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ORIGINAL RESEARCH

Comparative evaluation of animal manures and levels of applications on the growth performance of *Diospyros mespiliformis* Hochst ex A. Rich seedlings

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Abstract

Purpose *Diospyros mespiliformis* which is commonly known as African ebony is a valuable fruit tree species with important medicinal and nutritional values. The tree has a slow growth rate that discourages its propagation and at present attempts made towards improving its growth performance are scanty. This study, therefore, evaluates the effect of the type and quantity of animal manure on the growth performance of *Diospyros mespiliformis* to determine the suitable type of manure and quantity of application that will improve its growth performance.

Method Poultry, cow, and goat manures were applied to *Diospyros mespiliformis* seedlings at 0 g (control), 15 g (10 t/ha^{-1}), 30 g (25 t/ha^{-1}), and 40 g (35 t/ha^{-1}) in pots. The experiment was arranged in a 4 x 3 factorial in a completely randomized design with five (5) replicates.

Results Type of manure had a significant effect on seedlings' stem height growth. The highest stem height growth of 11.64±1.54 cm was recorded by seedlings that received goat manure. The collar diameter and the number of leaves produced were not significantly affected by the type of manure. The Quantity of manure applied did not significantly affect stem height and collar diameter increment; however, it significantly affected the number of leaves produced. Application of 40 g of manures improved leaf production in *Diospyros mespiliformis* seedlings.

Conclusion Application of animal manures improved the growth performance of *Diospyros mespiliformis*, however, seedlings that received goat manure had better growth performance.

Keywords *Diospyros mespiliformis,* African ebony, Animal manure, Stem height, Collar diameter increment

Introduction

Nutrients are key ingredients required for plant growth and development (Rashmi et al. 2020). The major source of these nutrients is the soil. However, the soil often cannot supply these nutrients at the required amount because of deficiency or other factors that may hinder their supply. To supplements the soil nutrient supply, various sources of nutrients such as inorganic fertilizer and organic fertilizer are added. Inorganic fertilizer provides easily accessible nutrients essential for plant growth (Rashmi et al. 2020). However, excessive use of it can

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result in nutrient leaching leading to surface and underground water pollution and accumulation of heavy metals in soil (Dharma-Wardana 2018). It is also expensive, particularly in developing countries like Nigeria. The use of organic fertilizer such as animal manure as an alternative means of supplying nutrients to plants in a sustainable way has attracted a lot of attention because it is available, affordable, and environmentally friendly (Zafar et al. 2011; Chemura 2014).

