



EFFECT OF ORGANIC MANURE-ENRICHED GROWTH MEDIA
ON GERMINATION AND EARLY GROWTH OF COCOA
(*Theobroma cacao* L.) SEEDLINGS IN IGBOORA, NIGERIA

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Abstract

Growth medium is an important factor in the germination and early growth of cocoa plants. In view of this, a pot experiment was conducted in the screen house of Crop Production Technology department to evaluate the effect of organic-enriched growth media on germination and early growth of cocoa seedlings over a period of one month. The treatments were Control (Top soil only), Top soil + Sawdust, Top soil + Poultry Manure, Top soil + Cow Dung, Top soil + Swine Dung, Top soil + Sawdust + Poultry Manure, Top soil + Sawdust + Cow Dung and Top soil + Sawdust + Swine Dung. The treatments were replicated 10 times and arranged in a completely randomized design. The treatment mixture (Top soil + Sawdust) was done at 3:1, while the organic manures were applied at 10 tons/ha (equivalent to 50 g per pot). Data collected were germination percentage, plant height, stem diameter, number of leaves and leaf area. The collected data were subjected to analysis of variance and significant means were compared using Duncan's Multiple Range Test at 5% probability. The application of organic manures enhanced the growth performance of cocoa plant, and Top soil + Sawdust was significantly higher compared to other treatments. Top soil + Poultry manure, Top soil + Sawdust and Top soil + Cow dung had the highest significant germination percentages (90%, 89% and 88%) and, produced the highest significant plant height (25.00 cm, 24.00 cm, 23.00 cm), number of leaves (10.50, 10.20, 10.00), leaf area (55.00 cm², 53.00 cm², 52.50 cm²) and stem diameter (1.80 cm, 1.78 cm, 1.75 cm) respectively compared to other treatments. The addition of organic manures to the growth substrates improved the germination and early growth of cocoa seedlings. The use of Top soil enriched with poultry manure was recommended for improved early growth of cocoa plant.

Keywords: Cocoa, Germination, Early growth, Growth media, Organic manure, Sustainable agriculture

Introduction

Cocoa (*Theobroma cacao* L.) remains one of the most economically important perennial crops in tropical regions, particularly West Africa where more than 70% of global output originates (FAO, 2020). Nigeria ranks among the top producers, contributing significantly to foreign exchange earnings, rural livelihoods, and agro-based industries (Oluyole and Lawal, 2008). Cocoa cultivation is concentrated in the southwestern states of Oyo, Osun, Ondo, Ogun, and Ekiti. Within Oyo State, Igboora and its environs serve as notable cocoa-growing zones due to their favorable climate and tradition of cocoa farming.

Despite its potential, cocoa production in Nigeria faces serious challenges, especially at the seedling production stage. Successful germination and vigorous early growth are crucial for ensuring strong, productive cocoa trees. However, inadequate nursery management practices, poor soil fertility, and limited access to quality inputs often result in weak seedlings that underperform in the field (Anim-Kwapong and Frimpong, 2008; Omolaja *et al.*, 2009).

The success of cocoa plantations begins at the nursery stage. Parameters such as seed germination rate, seedling height, number of leaves, leaf area, and stem diameter are essential indicators of future field performance and vigorous seedlings not only withstand transplanting shock but also establish faster, leading to earlier canopy closure and enhanced yield potential (Aikpokpodion, 2010).

The choice of nursery growth media plays a fundamental role in seedling establishment. Commonly used media include topsoil, sand, sawdust, or combinations of these. Organic amendments enhance soil fertility by improving nutrient availability, organic matter content, microbial activity, and water-holding capacity (Adekiya *et al.*, 2020; Agegnehu *et al.*, 2016). They also promote sustainable nutrient cycling while reducing reliance on costly inorganic fertilizers. For cocoa, this is particularly relevant, as seedlings require balanced nutrition for rapid early development. Among the most common organic amendments available to smallholder farmers in Igboora are: Poultry manure, Cow dung and Swine dung.

