# AGRONOMIC EVALUATION OF TWO PASSION FRUIT GENOTYPES IN CONTAINERS (MEGA-POT) PREDICTED CORRESPONDING PERFORMANCES UNDER FIELD CONDITIONS †

# [LA EVALUACIÓN AGRONÓMICA DE DOS GENOTIPOS DE FRUTA DE PASIÓN EN CONTENEDORES (MEGA-POT) PREDICE EL RENDIMIENTO CORRESPONDIENTE BAJO CONDICIONES DE CAMPO]

**Okorie Okoro Ndukwe[1*] and Paul Kayode Baiyeri[2]**

*[1]Department of Crop Science and Horticulture, Nnamdi Azikiwe University, P. M. B. 5025, Awka, Anambra State, Nigeria; Email: oo.ndukwe@unizik.edu.ng*
*[2]Department of Crop Science, University of Nigeria, Nsukka, Enugu State, Nigeria; Email: paul.baiyeri@unn.edu.ng*
**Corresponding author*

## SUMMARY

**Background.** The evaluation of crop variety in the field involves large expanse of land and could be expensive but container evaluation of crops is thought to complement field evaluation. **Objective.** To compare the growth and fruit yield of yellow passion fruit in the field and container (mega-pots) as influenced by varying rates of poultry manure with the hypothesis that vines grown in containers could predict the performance of the crop in the field. **Methodology.** Two yellow passion fruit genotypes (KPF-4 and 'Conventional') received varying rates of poultry manure (0, 10, 20, 30, 40 t/ha) in both the field and containers. These were laid out as split plot in randomized complete block design and completely randomized design, replicated four and ten times, respectively in the field and pots. **Results.** In both field and pot, days to first flowering and fruit dropping were earlier in KPF-4 than 'Conventional'. Vine girth and number of branches were not significant different (p>0.05) between the genotypes in both field and container. Most of the fruit yield traits obtained from either field or pot experiment did not statistically vary between the genotypes except fruit length and circumference. The application of poultry manure (PM) reduced the days to first flowering but enhanced the growth characteristics of the vines compared to vines that received no manure. Increase in PM rate increased the number of fruits picked per plant. The economic analysis of both studies indicated that net return and return per naira invested increased with increase in PM rates with the peak at 20 t/ha PM application. **Implications.** Pot studies could be utilized for preliminary evaluation of crops and prediction of field performances. **Conclusion.** The study revealed that phenology, growth and fruit yield of the two genotypes had relatively similar responses to PM rates in both pot and field studies, yet less inputs were made in the pot study.
**Keywords**: *Passiflora edulis*; evaluation; prediction; container; field.

## RESUMEN

**Antecedentes.** La evaluación de la variedad de cultivos en el campo implica una gran extensión de tierra y podría ser costosa, pero se cree que la evaluación de cultivos en contenedores maceta complementa la evaluación de campo. **Objetivo.** Comparar el crecimiento y el rendimiento de fruta de maracuyá amarilla en el campo y el contenedor (mega-macetas) según la influencia de las diferentes tasas de estiércol de aves de corral con la hipótesis de que las vides cultivadas en contenedores podrían predecir el rendimiento del cultivo en el campo. **Metodología.** Dos genotipos de maracuyá amarillo (KPF-4 y "Convencional") recibieron tasas variables de estiércol de aves de corral (0, 10, 20, 30, 40 t / ha) tanto en el campo como en los contenedores. Estos fueron presentados como parcelas divididas en diseño de bloques al azar y diseño completamente al azar, replicadas cuatro y diez veces, respectivamente en el campo y las macetas. **Resultados**. Tanto en el campo como en la maceta, los días hasta la primera floración y caída de la fruta fueron más tempranos en KPF-4 que en "Convencional". La circunferencia de la vid y el número de ramas no fueron diferentes (p > 0.05) diferentes entre los genotipos tanto en el campo como en el contenedor. La mayoría de los rasgos de rendimiento de fruta obtenidos del experimento de campo o de maceta no variaron estadísticamente entre los genotipos, excepto la longitud y la circunferencia de la fruta. La aplicación de estiércol de ave (PM) redujo los días hasta la primera floración, pero mejoró las características de crecimiento de las vides en comparación con las vides que no recibieron estiércol. El aumento en la tasa de PM aumentó la cantidad de frutas recogidas por planta. El análisis económico de ambos estudios indicó que el rendimiento neto y el rendimiento

† S*ubmitted August 7, 2018 – Accepted May 7, 2020.* 
ISSN: 1870-0462.

por Naira invertida aumentaron con el aumento de las tasas de PM con el pico en la aplicación de 20 t / ha PM. **Implicaciones.** Los estudios de macetas podrían utilizarse para la evaluación preliminar de los cultivos y la predicción del rendimiento del campo. **Conclusión.** El estudio reveló que la fenología, el crecimiento y el rendimiento del fruto de los dos genotipos tuvieron respuestas relativamente similares a las tasas de PM en los estudios de maceta y de campo, pero se hicieron menos aportes en el estudio de la maceta.
**Palabras clave:** *Passiflora edulis*; evaluación; predicción; contenedor; campo.

## INTRODUCTION

One of the major aims of crop variety evaluation is to predict its future performance (Smith *et al*., 2002). Crop performance evaluation is usually and commonly conducted in the field, where there are many environmental influences. There are some logistic and analytical constraints encountered when studying interactions and responses of plants in the field due to complexity of natural plant communities (Gibson *et al*., 1999). Assessment of belowground interactions of plants and the environment is challenging under field condition (Kawaletz *et al*., 2014) because of the difficulty in accessing the root architecture. In addition, field evaluation of crops involves a large expanse of land and could be expensive. However, evaluation of crop varieties in a pot or container is thought to complement the field evaluation. Kohout *et al*. (2011) stated that pot experiment has the advantage of allowing direct measurements under controlled conditions without the influence of distracting biotic and abiotic factors. It is also less expensive and consumes less land space compared to field evaluation. Apart from lower financial costs, plants in outdoor pot experiments can grow under near-natural conditions. The conditions are relatively comparable with natural habitats, and the results of these outdoor pot experiments are better transferable to field grown plants (Kawaletz *et al*., 2014). In contrast to *in situ* studies, other variable factors such as soil composition, soil moisture, nutrient content and plant characteristics can be standardized.

Passion fruit (*Passiflora edulis*) is a perennial climber whose fruits are cherished for the juice content. The juice has great flavor and taste. It is utilized mainly for fresh consumption as well as industrial purposes in manufacturing juice, jelly and ice cream products (Knight and Sauls, 1994; Santos, 2002) and wines. The juice is also appreciated because of its vitamins and mineral contents present in the juice (Sandi *et al*., 2003).

Nigeria spends more than ₦160 billion (USD 410,772,509) annually for importations of juice concentrates specifically for the juice and wine industries (Ibrahim, 2016; Jacobs, 2016). Commercial production of passion fruit in Nigeria will not only increase the food base of the country or farmers' income but could also decrease the amount of money the manufacturers spend in the importation of juice concentrates.

