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# Tomato varieties superiority assessment under organic and inorganic (granular and foliar) fertilization in sandy clay soil

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## Abstract

Tomato is valued for its nutritional importance and contribution to countries' GDP. Despite the importance of tomatoes, tomato cultivation remains a challenge in some cities, particularly Kumba, Cameroon. This results from a vast knowledge gap for a suitable variety and agronomic management practices. Thus this work was set out to investigate the response of three tomato varieties under organic, foliar, and granular inorganic fertilization at the Kumba I subdivision. This work comprised two factors; variety having three levels (Cobra $F_1$, Rio Grande, and Kiara tomato varieties) and fertilization having four levels (control, NPK 20:10:10 granular fertilizer, Foliar NPK 20:10:10 inorganic fertilizer, and Poultry manure) given twelve treatment combinations replicated three times randomly in a factorial design. Data was collected on soil physicochemical properties, plant growth parameters and fruit yield. The results showed that the variety did not significantly affect soil physicochemical properties, but soil physicochemical properties were significantly affected by fertilization. Poultry manure had the best OC (5.22 %), $N_{tot}$ (1.73 g/kg), and $P_{avail}$ (14.63 mg/kg), while K was highest (2.93 meq/100g) in NPK 20:10:10 granular fertilization. Rio grande, in combination with poultry manure, had the best plant growth; plant height (77.3 cm), number of branches (17), number of leaves (197), and leaf area (47.1 $cm^2$). Cobra $F_1$, in combination with foliar NPK 20:10:10 granular and poultry manure, had the best fruit yield; 13.42 $tha^{-1}$ and 13.56 $tha^{-1}$, respectively while Kiara variety at the control treatment had the lowest yield (8.36 $tha^{-1}$). Thus Cobra $F_1$ variety in combination with poultry manure yielded the best result from this study and offers the best option for tomato cultivation in the sandy clay soils of Kumba, Cameroon.

**Keywords:** Soil fertility, varieties, synthetic fertilizer, yield.



## Introduction

The mainstay of Cameroon's economy is agriculture, which harbors 44 % of the country's GDP serving the role of employment and food production (BCA, 2019). Tomato is a fruit vegetable grown in Cameroon. Tomato has massive economic value through its huge exportation and local consumption rate, significantly improving farmers' standard of living and adding to Cameroon's agricultural GDP (FAOSTAT, 2018). It is endowed with numerous nutritional benefits solely or in combination with other foodstuffs that have drifted so much production and consumption attention towards itself (Ingenbleek et al., 2017). With an increasing production of above 130 million tons annually, tomato is the largest vegetable category worldwide due to it nutritional and economic benefits (Ravindran et al., 2019). China, the EU, India, the US, and Turkey are the top 5 tomato-producers, accounting for about 70% of global production (ED, 2016). With an anticipated 889,800 tons of

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production and a 9.4% yearly growth rate, Cameroon is ranked as Africa's fifth-largest tomato producer (Tolly and Kamtchouing, 2016).

Tomato is grown in Cameroon's third, fourth, and fifth agro-ecological zones (Kirui and Abiodun, 2017) due to their favorable climatic and edaphic factors (Norbert et al., 2017). Nonetheless, tomato production in some cities like Kumba in the meme division of the fourth agro-ecological zone is challenging (Kimengsi and Tosam, 2013). This is because Kumba is characterized by unfavourable climatic conditions, high ambient temperatures, drought, soil fertility challenges, and a high incidence of diseases and pests (Kimengsi and Tosam, 2013; Okolle et al., 2014). Also, inadequate knowledge of tomato production reduces farmers' yield in Kumba, which could be attributed to wrong variety, fertilization, and management choices (Okolle, 2019; Nkongho et al. 2022). Therefore, farmers tend to abandon tomato cultivation and go for the production of other crops while buying tomatoes from other cities like Limbe, Buea, Bamenda, Tiko, Foumbot, and Dschang, which also suffer quality losses over time (Mengui et al., 2019). Thus this warrants the development of an adaptive tomato variety, fertilization, and management regime for tomato production to alleviate the population of Kumba from the tomato inland transportation challenges while enhancing their tomato production knowledge (Naz et al., 2018; Ngosong et al., 2018; Agbor et al., 2022a). Therefore, this work seeks to evaluate the growth and yield performance of three tomato varieties under different fertilizer regimes in the sandy clay soils of Kumba I Municipality in the Southwest Region of Cameroon.

