**GROWTH AND YIELD RESPONSE OF ROSELLE (*Hibiscus sabdariffa* L.) TO FARMYARD MANURE AND NPK FERTILIZER IN OWERRI, NIGERIA**

 **Abstract**

Soil fertility issues have become of mounting interest due to the growing need to achieve food security for a rapidly expanding population in Nigeria. Consequently, in order to boost soil fertility and optimize general crop output, systematic means of incorporating organic and inorganic fertilisers have shown auspicious outcomes in enhancing both crop performance and soil health in different cropping systems. However, the specific growth and yield response of roselle to these treatments/amendments in the acidic, low-fertility soils that characterise Owerri still remains underexplored. Hence, the study aimed to evaluate the response of roselle *(Hibiscus sabdariffa* L.) to varied levels of farmyard manure (poultry and pig source) and mineral NPK in Owerri. The experiment was laid out in a randomized complete block design (RCBD) in which farmyard manure [poultry manure (PM) and pig waste manure (PWM)], NPK fertilizers (NPK 15:15:15 and NPK 20:10:10) and their combinations at three levels (100%, 50% and 25%) and a control served as the treatments which was replicated thrice. Roselle was grown on a seedbed. Its growth parameters were measured at a bi-weekly interval, while yield parameters were measured after harvest. Analysis of Variance (ANOVA) was conducted on the data using Genstat Statistical Package Version 18. Results showed that farmyard manures and NPK fertilisers had significant (p<0.05) effects on the parameters measured. Combination of farmyard manure and NPK fertilisers significantly (p<0.05) enhanced all the parameters measured. A combination of farmyard manure and NPK fertilisers, especially at a 25% rate, improved the roselle growth and yield properties. Specifically, plant height (115.28 cm), number of leaves(29.92), number of branches per plant(17.39), fresh (345.2kgha-1) and dry calyx (65.9kg ha-1) yield and number of pod per plant (123.7) were significantly (p<0.05) improved by combination of poultry manure and NPK 15:15:15 fertilizer at 25% rate (T8). Farmers in the study area are encouraged to apply a combination of poultry manure and NPK15:15:15 at a 25% rate since the best performance was demonstrated by this mixture.

 **Keywords**: *Roselle; growth; yield; NPK fertiliser; farmyard manure; poultry manure*.

**1.0 INTRODUCTION**

Roselle (*Hibiscus sabdariffa* L**.**) is a well-known vegetable crop that is grown in the tropics. It is an upright, herbaceous shrub that can be either annual or perennial and is a member of the Malvaceae family (Bahaeldeen, 2012). Worldwide, *H. sabdariffa* is grown in tropical and subtropical climates for its widely consumed edible calyces, stem fibres, leaves, and seeds (Babatunde *et al*., 2002). The calyces are processed in Nigeria to create the well-known non-alcoholic beverage Zobo. These calyces of this plant have been shown to have therapeutic, diuretic, and antioxidant qualities. It has been used medicinally to treat kidney stones, pyrexia, liver damage, hypertension, and leukaemia (McKay *et al*., 2010; Akim *et al*., 2011). Olaleye (2007) also reported on the antibacterial activity of *H. sabdariffa*. Equally, the calyces are nutritionally rich in calcium, iron, phosphorus, and vitamins A, C, but they contain very little protein (FAO, 2004). Smallholder farmers primarily grow roselle in restricted growing environments, relying on rainfall and organic soil fertility without the use of inorganic chemicals. The plant is valued for its calyx, which is rich in water, fibre, protein and citric acid. The fibre content and other chemical properties make it a commercial crop next to jute and cotton (Rani et al., 2025).

Southern Jos (Plateau State), Kagara and Mokwa (Niger State), and the vicinity of Ibadan (Oyo State) are Nigeria's primary production areas. Kogi, Kwara, Kebbi, Sokoto, Zamfara, Katsina, Borno, Kaduna, Bauchi, and Kano States are also locations where it is extensively grown (Alegbejo, 1998). Roselle, also known as "Isapa" (Yoruba) and "Zobo" (Hausa), is tolerant of a variety of soil types (Mehdi, 2012). It is frequently grown on somewhat infertile soils, but the only soils that produce economically are those that have adequate organic matter and vital nutrients. Moreover, rosettes cultivated with rain feeding and using different agronomic techniques like weeding, intercropping, sowing dates, and nitrogen fertiliser have been shown to have a high potential for productivity (Badran and Safwat, 2004; Egharevba and Law Ogbomo, 2007). Roselle is usually propagated by seed but grows readily from cuttings, which results in shorter plants preferred in India for inter-planting with tree crops, though the yield of calyx obtained from this type of intercropping is relatively low (Inuwa et al., 2022).

Since the dawn of humankind, plants have been recognised as having been essential to maintaining human health (Osuagwu and Edeoga, 2012), as a food source and for therapeutic purposes. However, effective management strategies are critical to ensure that crops of any variety can reach their full potential even under stress conditions and give high-quality products. In fact, soil nutrient management has been a major component of cultural practices improvement for most crops, and since frequent cultivation has characterised most arable lands of Southeast Nigeria, supplemental fertiliser application is sacrosanct (Nnadi et al., 2025). In Nigeria, the roselle crop holds growing economic importance, especially in the local food and health industries. However, despite its potential, roselle cultivation is still limited by low yields, which are often attributed to poor soil fertility, particularly in the acidic, highly weathered soils of southeastern Nigeria, such as those found in Owerri (Nnaji et al., 2012).

To improve the soil fertility of any arable land, soil nutrients must be available in the right amount, proportion, and usable form at the right time for plants to grow healthily and produce at their best (Ibrahim *et al*., 2013). To meet these requirements, soil fertility decline due to continuous cultivation by peasant farmers and the inherent poor fertility of soils of the tropics must be made up for with chemical (inorganic) and/or organic fertilisers. Meanwhile, NPK fertilisers offer a more immediate nutrient supply, particularly nitrogen (N), phosphorus (P), and potassium (K), which are essential for vegetative growth, root development, and flowering. Actually, chemical fertilisers like NPK are applied to poor soils to improve their nutrient capacity and increase production. However, regrettably, due to frequent and inappropriate application systems, soil degradation occurs in cultivated areas (Niu et al., 2021). Applying more inorganic fertiliser than what plants actually need usually results in fertiliser loss and pollution of the environment, which increases environmental hazardousness and production costs (Kapoor *et al*., 2007). As a result, there is now more interest in using organic fertilisers.

Agriculture, as a climate-sensitive sector, plays an important role in the economies of poor countries, where the impact is larger and the relationship between crop responses and temperature follows an inverted U-shape relationship (Mendelsohn et al., 2006). Changes in crop yields, in turn, might affect the use of agricultural inputs, including nitrogen fertiliser. The resilience of agricultural production systems to climate change requires higher efficiency in the use of natural resources and inputs of agricultural production. While the change in the amount of nitrogen fertiliser consumed might help farmers to adapt to global warming, this change in and of itself alters nitrous oxide emissions from agriculture (Celikkol and Guven, 2017).

