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ORIGINAL RESEARCH

Early growth and dry matter partitioning of yellow passion fruit as affected by time of application and method of poultry manure placement

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Abstract

Purpose Passion fruit cultivation and utilization is fast emerging in Nigeria. Poultry farms are increasing with the corresponding increase in poultry manure production which is relatively affordable by farmers. Two experiments were conducted to evaluate the effect of placement method and time of poultry manure (PM) application on early growth and dry matter partitioning of yellow passion fruit.

Method PM placement methods were incorporation, top-dressing, bottom-dressing and split combination of top- and bottom-dressing while time of PM application comprised application at transplanting, 2, 4 and 6 weeks after transplanting (WAT). The experiments were laid out as completely randomized design, replicated five and six times, respectively for PM placement methods and time of PM application. Growth and dry matter yield were determined at two weeks' interval and 20 WAT, respectively.

Results Longest vines (78.5 cm) were significantly ($P<0.05$) produced by plants that were grown in PM incorporated medium. Thickest stems (6.75 mm), highest number of leaves (66.4) and dry matter accumulation were recorded in plants that received PM as top-dressing followed by PM incorporation. Application of PM at transplanting resulted in longest vines (95.8 cm), highest number of leaves (69.5) and dry matter partitioning to leaves, vines and roots.

Conclusion PM top placement performed best with respect to early growth parameters and dry matter accumulation followed by PM incorporation, hence PM top placement is recommended for production of vigorous passion fruit vines in container. Poultry manure should be applied at transplanting for vigorous vines and not delayed beyond 4 weeks after transplanting.

Keywords *Passiflora edulis*, Organic manure, Method, Time, Dry matter accumulation

Introduction

Passion fruit belongs to Passifloraceae family and has two recognized edible varieties, yellow (*Passiflora edulis* f. Flavicarpa Degener) and purple (*Passiflora edulis* Sims f. edulis) passion fruits (Thokchom and Mandal 2017). The natural juice concentrate is an important raw material in the juice and wine industries as the juice possesses a characteristic aroma and flavour as well as minerals, vitamins and anti-oxidants (Sandi et al. 2003; Appleby 2014). The natural juice can be consumed fresh or mixed with other fruits to make unique smoothies. The seeds also contain piceatanol and scirpusin B, polyphenolic compounds that have strong antioxidant activity which offers cardiovascular health benefits and exerts vasorelaxant effect (Sano et al. 2011).

The best management practices of fertilizer application are based on the concept of applying the correct fertilizer formulation at the appropriate rate, time and place (Fixen and Reetz 2006) as the management can have a major effect on the efficiency of nutrient use by crops as well as the potential impact on the surrounding environment (Gruhn et al. 2000; Snyder 2006). Hence,

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studying the response of passion fruit to fertilizer rates, time and placement method will be worthwhile.

In sub-Saharan African, inorganic fertilizers are frequently utilized for crop production by most farmers since nutrients are released faster from the inorganic fertilizer than the organic fertilizers. However, inorganic fertilizers are not easily affordable by the resource-poor farmers (Kugbe et al. 2019) while continuous use of the synthetic fertilizer pollutes agricultural soils at the long run (Yargholi and Azarneshan 2014). On the other hand, organic fertilizers provide organic matter to the soil beside the addition of available nutrients which are important to the growth and development of a crop. Among organic fertilizers, poultry manure had been reported to be the most valuable among other animal manure with respect to nutrient content, especially when handled properly (Adekiya and Agbede 2017). Poultry manure has higher proportion of nitrogen, phosphorus and potassium than other animal manures (Mohamed et al. 2010).

