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Morphophysiology, growth indices, and fruiting of pumpkin in response to organic amendments

Morfofisiologia, índices de crescimento e frutificação da abóbora em resposta a condicionadores orgânicos

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Highlights

Poultry dung enhances the vegetative growth and plant physiology of pumpkins.
AGR, RGR, LAI, LAR, LAD, and biomass of pumpkin affect positively by poultry dung.
Poultry dung stimulates the flowering, fruit formation, and quality of pumpkin.

Abstract

A field study was carried out to examine the effects of organic amendment on the morpho-physiology, growth indices, and fruiting of pumpkin (Cucurbita moschata) plants. The pumpkin seedlings were raised in polybags and treated without fertilizer (control), cow dung, goat dung, poultry dung, vermicompost, compost, and inorganic fertilizer (NPK). The results showed that poultry dung and cow dung treatments significantly increased the length of vine, leaf number, leaf area, and leaf dry weight of pumpkin plants. Poultry dung treatment increased the absolute growth rate (AGR), relative growth rate (RGR), leaf area index (LAI), leaf area ratio (LAR), leaf area duration (LAD), and fresh plant biomass by 345%, 287%, 770%, 384%, 415%, and 1139%, respectively over the control plants. Poultry dung treatment also increased the

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internode length and initiated flowers earlier than the control. Petiole length, stomatal conductance, and chlorophyll content were 5.59, 1.49, and 1.41 times higher with NPK treatment compared to the control group. In addition, poultry dung treatment increased the female flower number, male-female flower ratio, number of fruits, fruit weight, fruit diameter, fruit circumference, fruit length, and flesh thickness by 350%, 30%, 300%, 100%, 80%, 80%, 67%, and 105%, respectively, over the control plants. From this study, it can be concluded that poultry dung treatment enhanced the vegetative and reproductive growth, plant physiology, fruiting, and quality of pumpkin.
Key words: Organic manure. Vegetable. Growth indices. Yield. Quality.

Resumo

Foi realizado um estudo de campo para avaliar os efeitos de condicionadores orgânicos em índices morfofisiológicos de crescimento e frutificação de plantas de abóbora (Cucurbita moschata). As mudas de abóbora foram cultivadas sem fertilizante (controle), com esterco de vaca, esterco de cabra, esterco de aves, vermicomposto, composto e fertilizante inorgânico (NPK), em saco de polietileno. Os resultados mostraram que os tratamentos com esterco de galinha e de vaca aumentaram significativamente o comprimento da planta, o número de folhas, a área foliar e o peso seco das folhas das abóboras. O tratamento com esterco de aves aumentou a taxa de crescimento absoluto (AGR), taxa de crescimento relativo (RGR), índice de área foliar (LAI), razão de área foliar (LAR), duração da área foliar (LAD) e biomassa vegetal fresca em 345%, 287%, 770%, 384%, 415% e 1139%, respectivamente sobre as plantas de controle. O tratamento com esterco de aves também aumentou o comprimento do entrenó e iniciou as flores das plantas antes do controle. O comprimento do pecíolo, a condutância estomática e o conteúdo de clorofila foram 5,59; 1,49 e 1,41 vezes maiores com o tratamento NPK em comparação com o grupo controle. Além disso, o tratamento com esterco de ave aumentou o número de flores femininas, proporção de flores masculinas e femininas, número de frutos, peso do fruto, diâmetro do fruto, circunferência do fruto, comprimento do fruto e espessura da polpa em 350%, 30%, 300%, 100%, 80%, 80%, 67% e 105%, respectivamente, sobre as plantas do tratamento controle. A partir deste estudo, pode-se concluir que o tratamento com esterco de aves favoreceu o crescimento vegetativo e reprodutivo, a fisiologia da planta, a frutificação e a qualidade da abóbora..
Palavras-chave: Fertilizante orgânico. Hortaliças. Indices de crescimento. Produção. Qualidade.

Introduction

Pumpkin (*Cucurbita moschata*) is an annual fruit vegetable, which originated from middle America and is cultivated worldwide (Anim, 2017; Sekerci, Karaman, Yetisir, & Sagdic, 2017). In 2020, global production of pumpkins exceeded 28 million tons worth more than $4.5 billion (Food and Agriculture Organization of the United Nations [FAOSTAT], 2020). The largest producer of pumpkin is China (28.7%), followed by India (19.7%), Ukraine (4.8%), Russian Federation (4.3%), and Mexico (3.4%) (FAOSTAT, 2018). Pumpkin is the most favorable vegetable and a common cash crop grown by Malaysian farmers on small farms of one to ten acres (Kamarubahrin et al., 2018). Pumpkin vegetable is cultivated for nutritious plant food, culinary and medicinal uses. Pumpkin flesh and peels contain essential minerals, antioxidants, e.g., phenols, flavonoids, tocopherols, and carotenoids that can help with antiaging and improve the immune system. The pumpkin fruits contain protein (20.5 g), fat (45 g), carbohydrate (23 g), fiber (2.2 g), and total ash (4.8 g) (Badifu & Ogunsua, 1991). The leaf of pumpkin content is 29% protein, 18% fat, and 20% minerals and vitamins which make it of medicinal, nutritional, and industrial value (Tindal, 1986). Pumpkin seed oil is used in cooking and soap making (Fashina, Olatunji, & Alasiri, 2002), pumpkin fruits are used as blood purifiers and are useful to maintain good health (Aletor, Oshodi, & Ipinmoroti, 2002).

Pumpkin is a heat-loving plant, survives a wide range of temperatures, is short growing within around three months, and fruits can be harvested after 45 days after flowering with high storage ability (Margaret, Gisong, Modon, & Rusim, 2016; Kang, 2017; Kamarubahrin et al., 2018). Due to the short growing period of pumpkin, long postharvest shelf life, and high food value, farmers are encouraging pumpkin cultivation and have also considered export purposes (Norshazila, Irwandi, Othman, & Yumi Zuhanis, 2014). The light green vine of pumpkin trails on the ground and is vastly pubescent (Ajuru & Okoli, 2013a). Pumpkin leaves are also light green to green in color, alternate, simple, lobed, about 23 cm long and 28 cm wide, and have many hairs on the leaf adaxial surface forming a cushion. Pumpkin is a monoecious fruit vegetable plant that produces more male flowers than female flowers in the vine (Ajuru & Okoli, 2013b). Even with the valuable contribution of pumpkin to the human diet, pumpkin growers are facing problems regarding cultivation, especially in Southeast Asian countries with sandy podzolic and low naturally fertile soil. The productivity of pumpkin plants is increased with organic matter containing soil and sunny periods but is reduced due to problematic soil, high rainfall, and humidity during the growing season (Ajuru, Nmom, & Worlu, 2018). An imbalance in chemical fertilizer use can also cause negative effects on the soil health and microbial population which may reduce plant growth, yield, and quality of the crop. In addition, the use of inorganic fertilizer is limited due to its high price, limited availability, and low value for money (Ano & Agwu, 2005). However, the use of organic manure acts as a substitute for chemical fertilizer in improving soil productivity and fertility (Dauda, Ajayi, & Ndor, 2008). The depletion of soil nutrients and poor soil conditions creates a limitation to vegetable production and causes declining food production (Salako, 2003; Sanchez, Izac, Valencia, & Pieri, 1996). Thus, the application of organic manure is an important tool for supplying adequate nutrients to keep problematic soils productive and fertile for crop production.