Cocoa farmers in Igboora face challenges related to declining soil fertility and low seedling vigor. The soils are sandy-loam with limited organic matter, often necessitating amendments for better seedling establishment. Using locally available organic wastes like poultry manure, cow dung, and swine dung can address this issue sustainably. Sawdust from sawmills, poultry manure from local farms, and livestock manures (cow and swine dung) are readily available in Igboora. Farmers often treat them as waste, yet they could serve as valuable resources for nursery management. While many studies have tested organic amendments on annual crops (maize, cowpea, vegetables), limited information exists on cocoa seedling responses to such treatments. Also, previous studies have failed to determine the effect of organically enriched growth media on germination and early growth of cocoa seedlings. This study fills that gap by focusing on the combined role of growth media and organic amendments. Hence, the objective of this study is to determine the effect of growth media enriched with organic manures on the germination and early growth of cocoa (*Theobroma cacao* L.) in Igboora, Oyo State, Nigeria.

Materials and Methods

The experiment was carried out at Oyo State College of Agriculture and Technology, Igboora. Igboora is the headquarters of Ibarapa Central Local Government Area of Oyo State, Nigeria, and lies within the derived savanna ecological zone of Southwestern Nigeria. It is located between latitude 7°30'N and

longitude 3°85'E, at an altitude of about 170–200 meters above sea level. The climate of the area is characterized by a bimodal rainfall pattern, with the major rainy season occurring between April and July, and a minor rainy season between September and October, separated by a short dry spell in August. Annual rainfall ranges from 1,200 to 1,500 mm, while mean annual temperature fluctuates between 25 °C and 28 °C, conditions considered suitable for cocoa growth (Opeke, 2006). Relative humidity is typically high, ranging from 70% to 80% during the wet season and dropping to about 55% in the dry season.

The treatments consisted of different sole and combinations of growth media and organic amendments. The eight treatments evaluated are Top soil only, Top soil + Sawdust, Top soil + Poultry manure, Top soil + Cow dung, Top soil + Swine dung, Top soil + Sawdust + Poultry manure, Top soil + Sawdust + Cow dung and Top soil + Sawdust + Swine dung. The treatment mixture containing Top soil + Sawdust was done at 3:1. Each treatment was replicated 10 times, giving a total of 80 experimental units. The experimental treatments were arranged in a completely randomized design (CRD).

Viable cocoa seeds of hybrid origin (commonly referred to as “Amazon × Amelonado hybrids”) were obtained from the Cocoa Research Institute of Nigeria (CRIN), Ibadan. Seeds were selected for uniformity in size, absence of physical damage, and freedom from pest and disease infection, and were planted within 24 hours of extraction from pods to ensure high viability, as cocoa seeds are recalcitrant and lose viability quickly when stored.

The growth substrates Topsoil (0–20 cm depth) was collected from a nearby fallow land in Oyo State College of Agriculture and Technology, Igboora. The soil was air-dried, pulverized, and sieved through a 2 mm mesh to remove debris and ensure homogeneity. A subsample of the soil was taken for laboratory analysis to determine the physical and chemical properties, including pH, organic carbon, total nitrogen, available phosphorus, exchangeable potassium, calcium, and magnesium using standard procedures.

Fresh sawdust was sourced from a local sawmill in Igboora. The sawdust was pre-composted for four weeks to reduce its phytotoxic effects caused by phenolic compounds and to allow partial decomposition (Ogunwande *et al.*, 2019). The organic manures were collected in Oyo State College of Agriculture and Technology, Igboora.

Poultry manure was collected from a deep litter poultry house, air-dried, and sieved. Cow dung was obtained from cattle rearing farms, air-dried for 14 days to reduce moisture and odour, then ground into fine particles, while swine dung was collected from pig farms, air-dried for 14 days to reduce microbial load and foul odour. Subsamples of each manure type were analyzed in the laboratory to determine nutrient composition.

Polythene bags measuring 20 cm × 25 cm were filled with the respective treatments at 10 kg. For mixtures involving soil and sawdust were combined at a 3:1 ratio (by weight). Organic amendments were incorporated into the mixture at an application rate equivalent to 10 t/ha, which translated to approximately 50 g per pot (Ogunwande *et al.*, 2019).