Currently, there is dearth of documentation as regards agronomic studies on passion fruit in southeastern Nigeria. Very few farmers and researchers in Nigeria particularly in the southeastern region know the crop and as such it is scarcely cultivated. One of the major considerations of production protocol for a given crop in a location is the fertilizer requirement of such crop since fertility status varies with different locations. In addition, sustaining the yield and quality of a new crop in the farmer's field requires appropriate crop management practices, especially soil fertility management (Ani and Baiyeri, 2008). The production package of passion fruit with respect to fertilizer management for different accessions and at various locations in Nigeria will be a very useful knowledge. Inorganic fertilizers are scarce and have been reported to increase soil acidity and nutrient leaching. But the use of organic fertilizers in crop production is advocated because of the beneficial effects on the soil which include improving the soil organic matter, soil structure aside supplying plant nutrients slowly and steadily. When handled properly, poultry manure is the most valuable among other animal manure (Adekiya and Agbede, 2017). Hence, farmers utilize them more than other manure in southeastern Nigeria in addition to the increased availability of poultry manure because of increase poultry production in the region. The objective of this study was to compare the growth and fruit yield of yellow passion fruit in the field and container as influenced by varying rates of poultry manure with the hypothesis that vines grown in containers (mega-pots) could predict the growth and yield of yellow passion fruit in the field.

## MATERIALS AND METHODS

### Location

The experiments were carried out in the Department of Crop Science teaching and research farm of University of Nigeria, Nsukka (07° 29'N, 06° 51'E, and 400 m above mean sea level). A study (Uguru *et al*., 2011) characterized Nsukka to have lowland humid tropical conditions with bimodal annual rainfall distribution, which ranges from 1155 to 1955 mm with a shift in the second peak of rainfall from September to October. A mean annual temperature of 29°C to 31°C and relative humidity that ranges from

69 to 79% also prevail in Nsukka. Generally, the soil is classified as an ultisol (Asiegbu, 1989). Results of composite soil sample (0-15 cm) analyses of the field and media for the pot experiment and the physicochemical characteristics of poultry manure samples utilized are shown in Table 1. The meteorological data (rainfall, temperature and relative humidity) of the experimental sites were also collected (Table 2).

**Source of seed**

Hybrid seeds of yellow passion fruit (KPF-4) were sourced from Kenya Agricultural Research and Livestock Organization (KARLO), Kenya. Riped yellow passion fruits of the 'Conventional' genotype were obtained from research field of the Forestry Research Institute, Ibadan, Oyo State, Nigeria. The fruits were cut transversely, depulped and seeds extracted. The seeds and juice were separated by squeezing the pulp with cheesecloth in order to separate the aril from the seed. Extracted seeds were rinsed with water and air-dried, packaged in an air-tight container and kept at room temperature before planting.

**Cultural practices and experimental design**

Seeds from both the hybrid, KPF-4 and the 'Conventional' genotypes were planted in a six-week composted media (3:1 v/v, topsoil and ricehusk, respectively) potted in 3-litre buckets and kept under a nursery shade for raising of seedlings. Three months after seedling emergence, uniformly sized seedlings from each of the two genotypes were selected and transplanted to the field and pot separately. In the field, the experimental design was split plot arranged in randomized complete block design (RCBD) and replicated four times. The main plots comprised the two yellow passion fruit genotypes (KPF-4 and the 'Conventional') while the sub-plot consisted of five poultry manure rates, namely, 0, 10, 20, 30 and 40 t/ha. The seedlings were arranged in a single row plot of five plants for each poultry manure rate. The plant spacing was 2 m x 2 m. Planting holes (30 cm x 30 cm x 30 cm dimension) were dug according to the marked plant spacing and treatment allocation.

**Table 1. Physicochemical characteristics of composite soil sample of the experimental site, poultry manure and growing medium utilized during the 2014-2016 field and pot studies.**

| **Physical properties** | Top soil (0-20 cm) | Poultry manure | Medium (3:1, v/v topsoil+ricehusk) |
|---|---|---|---|
| pH ($H_2O$) | 5.00 | 8.8 | 4.5 |
| Organic carbon (%) | 0.279 | 12.369 | 1.995 |
| Sand (%) | 61 | - | 65 |
| Silt (%) | 7 | - | 7 |
| Clay (%) | 32 | - | 28 |
| Textural class | Sandy clay loam | - | Sandy clay loam |
| **Chemical properties** | | | |
| Nitrogen (%) | 0.154 | 2.942 | 0.182 |
| Available phosphorus (ppm) | 20.00 | 0.953 (%) | 78.24 |
| Potassium (meq/100g) | Trace | 0.145 (%) | Trace |
| Calcium (meq/100g) | 2.40 | 104.00 | 4.0 |
| Magnesium(meq/100g) | 19.60 | 384.00 | 9.2 |
| Sodium (meq/100g) | 1.243 | 0.0195 (%) | 1.243 |
| Cation exchangeable capacity (meq/100g) | 26.00 | - | 20.4 |
| Base saturation (%) | 44.49 | - | 23.20 |
| $Al^{3+}$ (meq/100g) | - | - | - |
| $H^+$ (meq/100g) | 29.0 | - | 46.8 |

**Table 2. Meteorological data of teaching and research farm of Department of Crop Science, University of Nigeria, Nsukka during the studies (2014 – 2016).**

| | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | **Year 2014** | | | | | | |
| Rainfall (mm) | 0.00 | 14.20 | 14.23 | 105.6 | 241.14 | 271.79 | 195.81 | 92.36 | 401.99 | 211.08 | 77.22 | 4.83 |
| Minimum Temp. (°C) | 19.29 | 22.00 | 22.52 | 22.30 | 21.06 | 20.87 | 20.90 | 20.71 | 20.33 | 20.84 | 21.00 | 19.03 |
| Maximum Temp. (°C) | 31.74 | 33.32 | 31.71 | 31.30 | 28.29 | 29.13 | 27.74 | 27.29 | 27.90 | 28.90 | 30.07 | 30.65 |
| Relative humidity (%) | 62.06 | 67.89 | 72.77 | 69.93 | 72.26 | 72.00 | 72.19 | 73.00 | 73.00 | 73.00 | 73.80 | 70.58 |
| | | | | | | **Year 2015** | | | | | | |
| Rainfall (mm) | 0.00 | 56.64 | 34.80 | 39.63 | 267.98 | 121.43 | 110.49 | 174.36 | 351.28 | 217.69 | 36.07 | 0.00 |
| Minimum Temp. (°C) | 20.52 | 22.68 | 22.61 | 22.40 | 21.81 | 21.17 | 20.61 | 20.84 | 20.87 | 21.42 | 20.07 | 20.87 |
| Maximum Temp. (°C) | 30.32 | 32.04 | 32.29 | 31.47 | 30.71 | 29.07 | 27.87 | 27.52 | 27.43 | 28.52 | 31.90 | 30.32 |
| Relative humidity (%) | 61.42 | 70.11 | 70.61 | 71.03 | 71.65 | 76.00 | 76.00 | 76.00 | 76.53 | 77.00 | 72.70 | 56.97 |
| | | | | | | **Year 2016** | | | | | | |
| Rainfall (mm) | 0.00 | 0.00 | 128.53 | 32.26 | 206.75 | 111.62 | 127.73 | 381.02 | 209.80 | 168.40 | 10.67 | 0.00 |
| Minimum Temp. (°C) | 20.26 | 23.79 | 22.87 | 22.57 | 22.06 | 21.67 | 20.93 | 20.84 | 20.90 | 21.39 | 21.47 | 19.87 |
| Maximum Temp. (°C) | 31.65 | 34.34 | 32.42 | 31.20 | 30.45 | 29.23 | 30.48 | 29.26 | 28.90 | 29.35 | 31.17 | 31.90 |
| Relative humidity (%) | 59.94 | 62.97 | 66.23 | 66.83 | 66.35 | 67.00 | 67.77 | 70.00 | 59.00 | 54.90 | 53.27 | 46.90 |