Earlier studies in Nigeria regarding fertilizer management in passion fruit revealed that passion fruit showed a positive response to fertilizer application. The several investigations showed that the application of poultry manure promoted growth, fruit yield and juice quality of passion fruit. While studying the effect of organic and inorganic fertilizers on growth of passion fruit in southwestern Nigeria, Aiyelaagbe et al. (2005) found that 20 t/ha of poultry manure application was the sub-optimal for a vigorous growth of passion fruit. Similarly, the application of 20 t/ha poultry manure was reported to be optimal for passion fruit yield in southeastern Nigeria (Ndukwe and Baiyeri 2018a). The study also noted that the number of days to flowering reduced while number of fruits and fruit yield increased with application of 20 t/ha poultry manure. As regards passion fruit juice quality, Ani and Baiyeri (2008) concluded that the application of 15 t/ha poultry manure generally resulted to the best quality. However, Ndukwe and Baiyeri (2018b) noted that nitrogen, zinc concentrations and total soluble solid of the juice were enhanced with the application of poultry manure as compared to no fertilizer application. The nutritional qualities of the passion fruit juice were significantly improved with the combined application of 10 t/ha poultry manure and 200 kg/ha NPK (Ndukwe and Baiyeri 2018c). However, the compositions of tannin and oxalate in the juice were reduced with 20 t/ha poultry manure application (Ndukwe and Baiyeri 2018b). In another study (Ndukwe and Baiyeri 2019), passion fruit juice percentage was enhanced when the crop was produced with 20 t/ha poultry manure or combined application of 10 t/ha poultry manure and 200 kg/ha NPK.

In order to harness the maximum economic value of plant nutrients in poultry manure, the application of the manure at the appropriate time and place is required to ensure the availability of the needed nutrients for the optimum nutrient uptake which will culminate into higher growth and yield of the crop (Ndukwe et al. 2011; Ozores-Hampton 2012; Adekiya and Agbede 2017). This implies that a standardization of the appropriate plant nutrient placement and proper timing of application will enhance the sustainable production of the crop. The results obtained from earlier studies revealed that poultry manure placement could influence the performance of maize (Lin et al. 2017) and plantain (Baiyeri and Tenkouano 2007, 2008; Baiyeri et al. 2012, 2013). On the other hand, the yield of tomato (Adekiya and Agbede 2017), plantain (Ndukwe et al. 2011) and corn (Ahmed et al. 2013) were significantly affected by the time of poultry manure application.

Presently, there is a scarcity of information on the early growth response of yellow passion fruit to method of placement and time of poultry manure application. Information regarding the response of yellow passion fruit to method of placement and time of poultry manure application will help passion fruit growers to optimally manage the nutrients for the optimal growth as well as higher fruit and juice production. Recent studies showed that the early growth of passion fruit at five months after transplanting determined the fruit yield as the vine girth positively correlated with the number of fruits and fruit yield, both in the field and container production (Ndukwe 2018). Therefore, the objective of this study was to determine the influence of method of placement and time of poultry manure application on early growth and dry matter yield of yellow passion fruit.

Materials and methods

Experimental site

The studies were carried out in the research and teaching farm of the Department of Crop Science and Horticulture, Nnamdi Azikiwe University, Awka, Nigeria. The research farm lies at the latitude of 06 °15 N and longitude 07 °08 E, with an average annual rainfall of 1810.3 mm and relative humidity of 72.3%. During the experiment, the average minimum and maximum temperatures of the field were 28.74 °C and 28.96 °C with average relative humidity of 63.48% (GEOMET-NAU 2017).

Experiment I: Effect of poultry manure placement method on growth and dry matter partitioning of yellow passion fruit

Treatments and experimental design

The treatments comprised four poultry manure (PM) placement methods namely PM incorporation, PM top (surface) dressing, PM bottom (base) dressing and PM split combination of top and bottom dressing applied to 'Conventional' yellow passion fruit grown in a container. The poultry manure was applied at the rate of 20 t/ha. Placements were imposed before transplanting for PM incorporation, PM bottom dressing and PM split combination of top and bottom dressing (half dose of 20 t/ha PM, each applied as bottom and top dressing) while full dose of the poultry manure was applied as top-dressing after transplanting of seedling. These poultry manure placement methods were laid out as a completely randomized design (CRD) and replicated five times.