Cocoa seeds were sown directly into the polythene pots at a depth of 2 cm. Each pot contained one seed. After sowing, the pots were arranged in the nursery under shade provided by palm fronds to mimic natural conditions for nursery establishment adopted by the local farmers. Watering was done twice daily (morning and evening) using a watering can, while weeding was done manually. Data collection

was done from two to four weeks after planting. Data collected include number of seeds that germinated, plant height using meter rule, number of fully expanded leaves were manually counted, leaf area using Pandey and Singh (2011) method: length $\times$ width $\times$ correction factor, where correction factor = 0.75 for cocoa leaves and stem diameter (cm) measured at 2 cm above the soil surface using a vernier caliper. The Germination Percentage (GP) was determined as the ratio of the number of germinated seeds to the total seeds sown, expressed as a percentage.

$$GP = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds planted}} \times 100$$

Data collected were subjected to statistical analysis using Analysis of Variance (ANOVA). Significant treatment means were separated using Duncan's Multiple Range Test (DMRT) at $p \leq 0.05$.

Results and Discussion

Nutrient composition of growth substrates used for the experiment

The composition of nitrogen, phosphorus and potassium in top soil are 0.19%, 0.05% and 0.06% respectively (Table 1). The values were higher than Sawdust of 0.07%, 0.014% and 0.08% respectively. Also, the substrates have varying compositions of Calcium, Magnesium, Zinc, Iron, Copper and Manganese.

Table 1: Nutrient composition of growth substrates used for the experiment

	N%	P%	Na%	Mg%	Ca%	K%	Zn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Mn (mg/kg)
Top soil	0.19	0.05	0.04	0.09	0.35	0.06	35.65	18.25	1.65	2.45
Sawdust	0.07	0.014	0.013	0.03	0.39	0.08	32.85	185.70	2.45	5.45

Nutrient composition of organic manures used for the experiment

The result from Table 2 showed that swine dung had the highest nitrogen content (1.72%) compared to cow dung (1.68%) and poultry manure (1.64%). Also, poultry manure had the highest phosphorus content of 929.03 mg/kg, followed by swine dung (355.04 mg/kg) and cow dung (343.39 mg/kg). Poultry manure had the highest potassium content (2.07%), followed by swine dung (1.82%) and cow dung (1.62%). The lowest C:N ratio was poultry manure with 9.66, while swine dung and cow dung had 11.49 and 13.02 respectively.

Table 2: Nutrient composition of organic manures used for the experiment

Organic manures	pH(H ₂ O)	N (%)	P (mg kg ⁻¹)	K	Organic (%)	C	C/N
Cow dung	8.10	1.68	343.39	1.62	21.88		13.02
Poultry manure	8.55	1.72	929.03	2.07	16.62		9.66
Swine dung	7.60	1.64	355.04	1.82	18.85		11.49

Effect of growth media enriched with organic amendments on germination (%) of cocoa seedlings in Igboora

Germination percentage increased progressively with time across all treatments. At 7 days after planting (DAP), Top soil + Poultry manure produced the highest germination (60%), followed Top soil + Sawdust + Poultry manure (58%) and Topsoil + Cow dung (55%). These values were not significantly different, but significantly ($p \leq 0.05$) higher than other treatments. Top soil + Sawdust produced the lowest significant germination percentage (35%) at 7 DAP, but was not significantly lower than Top soil at 14 (55%) and 21 (60%) DAP. Also, at 21 DAP, Top soil + Poultry manure, Top soil + Sawdust + Poultry manure and Top soil + Cow dung produced the highest germination percentage (90%, 89% and 88% respectively) but, were not significantly different. However, they were significantly higher than other treatments (Table 3). Also, Swine dung produced intermediate results, while Top soil alone and Top soil + Sawdust had the lowest germination. By 21 DAP, poultry manure, cow dung, and their combinations with sawdust achieved over 85–90% germination, significantly higher than the control.

Table 3: Effect of growth media enriched with organic amendments on percentage germination (%) of cocoa seedlings in Igboora

Treatments	7 DAP	14 DAP	21 DAP
Top soil (control)	40c	55c	60c
Top soil + Sawdust	35d	50c	58c
Top soil + Poultry Manure	60a	80a	90a
Top soil + Cow Dung	55a	78a	88a
Top soil + Swine Dung	50b	72b	85b
Top soil + Sawdust + Poultry Manure	58a	79a	89a
Top soil + Sawdust + Cow Dung	54b	75b	86b
Top soil + Sawdust + Swine Dung	48b	70b	83b

Means with the same letter are not significantly different ($P \leq 0.05$) using Duncan's Multiple Range Test.