In addition to improving the physical and chemical conditions of the soil, organic manures like farmyard and poultry manure have been shown to support improved plant growth, soil biological activity, and increased yield (Nithiya *et al*., 2015) since they are rich in potassium, phosphorus, nitrogen, and other vital nutrients (Oyewole and Oyewole, 2011). Again, farmyard manure (poultry manure or pig-waste manure) is an organic amendment that improves soil physical structure, water retention, and microbial activity, while gradually releasing nutrients to plants (Vasanthi and Kumaraswamy, 2000). A study has shown that application of 2.5 t/ha of farmyard manure significantly increased plant height and leaf area, which are critical reflectors of vegetative vigor (Mera et al., 2009). The researchers also reported increased calyx yield when FYM was applied in combination with moderate nitrogen levels, particularly 2.5 t/ha FYM + 50 kg N/ha. Similarly, Yirzagla et al. (2023) found that application of 69 kg N/ha and 30 kg P/ha, when used alongside FYM, produced the highest plant height and number of branches per plant, showing a positive synergy between organic and inorganic inputs. Additionally, Imoro and Yirzagla (2023) noted that organic fertilisation improved the economic returns from roselle cultivation, suggesting that FYM application could reduce dependency on costly chemical inputs.

Despite the fact that organic fertilisers are widely accessible, affordable, and simple to evaluate, they must be applied in significant quantities in order to meet the nutrient needs of crops (Prabu *et al*., 2003). When applying organic fertilizer over large hectares, this one fact significantly affects the cost of the treatment since it increases the cost of transportation. As a result, it has been recommended to combine organic and mineral nutrients (Prabu *et al*., 2003) because combining organic and synthetic nutrient sources not only provides necessary nutrients but also improves the effectiveness of chemical fertilizers, lowering environmental risks (Aluko and Oyedele, 2005). In fact, integrating organic and inorganic fertilisers has indicated promising results in enhancing both crop performance and soil health in various cropping systems (Adekiya et al., 2019; Okoli et al., 2021). However, the specific growth and yield response of Roselle to these treatments/amendments in the acidic, low-fertility soils that characterise Owerri still remains underexplored. On these bases, this study, therefore, aimed to evaluate the response of roselle (*Hibiscus sabdariffa L*.) to levels of farmyard manure (poultry source and pig waste manure) and mineral NPK in Owerri. Specifically, the objectives of the study were to:

1. determine the growth response of roselle (*Hibiscus sabdariffa* L.) to different rates of farmyard manure and NPK fertiliser and their various combinations;
2. Determine the yield attributes of roselle as affected by varying rates of farmyard manure and NPK fertiliser and their various combinations;
3. Estimate most suitable nutrient source combinations for the growth and yield of roselle

**2.0 MATERIALS AND METHODS**

**2.1 Site location**

The experiment was conducted at the Federal University of Technology Owerri (FUTO) Teaching and Research Farm, Owerri. The study area is located on latitude 5° 27' 50.23"N and longitude 7° 02' 49.33"E (Handheld global positioning system). Owerri has a rain forest agro ecology characterised with more than 2500 mm annual rainfall, 27-29 °C annual temperature and 89-93% humidity. The soils of the study area are fragile, infertile and therefore termed an Ultisol (Onweremadu *et a l*., 2007).

**2.2 Agronomic Practices**

**2.2.1 Land Clearing**

The field was manually cleared and packed using a cutlass and rake. Burning was completely avoided, this is to make sure that the lives of soil micro-organisms are protected and sustained, and the study soil is not contaminated by resultant ash.

**2.2.2 Land Preparations**

Flat beds (1m x 1m) were made to keep applied nutrients from being washed into other plots. The experimental design was a randomised complete block design replicated three times. Treatments consisted of farmyard manure (poultry manure (PM) and pig waste manure (PWM)), fertiliser (NPK 20:10:10 and 15:15:15) and various combinations of NPK and farmyard manure arranged in a 3 x 4 factorial experimental design. The treatments are as below;

|  |  |
| --- | --- |
| **Code** | **Treatments**  |
| **100%** |
| T1 | Control (no application of manure/fertiliser) |
| T2 | poultry manure(PM) (10,000 Kg) |
| T3 | Pig waste manure (PWM) (10,000 Kg) |
| T4 | NPK 20:10:10 (400 Kg) |
| T5 | NPK 15: 15: 15 (400 Kg) |
| **25%** |
| T6 | PM(2,500 Kg) + NPK 20:10:10(100 Kg) |
| T7 | PWM(2,500 Kg) + NPK 20:10:10(100 Kg) |
| T8 | PM(2,500 Kg) + NPK 15: 15: 15(100 Kg) |
| T9 | PWM(2,500 Kg) + NPK 15: 15: 15(100Kg) |
| **50%** |
| T10 | PM(5,000 Kg) + NPK 20:10:10(200 Kg) |
| T11 | PWM(5,000 Kg) + NPK 20:10:10(200 Kg) |
| T12 | PM(5,000 Kg) + NPK 15: 15: 15(200 Kg) |
| T13 | PWM(5,000 Kg) + NPK 15: 15: 15(200 Kg) |

List 1- Treatment Details

**2.2.3 Field planting**

The treatments were applied two weeks before four seeds of roselle were planted per hole at a spacing of 50cm apart. The plants were thinned down to one plant per stand at the first manual weeding (two weeks after sowing). Weeding was repeated at 6 WAP using hand hoe.

**2.3 Data Collection**

At two-week intervals, data on plant height, number of leaves, number of branches per plant, leaf area index and stem girth were measured as means of four randomly sampled plants. Plant height was measured using a meter rule, stem girth was measured using vernier callipers, while the number of leaves and the number of branches per plant were visibly counted. Days to 50% flowering were also counted. Individual treatment yields were computed on a fresh and dry weight basis as the sum of all harvests from individual net plots (kg), extrapolated to one hectare. The number of pods per plant and the number of seeds per plot were counted during harvest. Leaf area index was calculated using the formula:

Specific Leaf Area (cm2g-1)

Leaf weight per plant

Leaf Area Index = Leaf area per plant x No of plants m-2 (Amanullah et al., 2007).

**2.4 Soil laboratory analyses**

Particle Size Distributionwas determined by the hydrometer method according to the procedure of Gee and Or (2002) using water and sodium hexametaphosphate (calgon) as dispersant. Moisture content was determined using the gravimetric method. Soil pH was determined in water and 0.1 kCl using a pH meter in soil/liquid suspension of 1:2.5 (Hendershot *et al.,* 1993). Organic Carbonwas determined using the wet oxidation method (Walkley and Black, 1934). Available phosphoruswas determined using the Bray 2 solution method according to (Olsen and Sommers, 1982). Exchangeable K and Na were extracted using 1N Neutral Ammonium Acetate (NH4OAC) and determined photometrically using a flame photometer (Thomas, 1982). Exchangeable Magnesium and Calcium were determined using ethylene diamine tetraacetic acid (EDTA) (Thomas, 1982). Total Nitrogen was determined by the Kjeldahl digestion method using concentrated H2SO4 and a Sodium Copper Sulphate catalyst mixture (Bremner and Yeomans, 1988). Exchangeable Aciditywas determined titrimetrically (Mclean, 1982). Effective Cation Exchange Capacity (ECEC) was calculated from the summation of all exchangeable bases and exchangeable acidity (IITA, 1982). Percentage Base Saturation (%BS)was determined by computation.