Organic manures are essential for plant growth, development and yield due to their balanced nutrients. The effects of organic manure on the plants depend on the type and source of fertilizer. Drainage and moisture retention capacity of poor soil is improved by using plant-based organic fertilizer, whereas, animal-based organic fertilizer increases the growth of leafy plants (Khandaker, Rohani, Dalorima, & Nashriyah, 2017). The organic fertilizer acts as a plant nutrient reservoir due to its slow decomposition rate, it can improve soil structure, cation exchange capacity (CEC), water holding capacity, and maintain soil pH. Poultry manure consists of N (2.8%), P (0.32%), K (5.93%), Ca (5.30%), Mg (0.48%), Na (0.34%) and organic carbon (47.9%) (Idem, Ikeh, Asikpo, & Udoh, 2012). A considerable amount of nutrients are also present in cow dung (N;

2.10%, P; 4.5%, K; 1.10%, Ca; 1.10%, Mg; 0.87%, Na; 0.30% and organic carbon; 16.8%) and goat dung (N; 2.40%, P; 4.80%, K; 0.17%, Ca; 0.63%, Mg; 0.42%, Na; 0.26% and organic carbon; 16.9% (Umekwe, Eneruvie, & Okpani, 2020). Obasi, Nwadinigwe and Asegbeke (2008) stated that poultry manure and other organic manures increase agricultural production and solve waste disposal problems. An inadequate level of nitrogen, phosphorus, and potassium from inorganic sources results in poor growth, late flowering, poor fruit set, low yield, and low quality in many crops (Aduayi, Chude, Adebusuyi, & Olayiwola, 2002; Liu et al., 2010). Organic fertilizer contains growth hormones that play an important role in rapid vegetative growth, flower initiation, and fruiting in fruit and vegetable crops (Onofeghara, 1981). Shiyam and Binang (2014) reported that organic manure application increased leaf proliferation and the fresh and dry weight of pumpkin plants. The organic fertilizer treatment also increased leaf number, branch number, shoot fresh weight, and total shoot yield of pumpkin (Fubara-Manuel, Nwonuala, & Davis, 2012). Awodun (2007) also stated that organic fertilizer increased nutrient content in the pumpkin leaf and vine. The leaf chlorophyll content, stomatal conductance, net photosynthetic rate, fruit weight, anthocyanin content of watermelon increased with organic fertilizer treatments (Dalorima et al., 2019).

The use of poultry manure, cow dung, goat dung, and other organics as manure are important for not only reducing environmental pollution, hazards, and the use of inorganic fertilizers but also improving crop growth, yield, and quality. Though there has been some research reported related to organic manure effects on leaf yield and fruit quality of pumpkin, no research has been carried out for growth analysis, and flowering and fruiting behavior of pumpkin under organic and inorganic fertilization systems. Hence, in this research, first, we evaluate the regulatory role of organic manure on morphophysiological characteristics and growth indices; absolute and relative growth, leaf area index, leaf area ratio, and leaf area duration of pumpkin plants. Second, we evaluate the effect of organic manure on the flowering, fruiting behavior, and yield of pumpkin plants. The novel findings related to the growth analysis of pumpkin plants will be beneficial in improving the growth and development of vegetable and fruit crops.

Materials and Methods

Study area and planting materials

This study was carried out at the research field of Universiti Sultan Zainal Abidin, Besut Campus, Besut, Terengganu, Malaysia (Latitude 5°45'21.2" N and Longitude 102°37'38.8" E.) from June 2019 to August 2021. Terengganu has a tropical climate and the type of soil is BRIS soil (Beach Ridges Interspersed with Swales). Pumpkin seeds variety Labu Emas- 868 was obtained from Yong Fung Seed Company Sdn. Bhd. Johor, Malaysia. The variety is easy to grow and does not require much water during vegetative and reproductive growths. The variety Labu Emas-868 fruits have an even weight and a beautiful round shape, pulp contains more sugar and finer fiber than the other pumpkin verities. The seeds of this variety have high nutritional value and excellent source of good quality oil and protein. The mixture of topsoil, sand, and organic manure at a ratio of 3:2:1 was used for the growing of pumpkin seedlings. The mixture with a ratio of 4:2 was used for control (without organic fertilizer) and NPK treatment. Organic amendments (cow dung, goat dung, poultry dung, vermicompost, and compost) and NPK green (NPK15:15:15) and blue (NPK 12:12:17) were used in this study. This current experiment consisted of 7 treatments: T1 = control, T2 = cow dung, N 1.19%, P 0.3%, K 0.48% & Ca 2.6%; Abdulraheem, Omogoye and Charles (2018), T3 = goat dung, N 4.9%, P 4.1%, K 1.9% & Ca 1.0%; Awodun, Omonijo and Odeniyi (2007), T4 = poultry dung, N 4.5%, P 1.08%, K 1.66% & Ca 1.43; Almaz, Halim, Martini and Samsuri (2017), T5 = vermicompost, N 0.76%, P 1.09%, K 0.4% & Ca 2.5%; X. X. Wang, Zhao, Zhang, Zhang and Yang, (2017) and T6 = compost (plant parts used as residues) N 2.9%, P 3.01%, K 0.72%, & Ca 0.72%; X. X. Wang, Zhao, Zhang, Zhang and Yang (2017) and T7 = NPK, and each treatment consisted of 4 replicates (each replicate consisted of one pumpkin plant). A Randomised Complete Block Design (RCBD) with 4 replicates were used to set up the experiment in polybags to be cultivated under protected cultivation.

Seed sowing and treatment application

The seeds of pumpkin were germinated in a germination tray containing coco peat as a germination media. One pumpkin seed was planted in each hole and the germination tray was wrapped with white polythene to stimulate the germination process. The seedlings at the 4 leaf stage were transplanted to a polybag (size 16x18", capacity approx. 13.5 L) containing the above-mentioned growing media. The pumpkin seedlings were watered daily until the establishment of seedlings. The organic fertilizer was applied at 0, 15, 30, and 45 days after the transplanting of pumpkin seedlings (4 times). Meanwhile, inorganic fertilizer was applied 3 times (15, 30, and 45 days after seedling transplanting). The inorganic fertilizer of around 20 g was applied per seedlings for the NPK treatment. The green NPK (NPK15:15:15) (20 g) was applied during vegetative growth (at 15 and 30 DAT) and blue (NPK 12:12:17) (20 g) during the flowering stage (at 45 DAT). The data in this study was measured and collected every week depending on the studied parameters.

Plant morpho-physiological

Vine length of pumpkin plants was measured according to the procedure described by Grant and Todd (2001). The length of petioles and internodes were measured using a ruler with three times of reading per plant during the experimental period. The area of leaves was measured in length × width and the average of three different leaves per plant was recorded. Leaf dry weight was measured after harvesting the leaf from the plants. After obtaining the data of leaf fresh weight, we placed the pumpkin leaves of different treatments in aluminum foils and subsequently into a dryer (lab dryer, Model, FDD-720, Malaysia) at 80°C for 24 hours until achieving a constant dry weight. Leaf number and internode number for the first flowering were counted manually. The chlorophyll content in the leaves was measured using a SPAD-502 meter as per the method described in Buang, Yusoff, Nashriyah and Khandaker (2018). Leaf stomatal conductance was measured with a handheld leaf porometer according to the methods described by Jamaludin et al. (2020).

Growth analysis parameters

Absolute growth rate (AGR): Absolute growth rate can be expressed by the total growth per unit time. The rate of absolute growth represents the value of biomass between the time intervals. The absolute growth rate of pumpkin plants was calculated using the formula of Williams (1946) and expressed as cm day^{-1}

$$\text{Absolute growth rate (AGR)} = \frac{h2-h1}{t2-t1} \text{ ....equation 1}$$

Where, h2 and h1 represent the plant height or vine length at times t2 and t1, respectively

Relative growth rate (RGR): The relative growth of a plant is the slope of the curve that represents logarithmic growth over a time period. Relative growth rate (RGR) is the dry matter increment per unit biomass per time and is expressed as unit dry weight / unit dry weight /unit time (g g^{-1} day^{-1}). The RGR is calculated using the following formula described by Tylova-Munzarova, Lorenzen, Brix and Votrubova, (2005).

$$\text{Relative growth rate (RGR)} = \frac{\text{Log W2} - \text{Log W1}}{t2-t1} \text{ ....equation 2}$$

Where, W2 is the plant dry weight at time t2 and W1 is the plant dry weight at time t1. t2 and t1 are the time interval in days.