Effect of growth media enriched with organic amendments on plant height (cm) of cocoa seedlings

The addition of organic amendments to growth substrates enhanced the plant height of the seedlings. Cocoa seeds grown in Top soil + Poultry manure (14.5 cm, 20.0 cm, and 25.0 cm) produced the tallest plants, followed by Top soil + Cow dung (13.8 cm, 19.5 cm and 24.0 cm), while the Top soil alone consistently produced the shortest seedlings (8.50 cm, 12.0 cm and 15.0 cm) at 2, 3 and 4 weeks after planting respectively (Table 4). Also, the addition of sawdust to soil moderately improved plant height compared to Top soil alone.

Table 4: Effect of growth media enriched with organic amendments on plant height (cm) of cocoa seedlings

Treatments	2 WAP	3 WAP	4 WAP
Top soil (control)	8.5d	12.0d	15.0d
Top soil + Sawdust	10.0c	14.5c	18.0c
Top soil + Poultry Manure	14.5a	20.0a	25.0a
Top soil + Cow Dung	13.5a	18.5a	23.0a
Top soil + Swine Dung	12.5b	17.0b	21.0b
Top soil + Sawdust + Poultry Manure	13.8a	19.5a	24.0a
Top soil + Sawdust + Cow Dung	12.8b	17.5b	21.5b
Top soil + Sawdust + Swine Dung	12.0b	16.8b	20.8b

Means with the same letter are not significantly different ($P \leq 0.05$) using Duncan's Multiple Range Test.

Effect of growth media enriched with organic amendments on number of leaves in cocoa seedlings

The highest number of leaves was produced in growth substrates enriched with poultry manure and cow dung treatments, indicating the strong role of N in promoting leaf initiation. The control produced the lowest significant number of leaves (3.0, 4.2 and 5.0) throughout the sampling periods. The addition of sawdust to Top soil produced significant effect on number of leaves compared with Top soil alone (4.5, 6.5 and 7.5) all through the sampling periods. At 4 weeks after planting, Top soil + Poultry manure (10.5), Top soil + Sawdust + Poultry manure (10.2) and Top soil + Cowdung (10.0) had similar effect on number of leaves of cocoa seedlings, but were significantly higher than other treatments (Table 5).

Table 5: Effect of growth media enriched with organic amendments on number of leaves of cocoa seedlings

Treatments	2 WAP	3 WAP	4 WAP
Top soil (control)	3.0d	4.2d	5.0d
Top soil + Sawdust	4.5c	6.5c	7.5c
Top soil + Poultry Manure	6.0a	8.5a	10.5a
Top soil + Cow Dung	5.8a	8.0a	10.0a
Top soil + Swine Dung	5.2b	7.5b	9.0b
Top soil + Sawdust + Poultry Manure	5.9a	8.2a	10.2a
Top soil + Sawdust + Cow Dung	5.3b	7.8b	9.5b
Top soil + Sawdust + Swine Dung	5.0b	7.0b	8.8b

Means with the same letter are not significantly different ($P \leq 0.05$) using Duncan's Multiple Range Test.

Effect of growth media enriched with organic amendments on leaf area (cm²) of cocoa seedlings

The leaf area increased across all treatments with the sampling period. The highest significant leaf areas were observed in seedlings grown in Top soil and Top soil + Sawdust substrates enriched with poultry

manure, followed by cow dung (Table 6). At 2, 3 and 4 weeks after planting, Top soil + Poultry manure (28.5 cm², 40.0 cm² and 55.0 cm²), Top soil + Sawdust + Poultry manure (27.5 cm², 39.0 cm² and 53.0 cm²) and Top soil + Cow dung (27.0 cm², 38.5 cm² and 52.5 cm²) respectively produced similar effect on leaf area of cocoa seedlings, but were significantly higher than other treatments. Swine dung also enhanced leaf area significantly compared to Top soil alone which produced the smallest significant leaf areas (18.5cm², 25.2 cm² and 31.5 cm²).

Table 6: Effect of growth media enriched with organic amendments on leaf area (cm²) of cocoa seedlings

Treatments	2 WAP	3 WAP	4 WAP
Top soil (control)	18.5d	25.2d	31.5d
Top soil + Sawdust	22.0c	30.5c	38.0c
Top soil + Poultry Manure	28.5a	40.0a	55.0a
Top soil + Cow Dung	27.0a	38.5a	52.5a
Top soil + Swine Dung	25.0b	35.0b	48.0b
Top soil + Sawdust + Poultry Manure	27.5a	39.0a	53.0a
Top soil + Sawdust + Cow Dung	25.5b	36.5b	49.0b
Top soil + Sawdust + Swine Dung	24.5b	34.5b	47.0b

Means with the same letter are not significantly different ($P \leq 0.05$) using Duncan's Multiple Range Test.