Cultural practices

Seedlings (four months old) of yellow passion fruit obtained from a nursery located at the research and teaching farm of the Department of Crop Science and Horticulture, Nnamdi Azikiwe University,Awka were transplanted into polyethylene bags filled with 30 kg growing media (soil + poultry manure). At the time of transplanting, the seedlings had an average height of 30.9 cm, mean stem girth of 2.85 mm and average number of six leaves. The physicochemical characteristics of the topsoil and poultry manure utilized are presented in Table 1. The soil was acidic with low nutrient status as total nitrogen, available phosphorus, percentage organic carbon, potassium, calcium, magnesium and sodium were below critical levels. However, the poultry manure contained higher values of total nitrogen, percentage carbon and all the exchangeable cations. The growing media containing the seedlings were irrigated to container capacity during the dry season but the irrigation ceased after the commencement of rainfall. The potted nursery bags were spaced 2 m and 1 m apart between and within rows, respectively.

Staking was done with the aid of twine tied at the base of the seedlings and trellised to a single bamboo

Table 1 Physicochemical properties of the topsoil and poultry manure used during the study

	Top soil (0-20 cm)	Poultry manure
Physical properties		
Sand (%)	79.40	-
Silt (%)	10.00	-
Clay (%)	10.60	-
Textural class	Sandy Loam	-
Chemical properties		
pH (H_2O)	5.80[a]	7.9[a]
Available phosphorus (mg/kg)	9.28*	1.06*
Nitrogen (%)	0.098[b]	1.476[b]
Organic carbon (%)	0.113[c]	46.08[c]
Calcium (meq/100g)	2.80**	116.00**
Magnesium (meq/100g)	1.60**	98.00**
Potassium (meq/100g)	0.33**	1.83**
Sodium (meq/100g)	0.29**	0.63**
Exchangeable H^+ (meq/100 g)	1.52	-
(CEC (meq/100g	6.537	-
(%) Base saturation	76.75	-

[a] = Glass electrode pH meter in ratio of 1:2.5 (soil:water); * = Bray 1 method (Bray and Kurtz 1945); [b] = Micro-Kjeldahl method (Jackson 1969); [c] = Dichromate wet oxidation method (Walkley and Black 1934); ** = Ammonium acetate method

stick of 3 m height. Weeds found in the growing media were removed by hand pulling. The research area was also kept weed-free by periodic slashing of the weeds.

Data collection and analysis

Growth data recorded were vine length (measured with a flexible meter tape from the soil surface to the vine apex), vine girth (measured at 10 cm above the ground using digital vernier caliper) and number of leaves obtained by counting the total number of fully opened leaves. These were recorded at 2, 4, 6, 8, 12 and 16 weeks after transplanting (WAT). At 20 WAT, destructive sampling was performed. The fresh weights of the plant parts (leaves, vines and roots) were measured immediately after the destructive sampling. These plant parts were oven-dried at 105 °C for two days to obtain constant weight. Thereafter, the dry weights of the leaves, vines and roots were determined with the digital sensitive balance.

All the data collected were subjected to analysis of variance following the procedure for completely randomized design using GENSTAT Release 7.2 Discovery Edition (2007) statistical software package. Mean separation was done using least significant deference (LSD) at 5% probability level.

Experiment II: Effect of time of poultry manure application on early growth and dry matter partitioning of yellow passion fruit

Treatments and experimental design

Time of poultry manure (PM) application constituted four levels, that is, application at transplanting, 2, 4 and 6 weeks after transplanting. The poultry manure was applied as top-dressing in a production container at the rate of 20 t/ha. These treatments were laid out as completely randomized design with six replications.