Leaf area index (LAI): Leaf area index is the ratio of total leaf area of the plant and ground area covered by the plant (Williams, 1946). The total leaf area of a plant is calculated by counting the total number of leaves, multiplied by an individual leaf of the plant.

$$\text{Leaf area index (LAI)} = \frac{\text{Total leaf area of a plant}}{\text{Ground area occupied by the plant}} \text{ .... equation 3}$$

Leaf area ratio (LAR): The ratio between the leaf lamina area and total biomass of a plant is called the leaf area ratio (LAR). Leaf area ratio is calculated using the following formula and is represented as cm^{-2} g^{-1} plant dry weight (Radford, 1967).

$$\text{Leaf area ratio (LAR)} = \frac{\text{Leaf area per plant}}{\text{Plant dry weight}} \text{ ....equation 4}$$

Leaf area duration (LAD): Leaf area duration (LAD) is the integration of leaf area index with the dry matter yield over time (Power, Willis, & Reichman, 1967). LAD depends on the duration and extent of photosynthetic tissue of the crop canopy. The LAD was calculated according to the following formula and is expressed in days

$$\text{Leaf area duration (LAD)} = \frac{L1+L2}{2} \times (t2-t1) \text{ ....equation 5}$$

L1, is the LAI at the 1st time and L2, is the LAI at the 2nd time of the measurement. (t2 - t1) is the time interval in days between the measurements.

Plant physiological and fruit characteristics

In this study, we evaluated the total soluble solids (TSS) content of the pumpkin leaves because the content of soluble solids in leaves is a sign of carbon accumulation and photosynthates supply ability of the leaves. Leaf soluble solids content is also involved in flowering, fruit formation, and many other plants' physiological and biochemical processes. Leaf TSS express the percentage of soluble solids present in a pure solution and represents as Brix index (Samukelo & Linus, 2015) and is measured with a hand refractometer according to the steps described by Buang et al. (2018). The number of male and female flowers and their ratio were counted and calculated manually. Fruit characteristics; the number of fruits, fruit weight (kg), fruit diameter (cm), fruit circumference (cm), fruit length, and thickness of fruit pulp (cm) were counted and measured using vernier calipers and was recorded after harvesting the fruits. The pumpkin fruits from the treated and untreated plants were harvested around 3 months after the transplanting of seedlings. The fruit weight of the pumpkin was measured and recorded using an electronic weighing balance after harvesting (Model: Mettle PJ3000, Japan). At the end of this experiment, the weight for each plant (g) was recorded by cutting the plants and was measured using a weighing balance.

Statistical analysis

The obtained data of this study were analyzed using SPSS software (version 20.0; SPSS Inc). The numerical data related to the growth and development of the pumpkin plants were taken as means and standard deviations. The One-Way ANOVA test was used to compare variables between the control with other treatments. Data were considered statistically significant when the *p*-value was less than *0.05.* The Duncan Multiple Range Test (DMRT) was run to identify which treatments showed a significant difference from the control treatment.

Results and Discussion

Length of vine

Several vegetative and reproductive characteristics were measured and recorded to evaluate the effects of organic amendments on the pumpkin plants. Figure 1 represents the data of vine length for treated and control pumpkin plants which was measured and recorded until week 10. A significant difference in the length of pumpkin vines between the different organic fertilizer treatments and control plants was observed. Pumpkin seedlings treated with organic manure grew at a faster rate compared to the control group during the observations of growth. The growth of control plants was lowest at all growing periods (Figure 1). At the 7th week of growth, the vermicompost treatment had the highest vine length, 244 cm, followed by goat dung, cow dung, poultry dung, compost, and NPK treatments with a value of 233, 208, 204, 199, and 140 cm, respectively. Where the lowest vine length (28 cm) was recorded in the control plants (Figure 1).

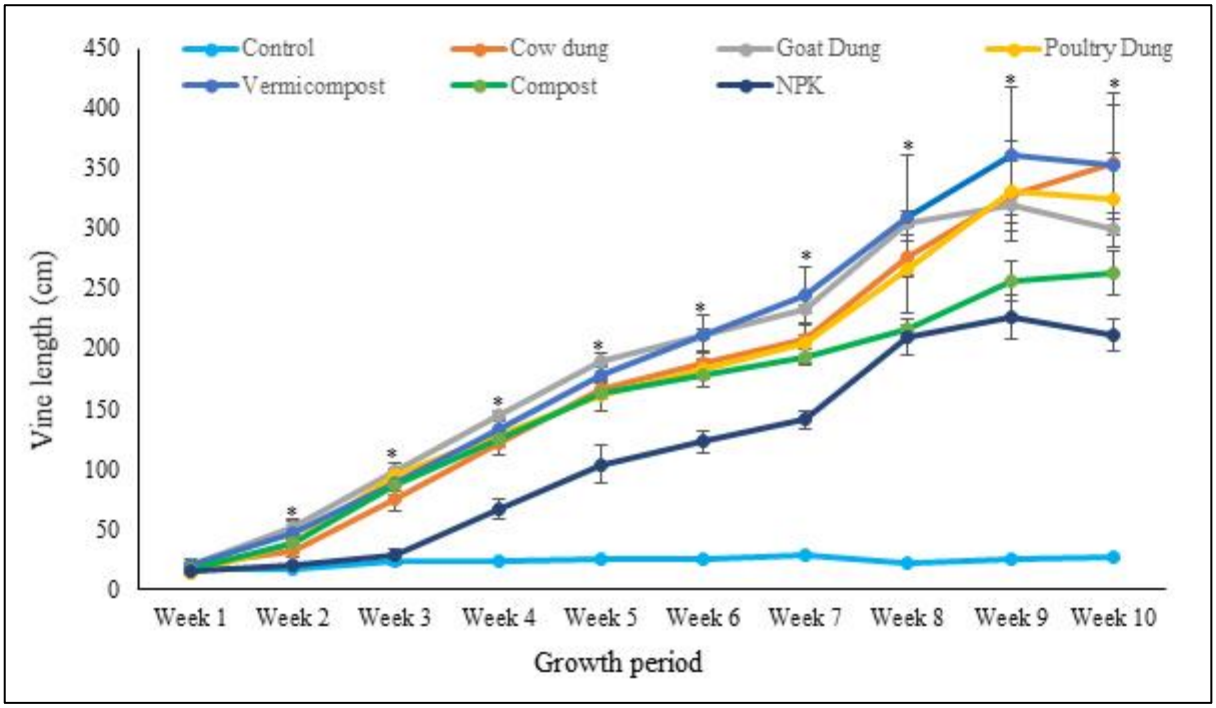

Figure 1. Vine length of pumpkin seedlings as affected by different organic amendments in polybag condition. Error bars indicate ± standard error (S.E.) and "*" indicates significance at $p < 0.05$ level of probability, Duncan's Multiple Range Test (DMRT).

In this study, pumpkin seedlings were grown with different types of organic amendment to see the effects on vegetative and reproductive growth and analyze the growth of pumpkin plants. Our results showed that the vine length of pumpkin plants significantly increased with vermicompost treatment. Khandaker et al. (2017) also reported that the application of vermicompost increased the growth and height of chili plants. The plant nutrients in the vermicompost can improve the soil's physical and chemical properties (Blouin et al., 2019). The growth improvement under vermicomposting may be due to improved soil properties and the higher availability of N, P, and K during the early establishment of the plants. Vermicompost also contains several plant hormones that enhance plant growth and provide readily available essential nutrients to the plants (Van Groenigen et al., 2014; Song et al., 2015). Vermicompost application is a slow and steady process of releasing nutrients which is beneficial for soil health and crop productivity (Mondal, Datta, & Mondal, 2015).

Number of leaves

The leaf number of pumpkin plants was affected significantly by different types of amendments and control treatment. The number of leaves was counted and recorded manually until 10 weeks of growth. The results showed that the leaf number in all treatments was significantly same in first week of observation and in the other weeks significant differences were found. Based on Figure 2, the poultry dung, vermicompost and cow dung treatments treatment produced the higher number of leaves (53, 47 and 46 leaves, respectively) at the 9th week of observation. The pumpkin plants with control treatment produced the lowest leaf number of only 5 leaves at the 9th week of observation. A similar increasing trend of leaf number at week 10 was also recorded for poultry dung, goat dung, cow dung, and vermicompost treatments (Figure 2). It was also observed that the treatments cow dung, poultry dung and vermicompost are statistically equal from week 8, which was matched with the NPK treatment at week 10.