In the pot experiment, fifty uniformly sized seedlings, each from the two genotypes were transplanted in 30-litre buckets containing composted media (topsoil + ricehusk at 3:1 v/v). The seedlings received varying poultry manure rates, equivalent to 0, 10, 20, 30 and 40 t/ha. Each poultry manure rate was applied as top-dressing in ten (30-litre) pots containing the transplanted seedlings. The experimental design was split-plot in completely randomized design and replicated ten times. The two genotypes were the main plots while the varying rates of poultry manure represented the sub-plots. Application of the poultry manure was done 4 weeks after transplanting (WAT) in both field and pot experiments. The experiments were rain-fed except in the dry season (December to March) when the soil and media were irrigated every other day using 10-litres of water per period of irrigation.

Treated wooden poles, (7.62 cm x 10.16 cm) and about 2.5 m length were used as trellis in the field experiment. Two poles were used to trellis a single row of five plants. Three bamboo poles were also inserted between the two wooden poles in order to help support the weight of the vine even under strong winds. The wooden poles were inserted into the ground (0.5 m) with 2 m above soil level. Ropes (3.25 mm in diameter) were tightly drawn horizontally to connect the two poles at their tops. Light stakes were driven into the ground alongside the young plants and tied to the wire trellis to help the seedlings climb faster to the main rope. The leader vines of each plant were then tied loosely at regular intervals up the light stake with the help of their tendrils. However, a single length (3.5 m) of bamboo was used to train the seedlings in the pot.

**Growth and yield variables**

Data collected in both experiments included the growth parameters, that is, length of longest vine at 10 WAT, stem girth at 10 WAT taken at 5 cm above ground level, number of branches at 5 cm above ground level, fresh weight of pruned branches from the leader vines taken before the leader vine attained 1 m length. Phenological data observed were average days to average days to fruit dropping. The fresh fruit yield data were number of fruits, fruits yields, length and circumference of fresh fruit.

**Economic analysis**

Data on economic analysis of producing the fresh yellow passion fruits included the production cost (PC), gross monetary return (GME), net return (NR), return per naira invested (RI) and benefit/cost ratio (B/C). Production cost was determined by adding the cost of inputs used and those of all farm operations (Ngbede *et al*., 2014). The gross monetary return was calculated as the product of the passion fruit fresh yield and the prevailing market price of fresh yield for the period considered while the net return was obtained from the differences between gross monetary return obtained and total production cost (NR = GME – PC) (Olukosi and Erhabor, 1988). Return per naira invested was determined by the ratio of the net return and production cost (RI = NR/PC) whereas the benefit/cost ratio was calculated as the ratio of the gross monetary return and production cost (B/C = GME/PC).

**Statistical analysis**

Data collected from these studies were subjected to analysis of variance (ANOVA) following the procedure for split-plot experiment in RCBD and CRD, respectively for the field and pot experiments, using GENSTAT (2007). Significant differences among treatment means were determined using Fisher's least significant difference at 5% probability level. Correlations among growth, phenology and fruit yield variables were performed using SPSS (2013).

## RESULTS

**Phenology**

The main effect of genotype, in the field, showed that the number of days to first flowering was significantly ($p<0.05$) earlier (169 days) in the hybrid, KPF-4, than in the 'Conventional' genotype (173.4 days), which significantly delayed for extra four days before the first flowering (Table 3). However, average days to flowering showed that the 'Conventional' genotype significantly ($p<0.05$) flowered 14 days earlier than the hybrid, KPF-4. The days to first fruit picking was also 13 days earlier with the KPF-4 (261 days) than the 'Conventional' genotype (273.8 days). The application of poultry manure generally reduced the number of days to flowering compared to the no manure plots (Table 3). However, there was no significant difference ($p>0.05$) among the poultry manure rates (10, 20, 30 and 40 t/ha) with respect to flowering except when the vines did not receive poultry manure (0 t/ha). The duration approximately ranged from 181 to 192 days, before 100% flowering, with the application of poultry manure. Poultry manure application increased the number of days before the first fruit picking (fruit maturation) as fruits produced by no manure plants matured earlier (237 days) than those fruits that received poultry manure (269-280 days).

Results from the pot (Table 3) indicated that the hybrid, KPF-4 also flowered earlier (198.1 days) than the 'Conventional' genotype (212.6 days). Although the number of days to first fruit picking was not significantly different between the two genotypes, the KPF-4 had lesser mean value (316.8 days) for days to first fruit picking than the 'Conventional' genotype (324.5 days). The poultry manure rates significantly influenced the average days to flowering and days to first fruit picking. The earliest flowered plants (181.9 days) were obtained with the application of 40 t/ha poultry manure. However, the mean value (181.9 days) was significantly at par with those obtained from the applications of either 10 or 30 t/ha poultry manure. On the other hand, earliest number of days (302.9) to first fruit picking was gotten with 10 t/ha poultry manure application although the mean value was statistically similar with 320.8 days observed with 30 t/ha poultry manure. The longest days before flowering (246.2 days) and first fruit picking (330.6 days) were attributed to plants that received no PM.

**Growth**

The vine girth, number of branches the field did not vary ($p>0.05$) between the passion fruit genotypes (Table 4). But poultry manure rate significantly influenced all the growth attributes in the field (Table 4). There were significant increase in vine girth and number of branches with the application of poultry manure. These growth parameters did not statistically vary with the application of 10, 20, 30 and 40 t/ha poultry manure. Vines that were grown without poultry manure had poorest growth ($p<0.05$). The interaction of genotype and poultry manure rate did not significantly influence the growth attributes of the passion fruit vines.

In the pot experiment, the growth parameters did not differ ($p>0.05$) between the genotypes except vine girth and number of branches at 5 months after treatment application (MAT) (Table 4). Thicker vines and greater number of branches were associated to the 'Conventional' genotype.

At 5 and 10 MAT, vine girth generally was thickest whit the application of 20 or 30 t/ha poultry manure produced widest stem (Table 4). The number of branches at both 5 and 8 MAT were significantly at par among the poultry manure rates but differed with no manure application.

**Fruit yield**

Results of fruit yield from the field study showed that the number of fruits per plant and fresh fruit yield per hectare were similar ($p>0.05$) between the two genotypes (Table 5). However, significantly longer (10.30 cm) and wider fruits (19.63 cm) were associated with the hybrid, KPF-4.

Main effect of poultry manure rate showed that the number of fruits, heavier fruits and wider fruits were significantly produced by the application of poultry manure when compared with no manure plants (Table 5). Precisely, the number of fruits, fresh fruit yield increased with increase in poultry manure rate.