Organic fertilizer has two main sources: animal manure (poultry, small ruminants, large ruminants) and agricultural waste (compost and crop residues). Animal manure is rich in essential nutrients and has the ability to improve soil's physical, chemical, and microbiological properties thereby improving plant growth and development (Sun et al. 2015; Zhang et al. 2016; Li et al. 2016). The nutrient content of animal manures varies depending on the type of animal and the nature of feeds the animals are fed with. Poultry manure is reported to be rich in Nitrogen (N) and phosphorus (P) and low in potassium (K) when compared to sheep, horse, and pig manure (Therios 1996). Cow manure is a good source of Nitrogen (N), Organic carbon (C), Magnesium (Mg), and Calcium (Ca) (Adegunloye et al. 2007), while the amount of N and K in goat manure was reported to be twice the quantities in cow manure (Midranisiah et al. 2021). The beneficial effects of animal manure on plants growth and development have been well documented (Odiete et al. 1999; Ojeniyi and Adegboyeaga 2003; Awodum et al. 2007; Adebayo et al. 2017; Naishima et al. 2019; Majolagbe et al. 2020; Unagwu and Ayogu 2020; Ibode et al. 2022). For example, the application of animal manure was reported to improve seedlings of the growths of *Albizia zygia* (Yisau et al. 2020). Furthermore, the seedling growth of *Massularia acuminate* was also reported to improve after the application of different types of animal manure (Majolagbe et al. 2020). Similarly, both Aduradola et al. (2016) and Bello and Gada (2015) reported an improvement in the seedling of the growth of *Treculia africana* and *Tamarindus indica* respectively after the application of animal manures. In *Massularia acuminate* seedlings, it was observed that seedlings' growth rate did not differ significantly among seedlings treated with different animal manure (Majolagbe et al. 2020). In *Eucalyptus camaldulensis* seedlings, a significant difference in growth variables among seedlings treated with a different type of animal manure was observed; seedlings treated with poultry manure had better growth compared to other types of manure (Naishima et al. 2019). The application of cow manure to *Entandrophragma angolense* seedlings significantly improved their growth performance according to Agbo-Adediran et al. (2020). Improved growth was recorded in okra, amaranthus, celosia, and maize after the application of goat manure (Odiete et al. 1999; Ojeniyi and Adegboyega 2003). Increased soil pH, N, and Yield of plantain were also attributed to the application of goat manure (Samuel et al. 2003). According to Unagwu et al. (2019) the growth performance of a plant is not only determined by the type of manure applied but the quantity and quality of manure applied also plays a key role. Excess nutrients may be detrimental, while inadequate nutrient application may not be enough to stimulate the desired growth in plants. For example, in *Massularia acuminate* seedlings, it was observed that when the quantity of animal manure was increased stem height, collar diameter, and the number of leaves produced decreased but when animal manure was moderately applied the seedling's performance improved significantly (Majolagbe et al. 2020). Information on the appropriate quantity of animal manure required by each plant species is therefore important to achieve optimal growth. *Diospyros mespiliformis* is commonly known as jackal berry, African ebony, west African ebony, ebony diospiros, etc. The plant (*Diospyros mespiliformis*) is an ethnomedicinal tree in the family of Ebenaceae (Orwa et al.

2009). It is usually recognised by its grey-black or black bark which is smooth in young trees and rough with small regular scales in older trees (Fig 1). The tree can reach a height of about 15-50m when fully matured (Orwa et al. 2009). *Diospyros mespiliformis* is one of the neglected and underutilized indigenous fruit tree species in Africa (Gnonlonfin et al. 2018). The fruit and tree parts are majorly used as food (Chivandi and Erlwanger 2011; Samuel et al. 2021) and in traditional medicine for the management of several ailments such as cough, cardiovascular diseases, cancer, arthritis, inflammation, and malaria (Luka et al. 2014; Olanlokun et al. 2021). People in Togo, Nigeria, Mali, and Benin were reported to rely on *Diospyros mespiliformis* trees during a famine (Traore and Jouquet 2020). This underscores the importance of this tree species. However, despite the several importance of this tree, it is yet to be domesticated (cultivated), it is only found in the wild. One of the major reasons discouraging its propagation is its slow growth rate. Several studies on *Diospyros mespiliformis* reveal that the species has a slow growth rate, and it hardly exceeds a height of 1-1.5 m after 5 years of planting (Osei-Begyina 2007; Jegede et al. 2015), in comparison with some indigenous timber species such as *Cordia allidora* and *Terminalia ivorensis* which were reported to reach a height of 1.34 -2.63 m and 1.8 m respectively after one year of planting (MacGregor 1934; Hazlett 1989). It is therefore important to carry out studies that would improve the growth performance of this important species thereby shortening its gestation period. Hence this study was conducted to determine the types of animal manure and appropriate quantity required to improve the growth performance of *Diospyros mespiliformis* in the nursery to encourage its propagation.

Fig. 1 Leaves, flowers, and ripe fruits of *Diospyros mespiliformis*

Materials and methods

Study area

The experiment was conducted at the seedlings nursery of the Department of Forestry and Wildlife Management, Federal University Gashua, Yobe State, Nigeria. Gashua town is located in the semi-arid region of Nigeria on latitude 12°51'.723"- 12°54'.723" N and longitude 11°00'.024" - 11°03'.475" E. The climate of the area is categorized into wet and dry seasons, with an average annual rainfall that ranged between 500 to 1000 mm and a minimum temperature of 23 to 28°C. The temperature peak at 40°C, though sometimes it exceeds 40°C (Wakawa and Suleiman 2022).