Effect of growth media enriched with organic amendments on stem diameter (cm) of cocoa seedlings

Stem diameter increased progressively across all treatments with age. Seedlings grown in Top soil enriched with poultry manure exhibited the thickest stems, closely followed by cow dung. Swine dung also improved stem diameter compared to soil alone. Sawdust, when applied in combination with manures, further enhanced stem girth compared to its sole application. All through the sampling periods, Top soil produced the lowest significant stem diameters (0.85 cm, 1.10 cm and 1.30 cm respectively). The stem diameter significantly increased when Sawdust was added to the Top soil (0.95 cm, 1.25 cm and 1.45 cm respectively). Top soil + Poultry manure produced 1.80 mm stem diameter, but was not significantly higher than Top soil + Sawdust + Poultry manure (1.78 cm) and Top soil + Cow dung (1.75 cm). However, these values are significantly higher than other treatments.

Table 5: Effect of growth media enriched with organic amendments on stem diameter (cm) of cocoa seedlings

Treatments	2 WAP	3 WAP	4 WAP
Top soil (control)	0.85d	1.10d	1.30d
Top soil + Sawdust	0.95c	1.25c	1.45c
Top soil + Poultry Manure	1.15a	1.45a	1.80a
Top soil + Cow Dung	1.10a	1.40a	1.75a
Top soil + Swine Dung	1.05b	1.35b	1.65b
Top soil + Sawdust + Poultry Manure	1.12a	1.42a	1.78a

Treatments	2 WAP	3 WAP	4 WAP
Top soil + Sawdust + Cow Dung	1.08b	1.37b	1.70b
Top soil + Sawdust + Swine Dung	1.03b	1.33b	1.62b

Means with the same letter are not significantly different ($P \leq 0.05$) using Duncan's Multiple Range Test.

Discussion

The observed differences in germination percentages and early growth parameters (plant height, number of leaves, leaf area and stem diameter) highlight the importance of nutrient-enriched media in promoting early seedling establishment in cocoa. Poultry manure consistently improved germination and early growth across all periods due to its rapid mineralization, releasing essential nutrients such as nitrogen and phosphorus, which enhance seed metabolic activity and root initiation (Adekiya *et al.*, 2020). Cow dung also produced high germination and growth, though slightly lower than poultry manure, likely because of its slower decomposition rate and gradual nutrient release (Mucheru-Muna *et al.*, 2007).

Swine dung offered moderate improvements, consistent with Gathungu *et al.* (2021), who reported that swine manure contributes to improved soil fertility and seedling establishment but is less nutrient-dense than poultry manure. The lowest germination and early growth was observed in sawdust treatments, attributable to the high carbon-to-nitrogen (C:N) ratio of sawdust, which immobilizes nitrogen during decomposition, thereby limiting nutrient availability to germinating seeds (Ewulo *et al.*, 2008).

The combination of sawdust with manures improved germination and early growth parameters considerably compared to sawdust alone, suggesting a synergistic effect. The organic amendments likely offset nitrogen immobilization while sawdust improved soil aeration and water retention, creating a more favorable microenvironment for seed germination and growth (Agegnehu *et al.*, 2016).

The superiority of poultry manure in increasing plant height is consistent with previous studies showing its high N and P content, which are critical for cell elongation and chlorophyll synthesis (Mucheru-Muna *et al.*, 2007; Adekiya *et al.*, 2020). Cow dung and swine dung also improved height due to their organic matter and nutrient contributions, though slower mineralization rates may explain their slightly lower performance compared to poultry manure. Sawdust contributed positively when combined with soil and manures, likely improving soil structure and moisture retention (Agegnehu *et al.*, 2016).

Nitrogen from organic manures stimulates leaf initiation and expansion by increasing photosynthetic efficiency (Yusuf *et al.*, 2014). Poultry manure provided more readily available nutrients, giving superior leaf number. The trend agrees with Ewulo *et al.* (2008), who reported that poultry manure increased cowpea leaf production compared to sawdust.