**Table 3. Main effects of genotype and poultry manure rates on phenology of yellow passion fruits grown in the field and pot in 2014-2016.**

| | Field experiment | | Pot experiment | |
|---|---|---|---|---|
| | Average days to flowering | Average days to first fruit picking | Average days to flowering | Average days to first fruit picking |
| **Genotype** | | | | |
| 'Conventional' | 187.6 | 273.8 | 212.6 | 324.5 |
| KPF-4 | 201.7 | 261.0 | 198.1 | 316.8 |
| $LSD_{0.05}$ | 6.30 | 10.57 | 9.25 | ns |
| **Poultry manure rate (t/ha)** | | | | |
| 0 | 228.7 | 237.1 | 246.2 | 330.6 |
| 10 | 186.3 | 275.0 | 194.1 | 302.9 |
| 20 | 191.8 | 269.2 | 207.0 | 322.0 |
| 30 | 180.9 | 280.2 | 197.6 | 320.8 |
| 40 | 185.5 | 275.5 | 181.9 | 327.0 |
| $LSD_{0.05}$ | 17.86 | 16.71 | 16.36 | 18.63 |

Field data adapted from Ndukwe and Baiyeri (2018); $LSD_{0.05}$ = Least significant difference at 5% probability level; ns = non-significant at 5% probability level

**Table 4. Main effects of genotype and poultry manure rates on vine girth and number of branches of yellow passion fruits grown in the field and pot in 2014-2016.**

| | Field experiment | | | Pot experiment | | |
|---|---|---|---|---|---|---|
| | Vine girth (cm) at 5 MAT | No. of branches at 5 MAT | Vine girth (cm) at 10 MAT | Vine girth (cm) at 5 MAT | No. of branches at 5 MAT | Vine girth (cm) at 10 MAT |
| **Genotype** | | | | | | |
| 'Conventional' | 3.94 | 4.27 | 10.58 | 7.15 | 2.84 | 7.62 |
| KPF-4 | 4.25 | 4.40 | 8.95 | 6.66 | 1.86 | 6.38 |
| $LSD_{0.05}$ | ns | ns | ns | 0.48 | 0.69 | ns |
| **Poultry manure rate (t/ha)** | | | | | | |
| 0 | 3.44 | 2.55 | 7.18 | 4.69 | 0.25 | 6.75 |
| 10 | 4.30 | 4.42 | 10.41 | 7.25 | 2.55 | 6.64 |
| 20 | 4.22 | 4.95 | 10.17 | 8.19 | 2.75 | 7.93 |
| 30 | 4.26 | 4.53 | 10.43 | 7.71 | 3.15 | 8.07 |
| 40 | 4.24 | 5.22 | 10.64 | 6.71 | 3.05 | 5.59 |
| $LSD_{0.05}$ | 0.45 | 0.88 | 1.03 | 0.78 | 0.78 | 1.52 |

MAT = Months after transplanting; $LSD_{0.05}$ = Least significant difference at 5% probability level; ns = non-significant at 5% probability level

**Table 5. Main effects of genotype and poultry manure rates on fresh fruit yield and yield components of yellow passion fruits grown in the field and pot in 2014-2016.**

| | Field experiment | | | | Pot experiment | | | |
|---|---|---|---|---|---|---|---|---|
| | Number of fruits/plant | Fruit circumference (cm) | Fruit length (cm) | Fruit yield (t/ha) | Number of fruits/plant | Fruit circumference (cm) | Fruit length (cm) | Fruit yield (t/ha) |
| **Genotype** | | | | | | | | |
| 'Conventional' | 55.1 | 17.03 | 8.512 | 50.1 | 32.9 | 16.93 | 8.33 | 0.65 |
| KPF-4 | 64.1 | 19.63 | 10.303 | 59.6 | 25.9 | 19.53 | 9.93 | 0.51 |
| $LSD_{0.05}$ | ns | 0.52 | 0.233 | ns | ns | 0.77 | 0.49 | ns |
| **Poultry manure rates (t/ha)** | | | | | | | | |
| 0 | 35.3 | 17.47 | 9.143 | 32.4 | 5.5 | 17.09 | 8.49 | 0.06 |
| 10 | 60.3 | 18.56 | 9.523 | 54.3 | 37.4 | 18.11 | 8.91 | 0.72 |
| 20 | 67.1 | 18.55 | 9.418 | 62.9 | 40.2 | 18.45 | 9.40 | 0.69 |
| 30 | 64.9 | 18.27 | 9.385 | 59.0 | 40.2 | 18.58 | 9.20 | 0.89 |
| 40 | 70.4 | 18.79 | 9.568 | 65.9 | 23.8 | 18.93 | 9.65 | 0.55 |
| $LSD_{0.05}$ | 15.28 | 0.822 | ns | 14.03 | 10.26 | 0.54 | 0.38 | 0.22 |

Field data adapted from Ndukwe and Baiyeri (2018); $LSD_{0.05}$ = Least significant difference at 5% probability level; ns = non-significant at 5% probability level

Although, the mean values for these yield parameters slightly dropped ($p<0.05$) with 30 t/ha poultry manure application, the highest mean values for the number of fruits/plant (70.4) and fruit yield (65.9 t/ha) were recorded in plants that received 40 t/ha poultry manure (Table 5). In comparison with no application of manure, the significant ($p<0.05$) increment in fruit yield with the application of 10, 20, 30 and 40 t/ha poultry manure were 67.6, 94.1, 82.1 and 103.4 %, respectively.

Fruit yield and fruit metric traits obtained from the study in the pot varied with the genotype except the number of fruits per plant, and fresh fruit yield (Table 5). The KPF-4 genotypes significantly produced longer (9.9 cm), wider (19.5 cm) than the 'Conventional' genotype. Increase in poultry manure rate, in the pot, progressively increased the number of fruits picked per plant (Table 5). The peak was at either 20 t/ha or 30 t/ha PM application, which produced highest number of fruits per plant (40.2). Longest fruits were obtained with the application of

40 t/ha poultry manure, although the mean value (9.7 cm) was significantly similar (p>0.05) with the mean value (9.4 cm) gotten from the application of 20 t/ha poultry manure. The fruit circumference and fruit length increased with increase in poultry manure rate (Table 5). The widest (18.9 cm) and longest fruits (9.65 cm) were associated to the fruits that received 40 t/ha poultry manure. But the application of either 10 or 20 t/ha poultry manure statistically produced similar (p>0.05) fruit circumference and weight with that of 40 t/ha poultry manure application. The fresh fruit yield was generally highest (p<0.05) with the application poultry manure, especially 10, 20 and 30 t/ha PM application.

**Pattern of fruit yield in the field and pot during the fruiting period (2015-2016) as influenced by genotype and poultry manure rates**

The pattern of fruit yield (number of fruits and fresh fruit weight) in the field and pot according to months of fruit picking as influenced by genotype and poultry manure rate are showed in Figures 1-2. Fruit picking commenced in March and April, 2015 (eight months after transplanting of seedlings) in the field and pot studies, respectively. The fruiting progressively (p<0.05) increased as the year progressed. The highest number of and heaviest fruits was picked from the 'Conventional' genotype in August 2015 but September and November 2015, respectively were the peaks for highest number of fruit picked and fruit weight obtained from KPF-4 in either field or pot studies (Figs. 5-6). However, there was a decline in fruit dropping in October, 2015, which increased again in November, 2015. Thereafter, the fruit dropping continuously declined from December, 2015. More fruits dropped and were picked from the 'Conventional' genotype from March, 2015 till August, 2015 while more fruits dropped and were picked from KPF-4 between September, 2015 and February, 2016.