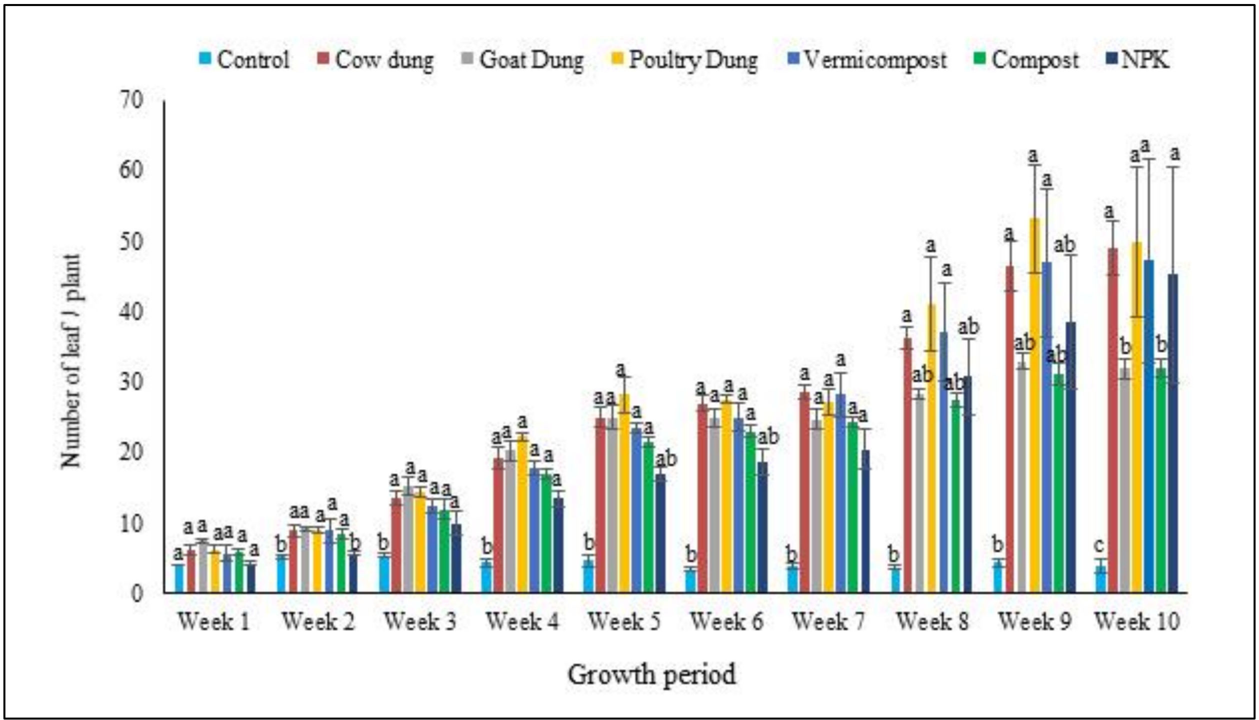

Figure 2. The influence of organic amendments on the leaf formation of pumpkin versus week. Error bars indicate ± standard error (S.E.). Different letters (a, b, & c) indicate statistical significance at 5% level, Duncan's Multiple Range Test (DMRT).

The leaf characteristics; leaf number, length of petiole, leaf area, and leaf dry weight were increased significantly by using poultry dung treatment in our study. The increment of the leaf growth may be due to the high macronutrient content of the organic amendments. Maathuis (2009) stated that Nitrogen promotes plant organ development and improves physiological characteristics, which affects the growth, yield, and quality of plant parts. Phosphorus plays a significant role in the formation of cellular membranes and regulates metabolic processes, and promotes plant growth and physiological metabolism (Maathuis, 2009; Plaxton & Tran, 2011). Potassium activates the various enzymes, which are involved in intracellular osmatic regulation, membrane protein transport, and photosynthates transport, which are beneficial for plant growth and development (Nieves-Cordones, Ródenas, Lara, Martínez, & Rubio, 2019). Bacteria and other organisms present in organic manure may facilitate biodegradation and release nutrients into the soil for plant growth (Ingham, 2005). Poultry dung application promotes the leaf formation of seedlings by increasing the number of effective microorganisms in the soil, enhancing the growth of microorganisms, and increasing the degradation process of soil humus which regulates plant growth and development (Owoloja & Oyewo, 2019; Oludele, Ogundele, Odeniyi, & Shoyode, 2019). Effective microorganisms transform the vitamins, organic acids, minerals, and antioxidants of poultry dung which lead to improving the restoration of the soil's natural health thus helping to improve the growth and development of plants (Muthaura, Musyimi, Ogur, & Okello, 2010). The application of organic manures increased the growth and leaf yield of pumpkins (Mohammad, Aroiee, Hamide, Atefe, & Sajede, 2010; Agbo, Chukwudi, & Ogbu, 2012). Organic matter application increased the level of crude protein, phosphorus, and potassium content of the pumpkin fruits (Oke, 2015).

Length of petioles and leaf area

The area between the vine and leaf lamina or leaf blade is known as the leaf petiole. According to Table 1, NPK treatment had the highest length of petiole 15.14 cm, followed by vermicompost, poultry dung, and goat dung treatments with a mean value of 11.9, 11.2, and 10.8 cm, respectively. Whereas, the smallest petiole of pumpkin leaves was found in the control treatment with a value of 2.7 cm (Table 1). The leaf area of treated and untreated pumpkin plants was calculated and is presented as a bar graph in Figure 3. Organic amendments and NPK treatment affected the leaf area of pumpkin plants significantly at $p < 0.05$. Up to 7 week, plants treated with poultry dung presented a greater foliar area. At the 5th week of observation, the leaf area of pumpkin plants was 5.48 times higher in the poultry dung treatment over the control plants. At the same week of observation, the leaf area was 3.98, 3.75, 3.74, 3.19, and 2.72 times higher in goat dung, vermicompost, cow dung, compost, and NPK treatments over the control. In weeks 8 and 9, treatments poultry dung, vermicompost and NPK were the ones with the highest leaf area and were significantly the same. At week 10, when all values decreased, treatment vermicompost was statistically superior. The leaf area of pumpkin plants in all treatments was significantly higher than the control during the growth period.

Table 1
Organic amendments and NPK effects on petiole and internode length, and physiological characteristics of pumpkin plants

Treatment	Length of petiole (cm)	Length of internode (cm)	Internode no. of 1st flowering	Stomatal conductance (mmol m^{-2} s^{-1})	Chlorophyll Content (SPAD)
Control	2.7c	4.0c	14b	122.93b	32.3c
Cow dung	10.8b	8.0b	14b	139.21a	36.9b
Goat dung	10.4b	9.4ab	12c	138.00a	34.7b
Poultry dung	11.2b	10.2a	11c	142.11a	38.1ab
Vermicompost	11.9b	9.8a	18a	163.24a	38.4ab
Compost	9.9b	8.6ab	14b	164.95a	32.6c
NPK	15.1a	9.0ab	14b	183.66a	45.7a

Different letters (a, b, & c) indicate the statistical significance and the same letters do not differ statistical significance in the same column of table at $p > 0.05$, Duncan's Multiple Range Test (DMRT).