Samples collections and preparation

Mature and healthy fruits of *Diospyros mespiliformis* were collected from tree stands within Gashua town, Yobe State, Nigeria. The fruit pericarps were depulped manually to expose the seeds. The seeds were then soaked in water for 24 hours to stimulate germination (Jegede et al. 2015). Cow, goat, and poultry manure were collected from farms within Gashua town and allowed to cure for 4 weeks after which it was air dried, milled, sieved, and stored for use.

Analysis of chemical properties of animal manures used

Cow, goat, and poultry manure were air-dried, crushed, and sieved through 2 mm mesh for analysis.
Organic carbon was obtained following Walkley-Black method (Nelson and Somners 1996). N was determined using the Kjeldhal method after digestion of material (A.O.A.C. 1999). Available P was determined according to Bray 1 method (Murphy and Rikey 1962). Exchangeable bases were done by extraction with 1 m NH4OAC. Calcium (Ca) and magnesium (Mg) in the extract were determined by atomic absorption spectrophotometer (AAS). Effective CEC was the summation of exchangeable bases (Ca, Mg, K, and Na); potassium (K) was determined by flame photometer. The pH meter was used to obtain the pH of the manures.

Experimental setup

The seeds of *Diospyros mespiliformis* were sown on a seedbed/seedling bed and watered twice (morning and evening) until the completion of germination (6 weeks). Seedlings of similar height were selected and transplanted into polythene pots of 15 × 8.5 cm size filled with topsoil. The seedlings were nursed for four (4) weeks, to allow them to acclimatize and recover from possible shock experienced after transplanting. Manures from poultry, cow, and goat were then applied to the seedlings at varying quantities: 15 g (10 t/ha$^{-1)}$, 30 g (25 t/ha^{-1}), and 40 g (35 t/ha^{-1}). Seedlings that did not receive organic manure served as control. The experiment was arranged in a 4 x 3 factorial in a completely randomized design (CRD) and replicated five (5) times. The treatment combination is shown in Table 1 below.

Table 1 Treatment combination of 4 x 3 factorial

Quantity	Organic manure			
	M_1	M_2	M_3	M_4
Q_1	M_1Q_1	M_2Q_1	M_3Q_1	M_4Q_1
Q_2	M_1Q_2	M_2Q_2	M_3Q_2	M_4Q_2
Q_3	M_1Q_3	M_2Q_3	M_3Q_3	M_4Q_3

Keys: M_1= Poultry manure; M_2= Goat manure; M_3= Cow manure; M_4= without manure (control)
Q_1= 15g (10 t ha^{-1}of animal manure; Q_2= 30g (25 t ha^{-1}) of animal manure; Q_3= 40g (35 t ha^{-1}) of animal manure

Growth variables assessed

The following variables were assessed at every 2 weeks' intervals for 16 weeks:

Stem height (cm): The stem height was measured from the bottom to the terminal bud of the seeding with a graduated ruler.

Collar diameter (mm): The stem diameter of each seedling was measured slightly above the collar height with a digital vernier caliper.

The number of leaves: The total number of leaves present on each seedling was counted by physical observation.

Data analysis

Data collected were analysed using two-way analysis of variance (ANOVA) with the aid of STATISTICA Version 12 at p<0.05 level of significance. Follow-up test (Post hoc) where applicable was done using Duncan Multiple Range Test (DMRT).

Results and discussion

Chemical properties of animal manures used

Laboratory analysis of animal manure as shown in Table 2 below revealed a high amount of C (43.23%) N (4.84%), P (3.94%), and Mg (0.83%) in goat manure when compared with cow and poultry manures. Goat manure had the lowest C/N (8.93), while cow manure had the highest (23.65). Poultry manure recorded the highest pH (7.9%), K (2.73%), and Ca (3.11%) in comparison with the other manures. Cow manure had the least percentage for the majority of the chemical properties analysed when it is compared with goat and poultry manures (Table 2).