Similarly, across the manure treatments, the highest number of fruit picked and the corresponding fruit weight were obtained in August 2015 (Figures 3-4). Most of the fruits as well as heaviest fruits were produced in that August, 2015 by all the vines irrespective of the poultry manure rates,. The highest number of fruits and heavier fruits in that August, 2015 was produced by the application of 20 t/ha poultry manure, followed by 30 t/ha, 40 t/ha, 10 t/ha and then no poultry manure application. The number of fruits dropped and picked declined after August, 2015 but gradually increased again in November, 2015 in all the poultry manure rates.

**Correlations between growth parameters and fruit yield variables as influenced by poultry manure rates in the field and pot experiments**

Among the growth parameters studied, the vine girth at 5 months after transplanting (MAT) had strongest correlation with the fruit yield traits (Table 6). The vine girth at 5 MAT had strong significant and positive relationship with the number of fruits (r = 0.780**) and fruit yield per hectare (r = 0.803**). An average significant association was recorded between number of branches at 5 MAT and number of fruits (r = 0.567**) and fruit weight (r = 0.578**) per hectare. The vine girth and number of branches at 5 MAT, as observed from the pot study, was highly significant and positively correlated with the number of fruits (r = 0.558** and 0.470**, respectively) and fruit yield (r = 0.355** and 0.350**, respectively) per hectare (Table 6).

**Correlations between phenology and fruit yield variables as influenced by poultry manure rates in the field and pot experiments**

The phenology had significant but inverse relationship with the fruit yield parameters (Table 6). The correlation coefficients between the phenology and number of fruits picked per hectare were -0.542** and -0.429** for number of days to flowering and days to first fruit picking, respectively. The fruit weight per hectare also was significantly related to days to flowering (r = -0.476**) and days to first fruit picking (r = -0.364*).

On the other hand, number of days to flowering and first fruit picking were highly significant and negatively associated with the number of fruits (r = -0.370** and -0.306**) and fruit weight (r = -0.307** and -0.273*, respectively) per hectare in the pot experiment (Table 6).

**Economic analysis of yellow passion fruit production in the field and pot experiment as influenced by poultry manure rates in 2014-2016 production cycle**

The economic analysis of passion fruit production in the field showed that the production cost (in naira) per hectare increased with increase in poultry manure rates applied (Table 7). The least (USD 4,325.95 i.e. ₦1,685,000) and highest (USD 8,016.48 i.e. ₦3,122,500) production cost was obtained with no manure application and 40 t/ha PM application, respectively. Highest gross monetary return (USD 16,912.35 i. e. ₦6,587,530) was associated to 40 t/ha poultry manure application. However, net return (USD 9,779.87 i.e. ₦3,809,359), return per naira invested (1.53) and benefit/cost ratio (2.53) were

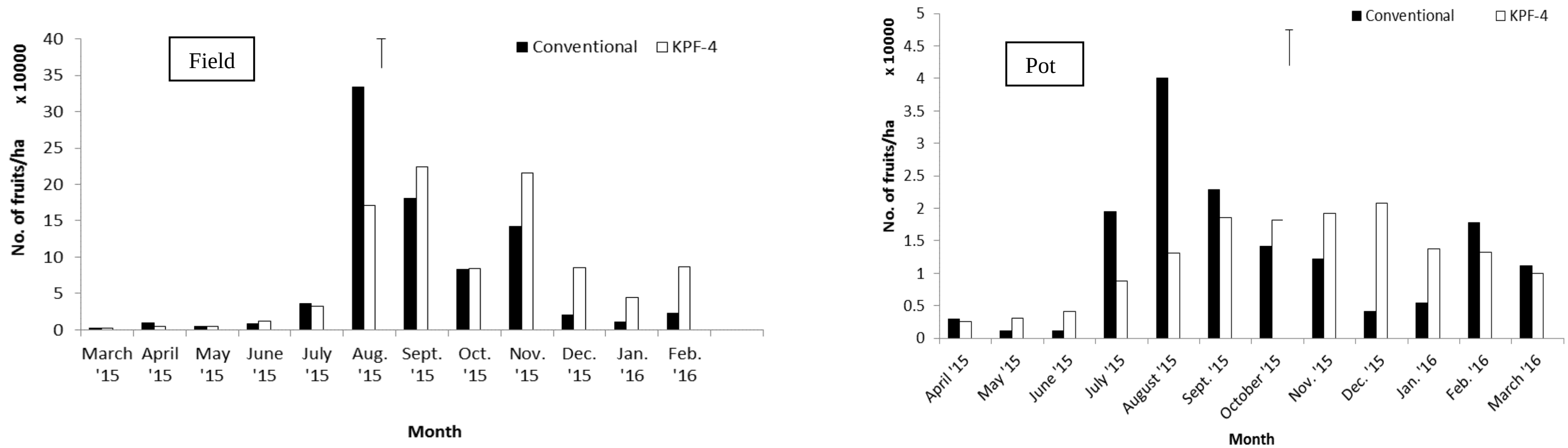


**Figure 1.** Number of fruits picked per hectare from field and pots (in months) during the fruiting period (2015-2016). Vertical bar represents $LSD_{0.05}$ value.

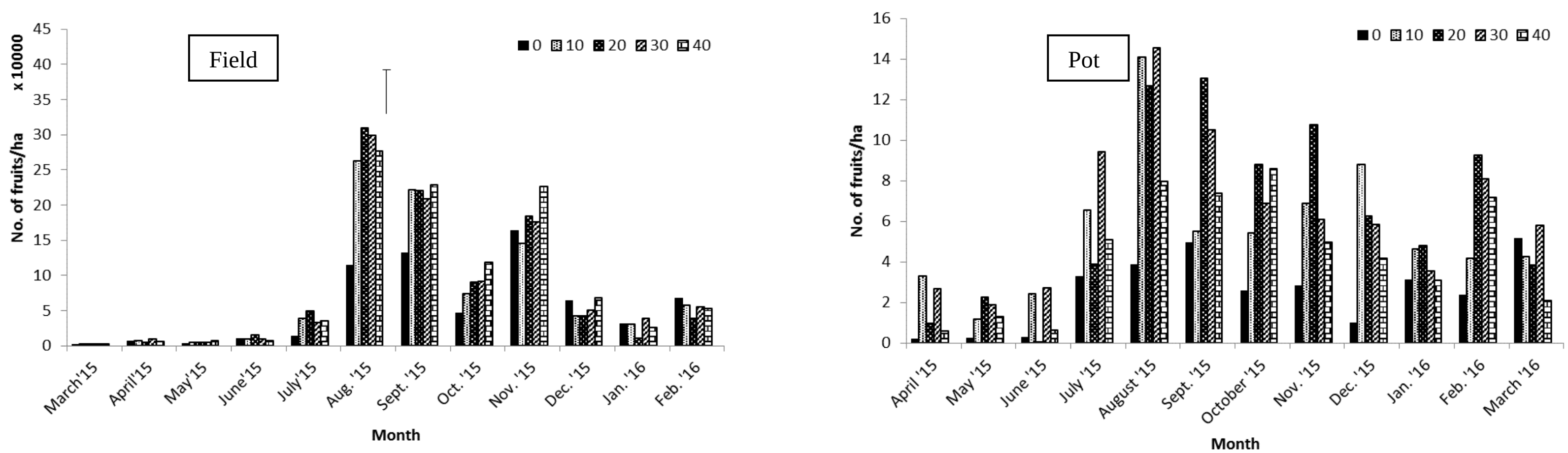


**Figure 2.** Number of fruits picked per hectare from field and pots (in months) as influenced by poultry manure rates during the fruiting period (2015-2016). Vertical bar represents $LSD_{0.05}$ value.