Cultural practices

Four-month-old seedlings of yellow passion fruit were raised in a nursery located at the research and teaching farm of Department of Crop Science and Horticulture, Nnamdi Azikiwe University, Awka. The seedlings were transplanted into polyethylene bags filled with 30 kg topsoil. The physicochemical properties of the topsoil and poultry manure utilized are shown in Table 1. Other cultural practices were as recorded in Experiment I (Effect of poultry manure placement method on growth and dry matter partitioning of yellow passion fruit).

Data collection and analysis

Vine length, vine girth and number of leaves as well as fresh and dry weights of leaves, vines and roots were determined according to the procedure outlined in Experiment I. The collected data were analyzed according to the procedure for completely randomized design using GENSTAT (2007) while mean separation was performed using least significant deference (LSD) at 5% probability level.

Results and discussion

Experiment I: Effect of poultry manure placement method on growth and dry matter partitioning of yellow passion fruit

The vine length of passion fruit varied significantly ($P \leq 0.05$) among the poultry manure placement methods (Table 2). Incorporating or top-dressing the poultry manure produced the longest vines which was explicit from 6 WAT. The thickest vines, across all the sampling periods, was also obtained in plants that received the manure either as top placement or incorporated (Table 2). The order from the thickest vines was PM Top > PM Incorporation > PM Top+PM Bottom > PM bottom placement. Similarly, there were significant ($P \leq 0.05$) differences in the number of leaves of the yellow passion fruit as affected by PM placement methods (Table 3).

The placement method with the highest number of leaves was PM top placement method while the lowest number of leaves were produced by bottom application of the manure. The PM top placement method had 51.6 number of leaves more than the PM bottom placement method which produced the lowest number of leaves and branches. The order from the highest number of leaves was PM Top placement > PM Incorporation > PM Top+PM Bottom > PM Bottom. Placing the poultry manure as top-dressing also produced highest number of branches at 4, 6, 8, 12 and 16 WAT (Table 3). The order from the highest number of branches was PM Top > PM Incorporation > PM Top+PM Bottom > PM bottom placement.

Table 2 Effect of poultry manure (PM) placement on the vine length and vine girth of yellow passion fruit in weeks after transplanting (WAT)

PM Placement method	2 WAT	4 WAT	6 WAT	8 WAT	12 WAT	16 WAT
			Vine length (cm)			
PM Incorporation	39.1	48.0	59.1	64.8	74.2	78.5
PM top-dressing	31.6	44.6	56.0	67.0	67.6	71.2
PM bottom-dressing	27.9	30.4	31.2	31.7	35.0	37.2
PM top-dressing + PM bottom-dressing	30.2	35.1	35.0	38.9	46.6	54.0
$LSD_{0.05}$	9.1	16.0	17.8	25.1	ns	ns
			Vine girth (mm)			
PM Incorporation	3.87	4.19	5.13	5.53	5.94	6.51
PM top-dressing	2.73	3.89	5.76	5.76	5.98	6.75
PM bottom-dressing	2.83	3.13	3.51	3.76	4.10	4.38
PM top-dressing + PM bottom-dressing	2.62	3.24	4.26	4.40	4.79	5.21
$LSD_{0.05}$	ns	ns	1.65	1.79	ns	1.99

LSD = Least significant difference; 0.05 = 5% level of significant; ns = non-significant

Table 3 Effect of poultry manure (PM) placement on number of green leaves and branches of yellow passion fruit in weeks after transplanting (WAT)

PM Placement method	2 WAT	4 WAT	6 WAT	8 WAT	12 WAT	16 WAT
			Number of green leaves			
PM Incorporation	6.2	16.6	26.4	35.4	39.4	44.0
PM top-dressing	14.0	26.4	42.8	54.4	60.2	66.4
PM bottom-dressing	4.8	11.6	15.2	13.6	12.2	14.8
PM top-dressing + PM bottom-dressing	7.2	13.8	18.6	21.8	29.2	35.8
$LSD_{0.05}$	5.9	12.0	19.2	23.4	33.6	38.0
			Number of branches			
PM Incorporation	0	2.4	4.8	4.4	4.0	5.2
PM top-dressing	0	2.6	7.8	7.0	5.4	7.0
PM bottom-dressing	0	0.8	1.0	0.6	0.0	0.0
PM top-dressing + PM bottom-dressing	0	0.6	2.2	1.8	2.0	2.4
$LSD_{0.05}$	0	ns	4.4	3.6	3.5	4.3