## Material and Methods

### Research area description

This research was done in the Kumba I subdivision, Meme division of the Southwest Region, in Cameroon, with geographical coordinates: 4°38′N 9°27′E, 240 m above sea levels. Kumba lies in the Humid Forest Agro-ecological zone IV with a mono-modal rainfall regime (IRAD, 2013). The equatorial climate of Kumba has two seasons: the dry season, which lasts from November to March, and the rainy season, which lasts from April to October. The average annual rainfall in Kumba is between 3000 and 4000 mm. The mean annual relative humidity and temperature are between 70 % to 84 % and 24˚ C to 35˚ C, respectively, characterized by hot days with high intensity of sunlight. Kumba has sandy clay soil, brownish-yellow coloration, with high organic matter content (Giresse et al., 1994).

### Tomato nursery establishment

Three ridges of 2.2 m by 1.2 m each were raised to 20 cm height with a hoe, and 15 kg of poultry manure was mixed on the ridges 5 kg per ridge, two weeks before seeding. The ridges were watered and disinfection was done using 80 g/15L Mancozep (Fungicide) and 30 ml/15 parastal (insecticide), all mixed in a 15L knapsack and sprayed on the bed to get rid of insect pests and diseases. Ten grams of each variety (Cobra $F_1$, Rio grande and Kiara) was bought from an agro-shop in Kumba, Cameroon, these varieties were selected for this research based on the fact that they are commonly grown in the Sahelian and Tropical areas as seen in Mahbou et al. (2022) and Ngosong et al. (2018). Each variety was seeded on the respective ridge by broadcasting method, followed by watering of the ridges. Plantain leaves were used to cover the ridges to create a microclimate for rapid germination of tomato varieties and were removed three days after germination.

### Experimental design and treatments

The experimental field of 208 m² was cleared with a cutlass and raked. The design was a 3 by 4 factorial design. Factor one was variety with three levels; Cobra $F_1$, Rio Grande, and Kiara tomato varieties. While factor two had fertilizer types of four levels; control, NPK 20:10:10 granules at rate of 300 kgha$^{-1}$ (Ilupeju et al., 2015), Foliar NPK 20:10:10 fertilizer 50 g per 15 L knapsack , and Poultry manure applied at the rate of 10 tha$^{-1}$ (Ilodibia and Chukwuma, 2015).. This gave a total of 12 variety and fertilization combination treatments. The treatments were replicated three times giving 36 plots. Thirty six ridges of 4.30 m by 1.7 m each were raised 25 cm above the ground with the aid of a hoe. Treatments within a replicate were separated with a 0.5 m distance, while replicates were separated with a 1 m distance. Planting spots were dug and pegged at distances of 75 cm by 50 cm (Mahbou et al., 2022) giving 6 intra-row and 3 inter-rows, equaling 18 stands per plot.

Table 1. Treatments

| Cultivar / Fertilizer levels | Tomato Cultivars | | |
|---|---|---|---|
| | Cobra $F_1$ (CF1) | Rio Grande (RG) | Kiara (K) |
| Control (C) | CCF1 | CRG | CK |
| NPK 20:10:10 granules (NPK) | NPKCF1 | NPKRG | NPKK |
| Foliar fertilizer (FF) | FFCF1 | FFRG | FFK |
| Poultry manure (PM) | PMCF1 | PMRG | PMK |

| | | | | |
|---|---|---|---|---|
| | CCF1 | NPKCF1 | FFCF1 | PMCF1 |
| Replicate 1 | CRG | NPKRG | FFRG | PMRG |
| | CK | NPKK | FFK | PMK |
| | NPKCF1 | FFCF1 | PMCF1 | CCF1 |
| Replicate 2 | NPKRG | FFRG | PMRG | CRG |
| | NPKK | FFK | PMK | CK |
| | FFCF1 | PMCF1 | CCF1 | NPKCF1 |
| Replicate 3 | FFRG | PMRG | CRG | NPKRG |
| | FFK | PMK | CK | NPKK |