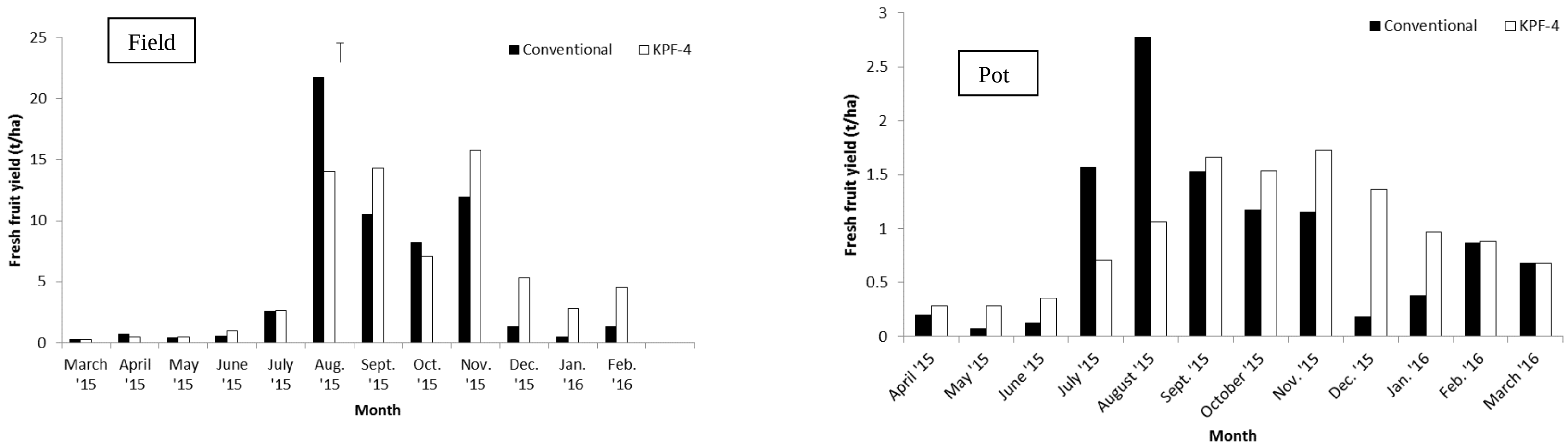


**Figure 3.** Fresh fruit (yield) of yellow passion fruits picked from field and pots (in months) during the fruiting period (2015-2016).

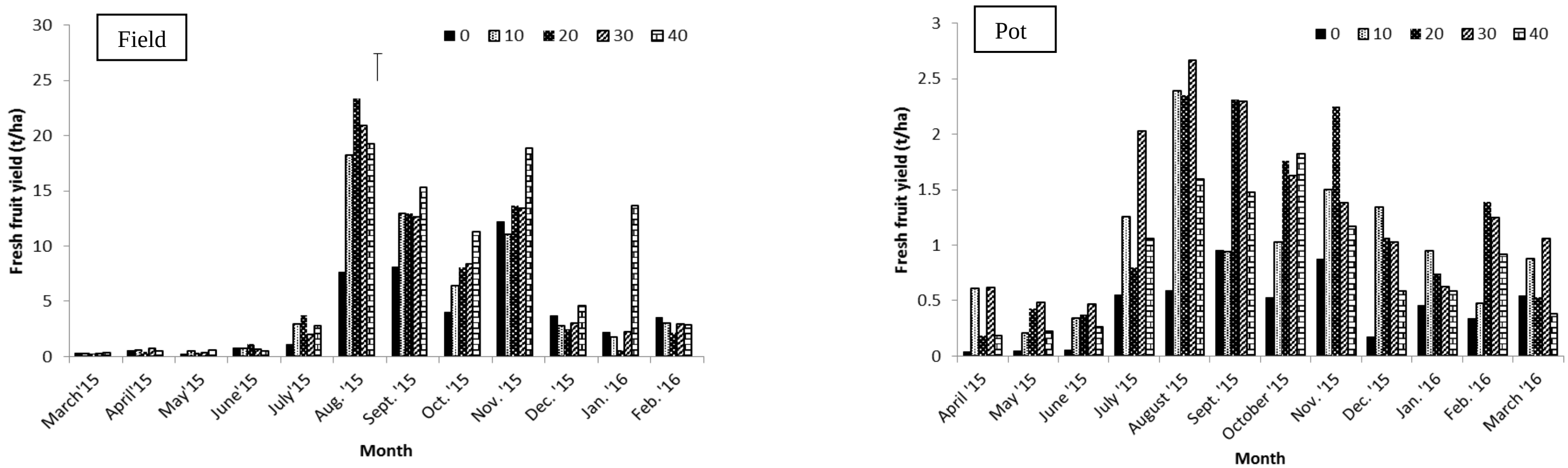


**Figure 4.** Fresh fruit (yield) of yellow passion fruits picked from field and pots as influenced by poultry manure rate during the fruiting period (2015-2016).

**Table 6. Correlations between growth parameters and fruit yield variables of yellow passion fruit grown in the field and pot as influenced by poultry manure rates.**

| | Field experiment | | Pot experiment | |
|---|---|---|---|---|
| | No. of fruits/ha | Fruit weight (t/ha) | No. of fruits/ha | Fruit weight (t/ha) |
| **Growth parameter** | | | | |
| Vine girth @ 5MAT | 0.780** | 0.803** | 0.558** | 0.355** |
| No. of branches @5MAT | 0.567** | 0.578** | 0.470** | 0.350** |
| **Phenology** | | | | |
| No. of days to flowering | -0.542** | -0.476** | -0.370** | -0.307** |
| No. of days to 1st picking | -0.429** | -0.364** | -0.306** | -0.273* |

MAT = Months after transplanting; * and ** = Significant at 0.05 and 0.01 probability level, respectively

recorded for 20 t/ha PM application. No manure application produced the least gross monetary return (USD 8,320.62 i.e. ₦3,240,963), net return (USD 3,994.67 i.e. ₦1,555,963), return per naira invested (0.92) and benefit/cost ratio (1.92).