**2.5 Statistical Analysis**

The growth and yield parameters data collected were subjected to analysis of variance (ANOVA) (Genstat Statistical Package Version 18) to evaluate the effect of the farmyard manure and NPK fertiliser on roselle performance. Means were separated using Least Significant Difference (LSD) at 5% probability level (P<0.05).

**3.0 RESULTS**

**3.1 Pre-planting Soil** **physico-chemical properties**

The results of the physical and chemical properties of soil are displayed in Table 1.

The pH measured in water was 5.87 as total Nitrogen, organic carbon, organic matter and available Phosphorus were 0.94 g kg-1, 0.94 g kg-1, 16.79 g kg-1, and 13.22 mg kg-1, respectively. In terms of Exchangeable cations in cmol/kg, Ca++, Mg++, K+, and Na+ were 1.78, 1.11, 0.327, and 0.08cmol/kg, respectively. The value, 1.26 cmol/kg was recorded for Total Exchangeable Acidity. The Cation Exchange Capacity (CEC) was 4.56cmol/kg, whereas Base Saturation (BS) was 72.4%. (Table 1).

The soil texture was Sandy with 85.3 g kg-1 sand, 89.4 g kg-1 silt and 57.6 g kg-1 clay contents (Table 1)

**Table 1: Pre-planting Soil** **physico-chemical properties**

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| pH | 5.16 |
| Total Nitrogen (gkg-1) | 0.94 |
| Organic carbon (gkg-1) | 9.74 |
| Organic matter(gkg-1) | 16.79 |
| Available phosphorus (mgkg-1) | 13.22 |
| Ca2+ | 1.78 |
| Mg2+ | 1.11 |
| K+ | 0.327 |
| Na+ | 0.08 |
| Total Exchangeable Acidity (cmolkg-1) | 1.26 |
| Effective Cation Exchange Capacity | 4.56 |
| %BS | 72.4 |
| Sand(gkg-1) | 853 |
| Silt(gkg-1) | 89.4 |
| Clay(gkg-1) | 57.6 |
| Soil textural class | Sand |
| Moisture(%)  | 8.11 |

**3.2 Effects of farmyard manure and NPK fertiliser on roselle plant height**

Results of the impact of farmyard manure and NPKfertiliser on roselle plant height are displayed in Table 2**.** Analysis of variance showed that plantsdiffered in all the weeks of measurement (2-18WAP). At 2WAP, plant height ranged from 3.9-7.7. The tallest plant (7cm) at 2WAP occurred in 25% (PWM + NPK 15: 15: 15). It was also shown that during the planting season, T9 recorded the tallest plant height (14.95cm) at 4WAP and 18WAP (148.45cm), showing significant difference (p<0.05) with the control and few other treatments. While, 25% (PM+ NPK 15: 15: 15) recorded the tallest plant at 10WAP (149.65cm) and 16 WAP (187.8cm), tallest plant at 12WAP (165.65cm) was recorded with significant difference (p<0.05) with the control in the plot that received 25%(PM + NPK 20:10:10) treatment.

**Table 2: Effects of farmyard manure and NPK fertilizer on rosselle plant height (cm)**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Trt** | **2WAP** | **4WAP** | **6WAP** | **8WAP** | **10WAP** | **12WAP** | **14WAP** | **16WAP** | **18WAP** | **Mean** |
| **T1** | 3.9 | 8.8 | 9.65 | 18.05 | 18.02 | 23.42 | 30.05 | 37.54 | 33.75 | **20.35** |
| **T2** | 6.6 | 11.05 | 18.55 | 38 | 50.45 | 61.91 | 78.965 | 91.1 | 65.9 | **46.95** |
| **T3** | 6.6 | 10.8 | 15.15 | 23.55 | 27.69 | 37.85 | 50.75 | 55.25 | 45.6 | **30.36** |
| **T4** | 5.8 | 10.7 | 14.95 | 33.05 | 40.03 | 49.96 | 50.75 | 70.65 | 64.1 | **37.78** |
| **T5** | 6.3 | 11.05 | 19.42 | 37.3 | 58.55 | 71.6 | 78.365 | 91.65 | 85.9 | **51.13** |
| **T6** | 7 | 13.8 | 58.05 | 107.6 | 144.8 | 165.65 | 163.15 | 168.75 | 147.3 | **108.46** |
| **T7** | 6.6 | 14.35 | 58.65 | 90.15 | 148.3 | 151.85 | 163.4 | 163.55 | 144.7 | **104.62** |
| **T8** | 7.6 | 13.9 | 67.75 | 128.05 | 149.65 | 157.55 | 179.15 | 187.8 | 146.05 | **115.28** |
| **T9** | 7.7 | 14.95 | 54.1 | 108.95 | 126.75 | 157.6 | 141.45 | 154 | 148.45 | **101.55** |
| **T10** | 6.4 | 10.8 | 40.05 | 73.3 | 126.35 | 135.475 | 119.75 | 147.2 | 129.2 | **87.61** |
| **T11** | 6.4 | 12.1 | 41.55 | 73.5 | 109.25 | 107.1 | 140.25 | 129.7 | 130.4 | **83.36** |
| **T12** | 6.3 | 13.05 | 34.55 | 47.95 | 81.85 | 86.95 | 118.7 | 131.2 | 108.85 | **69.93** |
| **T13** | 6.2 | 11.4 | 35.95 | 48.55 | 70.95 | 109.05 | 98.05 | 117.25 | 98.55 | **66.22** |
| **LSD (0.05)** | **0.52** | **1.01** | **10.92** | **20.17** | **26.90** | **27.93** | **27.15** | **26.17** | **23.15** | **17.89** |

 Key: Trt=treatment, WAP=weeks after planting, T1=0-control, T2=poultry manure(PM), T3=pig waste manure (PWM), T4=NPK 20:10:10, T5= NPK 15: 15: 15, T6= 25%(PM + NPK 20:10:10), T7= 25%(PWM+NPK 20:10:10),T8= 25%(PM+ NPK 15: 15: 15),T9=25%(PWM + NPK 15: 15: 15), T10= 50% (PM + NPK 20:10:10, T11= 50% (PWM + NPK 20:10:10), T12= 50%(PM + NPK 15: 15: 15), T13= 50%(PWM+ NPK 15: 15: 15.

**3.3 Effects of farmyard manure and NPK fertiliser on roselle number of leaves**

Table 3 depicts the results of the impact of different farmyard manure and NPKfertiliser on roselle. It was shown that the number of leaves varied markedly in all the growth stages irrespective of planting season. Number of leaves ranged from 1.72 in 0-control to 46.15 in PM (2,500Kg) + NPK 20:10:10(100Kg). The number of leaves was generally observed to decrease in the second season, whereas, slight increase was observed for plots that received treatments. It was also observed that a combination of farmyard manure and fertiliser gave a relatively higher number of leaves than 100% dosages of each of the nutrient sources.