LSD = Least significant difference; 0.05 = 5% level of significant; ns = non-significant

Although fresh and dry weights of leaves, vines and roots did not differ statistically (P>0.05) among the poultry manure placement methods, the mean values for the fresh and dry biomass were highest with top application of full dose of poultry manure except dry weight of leaves which was highest with PM incorporation.

The superior performance of the yellow passion fruit with top placement of poultry manure with respect to longest vines, thickest stems, highest number of leaves and highest dry matter accumulation was because the top-placed poultry manure absorbed water quicker than other placement methods. This might have facilitated earliest decomposition process and the corresponding timely release and distribution of their nutrients within the medium compared with bottom-dressing and split combination of top- and bottom-dressing of the manure. Correspondingly, the mineralized nutrients from top-placement of poultry manure concentrated at the sub-soil where most of the plant roots existed since passion fruit has fibrous root system. The results corroborated with the finding of Baiyeri and Tenkouano (2008) which noted that surface application of poultry manure enhanced shoot growth as well as root number and length of individual roots of PITA 14 plantain hybrid at 3 months after transplanting.

Poultry manure incorporation also promoted longer vines, wider vine diameter, higher number of leaves and branches of yellow passion fruit than bottom dressing and split combination of top- and bottom-dressing due to the fact that there was a uniform release and distribution of nutrients from the poultry manure as a result of even distribution of the manure within the growing medium. Hence, the roots of the seedlings were able to efficiently absorb the nutrients for their growth and development since the nutrients were available everywhere in the soil. Incorporation of manure in growing medium reduced 50-90% ammonia loss through volatilization in comparison with surface application (Eghball and Power 1999; Jokela and Meisinger 2008).

On the other hand, applying the poultry manure at the bottom consistently resulted in shortest and tiniest vines, lowest number of leaves, branches at all the sampling periods as well as the lowest dry matter accumulation to the leaves, vines and roots. More time would have been expended both for the accessibility and absorption of the mineralized nutrients by the plant roots. This plausibly explained why there was a delayed growth and the lowest dry matter distribution to the plant parts with bottom-dressing of the poultry manure.

Experiment II: Effect of time of poultry manure application on early growth and dry matter partitioning of yellow passion fruit

The time of poultry manure application influenced the vine length at 6, 8, 10, 12 and 14 weeks after transplanting (WAT) (Fig. 1). The application of poultry manure at transplanting resulted in the production of the longest vines during the periods of sampling. Similarly, the thickest stems were obtained from plants that received poultry manure at transplanting for all the sampling periods, although the mean values were not statistically (P>0.05) different with the mean values obtained from the other times of poultry manure application (Fig. 2). The application of the manure at transplanting produced the highest number of leaves especially at 14, 16 and 18 WAT (Fig. 3).

More vigorous vines produced with the application of poultry manure at transplanting could be attributed to the early application of the manure which necessitated earlier decomposition, mineralization, release and absorption of nutrients for enhanced leaf development than those in plots that received the manure at 2, 4 and 6 WAT. This early leaf development would have enhanced higher source-sink efficiency which resulted in higher values of vine length, vine girth, fresh and dry biomass observed in plants that received poultry manure at transplanting compared to other times of application. This is also consistent with earlier supply of manure, decomposition, mineralization, release and absorption of the nutrients by the crops. The results