The production cost of growing yellow passion fruits in pots also increased with increase in poultry manure rates (Table 7). The economic analysis indicated that gross monetary return, net return, return per naira invested and benefit/cost ratio increased with increase in poultry manure rates. These variables were at their peak with 20 t/ha poultry manure application. The 20 t/ha poultry manure application produced highest gross return (USD 13,338.31 i.e. ₦5,195,404), net return (USD 8,534.86 i.e. ₦3,324,413), return per naira invested (1.78) and benefit/cost ratio (2.78). It is important to note that there was significant ($p<0.05$) increase in return per naira invested (ranged from 1.05 to 1.78) with poultry manure application compared to no manure application where there was no production profit (0.99).

## DISCUSSION

The growing of yellow passion fruits as pot-plants indicated that the KPF-4 genotype flowered earlier than the 'Conventional' genotype as was observed in the field. The number of days it took the KPF-4 to flower, both in the field and pot studies, fell within the recommended period of 6 months for the flowering of vigorous seedlings from time of transplanting to the field (DOASL, 2006). Also, in both studies, poultry manure significantly reduced the days to flowering and first fruit picking compared to the plants that were not fertilized. The poultry manure might have released adequate nutrients and improved the soil biophysical properties, which enhanced the growth of the vines and their earlier attainment to reproductive stage. Poultry manure application at 40 t/ha may mean availability of more nutrients and better improvement of the physical properties of the soil, for the crop's better growth and development. But plants that received no poultry manure had delayed flowering and fruit maturity. This is in agreement with the report of Ani and Baiyeri (2008) on yellow passion fruit grown in the same study area. They noted that plants that received no poultry manure were not able to flower in the first crop cycle (12 months).

Poultry manure rate significantly influenced the yield and yield components of the passion fruit grown in the pots. The increase in fruit yield parameters as the poultry manure rate increased indicated that the poultry manure provided adequate nutrients, which the roots of the crop were able to absorb efficiently. The study revealed that the fruit and dry matter yield performances were mostly better with 20 and 30 t/ha application indicating that this could be the highest rate of poultry manure to be applied in the pots for optimum growth, development and production of fresh fruits and dry matter yield.

**Table 7. Economic analysis of fresh yellow passion fruit production in field and pot from two genotypes as influenced by poultry manure (PM) rates during 2014-2016 production cycle.**

| | Field experiment | | | | | Pot experiment | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Production cost (₦/ha) | Gross Return (₦/ha) | Net Return (₦/ha) | RI | B/C | Production cost (₦/ha) | Gross Return (₦/ha) | Net Return (₦/ha) | RI | B/C |
| **Genotype** | | | | | | | | | | |
| 'Conventional' | 2,451,000 | 5,013,663 | 2,562,663 | 1.01 | 2.01 | 1,855,900 | 2,272,228 | 416,171 | 0.21 | 1.21 |
| KPF-4 | 2,453,500 | 5,964,783 | 3,513,783 | 1.46 | 2.46 | 1,858,400 | 4,829,644 | 2,973,719 | 1.59 | 2.59 |
| $LSD_{0.05}$ | ns | ns | ns | ns | ns | ns | 1,261,927 | 1,261,896 | 0.67 | 0.67 |
| **Poultry manure rate (t/ha)** | | | | | | | | | | |
| 0 | 1,685,000 | 3,240,963 | 1,555,963 | 0.92 | 1.92 | 1,700,000 | 249,084 | 1,949,430 | 0.99 | 0.01 |
| 10 | 2,162,500 | 5,425,297 | 3,262,797 | 1.51 | 2.51 | 1,823,000 | 4,079,942 | 2,256,894 | 1.26 | 2.26 |
| 20 | 2,482,500 | 6,291,859 | 3,809,359 | 1.53 | 2.53 | 1,871,000 | 5,195,404 | 3,324,413 | 1.78 | 2.78 |
| 30 | 2,802,500 | 5,900,466 | 3,097,966 | 1.11 | 2.11 | 1,918,500 | 4,613,255 | 2,694,739 | 1.40 | 2.40 |
| 40 | 3,122,500 | 6,587,530 | 3,465,030 | 1.11 | 2.11 | 1,967,000 | 4,115,164 | 2,148,108 | 1.05 | 2.05 |
| $LSD_{0.05}$ | | 1,402,869 | 1,402,869 | ns | ns | | 1,433,939 | 1,433,938 | 0.78 | 0.78 |

Fresh fruit price was ₦500/kg = USD 12.66/kg; Exchange rate = ₦389.51 per USD; RI = Return per naira invested; B/C = Benefit cost ratio; $LSD_{0.05}$ = Least significant difference at 5% probability level; ns = non-significant at 5% probability level

One of the key reasons for the pot experiment was the hypothesis that the pot experiment could predict field performance. The present study revealed that growth and yield performances were relatively similar in both pot and field experiments. Precisely, fruit yield and economic analysis of both experiments showed that the application of 20 t/ha poultry manure was the optimum rate for optimum passion fruit production in the study area. This implied that field predictions and simulations could be made from pot studies. As such, cost of research will be reduced, space conserved and time saved.

The pattern of fruit picking with respect to months of the year showed that the duration of highest fruit drops and picking was between April and February of the following year. The peak was between August and September in both field and pot studies. This pattern could serve as a veritable tool to plan for raising seedlings, transplanting of seedlings to the field and for supplying fruits to industries as well as irrigation scheduling. This known pattern of fruit pick will enhance postharvest management for fruit storage and reduction of fruit damages and wastages. Nevertheless, further investigations could be carried out to ascertain whether transplanting periods in a year could influence phenological traits and the duration of fruit picking and fruit yield.

Similar relationships existed between the growth and phenology and the fruit yield of the passion fruit in field and pot studies. This further reiterated the fact that field performances of crops can be stimulated from corresponding pot studies. The present study agreed with the finding that more vigorous crops at early growth stage significantly culminate into higher yield of such crop. Broad and many deep green leaves characterize vigorous plants, which photosynthesizes efficiently. These leaves, which are photosynthetically active could produce more photo-assimilates thereby enhancing fruit bulking; this will invariably affect fruit weight and other yield components as was also reported in plantain (Tenkouano *et al*., 2002; Ndukwe *et al*., 2011). Therefore, the implication is that any crop management strategies, such as fertilizer application, that will improve the plant's vigour especially at the juvenile stage, may eventually translate into higher yield (Baiyeri and Tenkouano, 2008). The significant and negative association that existed between the fresh fruit yield (number of fruit picked and fruit weight per hectare) of passion fruit and number of days to flowering and first fruit picking implied that agronomic practices that will delay flowering and increase the period before fruit dropping (maturation) will result in lower fruit yield. Hence any factor, such as nitrogen fertilization, that promotes luxuriant growth of the plant may eventually prolong the flowering period with the consequent longer days to fruit maturation and dropping. This had also been reported in plantain and banana (Ndukwe *et al*., 2011).

The economic analysis revealed varying production cost which can be attributed to the different poultry manure rates. The high production cost with 30 and 40 t/ha poultry manure application could not be compensated with high net return. On the other hand, the values for yield, high net return and return per naira invested which were obtained with 20 t/ha poultry manure application were enough to compensate for the production cost for this treatment. This agreed with the report of Ngbede *et al*. (2014). It therefore, showed that it was most profitable to apply 20 t/ha poultry manure both in the field and pot since the benefit/cost ratios (2.53 and 2.78, respectively for field and pot) were highest with this treatment. It is noted that for a business to break even, the benefit/cost ratio value must be one. When the value is greater than one, then it is making profit and if less than one, then the business is running at a loss (Olukosi and Erhabor, 1988). Thus, production of passion fruit with 20 t/ha poultry manure was the most profitable in the study area, and so recommended.