Significantly (p<0.05) highest number of leaves was recorded by PM(2,500Kg) + NPK 15: 15: 15(100Kg) at 2WAP(9.02), 8WAP(30.77), 12WAP(35.12), 14WAP(39.49) and 18WAP(41.07) during the planting season. Besides, a greater number of leaves was also recorded by T6 at 4WAP (18.86), 6WAP (28.80) and 16WAP(46.15). When averaged over WAP, the maximum number of leaves (29.92) was recorded in PM (2,500Kg) + NPK 15: 15: 15(100Kg). (Table 3)

**Table 3: Effects of farmyard manure and NPK fertilizer on rosselle number of leaves**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Trt** | **2WAP** | **4WAP** | **6WAP** | **8WAP** | **10WAP** | **12WAP** | **14WAP** | **16WAP** | **18WAP** | **Mean** |
| **T1** | 1.72 | 3.56 | 6.61 | 8.64 | 10.90 | 11.29 | 12.05 | 11.86 | 10.46 | **8.56** |
| **T2** | 2.31 | 6.25 | 8.55 | 10.40 | 13.04 | 14.71 | 15.15 | 17.35 | 16.95 | **11.63** |
| **T3** | 2.04 | 4.60 | 7.48 | 9.19 | 11.59 | 13.66 | 13.90 | 12.78 | 12.49 | **9.75** |
| **T4** | 2.23 | 4.20 | 8.51 | 10.39 | 13.27 | 13.93 | 14.30 | 15.06 | 12.04 | **10.43** |
| **T5** | 2.81 | 7.08 | 11.04 | 12.74 | 14.34 | 14.91 | 16.98 | 18.04 | 17.04 | **12.77** |
| **T6** | 7.92 | 18.86 | 28.80 | 25.16 | 30.81 | 34.32 | 36.96 | 46.15 | 40.16 | **29.90** |
| **T7** | 6.21 | 15.48 | 18.06 | 23.24 | 31.47 | 32.61 | 34.13 | 37.86 | 35.64 | **26.08** |
| **T8** | 9.02 | 16.69 | 19.54 | 30.77 | 31.46 | 35.12 | 39.49 | 46.09 | 41.07 | **29.92** |
| **T9** | 5.94 | 12.57 | 17.21 | 18.76 | 24.84 | 30.14 | 34.12 | 35.11 | 34.96 | **23.74** |
| **T10** | 6.74 | 13.96 | 16.18 | 17.82 | 19.07 | 25.34 | 29.56 | 31.78 | 29.22 | **21.07** |
| **T11** | 5.11 | 13.47 | 14.28 | 15.68 | 17.20 | 18.71 | 24.97 | 27.68 | 23.58 | **17.85** |
| **T12** | 3.54 | 10.97 | 13.71 | 14.66 | 16.01 | 17.56 | 20.97 | 25.31 | 22.46 | **16.13** |
| **T13** | 3.06 | 10.69 | 11.84 | 14.11 | 15.01 | 16.46 | 18.69 | 20.14 | 19.11 | **14.34** |
| **LSD (0.05)** | **1.38** | **2.86** | **3.45** | **3.78** | **4.36** | **4.93** | **5.50** | **6.75** | **6.11** | **4.26** |

Key: Trt=treatment, WAP=weeks after planting, T1=0-control, T2=poultry manure(PM), T3=pig waste manure (PWM), T4=NPK 20:10:10, T5= NPK 15: 15: 15, T6= 25%(PM + NPK 20:10:10), T7= 25%(PWM+NPK 20:10:10),T8= 25%(PM+ NPK 15: 15: 15),T9=25%(PWM + NPK 15: 15: 15), T10= 50% (PM + NPK 20:10:10, T11= 50% (PWM + NPK 20:10:10), T12= 50%(PM + NPK 15: 15: 15), T13= 50%(PWM+ NPK 15: 15: 15.

**3.4 Effects of farmyard manure and NPK fertiliser on roselle number of branches per plant**

Results of Table 4 displayed the effects of farmyard manure and NPKfertiliser on roselle number of branches per plant. Based on analysis, there was significant difference (p<0.05) on the number of branches per plant as a result of the varying treatments. Number of branches per plot across the various stages of growth (2-18WAP) ranged from 0-26.55 and it was lower in control plots whereas, slight increase was observed for plots that received treatments. Generally, relatively higher number of branches per plant was observed for plots that received the application of mixed treatments than single treatments.

During the planting season, greater number of branches per plant was recorded for 25% (PM + NPK 20:10:10) at 10WAP (23.10), 12WAP (22.90), and 14WAP(24.75). Also, greater number of branches per plant at 2WAP(0.77), 4WAP(8.35), 6WAP(10.35),16WAP(26.55) and 18WAP(25.90) were recorded in plots that received PM(2,500Kg) + NPK 15: 15: 15(100Kg) whereas at 8WAP(19.70), PWM(2,500Kg) + NPK 20:10:10(100Kg) (combination of 25% PWM + NPK 20:10:10) obtained the highest number of branches per plant, significantly (p<0.05) higher than the control and some other treatments as shown in the Table 4

**Table 4: Effects of farmyard manure and NPK fertilizer on rosselle number of branches per plant**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Trt** | **2WAP** | **4WAP** | **6WAP** | **8WAP** | **10WAP** | **12WAP** | **14WAP** | **16WAP** | **18WAP** | **Mean** |
| **T1** | 0 | 0.46 | 2.76 | 3.5 | 5.435 | 6.65 | 9.785 | 11.4 | 8.6 | **5.40** |
| **T2** | 0.37 | 1.60 | 3.90 | 6.05 | 11.57 | 12.20 | 17.32 | 17.50 | 16.65 | **9.68** |
| **T3** | 0.40 | 1.15 | 3.55 | 5.03 | 7.65 | 10.20 | 13.65 | 15.87 | 15.35 | **8.09** |
| **T4** | 0.46 | 1.40 | 3.65 | 6.66 | 9.50 | 10.30 | 16.25 | 16.54 | 17.75 | **9.17** |
| **T5** | 0.37 | 1.69 | 4.00 | 8.35 | 10.50 | 15.21 | 15.94 | 17.78 | 15.60 | **9.94** |
| **T6** | 0.74 | 8.10 | 9.05 | 17.48 | 23.10 | 22.90 | 24.85 | 24.75 | 22.60 | **17.06** |
| **T7** | 0.53 | 6.85 | 8.15 | 19.70 | 17.25 | 20.15 | 23.50 | 22.78 | 21.64 | **15.62** |
| **T8** | 0.77 | 8.35 | 10.35 | 17.40 | 20.35 | 22.85 | 23.95 | 26.55 | 25.90 | **17.39** |
| **T9** | 0.63 | 5.00 | 7.60 | 16.55 | 16.12 | 18.85 | 19.15 | 25.65 | 22.45 | **14.67** |
| **T10** | 0.57 | 4.80 | 7.27 | 16.30 | 15.90 | 18.50 | 18.45 | 19.69 | 21.80 | **13.70** |
| **T11** | 0.60 | 4.05 | 6.01 | 14.72 | 14.22 | 17.45 | 17.75 | 18.75 | 18.77 | **12.48** |
| **T12** | 0.59 | 2.81 | 5.42 | 12.05 | 14.32 | 16.42 | 16.95 | 18.40 | 16.60 | **11.50** |
| **T13** | 0.53 | 2.15 | 5.55 | 12.10 | 11.85 | 16.50 | 16.85 | 18.11 | 15.90 | **11.06** |
| **LSD (0.05)** | **0.11** | **1.52** | **1.34** | **3.09** | **2.80** | **2.80** | **2.35** | **2.43** | **2.51** | **2.02** |