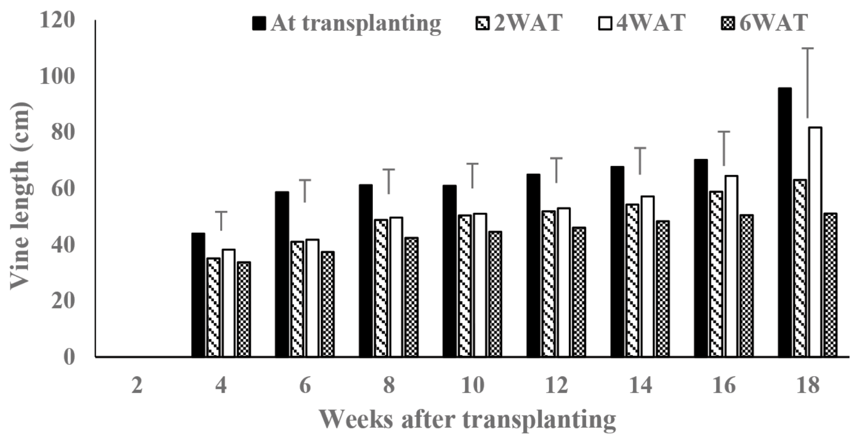

Fig. 1 Effect of time of poultry manure application on vine length of yellow passion fruit

Vertical bars show least significant difference value (LSD) at 5% probability level comparing means of time of manure application per sampling week.

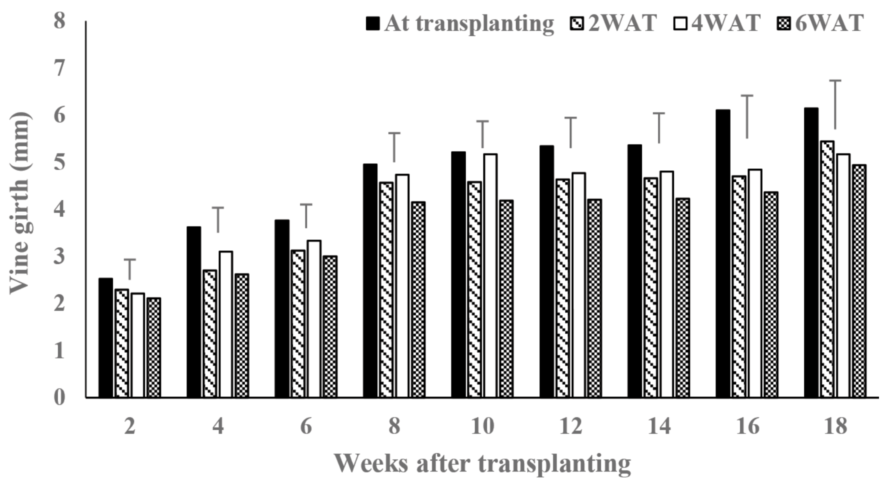

Fig. 2 Effect of time of poultry manure application on vine girth of yellow passion fruit

Vertical bars represent least significant difference (LSD) value at 5% probability level comparing means of time of manure application per sampling week.

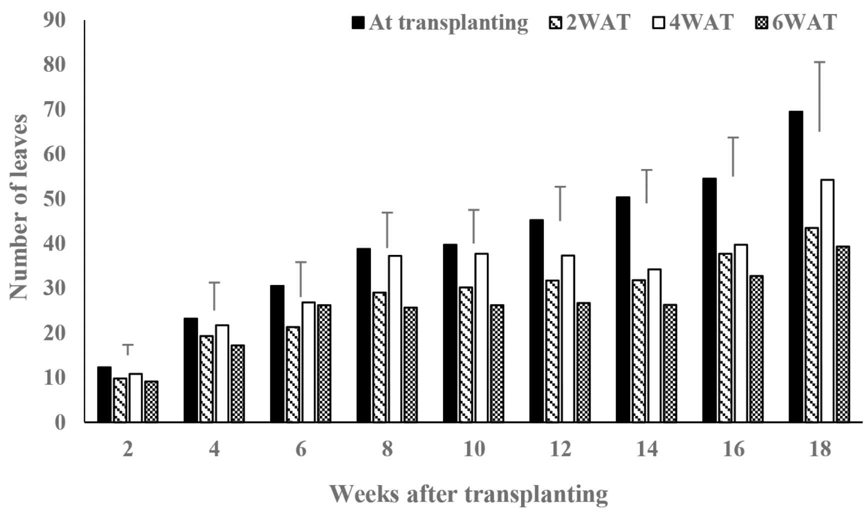

Fig. 3 Effect of time of poultry manure application on number of leaves of yellow passion fruit