Table 2 Chemical properties of organic manures

Manure	C (%)	pH	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	C/N
Cow	31.93	7.1	1.35	0.47	1.78	1.29	0.52	23.65
Goat	43.23	7.44	4.84	3.94	1.82	1.24	0.83	8.93
Poultry	20.4	7.9	2.05	0.92	2.75	3.11	0.63	9.95

C: organic carbon, N: nitrogen, P=phosphorus, K=potassium, Ca=calcium, Mg=magnesium

Effects of types of animal manure on the growth performance of *Diospyros mespiliformis*

The result of the analysis of variance (ANOVA) conducted on the growth variables assessed shows that the type of animal manure received by *Diospyros mespiliformis* seedlings significantly affects its stem height growth (Table 3). Since stem height growth in plants is regarded as one of the important indicators used in assessing seedlings' growth performance, it may be right to imply that the type of organic manure used could influence the growth performance of *Diospyros mespiliformis*. This is because the amount of essential nutrients element in each type of manure varies as can be seen from the result of the chemical analysis of manures used in this study in Table 2. According to Therios (1996), the nutrient composition of animal manures varied depending on the type of animal and feeds consumed. Our finding collaborated with that of Ibode et al. (2022) who reported a significant difference in the seedlings of *Cedrela odorata* tree species after the application of different type of animal manure. Seedlings of *Diospyros mespiliformis* that received goat manure had the highest stem height growth of 11.64±1.54 cm, while the control had the least 9.90±1.08 cm (Table 4). The high stem height growth recorded by *Diospyros mespiliformis* seedlings after the application of goat manure could be attributed to the high amount of P in goat manure when compared with the other manures as shown in our result of chemical analysis of manures in Table 2. The process of stem height growth includes cell division, and P is one of the essential elements required during cell division in a plant (Unagwu et al. 2019). Therefore, high content of P soil would be expected to be accompanied by improved stem height growth. Other elemental nutrients such as N and K are also essential for plant growth and development (Chmelíková and Hejcman 2012; Gil et al.

2012; Tanoi and Kobayashi 2015). Therefore the addition of more N and K to *Diospyros mespiliformis* seedlings will also be expected to be accompanied by improved seedling growth as shown in this study. Seedlings that received goat manure maintained a steady superior height increment throughout the experiment in comparison with those that received cow and poultry manures (Fig 2). The collar diameter and the number of leaves produced by *Diospyros mespiliformis* seedlings were not significantly affected by the type of animal manure used. Seedlings collar diameter ranged from 2.05±0.30 mm (control) to 2.30±0.30 mm (poultry manure), while the number of leaves increased from 13.8±1.82 (Control) to 15.07±3.61 (goat manure) as shown in Table 4. Marginal improvement in the number of leaves produced by *Diospyros mespiliformis* seedlings after the application of goat manure when compared with other manures could be attributed to high N and low K (N/K) which favour vegetative growth. A similar result was reported by Majolagbe et al. (2020) in *Massularia acuminate* seedlings after being subjected to different animal manures. They reported a lack of significant difference in collar diameter and number of leaves assessed. However, in *Eucalyptus camaldulensis*, a contrary result was observed (Naishima et al. 2019). They reported that the application of different animal manures significantly affects the leaf length and collar diameter of *Eucalyptus camaldulensis*. This contradiction could be attributed to species differences. *Diospyros mespiliformis* is a tropic species while *Eucalyptus camaldulensis* is a temperate species even though it has been naturalized in the tropics. Different growth performance was also observed in five popular agroforestry tree species when they were subjected to varied types of animal manure (Uddin et al. 2012). Application of poultry manure gave a better collar diameter increment at the early stage of the experiment (2-4 weeks) but as time progresses; it was overtaken by seedlings that were applied to goat manure (Fig. 3). Overall *Diospyros mespiliformis* seedling performance improved after the application of animal manure irrespective of the type though seedlings that received goat manure had the best performance compared to those that received cow and poultry manure. Application of animal manure generally enhances nutrient availability and creates a favourable soil physical condition thereby enhancing plant growth and development (Gulshan et al. 2013; Unagwu and Ayogu 2020). Improved growth performance of several plants after the application of goat manure has been reported by several scholars (Odiete et al. 1999; Ojeniyi; Adegboyeaga 2003; Awodum et al. 2007).