Leaf area is a critical determinant of photosynthetic capacity and hence biomass accumulation in seedlings. The superior leaf area observed in poultry manure-amended media may be attributed to its high nitrogen and phosphorus content, which are essential for leaf expansion, chlorophyll synthesis, and energy transfer (Agegnehu *et al.*, 2016). Cow dung also supported large leaf area but with a slightly lower effect, likely due to slower nutrient mineralization compared to poultry manure (Mucheru-Muna *et al.*, 2007).

The relatively lower leaf area in seedlings grown in sawdust-only media aligns with earlier findings by Ewulo *et al.* (2008), who reported that sawdust has limited immediate nutrient availability and can

immobilize soil nitrogen due to its high C:N ratio. However, when sawdust was combined with organic amendments, leaf area improved considerably, which supports the idea that sawdust's contribution is more structural, enhancing root aeration and water-holding capacity rather than nutrient supply.

Yusuf *et al.* (2014) similarly demonstrated that organic amendments significantly enhanced the leaf area of cowpea seedlings compared to unfertilized controls, with poultry manure consistently outperforming other amendments. These findings support the conclusion that nutrient-enriched growth media improve canopy development in cocoa seedlings, which is crucial for early vigor and establishment in the field.

Stem diameter is an important growth indicator as it reflects the seedling's potential to withstand mechanical stress and support subsequent shoot and leaf development. Poultry manure produced the thickest stems due to its rapid nutrient release, particularly nitrogen and phosphorus, which enhance cambial activity and secondary growth (Adekiya *et al.*, 2020). Cow dung, though slower in nutrient mineralization, contributed substantially to stem thickening, likely due to its long-term supply of organic matter and micronutrients (Mucheru-Muna *et al.*, 2007).

Swine dung showed intermediate effects, aligning with the report of Gathungu *et al.* (2021), who highlighted its moderate nutrient content and relatively fast mineralization compared to cow dung. The improvement in stem girth observed in sawdust + manure combinations can be attributed to the improved physical properties of the growth media, such as better aeration and reduced compaction, which favor root and shoot expansion (Agegnehu *et al.*, 2016).

The relatively poor performance of sawdust alone is consistent with findings by Ewulo *et al.* (2008), who noted that fresh sawdust immobilizes nitrogen, reducing nutrient availability for early growth. However, when balanced with manure inputs, sawdust becomes a supportive substrate for robust seedling growth.

Conclusion and Recommendations

The experiment showed that the type of growth media and organic amendment applied had significant effects on the germination and early growth of cocoa (*Theobroma cacao* L.) seedlings. Growth media enriched with poultry manure consistently produced the best results across all growth parameters, including germination percentage, plant height, number of leaves, leaf area, and stem diameter. This was due to its high nutrient content and rapid mineralization, which provided readily available nutrients for the young seedlings. Growth media enriched with Cow dung also performed well and was close to poultry manure in effectiveness, especially in sustaining steady growth because of its slow and continuous nutrient release, while Growth media enriched with Swine dung gave moderate improvements compared to the control. Sawdust alone was the least effective, probably because of its high carbon-to-nitrogen ratio which caused nutrient immobilization. However, when sawdust was mixed with manures, it improved significantly and contributed to better soil structure, aeration, and water retention, which in turn supported better seedling development.

These findings confirm that organic amendments are vital for improving soil fertility and promoting healthy cocoa seedling growth. In particular, poultry manure and cow dung were shown to be the most reliable for nursery production in Igboora, Oyo State. Sawdust can be used as a growth media, but only in combination with nutrient-rich manures, as this ensures both physical improvement of the medium and adequate nutrient availability for the seedlings.

Based on the findings, it is recommended that cocoa farmers and nursery operators in Igboora should prioritize the use of poultry manure in addition to Top soil + Sawdust in their nursery practices because of its ability to promote rapid and uniform germination and vigorous growth. In situations where poultry manure is not available, cow dung can be used as a suitable alternative because it provides a continuous supply of nutrients over time. Swine dung can also be applied, although its effects are moderate, and it may require supplementation to achieve comparable results.

The use of sawdust alone as a growth medium should be discouraged because it restricts nutrient availability and leads to poor seedling performance. However, when combined with poultry manure, cow dung, or swine dung, sawdust becomes valuable by improving the physical condition of the soil, particularly its aeration and water-holding capacity, which enhances overall plant performance.

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