Figure 1. Factorial design experimental layout

**Seedling transplant:** Seedlings of the three varieties were transplanted to their respective experimental plots at a planting distance of 75 cm by 50 cm at a 3 cm depth following the spots (Table 1, Figure 1). Per stand, two seedlings were initially transplanted before being culled to one (Ngosong et al., 2018), one week after transplanting. Prior to and after the transplanting, the plots were irrigated using watering can.

**Field management**

**Weed management and irrigation:** Weeding was done by hand, and the use of hoe weekly based on the need. Watering was done twice a day, in the morning and evening, during periods of no rain.

**Management of diseases and pests:** 80 g/15L Mancozep and 30 mL/15L parastar, all mixed in a 15L knapsack and sprayed on the bed to get rid of insect pests and diseases weekly.

**Staking of tomato plants:** Staking was done in the fourth week after transplanting by drilling 60 cm sticks, 10 cm into the soil about 10 cm away from the root zone of the plant. Staking was done to support tomato plants to grow upright, preventing branches from lying on the soil, improving fruit quality and quantity, and preventing soil-borne diseases.

**Data collection:** Five randomly selected plants were tagged for data collection per plot.

**Growth parameters:** Vegetative data was collected from 3 weeks after transplanting and continued at 2 week intervals. Plant height was measured using a meter rule, the number of leaves, the number of flowers and the number of branches were counted and the area of the leaf was measured according to Blanco and Folegatti (2003), all recorded as aspects of plant growth.

**Yield data:** The yield of tomato plants was collected based on the weight of fruits in tons per hectare.

**Soil and organic manure analysis :** At the experimental site, augers were used to randomly collect pre- and post-soil samples from a depth of 0 to 15 cm. For the pre-soil analysis, four samples were taken and bulked into a single sample. A 2 mm sieve was used to filter the soil sample after it had been air dried. For the post-soil analysis, soils were collected per replicate per treatment from the field and air-dried. Soil samples were sent for analysis at the Soil Science Laboratory of the University of Dschang. The soil texture was sandy clay.

Utilizing the pipette method and sodium hexametaphosphate as the dispersing agent, the soil's particle size was assessed (Kalra and Maynard, 1991). After 24 hours of suspension (solid/liquid = 1/2.5 w/v), the soil pH was measured using the potentiometric method in both water ($H_2O$) and 1M potassium chloride (KCl) solutions. Using a neutral ammonium acetate solution, exchangeable bases were extracted. Atomic absorption spectrophotometry was used to determine the amounts of calcium (Ca) and magnesium (Mg), whereas flame photometry was used to determine potassium (K) and sodium (Na) (Jones, 2001). By using the KCL extraction procedure, exchangeable acidity was produced (Jones, 2001). The macrokjeldahl digestion process yields the total nitrogen (N) (Bremner and Mulvaney, 1982), and the Bray II method is used to determine the availability of phosphorus (P) (Jones, 2001). The Walkey-Black method is used to determine the soil's organic carbon content (Walkey and Black, 1934).

### Statistical analysis

With P ≤.05, two-way analysis of variance was performed using SPSS version 25 on the physical and chemical characteristics of post-soil, growth, and yield parameters to test the aftermath of treatments as categorical predictors. Duncan Multiple Range Test (DMRT) was used to distinguish means that were significantly different at P ≤ 0.05.

## Results

### Soil chemical properties as affected by sole and interaction of factors

The soil chemical properties were not significantly affected by the variety factor, whereas the fertilization types significantly affected the soil's physicochemical properties.