Effects of the quantity of animal manure on the growth performance of *Diospyros mespiliformis*

The quantity of animal manure received by *Diospyros mespiliformis* seedlings significantly influence the number of leaves produced (Table 3). This finding was in agreement with that of Adebayo et al. (2017) who reported a significant difference in the number of leaves produced by *Moringa oleifera* seedlings after the application of a different quantity of animal manure. The application of 40 g (35 t/ha^{-1}) of all types of animal manures significantly improved the number of plant leaves produced in comparison with the application of 30 g (25 t/ha^{-1}) of animal manures which gave the least (Table 4). This finding agrees with that of Adebayo et al. (2017) who noticed a significant improvement in leaf production of *Moringa oleifera* seedlings that received the highest quantity of animal manure. Significant improvement in the number of leaves produced by *Diospyros mespiliformis* seedlings after the application of 40 g (35 t/ha^{-1}) of animal manure could be attributed to the presence of a high quantity of nutrients in the manure, particularly P. Nutrient P enhances root development and

Nutrient uptake. Nutrient N is regarded as one of the major elements of proteins, nucleic acids, and chlorophyll, and plays an important role in the leaf production phase (Midranisiah et al. 2021). Therefore, an increase in N content in soil is expected to increase leaf production in the plant. Application of 40 g (35 t/ha^{-1}) of animal manure also gave the highest collar diameter increment of 2.21±0.27 mm and stem height growth of 11.1±1.33 cm even though it did not vary significantly with the other treatments (Table 4). Increased in the quantity of animal manure received by *Diospyros mespiliformis* seedlings resulted in improved diameter increment and stem height growth. This implies that the higher the quantity of animal manure received by *Diospyros mespiliformis* seedlings the more the number of leaves produced.

A similar observation was reported by Adebayo et al. (2017) in *Moringa oleifera* seedlings. This observation was in agreement with that of Aduradola et al. (2016) who opined that an increase in the quantity of organic manure usually leads to better plant growth. *Diospyros mespiliformis* seedlings that received 40 g (35 t/ha^{-1}) of animal manure maintained an appreciable increase in leaf production, collar diameter, and stem height growth every 2 weeks of counting throughout the experiment (Fig. 3). A steady and appreciable increase in growth variables observed at every 2 weeks of measurement in *Diospyros mespiliformis* seedlings throughout the experiment could be attributed to the gradual and steady release of N from animal manure to plant over a longer time for its growth and development (Adekiya et al. 2020).

Table 3 Analysis of variance (ANOVA) for growth variable of *Diospyros mespiliformis* subjected to types and levels of animal manure application

Stem height (cm)	**DF**	**SS**	**MS**	**F**	**P**
M	3	29.786	9.929	5.700	0.002020*
Q	2	3.238	1.619	0.929	0.401773
M*Q	6	12.735	2.122	1.218	0.313385
Error	48	83.608	1.742		
Total	59	129.366			
Number leaves					
M	3	13.38	4.46	0.579	0.631402
Q	2	50.63	25.32	3.288	0.045898*
M*Q	6	56.57	9.43	1.224	0.310498
Error	48	369.60	7.70		
Total	59	490.18			
Collar diameter (cm)					
M	3	0.6199	0.2066	2.414	0.078044
Q	2	0.1029	0.0514	0.601	0.552331
M*Q	6	0.3740	0.0623	0.728	0.629071
Error	48	4.1083	0.0856		
Total	59	5.2051			

Note: * signify significant at $p \leq 0.05$; M= type of manure, Q= quantity of manure, M*Q=interaction effect between type and quantity of manure

Interaction effects between the type and quantity of manure application on the growth performance of *Diospyros mespiliformis*