Our results of this study show that the application of organic amendment increased the leaf area of pumpkin cultivated in polybags. Usman (2015) mentioned that poultry manure produced high and significant effects on tomato growth and development compared to cow dung and goat dung. It may be that the applied poultry manure supplied adequate amounts of nutrients to the root zone soil and retained nutrients in an available form that the plant can take easily thus enhancing cell division, leaf formation, and expanding the leaf area. Organic manure supplies macro and micronutrient elements slowly which prevents loss of nutrients and improves soil's physical and chemical characteristics (Arisha, Gad, & Younes, 2003). Higher vegetative growth of pumpkin plants due to the application of organic matter may be attributed to a lower carbon: nitrogen and carbon: phosphorus ratio of applied manure. The applied organic manure increased the root growth which is associated with nutrient absorption and vegetative growth of the pumpkin. Although in this study the organic matter effects on the soil characteristics were not evaluated, it is assumed that nutrient content and the beneficial microbes in the manure improved the leaf characteristics of the pumpkin plants. Awodun (2007) also reported that pumpkin leaf biomass content was significantly higher with a poultry manure treatment.

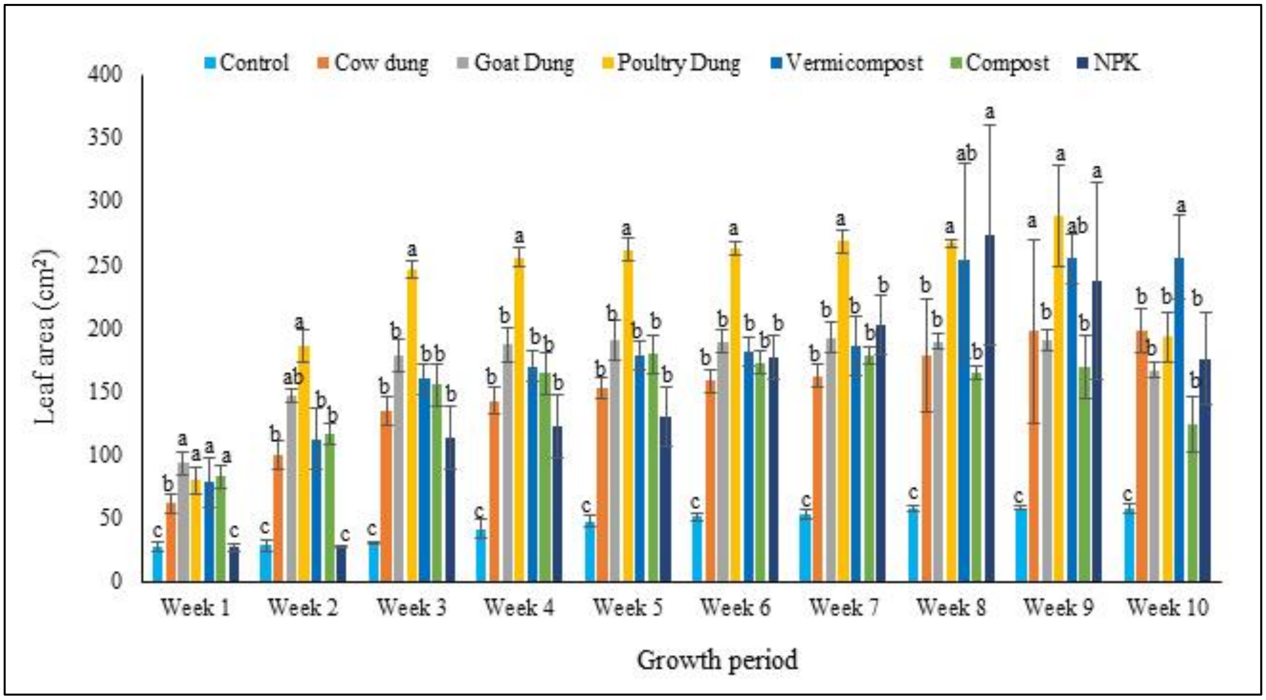

Figure 3. Leaf area of pumpkin plant as affected by different types of organic amendments. Error bars indicate ± standard error (S. E.). Different letters (a, b, & c) indicate statistical significance at 5% level, Duncan's Multiple Range Test (DMRT).

Leaf dry weight and length of internodes

Figure 4 shows the leaf dry weight of pumpkin plants as affected by different organic amendments and inorganic fertilizer over 10 weeks of observation. Leaf dry matter content of pumpkin plants was also affected significantly by organic amendments and NPK treatments. From week 1 until week 10, it can be seen that organic amendment treated plants produced higher leaf dry weight than the untreated plants. At week 10 of observation, leaf dry weight of pumpkin plants was 2.71-, 2.11-, 2.15-, 2.1-, 2.15- and 197- fold higher in cow dung, goat dung, poultry dung, vermicompost, compost, and NPK treatments compared to the control (Figure 4). From week 1 until week 10, the leaf dry weight of pumpkin plants was higher in treated plants than the untreated plants. It was also observed that cow dung and poultry treatments produced the highest leaf dry weight compared to other treatments and control pumpkin plants. Data for the length of internodes was recorded, analyzed, and is presented in table 1. The results of this study show that the poultry manure and vermicompost treatments had the highest internode length, 10.15 and 9.8 cm, respectively. The control treatment without fertilizers yielded the shortest internode length of only 4.0 cm (Table 1).

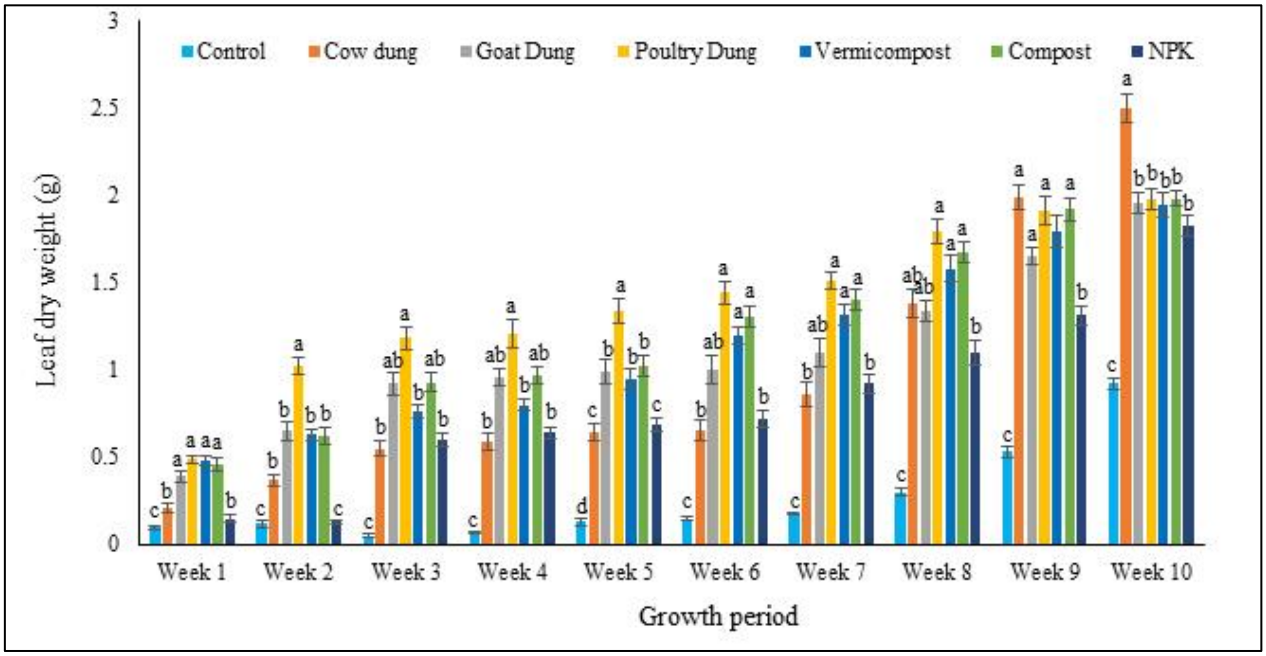

Figure 4. The influence of different types of organic amendments and NPK treatment on the leaf dry weight of pumpkin grown in polybags. Error bars indicate ± S. E. (standard error) and a, b, & c represent statistical significance at 5% level, Duncan's Multiple Range Test (DMRT).