## CONCLUSION

The hypothesis that the vines grown in pots could predict the field performance with respect to evaluation of genotypes and determining the optimum rate of poultry manure for optimum production of yellow passion fruit in the study area was confirmed. Phenology, growth and fruit yield of the two genotypes had relatively similar responses in both the pot and field studies. Hence, utilizing pot study to predict field performances is recommendable. In the study, fewer expenses were incurred in the pot experiment, yet similar result trends were obtained as was in the field evaluation.

Applying 20 t/ha poultry manure was recommended for optimum growth and yield of yellow passion fruit in either the container or field within the study area. Highest monetary net return was recorded with the 20 t/ha poultry manure application in both field and container studies.

**Acknowledgement**
The authors acknowledge Mr. Simon Asogwa for the assistant he offered during the study.

**Funding.** The authors received funding for this study from Tertiary Education Trust Fund of Federal Republic of Nigeria.

**Conflict of interest**. The authors declare that there are no known conflicts of interest related with this publication.

**Data availability.** Data are available with the corresponding author (Okorie Okoro Ndukwe, oo.ndukwe@unizik.edu.ng) upon reasonable request.

## REFERENCES

Adekiya, A.O. and Agbede, T.M. 2017. Effect of methods and time of poultry manure application on soil and leaf nutrient concentrations, growth and fruit yield of tomato (*Lycopersicon esculentum* Mill). Journal of Saudi Society of Agricultural Sciences, 16, 383-388. https://doi.org/10.1016/j.jssas.2016.01.006.

Ani, J.U. and Baiyeri, K.P. 2008. Impact of poultry manure and harvest season on juice quality of yellow passion fruit (*Passiflora edulis* var. flavicarpa Deg.) in the sub-humid zone of Nigeria. Fruits, 63, 239-247. DOI: 10.1051/fruits:2008017.

Asiegbu, J.E. 1989. Response of onion to lime and fertilizer nitrogen in a tropical ultisol. Tropical Agriculture. 66 (2), 161-166.

Baiyeri, K.P. and Tenkouano, A. 2008. Variability in agricultural and biological yields of ten Musa genotypes evaluated for two cropping cycles in a sub-humid environment of Nigeria. Journal of Crop Improvement. 21 (1), 27-40.

DOASL (Department of Agriculture, Sri Lanka). 2006. Passion fruit. [online] Available at <http://www.doa.gov.lk/index.php/en/crop-recommendations/1099> [Accessed on 24th May 2016.

GENSTAT. 2007. GENSTAT for Windows, Release 7.2 DE Discovery Edition 3, Lawes Agricultural Trust (Rothamsted Experimental Station), VSN International Ltd., Hemel Hempstead, UK.

Gibson, D.J., Connolly, J., Hartnett, D.C. and Weidenhamer, J.D. 1999. Designs for greenhouse studies of interactions between plants. Journal of Ecology, 87, 1-16.

Ibrahim, H. 2016. Nigeria imports N165bn fruit juice annually. [online] <http://sundiatapost.com/2014/10/21/nigeria-imports-n165bn-fruit-juice-annually/> [Accessed on 3rd May 2016].

Jacobs, F.U. 2016. Nigeria imports N165bn fruit juice annually - MAN. [online] <http://sunnewsonline.com/nigeria-imports-n165bn-fruit-juice-annually-man/> [Accessed on 3rd May 2016].

Kawaletz, H., Molder, I., Annigho P., Terwei, A., Zerbe, S. and Ammer, C. 2014. Pot experiments with woody species – a review. Forestry, 87, 482-491. doi:10.1093/forestry/cpu017.

Knight, R.J. and Sauls, J.W. 1994. The Passion Fruit. Fact Sheet HS-60. IFAS Publ., University of Florida, Gainesville.

Kohout, P., Sykorova, Z., Bahram, M., Hadincova´, V., Albrechtova´, J., Tedersoo, L. and Vohnı´k, M. 2011. Ericaceous dwarf shrubs affect ectomycorrhizal fungal community of the invasive *Pinus strobus* and native *Pinus sylvestris* in a pot experiment. Mycorrhiza, 21, 403-412.

Ndukwe, O.O. and Baiyeri, K.P. 2018. Influence of genotype and poultry manure rate on phenology and fruit yield of yellow passion fruit (*Passiflora edulis* f. flavicarpa Degener) in Nsukka, southeastern Nigeria. Acta Horticulturae, 1225, 139-144. https://doi.org/10.17660/ActaHortic.2018.1225.18.

Ndukwe, O.O., Baiyeri, K.P., Muoneke, C.O. and Tenkouano, A. 2011. Studies on intra and inter correlative responses of phenological, yield and postharvest traits in some plantain (*Musa* spp.) genotypes in Nigeria. Journal of Tropical Agriculture, Food, Environment and Extension, 10 (2), 69-77.

Ngbede, S.O, Onyegbule, U.N., Ibekwe, H.N., Uwalaka, O.A.and Okpara, S.C. 2014. Economic analysis of okra (*Abelmoschus esculentus* L. Moench) production under different rates of organic manure in Okigwe, Southern Nigeria. Asian Journal of Agriculture and Food Science, 2 (2), 96-99. https://ajouronline.com/index.php/AJAFS/article/view/1014.

Olukosi, J.O. and Erhabor, P.O. 1988. Introduction to Farm Management, Economic Principle and Application. AGITAB Publisher, Zaria, Nigeria. pp. 48-56.

Sandi, D., Chaves, J.B.P., Parreiras, J.F.M., de Souza, A.G. and da Silva, M.T.C. 2003. Evaluation of the sensory quality of yellow passion fruit juice (*Passiflora edulis* var. flavicarpa) submitted to pasteurization and storage. Bull Food Process Res Cent 21 (1): 141-158. https://doi.org/10.5380/cep.v21i1.1155.

Santos, B.M. 2002. Influencia de la fertilization nitrogeneda en la interferencia de Digitaria sanguinalis sobre maracaya. Manejo Integrado de Plagas y Agroecologia, 64, 72-76.

Smith, A., Cullis, B. and Gilmour, A. 2002. Applications: The analysis of crop variety evaluation data in Australia. Australian and New Zealand Journal of Statistics, 43 (2), 129-145. doi.org/10.1111/1467-842X.00163.

SPSS. 2013. IBM SPSS Statistics Version 22, Release 22.0.0.0. IBM Corporation and other (s) 1989, 2013.

Tenkouano, A., Ortiz, R. and Baiyeri, K. P. 2002. Phenotypic and genetic correlation in Musa populations in Nigeria. African Crop Science Journal 10 (2), 121-132.

Uguru, M. I., Baiyeri, K. P. and Aba, S. C. 2011. Indicators of climate change in the derived savannah niche of Nsukka, Southeastern Nigeria. Agroscience, 10 (1), 1-10.