The interaction effects between the type and quantity of animal manure on the growth performance of *Diospyros mespiliformis* seedlings were not significant (Table 3). When cow, poultry, and goat manures were applied at the high amount (40 g), *Diospyros mespiliformis* seedlings' growth performance improved but this improvement was not significantly different from the other treatment combinations (Table 4). Irrespective of the quantity or type of manure received by *Diospyros mespiliformis* seedlings, there seems to be an improvement in its growth performance compared to those that did not receive any manure (control). This could be due to the presence of essential nutrients elements such as N, P, and K in all animal manure which plays a critical role in plant growth and development (Chmelíková and Hejcman 2012; Gil et al. 2012; Tanoi and Kobayashi 2015). Several researchers reported an improved growth performance of plants irrespective of the type or quantity of manure applied when compared with those that were not received manure (Han et al. 2015, Imoro et al. 2012; Naishima et al. 2019).

Table 4 Growth performance of *Diospyros mespiliformis* subjected to types and levels of animal manure application at 16 weeks of assessment

Treatments			SH (cm)	CD (mm)	NL
M	M1		11.44±1.45[ab]	2.30±0.30	14.13±2.90
M	M2		11.64±1.54[a]	2.24±0.24	15.07±3.61
M	M3		10.50±1.22[bc]	2.10±0.30	14.13±3.04
M	M4		9.90±1.08[c]	2.05±0.30	13.8±1.82
Q	Q1		10.69±1.51	2.12±0.34	13.75±2.51[b]
Q	Q2		10.72±1.61	2.2±0.0.28	14.75±2.45[ab]
Q	Q3		11.1±1.33	2.21±0.27	15.1±3.29[a]
M*Q	M1	Q1	12.12±1.21	2.25±0.41	15.6±4.77
M*Q	M1	Q2	10.6±1.23	2.31±0.19	12.2±2.28
M*Q	M1	Q3	11.6±1.69	2.34±0.33	14±3.24
M*Q	M2	Q1	11.45±0.78	2.18±0.16	15.8±3.11
M*Q	M2	Q2	11.07±1.78	2.23±0.28	13.8±3.19
M*Q	M2	Q3	12.39±1.84	2.31±0.30	16.2±1.92
M*Q	M3	Q1	11.27±1.47	2.11±0.30	14.6±1.67
M*Q	M3	Q2	9.82±0.45	2.01±0.40	12±2.73
M*Q	M3	Q3	10.43±1.22	2.19±0.21	15.8±3.56
M*Q	M4	Q1	9.96±1.03	2.24±0.28	12.4±1.14
M*Q	M4	Q2	9.96±0.71	1.88±0.17	14±1.73
M*Q	M4	Q3	9.79±1.58	2.02±0.34	15±1.73

Note: Mean carrying the same alphabet did not vary significantly at $p \leq 0.05$. Mean values are followed by the standard deviation **M_1=** Poultry manure, **M_2=** Goat manure, **M_3=** Cow manure, **M_4=** without manure (control), **Q_1=** 15 g (10 t/ha^{-1}) of manure, **Q_2=** 30 g (25 t/ha^{-1}) of manure, **Q_3=** 40 g (35 t/ha^{-1}) of manure, SH=stem height, CD=collar diameter, NL=number of leaf, * =interaction