Key: Trt=treatment, WAP=weeks after planting, T1=0-control, T2=poultry manure(PM), T3=pig waste manure (PWM), T4=NPK 20:10:10, T5= NPK 15: 15: 15, T6= 25%(PM + NPK 20:10:10), T7= 25%(PWM+NPK 20:10:10),T8= 25%(PM+ NPK 15: 15: 15),T9=25%(PWM + NPK 15: 15: 15), T10= 50% (PM + NPK 20:10:10, T11= 50% (PWM + NPK 20:10:10), T12= 50%(PM + NPK 15: 15: 15), T13= 50%(PWM+ NPK 15: 15: 15.

**3.5 Effects of farmyard manure and NPK fertilizer on roselle leaf area index**

Table 5 showed the effects **of** farmyard manure and nitrogenous fertilizer on leaf area index (LAI) of roselle plant. Statistical analysis showed that LAI was significantly (p<0.05) impacted by the treatments in both planting seasons and across the growth stages. It ranged between 0.09cm and 2.49cm for control at 2WAP and T8 at 16WAP. LAI was largest in plots that received PM(2,500Kg) + NPK 15: 15: 15(100Kg) at 2WAP (0.30cm), 6WAP (1.72cm), 8WAP (1.91cm), 10WAP (2.04cm), 14WAP (2.23cm), 16WAP (2.49cm) and 18WAP (2.23cm) whereas greatest LAI at 4WAP (1.43cm) and 12WAP(2.09cm) were found in plots that received PWM(2,500Kg) + NPK 20:10:10(100Kg) and PM(2,500Kg) + NPK 20:10:10(100Kg) treatments respectively.

**Table 5: Effects of farmyard manure and NPK fertilizer on rosselle leaf area index(cm)**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Trt** | **2WAP** | **4WAP** | **6WAP** | **8WAP** | **10WAP** | **12WAP** | **14WAP** | **16WAP** | **18WAP** | **Mean** |
| **T1** | 0.09 | 0.60 | 0.61 | 0.63 | 0.64 | 0.66 | 0.67 | 0.69 | 0.66 | **0.58** |
| **T2** | 0.15 | 0.68 | 0.74 | 0.99 | 1.03 | 1.06 | 1.51 | 1.64 | 1.24 | **1.00** |
| **T3** | 0.14 | 0.65 | 0.74 | 0.82 | 0.85 | 0.86 | 0.93 | 1.13 | 1.06 | **0.80** |
| **T4** | 0.15 | 0.67 | 0.73 | 0.92 | 0.99 | 1.03 | 1.28 | 1.24 | 1.60 | **0.95** |
| **T5** | 0.16 | 0.69 | 0.80 | 1.04 | 1.25 | 1.39 | 1.67 | 1.71 | 1.68 | **1.15** |
| **T6** | 0.23 | 1.42 | 1.55 | 1.86 | 1.96 | 2.09 | 2.09 | 2.27 | 2.19 | **1.74** |
| **T7** | 0.18 | 1.43 | 1.49 | 1.82 | 1.96 | 2.06 | 2.08 | 2.19 | 2.11 | **1.70** |
| **T8** | 0.30 | 1.37 | 1.72 | 1.91 | 2.04 | 2.06 | 2.23 | 2.49 | 2.23 | **1.81** |
| **T9** | 0.14 | 1.18 | 1.46 | 1.63 | 1.70 | 1.94 | 1.99 | 2.09 | 1.99 | **1.57** |
| **T10** | 0.21 | 1.10 | 1.45 | 1.61 | 1.66 | 1.70 | 1.98 | 2.01 | 1.95 | **1.52** |
| **T11** | 0.19 | 1.11 | 1.24 | 1.54 | 1.60 | 1.69 | 1.84 | 1.98 | 2.00 | **1.46** |
| **T12** | 0.20 | 0.82 | 1.23 | 1.45 | 1.56 | 1.64 | 1.86 | 1.95 | 1.91 | **1.40** |
| **T13** | 0.18 | 0.72 | 0.86 | 1.38 | 1.43 | 1.66 | 1.73 | 1.75 | 1.60 | **1.25** |
| **LSD (0.05)** | **0.03** | **0.18** | **0.22** | **0.24** | **0.25** | **0.27** | **0.27** | **0.28** | **0.27** | **0.22** |

Key: Trt=treatment, WAP=weeks after planting, T1=0-control, T2=poultry manure(PM), T3=pig waste manure (PWM), T4=NPK 20:10:10, T5= NPK 15: 15: 15, T6= 25%(PM + NPK 20:10:10), T7= 25%(PWM+NPK 20:10:10),T8= 25%(PM+ NPK 15: 15: 15),T9=25%(PWM + NPK 15: 15: 15), T10= 50% (PM + NPK 20:10:10, T11= 50% (PWM + NPK 20:10:10), T12= 50%(PM + NPK 15: 15: 15), T13= 50%(PWM+ NPK 15: 15: 15.

**3.6 Effects of farmyard manure and NPK fertiliser on roselle stem girth**

Results of the impact of farmyard manure and nitrogenous fertiliser on roselle stem girth are shown in Table 6. Roselle stem girth was significantly (p<0.05) affected by the organic and inorganic fertilisers and their combinations. Stem girth varied from 0.49-5.88cm. It was significantly (p<0.05) improved in plots that received the application of PM(2,500Kg) + NPK 20:10:10(100Kg) at 6 WAP(3.97cm), 10 WAP(5.05cm), 16 WAP(5.88cm) and 18 WAP(5.51cm). Whereas it was improved by PWM(2,500Kg) + NPK 20:10:10(100Kg) at 8 WAP(4.64cm), 12 WAP(4.98cm) and 14 WAP(5.11cm), it was improved in plots of PM(2,500Kg) + NPK 15: 15: 15(100Kg) at 2 WAP(2.24cm) and 4WAP(2.89cm).