Our results showed that organic amendment increased the internode length of pumpkin plants. Usman (2015) also stated that organic manure treatment increased the branching and branch length of tomato plants. It has been stated earlier that organic manure provided nutritional requirements for the plants without creating an undesirable effect on the environment and ecology. Growth hormone presence in organic fertilizer may improve cell activity, enhance cell division and multiplication of pumpkin plants (Aletor et al., 2005). Thus, improved cellular activity may play a significant role in vine length increment in pumpkins. Grubben et al. (2004) reported that the application of organic manure significantly increased the vine number, length of vine, and leaf number of vegetables which depends on the types and rate of fertilizer. Organic amendment application may increase the number of roots and root growth, thus increasing nutrient uptake and utilization. Organic fertilizer releases nutrients steadily and prevents chemical fertilizer losses through volatilization, nitrification, and denitrification which increases the chemical fertilizer efficiency and soil properties (Abedi, Alemzadeh, & Kazemeini, 2010). Organic fertilizer maintains a bacterial population in the soil by adding humus and maintaining the soil pH. Organic fertilizer application increases the survivability of nitrogen and phosphorus fixing bacteria which create a favorable condition for vegetable and fruit cultivation (Kumar, Solanki, & Sharma, 2009).

Early flowering, stomatal conductance, and chlorophyll content

The number of internodes for fast flowering was manually recorded and is represented in table 1. As can be seen from table 1, the results show that poultry and goat dung treatment produced early flowering at the 11and 12th internode, respectively, followed by control, cow dung, compost, and NPK treatments with an internode number of 14, 14, 14 and 14, respectively. The vermicompost treatment produced flowering later and it produced flowers at the 18th internode stage of growth (Table 1). The results indicate that vermicompost has a greater number of internodes before the flower formation compare to other treatments. In this study, pumpkin plants treated with organic amendment promoted more flowering than the control plants. Organic manure application may activate nutrients in the matrix, stimulate the absorption of plant nutrients and promote flowering and fruiting of crop plants (X. D. Wang, Liu, & Ruan, 2007). Iwanyanwu and Nze (2015) mention that poultry manure promotes and enhances soil biological activity, biodiversity, and biological cycles in organic production systems. This ecology management encourages nutrient availability for the healthy growth of kola seedlings, reduces soil salinity, and extractable ions immobilization. Organic fertilizer application provides readily available plant nutrients needed for vegetative and reproductive growth, as well as flowering and dry matter production in the plants (Tang, 2003).

Leaf stomatal conductance of pumpkin plants was non-significant among the different treatments but it was statistically higher than the control (Table 1). The lowest stomatal conductance was recorded in the control treatment. The result shows that NPK treatment yielded the highest amount of chlorophyll content (45.7 SPAD value). The control treatment produced the lowest amount of chlorophyll (Table 1). Organic amendment application increased the stomatal conductance and leaf chlorophyll content of the pumpkin plants in our study. It has been reported earlier that organic fertilizer application increases the K uptake, thus the elevated level of K increased the stomatal conductance of pumpkin plants. Gimenez, Gallardo and Thompson (2013) stated that stomatal conductance is the degree of stomatal opening which is an indicator of plant water status and depends on the growing conditions and environmental conditions. Organic fertilizer improved the soil structure that leads to an increase in the root area, nutrient uptake, a release in nutrients in available form, and enhances the efficiency of fertilizer use (Ngoc-Son, Ngoc-Diep, & Minh Giang, 2006). These improved favorable conditions may affect plant physiology, metabolism, and production. Chlorophyll is a green pigment that absorbs light energy from the sun and is an important pigment for plant photosynthesis (Li et al., 2018). The higher level of leaf chlorophyll content may be due to the effects of nutrients and growth hormones present in organic manure. Ye, Liu and Niu (2020) also reported that organic fertilizer application increased chlorophyll content, leaf area index (LAI), stomatal conductance, and net photosynthetic rate of pear jujube trees.

In this current study, pumpkin plant growth was analyzed to see the influence of different organic amendments and inorganic fertilizer. The absolute and relative growth rate (AGR and RGR) of pumpkin plants under different treatments were calculated from week 1 until week 10 and are presented in figures 5 and 6. Figure 5 shows the absolute growth rate of treated and untreated pumpkin plants until the 10th week of observation. The results indicate that the absolute growth rate of pumpkin plants was affected significantly by the organic amendment treatments (Figure 5) and the growth rate of pumpkin vine showed a favorable increase at all weeks of observation from week 1 to week 9. At the 7th week of observation, the absolute growth rate of pumpkin plants for cow dung, goat dung, poultry dung, and vermicompost was 12.4, 13.2, 11.4, and 10.6- fold higher over the control plants. The absolute growth rate of pumpkin plants was also 6.6 and 5.6 times higher in compost and NPK treatment over the control group. The lowest absolute growth rate was recorded in the control plants. The absolute growth rate started to decrease at week 9 except for the cow dung treated pumpkin plants.

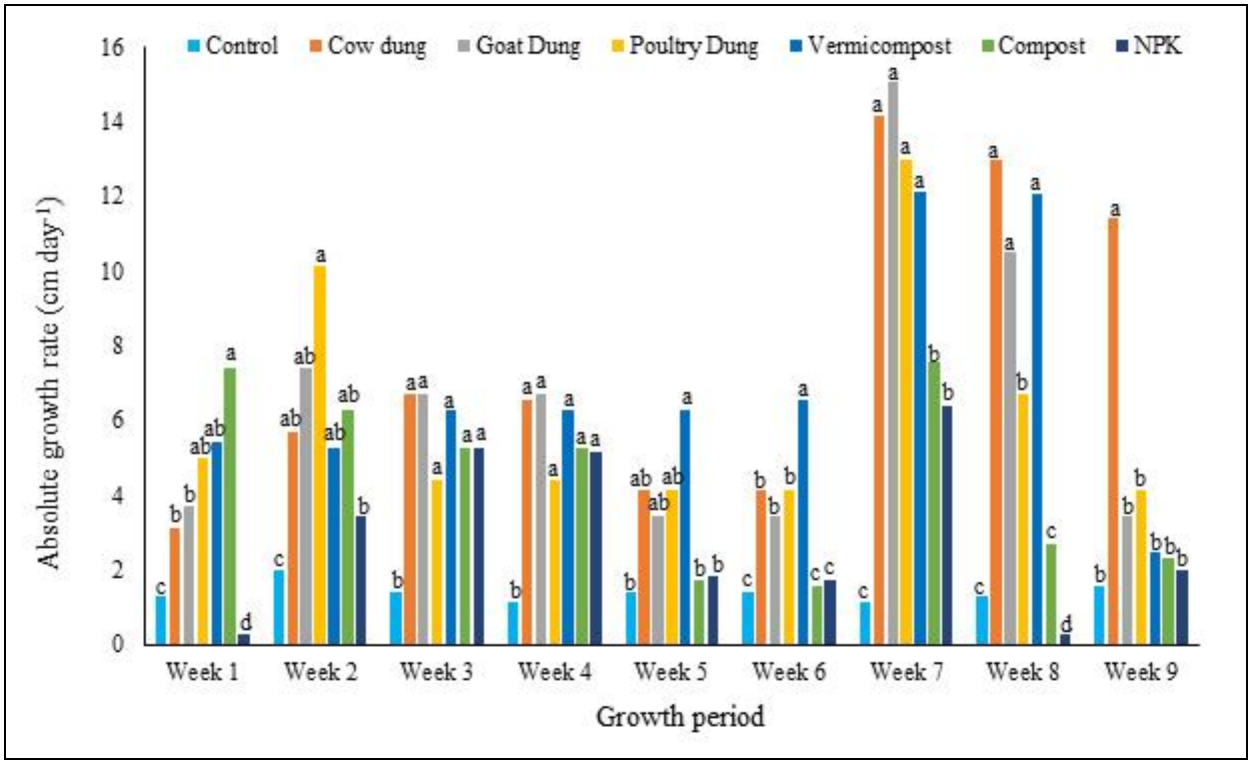

Figure 5. Effects of different organic and inorganic amendments on absolute growth rate (AGR) of pumpkin at week 1 to week 9. Different letters in growth bars indicate statistical significance at 5 % level of probability, Duncan's Multiple Range Test (DMRT).