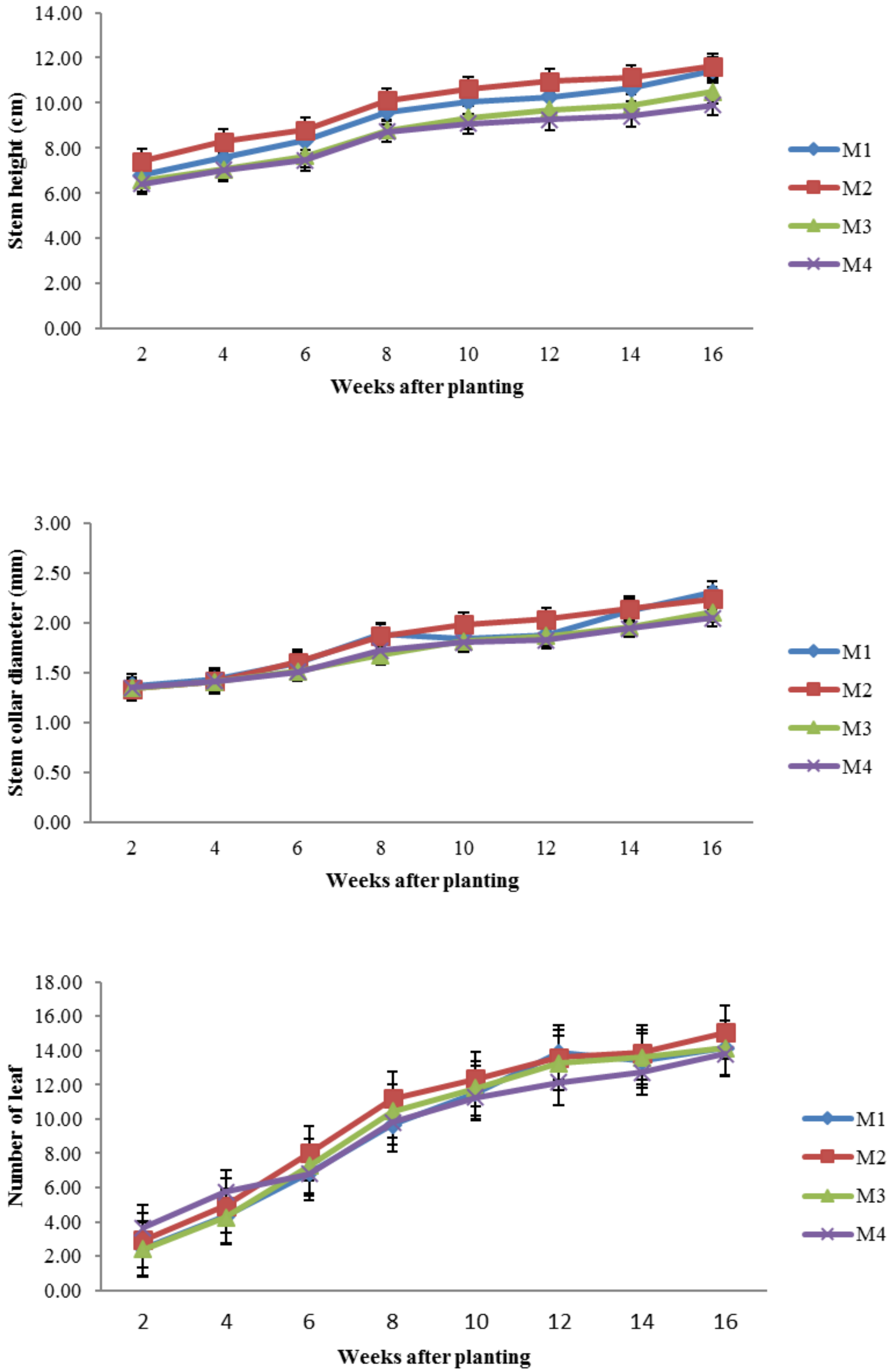

Fig. 2 Time series plot showing the growth trend of *Diospyros mespiliformis* based on the type of manure applied