**Table 6: Effects of farmyard manure and NPK fertilizer on rosselle stem girth(cm)**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Trt** | **2WAP** | **4WAP** | **6WAP** | **8WAP** | **10WAP** | **12WAP** | **14WAP** | **16WAP** | **18WAP** | **Mean** |
| **T1** | 0.49 | 0.89 | 1.28 | 1.57 | 1.69 | 1.88 | 2.17 | 2.66 | 2.4 | **1.67** |
| **T2** | 0.86 | 1.47 | 1.6 | 1.87 | 2.22 | 2.62 | 3.09 | 3.42 | 3.14 | **2.25** |
| **T3** | 0.64 | 0.99 | 1.46 | 1.65 | 1.82 | 1.91 | 2.43 | 2.94 | 2.98 | **1.87** |
| **T4** | 0.95 | 1.49 | 1.59 | 1.71 | 1.83 | 1.55 | 2.63 | 3.11 | 3.05 | **1.99** |
| **T5** | 0.89 | 1.47 | 1.6 | 1.87 | 2.12 | 2.62 | 3.09 | 3.43 | 3.49 | **2.28** |
| **T6** | 2.23 | 2.69 | 3.97 | 4.58 | 5.05 | 4.34 | 4.95 | 5.88 | 5.51 | **4.35** |
| **T7** | 2.27 | 2.68 | 3.77 | 4.64 | 4.84 | 4.98 | 5.11 | 5.44 | 5.43 | **4.35** |
| **T8** | 2.24 | 2.89 | 3.78 | 4.19 | 4.83 | 4.9 | 5 | 5.36 | 4.85 | **4.23** |
| **T9** | 1.97 | 1.99 | 2.64 | 3.44 | 3.97 | 4.11 | 4.27 | 4.55 | 4.5 | **3.49** |
| **T10** | 1.9 | 2 | 2.49 | 2.9 | 3.7 | 4.03 | 4.14 | 4.43 | 4.21 | **3.31** |
| **T11** | 1.51 | 1.82 | 2.01 | 2.33 | 2.97 | 3.45 | 4.02 | 4.28 | 4.1 | **2.94** |
| **T12** | 1.51 | 1.84 | 2 | 2.57 | 2.97 | 3.44 | 4.05 | 4.29 | 4.1 | **2.97** |
| **T13** | 1.33 | 1.53 | 1.8 | 2.27 | 2.65 | 3.12 | 3.34 | 4.06 | 3.99 | **2.67** |
| **LSD (0.05)** | **0.36** | **0.35** | **0.54** | **0.63** | **0.69** | **0.64** | **0.56** | **0.57** | **0.54** | **0.53** |

Key: Trt=treatment, WAP=weeks after planting, T1=0-control, T2=poultry manure(PM), T3=pig waste manure (PWM), T4=NPK 20:10:10, T5= NPK 15: 15: 15, T6= 25%(PM + NPK 20:10:10), T7= 25%(PWM+NPK 20:10:10),T8= 25%(PM+ NPK 15: 15: 15),T9=25%(PWM + NPK 15: 15: 15), T10= 50% (PM + NPK 20:10:10, T11= 50% (PWM + NPK 20:10:10), T12= 50%(PM + NPK 15: 15: 15), T13= 50%(PWM+ NPK 15: 15: 15.

**3.7 Effects of farmyard manure and NPK fertilizer on days to 50% flowering of roselle and yield parameters**

Table 7 displayed the impact of different farmyard manure and NPKfertilizers on yield parameters of roselle. As shown in the Table, all the growth parameters were significantly (p<0.05) improved by farmyard manure and nitrogenous fertilizers in both seasons. Highest number of days (114.4) to 50% flowering was recorded in PM (5,000Kg) + NPK 15: 15: 15(200Kg) while the shortest (77.1) days to 50% flowering was recorded in 0-control plots.

Fresh calyx yield varied significantly at p<0.05 with a range of 136.9-345.2 kg ha-1. Highest (345.2 kg ha-1) fresh calyx yield during the planting season was recorded in PM(2,500Kg) + NPK 15: 15: 15(100Kg) while lowest (136.9 kg ha-1) was recorded in control plot. Similarly, highest (65.9 kgha-1) and lowest (18.3 kgha-1) dry calyx yield during the planting season were recorded in 25% combination of poultry manure and NPK 15:15:15 and control plot respectively. It was observed that combination of organic manure and nitrogenous fertilizer did better than inorganic fertilizer alone in terms of both fresh and dry calyx yield.

During the cropping season, number of pod per plant varied significantly (p<0.05) from 33.2-123.7. Highest (123.7) number of pod per plant was recorded in PM(2,500Kg) + NPK 15: 15: 15(100Kg) whereas the least (33.2) was recorded in the control plot and others showed statistical similarities. As also shown in Table 7, number of seed per pod was significantly (p<0.05) increased by farmyard manures and nitrogenous fertilizers. It varied between 11.0 and 33.5.

**Table 7: Effects of farmyard manure and NPK fertilizer on days to 50% flowering rosselle and yield parameters**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Trt** | **Days to 50% flowering** | **Fresh calyx yield (kg ha-1)** | **Dry calyx yield (kg ha-1)** | **NOPP** | **NOSPP** |
| **T1** | 77.1 | 136.9 | 18.3 | 33.2 | 11.0 |
| **T2** | 105.1 | 151.6 | 24.4 | 45.9 | 19.6 |
| **T3** | 94.5 | 175.1 | 28.7 | 62.3 | 21.4 |
| **T4** | 91.7 | 164.8 | 27.5 | 57.8 | 20.0 |
| **T5** | 92.5 | 171.8 | 27.7 | 60.1 | 21.5 |
| **T6** | 93.3 | 237.3 | 30.2 | 78.7 | 22.4 |
| **T7** | 88.9 | 289.8 | 44.9 | 103.1 | 27.8 |
| **T8** | 75.0 | 345.2 | 65.9 | 123.7 | 31.4 |
| **T9** | 82.4 | 319.0 | 56.3 | 105.1 | 33.5 |
| **T10** | 85.7 | 275.3 | 42.3 | 97.1 | 26.6 |
| **T11** | 88.2 | 253.3 | 36.9 | 87.7 | 24.2 |
| **T12** | 114.4 | 306.8 | 51.0 | 102.7 | 28.8 |
| **T13** | 100.5 | 256.7 | 46.7 | 99.3 | 26.9 |
| **LSD (0.05)** | **6.12** | **39.33** | **7.87** | **15.26** | **3.31** |

Key: Trt=treatment, NOPP=number of pod per plant, NOSPP=number of seed per pod, T1=0-control, T2=poultry manure(PM), T3=pig waste manure (PWM), T4=NPK 20:10:10, T5= NPK 15: 15: 15, T6= 25%(PM + NPK 20:10:10), T7= 25%(PWM+NPK 20:10:10),T8= 25%(PM+ NPK 15: 15: 15),T9=25%(PWM + NPK 15: 15: 15), T10= 50% (PM + NPK 20:10:10, T11= 50% (PWM + NPK 20:10:10), T12= 50%(PM + NPK 15: 15: 15), T13= 50%(PWM+ NPK 15: 15: 15.

**4.0 Discussions**

**4.1 Pre-planting soil** **physico-chemical properties**

The soil used for the study was acidic (pH=5.16). The nutrient components of the soil with the exception of Ca were moderate. Phosphorus, organic carbon, N, K, and Mg were within the moderatevalues of 10-15gkg-1, (Esu, 1991), 2-5 mgkg-1 (Landon, 1991), 10-20 mgkg-1(Esu, 1991), 0.3-0.7 Cmolkg-1 and 1-3 Cmolkg-1 (Hazelton and Murphy, 2007) respectively. However, Ca and ECEC of the soils were below the critical levels of 2-5 Cmolkg-1 (Hazelton and Murphy, 2007) and 5-15 Cmolkg-1 (Landon, 1991), respectively. Moisture content (8.11%) of the soil was also low as it was within 8 – 12% stipulated as low (Beernaert, 1990). Total exchangeable acidity (1.26 cmolkg-1) of the soil was high resulting in lower %BS(72.4). In the tropics, aluminium toxicity is one of the major factors limiting crop growth. However, toxicity of Al depends on species. These findings signify that the soil requires amendment for high growth and yield of the crop.