Figure 6 represents the relative growth rate of treated and untreated pumpkin plants for the polybag conditions. The results show that the relative growth rate was significantly affected at all weeks of observation (Figure 6). At the 4th week of observation, the highest relative growth rate was recorded for the goat dung treatment (0.06 mg g^{-1} day^{-1}) and poultry dung (0.05 mg g^{-1} day^{-1}) treated pumpkin. Whereas, the lowest relative growth rate (0.009 mg g^{-1} day^{-1}) was recorded in the compost treatment. The relative growth rate was 4.3 times higher in cow dung treatment over the control treatment at the 7th week of observation. The results also indicate that the relative growth rate was comparatively lower after the 8th week of growth. Several leaf growth analysis parameters and fresh biomass of pumpkin plants were analyzed to see the effects of organic amendment and NPK fertilizer. LAI, LAR, and LAD of pumpkin plants were affected significantly with the organic fertilizer treatment. The results in Figure 7A indicate that poultry dung produced the highest leaf area index (10.2). The lowest leaf area index (1.2) was recorded in the control plants (Figure 7A).

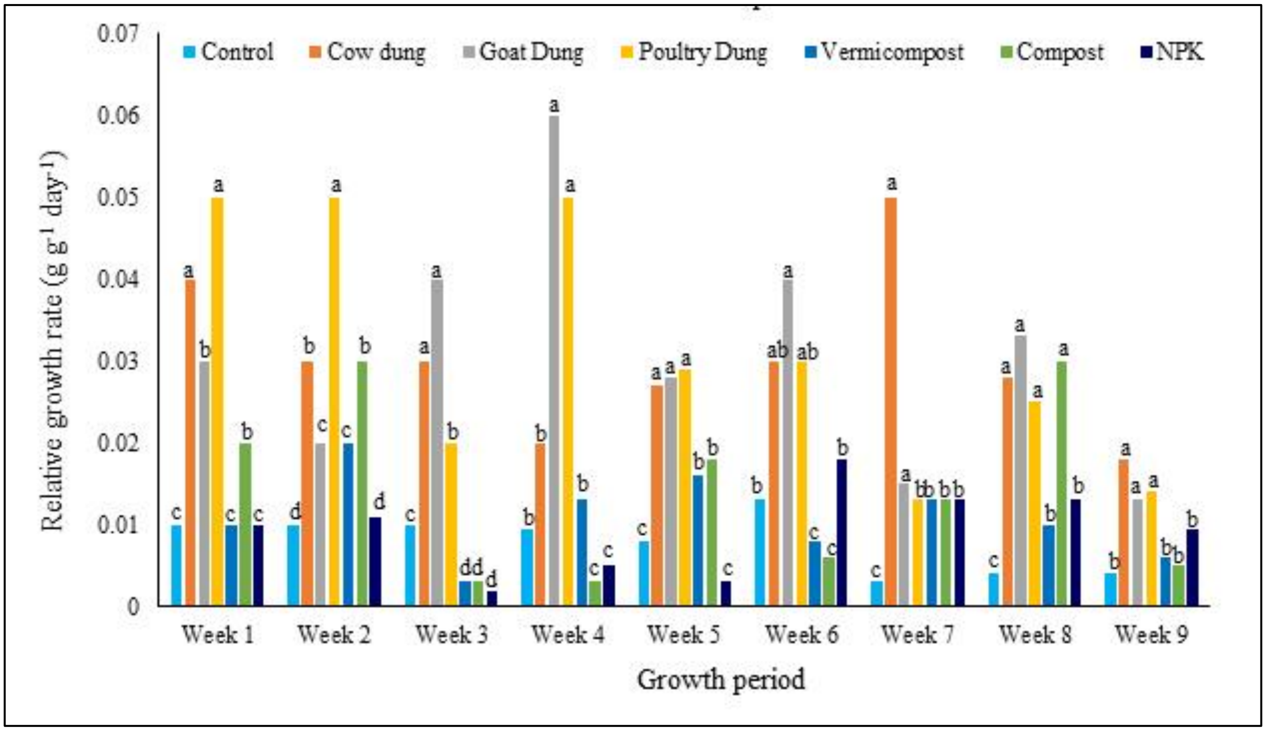

Figure 6. Organic amendment effects on relative growth rate (RGR) of pumpkin at week 1 to week 9 growth period. Different letters in growth bars indicate statistical significance at 5 %level of probability, Duncan's Multiple Range Test (DMRT).

Our results show that organic amendment application improved the growth indices; AGR, RGR, LAI, and LAR of pumpkin plants. The results of this study also indicate that AGR and RGR were associated with high LAI, LAR, and LAD of the treated pumpkin plants. Veras et al. (2016) reported that a mixture of cattle manure and organic manure increased the absolute and relative growth rate of guava rootstock. It may be that the applied organic amendment improved the availability of nutrients, root growth, increase the water holding capacity of the root zone soil, and made available phytohormones in the plants thus promoting the absolute and relative growth rate of the pumpkin plants. Parwada, Chigiya, Ngezimana and Chipomho (2020) reported that the leaf area index (LAI) of baby spinach was significantly increased by organic manure treatment. The improved LAI might be credited to the positive effects of the nutrient release rate of organic manure which improved the availability of nutrients, uptake, and translocation by the pumpkin plants. Ogunlela, Masarirambi and Makuza (2005) also stated that organic manure application significantly affects the LAI of sunflower plants. In this study, higher LAI values of treated plants caused more absorption of light energy which increased the absolute and relative growth rate of the pumpkin plants.

