision, writing, review and editing. All authors read and approved the final manuscript.

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## Conflict of Interest Statement

The authors declare no conflict of interest.

## Data Availability Statement

The field data supporting the findings of this study, including plant-level growth and yield measurements and the associated analysis of variance outputs generated in Statistix 8.1, are available from the corresponding author upon reasonable request. This includes the raw records for plant height, shoot and root fresh and dry weights, shoot and root length, and marketable and non-marketable fresh weight collected from the three plants per plot across the five treatments and three replications, underlying the summary statistics reported in Tables 2 and 3.

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