**4.2 Effects of farmyard manure and NPK fertilizer on roselle plant height**

The significant difference recorded in 2WAP is in disagreement with the findings of Anyinkeng and Mih (2011) that from germination up to two weeks after sowing, the young seedlings are supported from nutrient reserves in cotyledons, so there were no significant differences in growth rate since the nutrient sources are similar.

It was shown that the tallest plant that occurred at 12WAP was recorded in a plot that received 25%(PM + NPK 20:10:10) treatment. This is similar to the findings of Lemma *et al*. (2019), where a combination of 69/30N/P and 15 tha-1 farmyard manure gave the highest plant height of 194.33cm in the study. Plant height in this present study was slightly higher than that of Egharevba and Law-Ogbomo (2007), who reported 1.50 m at 60 kg N.ha-1. Moreover, Selim *et al*. (1993) reported a plant height of 1.60 m at the highest nitrogen level (180 kg N.ha-1). These results also suggested that the response of *H. sabdariffa* to poultry manure treatment is level-dependent. Relatively taller plants in plots that received poultry manure solely and in integrations are similar to the findings of Tiamiyu *et al*. (2012), who reported that application of poultry droppings to the soil led to greater plant height in okra. Aniefiok (2013) also noted that poultry manure increases plant height. Similar taller plants in plots that received pig waste manure indicate a mode of action of this manure similar to that of poultry manure and highlight the importance of pig waste in soil improvement. In the study of Lemma *et al.,* (2019), plants that received both organic (FYM) and inorganic (NP) fertiliser applied simultaneously grew taller than those found in the control plot. The tallest roselle plants (194.33 cm) were produced by applying 69/30 kg ha of NPK plus 15 t ha of FYM, while the shortest roselle plants (120.40 cm) were seen for the control treatment. Chand *et al*. (2006) have reported that the mixed use of Nitrogen-phosphorus-potassium (NPK) chemical fertiliser and livestock organic manure increases the mean growth of mint (Mentha arvensis) and mustard (*Brassica juncea*) by 46%. Overall, plant height of plots that received a combination of 25% PM + NPK 15: 15: 15 was superior (115.28cm) compared to other plots. It was observed that plant height at every growth stage were better in plots that received treatments than in control plots. Plants treated with poultry manure showed the most effective and noticeable increase in height, most likely as a result of the adequate N (Sa-nguansak, 2004). Since the plant in untreated plots had to rely on the native fertility of the soil, which was demonstrated to be deficient in total N, the shorter response of the plants could likely be attributed to insufficient N uptake. According to Sharma's (1991) research, plant height is dependent on an appropriate supply of nutrients. These results are in harmony with other investigators such as (Singh *et al.,* 1999) who indicated that increment of vegetative growth of plants as a result of combining of inorganic fertilizer and organic manure may be attributed to continuous application of chemical fertilizer causes a drastic reduction in organic carbon concentration, whereas addition of farmyard manure in combination with N fertilizer helped in maintaining the original organic matter status of the soil. According to Adekiya and Agbede (2009), it can be said that the addition of NPK fertiliser to manure aided mineralisation of nutrients in manure due to enhanced supply of nutrients, leading to better crop growth.

**4.3 Effects of farmyard manure and NPK fertiliser on roselle number of leaves**

It was observed that a relatively higher number of leaves was found in a moderate combination of farmyard manure and inorganic manure. This is contrary to the report of Qasim *et al*. (2001) that the higher rates of the combined soil amendments produced more leaves per plant. Blay et al. (2002) conducted a study in 1998–1999 to ascertain the ideal concentrations of poultry manure and inorganic fertiliser, as well as the combined impact of these factors on the yield of shallots grown on sandy Anloga soils in Ghana, Africa, which are comparable to the study's soils. The four x three factorial treatments included three levels of NPK 15-15-15 fertiliser at 0, 300, and 600 kg /ha and four levels of poultry manure at 0, 10, 20, and 40 t/ha. Increased leaf production per plant was achieved by combining 40 tonnes of poultry manure per hectare with 300 kg/ha and 600 kg of NPK 15-15-15 fertiliser per hectare. Increase in the number of leaves per plant occasioned by integrated fertiliser and farmyard manure application is bound to affect the plant growth and vigour positively. This is because leaves are the major organs of photosynthesis in plants (Law-Ogbomo *et al*., 2017).

**4.4 Effects of farmyard manure and NPK fertiliser on roselle number of branches per plant**

Greater number of branches per plant was recorded in plots that received T8 treatment, especially in 2, 4, 6, 16 and 18WAP. This indicated that supplementation of farmyard manure with nitrogenous fertiliser is superior in terms of producing more number of branches per plant than separate dosages of each of the nutrient sources. This result is in agreement with the work of Yirzagla et al. (2023), who found that application of 69 kg N/ha and 30 kg P/ha, supplemented with FYM, produced the highest number of branches per plant (including height), showing a positive synergy between organic and inorganic inputs. Similarly, in the study by Lemma et sal. (2019), plots treated with 10 t ha of farmyard manure plus 69/30 kg ha of NP were found to have the highest mean number of branches per plant (13.83), outperforming all other treatments. Moreover, the control treatment produced the fewest number of branches per plant (5.2). This could be explained by the plants receiving more nutrients from farmyard manure and NP fertiliser, which might have encouraged the development of lateral shoots. This outcome is consistent with the research conducted by Akanbi *et al.* (2009), who found that all fertilised roselle plants gradually increased the number of main branches on each plant, going from three in the control treatment to eight or ten in the treated group. According to Arsham (2013), application of 150 and 100 kg ha-1 NPK) and 20 t ha-1 of ostrich manure showed high branch number (4.66 branches) compared to the control treatment (1.66 branches). Organic fertiliser apart from releasing nutrient elements to the soil, has also been shown to improve other soil chemical and physical properties, which enhance crop growth and development (Ogbonna, 2008; Dauda *et al.*, 2008; Uko *et al*., 2009). This may be responsible for the better performance recorded in plants that had a combination of poultry manure and inorganic fertiliser than crops that received either sole poultry manure or sole inorganic fertiliser treatments. This agrees with results obtained by other researchers in other crops (Adekiya et al., 2019; Okoli et al., 2021; Ullah *et al.,* 2008; Ogbonna, 2008; Bayu *et al.,* 2006; Ndaeyo *et al.,* 2005; Uko *et al*., 2009).

**4.5 Effects of farmyard manure and NPK fertiliser on roselle leaf area index**

When averaged over WAP highest LAI (1.81cm) was recorded in PM(2,500 Kg) + NPK 15: 15: 15(100Kg) plots. This suggested that considering plots that received treatment application, LAI was better in plots treated with a combination of 25% (PM+ NPK 15: 15: 15) compared to other treatments. Higher LAI signifies greater leaf production rates, leaf area expansion and leaf area duration and could signify the relative amount of light interception by the plant. An increase in the number of leaves was a precursor to a greater amount of assimilates. This appears to align with Mauromicale *et al.,* (2006), who noted that nitrogen increases leaf expansion, stem branching capacity and stimulates photosynthetic capacity.