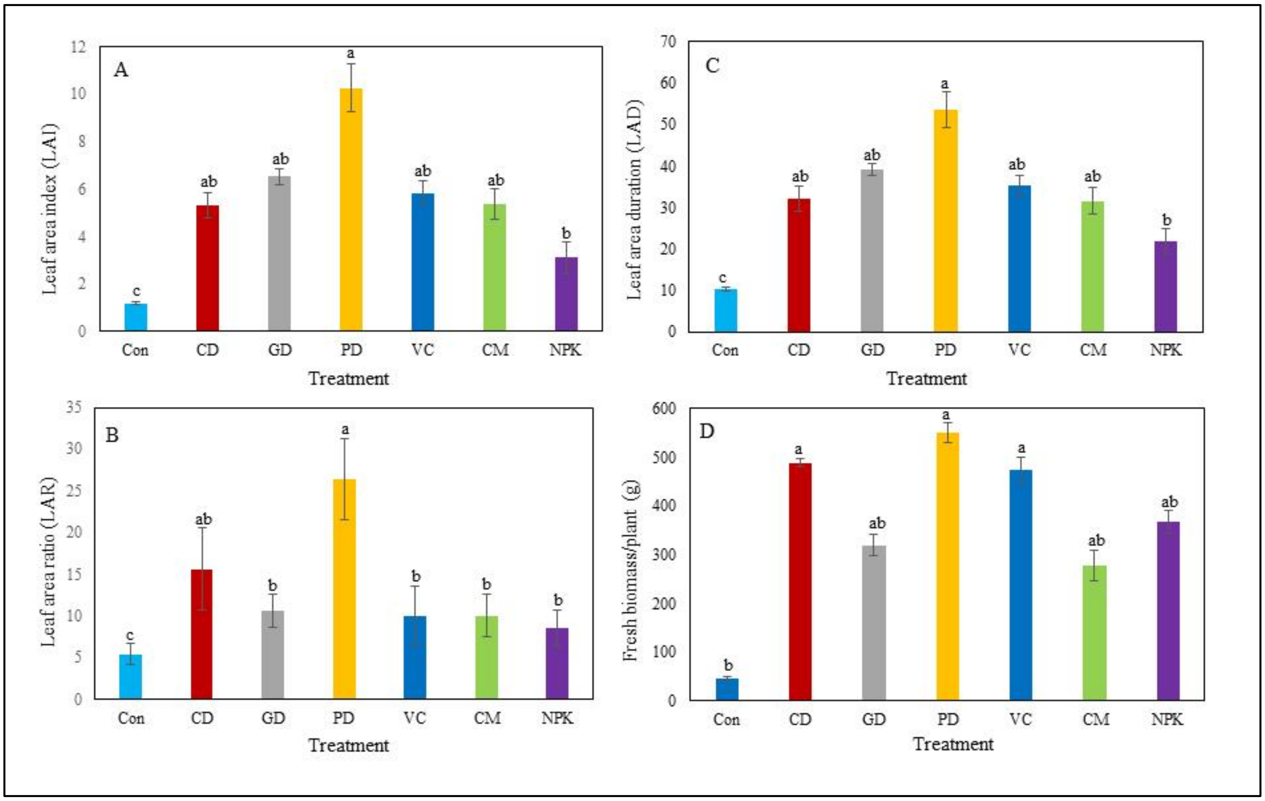

Figure 7. The effects on different organic amendments on morpho-physiological properties of pumpkin plants. A. Leaf Area Index (LAI), B. Leaf Area Ratio (LAR), C. Leaf area duration (LAD) & D. Fresh biomass of pumpkin plants. Error bars indicate ± S.E. and a, b, & c in the bars represent statistically significant at 5 % level of probability, Duncan's Multiple Range Test (DMRT). Con-Control, CD- Cow dung, GD- Goat dung, PD- Poultry dung, VC- Vermicompost, CM- Compost and NPK- Nitrogen, Phosphorus and Potassium.

Table 2
The effects of different amendments on the total soluble solids (TSS) content of leaf, flower and fruit formation of pumpkin plants

Treatment	Leaf TSS content (% BRIX)	No of male flower	No of female flower	Female and male flower ratio	Number of fruits
Control	5.10d	6d	2d	0.33a	2.0c
Cow dung	12.53a	19ab	6b	0.32b	4.0b
Goat dung	11.04b	25ab	5b	0.20b	5.0b
Poultry dung	11.28ab	21ab	9a	0.43a	8.0a
Vermicompost	11.34ab	30a	6a	0.20b	4.0b
Compost	7.85c	18b	5b	0.28b	2.0c
NPK	11.22ab	12c	3c	0.25b	3.0b

Different letters (a, b, & c) indicate the statistical significance and the same letters do not differ statistical significance in the same column of table at $p > 0.05$, Duncan's Multiple Range Test (DMRT).

Our results show that organic amendment application increased the leaf TSS content, improved flowering, fruit characteristics, and yield attributing characters of pumpkin. The results of this study are supported by the findings of Khandaker et al. (2017), who stated that organic fertilizer treatment improved the flowering, fruit weight, and fresh biomass of chili plants. Organic fertilizer application improved the total soluble solids content, juice content, and fruit quality of Jujube and citrus (Ye et al., 2020). The application of organic manure increased the leaf yield, leaf TSS content, and pumpkin quality (Agu, 2004). Habibi, Heidari, Sohrabi, Badakhshan and Mohammadi (2011) also stated that organic fertilizer alone or combined with chemical or biofertilizers increased the yield and medicinal properties of pumpkin plants.

Fruit characteristics

Organic amendment treatment significantly affects the number of pumpkin fruits per plant. Poultry dung treatment yielded the highest number of fruits (8), followed by goat dung, cow dung, vermicompost, and NPK with a fruit number of 5, 4, 4, and 3, respectively. The control plant produced the lowest number of pumpkin fruits (2) (Table 2). Table 3 represents the data of fruit characteristics of pumpkin plants as affected by different organic amendment treatments. The results show that the weight, diameter, length, and flesh thickness of fruits were significantly affected by different organic amendment treatments. Fruit weight was 100 % higher (poultry dung), 77% higher (vermicompost), 67% higher (goat dung and compost), 56% (cow dung) and 33% (NPK) compared to the control plants. Fruit diameter was 1.8-, 1.6-, 1.5-, 1.4-, 1.3-, and

1.2-fold higher in poultry dung, vermicompost, goat dung, compost, cow dung, and NPK treatment, respectively, compared to the untreated plants. The smallest fruit diameter was recorded in the control plants.

The highest fruit circumference (56.5 cm) was recorded with the poultry dung treatment followed by goat dung, vermicompost, compost, cow dung, and NPK treatments with a value of 51.1, 44.9, 42.5, 39.2, and 37.6 cm respectively. The lowest fruit circumference was recorded in the control plants (Table 3). The pumpkin fruit length was 67% higher for poultry dung, 64% (goat dung), 47% (vermicompost), 40% (cow dung and compost), and 20 % (NPK) treatments, respectively. In contrast, the control pumpkin plants produced the lowest fruit length (Table 3).

The results of this study indicate that pumpkin fruit flesh thickness increased for the treated plants with the following percentage change; poultry dung at 106%, goat dung at 88%, cow dung at 76%, vermicompost at 47%, compost at 18%, and NPK at 12%, respectively, when compared with the control plants. At the end of the experiment, the weight of each pumpkin plant was measured using a weighing balance to compare the biomass accumulation among the treatments and control. The plants were cut down and folded to reduce their size during the weighing process. The results show that the fresh biomass content of the pumpkin plants was 12.5- (poultry dung), 11 -(cow dung), 10.8- (vermicompost), 8.3- (NPK), 7.2- (goat dung), and 6.3- (compost) fold higher over the control plants (Figure 7D).

Table 3
Effects of different treatments of organic amendments on the fruit characteristics of pumpkin plants

Treatment	Fruit weight (kg)	Fruit diameter (cm)	Fruit circumfer. (cm)	Fruit length (cm)	Flesh thickness (cm)
Control	0.9c	10.0b	31.40c	7.5d	1.7c
Cow dung	1.4ab	12.5b	39.25b	10.5b	3.0a
Goat dung	1.5ab	16.3a	51.18b	12.3a	3.2a
Poultry dung	1.8a	18.0a	56.52a	12.5a	3.5a
Vermicompost	1.6a	14.3b	44.90b	11.0b	2.5a
Compost	1.5ab	13.5b	42.52b	10.5b	2.0b
NPK	1.2b	12.0b	37.68b	9.0c	1.9b

Different letters (a, b, & c) indicate the statistical significance and the same letters do not differ statistical significance in the same column of table at $p > 0.05$, Duncan's Multiple Range Test (DMRT).

The fruit weight, fruit diameter, circumference, fruit length, and flesh thickness of pumpkin fruits increased significantly in our study with organic fertilizer treatments. Organic fertilizer application may increase crop yield by maintaining soil health, developing a healthy root system, improving soil fertility and productivity (Min-gang et al., 2008). The fresh weight of pumpkin plants also increased significantly with different organic amendment treatments in the study. The constant release of plant nutrients from organic manure is favorable to coordinating with the physiological needs and yield improvement of crops. Thus, organic fertilizers can enhance nutrient absorption, metabolism and ensure high yield and crop quality (Y. P. Wang, Liu, & Ruan, 2011). Based on this above discussion, it can be summarised that organic amendment application positively affects the morpho-physiological characteristics, growth, and productivity of pumpkin plants.

Conclusions

Results indicate that the application of different organic amendments produced significant effects on the growth, development, and yield of pumpkin grown in polybags. The application of organic amendments; in particular treatments with poultry dung, increased plant morpho-physiological parameters, length of vines, leaf number, petiole length, leaf area, number of internodes for first flowering, number of flowers, and biomass of pumpkin plants. Leaf chlorophyll and total soluble solids content of pumpkin leaves were also positively affected by the poultry dung treatment. Growth indices; absolute and relative growth rate, leaf area index, leaf area ratio, and leaf area duration were significantly affected by different treatments of organic amendments. The poultry dung treatment also significantly increased the number of female flowers, male and female flower ration, fruit weight, fruit diameter, fruit length, fruit circumference, flesh thickness, and fresh biomass of pumpkin plants. From this study, it can be concluded that poultry dung treatment modulates growth indices positively and improves morphophysiological characteristics, flowering, and fruiting of pumpkin vegetables.

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