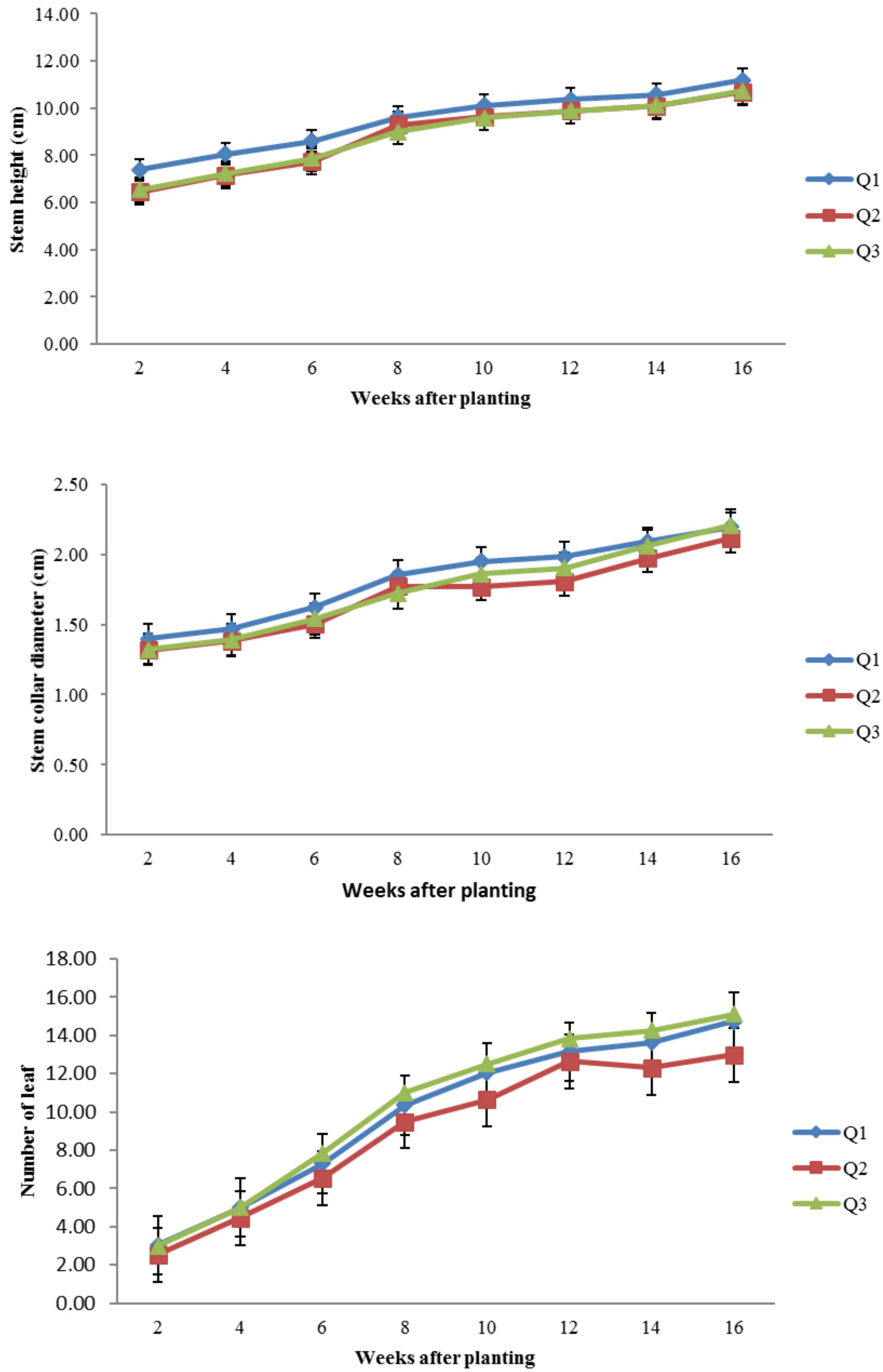

Fig. 3 Time series plot showing the growth trend of Diospyros mespiliformis based on the quantity of animal manure applied

Conclusion

We carried out a study to ascertain the effects of type and quantity of animal manure (poultry, cow, and goat) application on the growth performance of *Diospyros mespiliformis* seedlings in the nursery. Our findings revealed that the growth performance of *Diospyros mespiliformis* seedlings improved after the application of animal manures irrespective of the type and the level of the application when compared with those that did not receive manure. However, *Diospyros mespiliformis* seedlings that received goat manure had a better performance when compared with cow and poultry manures. *Diospyros mespiliformis* seedlings that received 40 g (35 t/ha^{-1}) of cow, goat, and poultry manures seem to perform better in all the variables assessed. The application of cow, goat, and poultry manures at any of the levels can enhance the growth performance of *Diospyros mespiliformis* seedlings. However, we recommend the application of goat manure at 40 g (35 t/ha^{-1}) to improve growth performance as was demonstrated in this study.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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