Vertical bars show least significant difference (LSD) value at 5% probability level comparing means of time of manure application per sampling week.

obtained in the present investigation corroborate with the report of Adekiya and Agbede (2017) for tomato. Earlier study by Ozores-Hampton (2012) also noted that nutrients from animal manure should be applied to match the needs of the crops for optimum yield and higher profit by the farmer. The mean values of number of leaves obtained from plants that received poultry manure at transplanting were statistically (P>0.05) at par with the mean values recorded with poultry manure applied at either 2 or 4 WAT.

The mean values of fresh weight of leaves (227 g), vine (198 g) and roots (45.9 g) were highest in plants that received poultry manure at transplanting and the lowest in the plants that had the poultry manure applied at 2 WAT except for fresh leaf weight (Table 4). Dry weights of leaves, vines and roots varied significantly (P≤0.05) among the different timings of poultry manure application. Applying the manure at transplanting of seedlings increased partitioning of the highest dry matter to the leaves (65.2 g), vines (44.3 g) and roots (17.2 g).

Table 4 Effect of time of poultry manure (PM) application on fresh and dry weights of leaves, vine and roots of yellow passion fruit

	Fresh weight (g)			Dry weight (g)		
Time of PM application	Leaves	Vine	Roots	Leaves	Vine	Roots
Application at transplanting	227.0	198.0	45.9	65.2	44.3	17.2
2 weeks after transplanting	146.0	49.0	25.3	18.8	12.2	5.3
4 weeks after transplanting	180.0	133.0	52.9	41.5	30.3	14.3
6 weeks after transplanting	106.0	68.0	35.6	22.9	22.6	11.2
$LSD_{0.05}$	ns	122.4	ns	16.2	13.7	6.1

LSD = Least significant difference; 0.05 = 5% level of significant; ns = non-significant

On the other hand, the application of poultry manure at 6 WAT consistently resulted in a shorter and the tiniest vines as well as the lowest number of leaves in all the sampling periods (Figs 1, 2, 3). Similarly, plants that received poultry manure at 6 WAT significantly ($P \leq 0.05$) produced lower dry matter accumulation to the plant parts than the application of the manure at transplanting (Table 4). The poorest growth and dry matter yield associated with plants that received poultry manure at 6 WAT was due to delayed manure application. A significant positive relationship between vine length at 6 WAT, vine girth 6 WAT and number of fruits as well as fruit yield of yellow passion fruit had been reported by Ndukwe (2018). Thus, any agronomic practice that can increase the vine length and girth at 6 WAT would also improve the fruit yield of yellow passion fruit. Hence, the release of nutrients from the applied poultry manure at 6 WAT might have been delayed to coincide with the nutrient demand of the developing yellow passion fruit.

Conclusion

Top placement of poultry manure enhanced the production of most vigorous plants as well as the highest dry matter yield of yellow passion fruit followed by incorporating the poultry manure in the topsoil. Hence, top placement of the manure is recommended for production of vigorous vines and higher dry matter accumulation in container production. However, surface incorporation of poultry manure can be recommended considering potential nutrient losses through volatilization and nutrient erosion which can be encountered if manure is placed at the soil surface.

On the other hand, application of poultry manure at transplanting is recommended for enhanced growth and higher accumulation of dry matter in yellow passion fruit. If for any reason the manure cannot be applied at transplanting, it should not be delayed beyond 4 weeks after transplanting.

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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