**4.6 Effects of farmyard manure and NPK fertiliser on roselle stem girth**

Roselle stem girth in plots that received treatment was better than control plots. The poor development of vegetative characters observed in treatment without manure (control) further confirmed the report of Akanbi *et al* (2000) and Akanbi 2002, that nutrient availability, especially nitrogen determine plant vegetative grow. This observation is consistent with a prior study by Ayoola and Adeniyan (2006), whow found that a substantial variation in the stem girth of each plant is caused by variations in the sources of nutrients among treatments.

**4.7 Effects of farmyard manure and NPK fertiliser on days to 50% flowering roselle and yield parameters**

Plots that received the application of 50% (PM + NPK 15: 15: 15) showed the longest days to 50% flowering (114.4), while the shortest (77.1) days to 50% flowering was recorded in 0-control plots. This outcome is in consonance with the study conducted by Oyewole (2011) who found that the farmyard manure with the highest amount and the N fertiliser rate (7.5 t ha-1 and 75 kg N ha-1, respectively) were also the least to reach 50% flowering in roselle. These indices of crop earliness indicated that, roselle crop in control starts bearing earlier than others. This may have implications on the use of production resources and probably on crop productivity (Timothy and Futuless, 2014). According to Oyewole and Mera (2010), one possible explanation for the longer time taken by plots treated with higher rates of farmyard manure and N-fertiliser to reach 50% flowering could be the contribution made by treatments to the soil's fertility status. Manure application has been reported to promote vegetative growth in plants (Udoh *et al*., 2005), while nitrogen has also been observed to elongate the juvenile stage in plants, thus delaying crop maturity. It can be said that the effect of farmyard manure is attributed to the enhancement of physical criteria of the soil, including better aeration, better water holding capacity, better nutrient availability and good balance between nutrients in the soil solution and improvement of nutrient exchange between of the soil (Zebarth *et al.,* 1999). Slow release of nutrients from farmyard manure during the growth period and hence low leaching of the nutrients could also be other criteria for farmyard manure, which improved vegetative growth and flower induction. The significant results of the present study are, however, contrary to the findings of Haruna *et al*. (2011) who reported that number of days to 50 per cent flowering was neither significantly enhanced by nitrogen nor poultry manure application.

The highest fresh calyx yield was recorded in PM(2,500 Kg) + NPK 15: 15: 15(100 Kg), while the lowest was recorded in the control plot. Similarly, the highest and lowest dry calyx yields during the planting season were recorded in a 25% combination of poultry manure and NPK 15:15:15 and the control plot respectively. Therefore, it was observed that a combination of organic manure and nitrogenous fertiliser did better than inorganic fertiliser alone in terms of both fresh and dry calyx yield. This agrees with the works of some researchers who observed that integrating organic and inorganic fertilisers has resulted in enhancing both crop yield and soil health in various cropping systems (Adekiya et al., 2019; Okoli et al., 2021). Similarly, Haruna *et al*. (2011) in their study, found that the application of 60 kg/ha of nitrogen fertilizer and 5tons/ha of poultry manure significantly increases calyx yield and profitability of roselle. Similar investigations by Mera et al. (2009), Oyewole and Mera (2010), and Atta et al. (2010) reported that increased N application rates of nitrogenous fertilisers, the use of poultry manure, or farmyard manure correlated with increased roselle growth and yield.

Meanwhile, the results of this study have demonstrated an enrichment of the organic sources by the mineral fertilisers. Other researchers (Swift, 1997; Gitari and Friesen, 2001; Makinde, 2007) have noted that the combined use of organic and mineral fertilisers results in higher yields than either source used alone. This explains why the combined fertilisers' yield was found to be significantly higher than that of the organic sources alone. Specifically, Vasanti and Kumaraswamy (2000) found that poultry litter is more effective at generating both soil fertility and green and dry fodder yields for cereal crops than sheep and goat manure, farmyard manure, and biogas manure. Hence, the yield advantages of the organic manures over inorganic fertiliser could be ascribed to the probable effects of the organic manures in improving the physical characteristics of the soil (Mbagwu and Ekwealor, 1990) and to their supply of the macro- and trace elements not contained in the inorganic fertiliser. The lower fresh and dry calyx yield in plots treated with fertilisers alone might be due to the fact that nitrogen stimulated vegetative growth over reproductive growth, which decreased yield (Ali *et al*., 2005). In addition, better yield recorded in a 25% combination of poultry manure and NPK 15:15:15 could be due to the fact that poultry manure, in comparison to other supplies more nutrients to the plant (Garg and Bahl, 2008). In addition to releasing nutrients, poultry manure is rich in organic matter, which improves the physical properties of soil (Ayeni, 2011). Nutrient content from manure varies because diet, bedding quantity, storage conditions, and application technique all have a significant impact on the fertiliser value of manure (Harris *et al.*, 2001). Poultry manure has a fairly high nutrient composition when compared with other animal sources such as goats, pigs, and cattle manures.

Furthermore, the highest number of pods per plant also occurred in plots amended with PM(2,500 Kg) + NPK 15 15: 15(100Kg), whereas the least (33.2) was recorded in the control plot, varying between 11.0 and 33.5. These values were higher than 48.4 and 49.0 number of pods per plant recorded by Oyewole (2011)in farmyard manure (7.5 t ha-1) and N-fertiliser (75 kg N ha-1). Differences in the values could be a result of variation in soil and climatic conditions. Meanwhile, a lower number of pods per plant in the control was similar to the findings of Gendy *et al*. (2012) who reported that application of cattle manure fertiliser tended to a significant increase in fruit number/plant compared to the control treatment. This could be because farmyard manures and inorganic fertilisers release enough nutrients into the soil, promoting vigorous plant growth with larger leaf areas and the production of dry matter. This increases the number of pods produced by each plant because nutrients from FYM and NPK improve vegetative growth, synthesis, and the translocation of photosynthesis from the sources to the sink (Lemma *et al*.,2019).

**5.0 Conclusions**

Analysis of variance showed that the combination of farmyard manure and NPK fertilisers at 25% rate improved the roselle growth and yield properties. Plant height, number of leaves, number of branches per plant, fresh and dry calyx yield, including number of pods per plant, were significantly (p<0.05) improved by the combination of poultry manure and NPK 15:15:15 fertiliser at 25% rate. However, a combination of farmyard manure and NPK fertilisers at a 50% rate gave the longest days to 50% flowering. The findings therefore showed that the application of combined organic and inorganic fertilisers, especially 25% rates of poultry manure and NPK15:15:15, demonstrated superiority in terms of growth and yield performance of the roselle plant. Based on the findings of this, farmers in the study area are advised to apply a combination of poultry manure and NPK15:15:15 at a 25% rate since it gave the best performance than other amendments.

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Details of the AI usage are given below:

1.

2.

3.

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