Poultry manure raised the soil pH ($H_2O$) to 5.50 while NPK 20:10:10 reduced it to 4.97 without significant differences same with soil pH (KCl). Poultry manure had a higher OC content (5.22 %) and the best C/N ratio (49), while $N_{tot}$ content was highest in NPK 20:10:10 (1.73 g/kg). There were fluctuations among fertilizer types for exchangeable cations, with poultry manure producing arguably the best results while NPK 20:10:10 had the highest CEC (18.05 %). $P_{avail}$ was highest in poultry manure fertilization type.

Apart from soil pH, the soil's chemical properties were significantly affected by interaction of factors. While treatment combinations with poultry manure had the best OC content (Cobra $F_1$ and poultry manure 5.24 %, Rio grande and poultry manure 5.14% and Kiara $F_1$ and poultry manure 5.27%) and C/N ratio, treatment combinations with NPK 20:10:10 had the highest $N_{tot}$. Treatment combinations with poultry manure were the best in exchangeable cations as treatment combinations with NPK 20:10:10 dominate CEC. $P_{avail}$ was highest in poultry manure treatment combination.

Table 2. Soil chemical properties as affected by sole variety and fertilization in sandy clay soil

| Soil properties | Pre-soil analysis | Post soil analysis | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Variety | | | | Fertilization types | | | | |
| | | Cobra $F_1$ | Rio grande | Kiara | *P*=.05 | Control | NPK 20:10:10 | Foliar NPK 20:10:10 | Poultry Manure | *P*=.05 |
| pH ($H_2O$) | 5.10 | 5.28$^{a}$ | 5.27$^{a}$ | 5.28$^{a}$ | 0.999 | 5.12$^{b}$ | 4.97$^{a}$ | 5.02$^{a}$ | 5.50$^{a}$ | 0.100 |
| pH (KCl) | 4.70 | 4.56$^{a}$ | 4.56$^{a}$ | 4.56$^{a}$ | 1.000 | 4.70$^{a}$ | 4.41$^{a}$ | 4.72$^{a}$ | 4.77$^{a}$ | 0.137 |
| OC, % | 4.60 | 4.73$^{a}$ | 4.65$^{a}$ | 4.76$^{a}$ | 0.493 | 4.50$^{a}$ | 4.54$^{a}$ | 4.60$^{a}$ | 5.22$^{a}$ | 0.000 |
| $N_{tot}$, g/kg | 0.82 | 1.11$^{a}$ | 1.08$^{a}$ | 1.11$^{a}$ | 0.283 | 0.74$^{d}$ | 1.73$^{a}$ | 0.90$^{c}$ | 1.02$^{b}$ | 0.000 |
| C/N | 56.00 | 53.00$^{ab}$ | 53.00$^{a}$ | 52.00$^{b}$ | 0.021 | 57.00$^{a}$ | 53.00$^{b}$ | 51.00$^{c}$ | 49.00$^{a}$ | 0.000 |
| $P_{avail}$, mg/kg | 9.21 | 11.97$^{a}$ | 11.63$^{b}$ | 12.17$^{a}$ | 0.001 | 8.95$^{d}$ | 11.48$^{c}$ | 12.62$^{b}$ | 14.63$^{a}$ | 0.000 |
| Exchangeable cations, meq/100g | | | | | | | | | | |
| Ca | 1.44 | 1.46$^{a}$ | 1.45$^{a}$ | 1.49$^{a}$ | 0.087 | 1.35$^{a}$ | 1.47$^{b}$ | 1.50$^{ab}$ | 1.53$^{a}$ | 0.000 |
| Mg | 1.08 | 1.10$^{b}$ | 1.09$^{b}$ | 1.13$^{a}$ | 0.003 | 1.04$^{c}$ | 1.11$^{b}$ | 1.14$^{a}$ | 1.13$^{ab}$ | 0.000 |
| K | 2.61 | 2.69$^{ab}$ | 2.66$^{b}$ | 2.71$^{a}$ | 0.013 | 2.55$^{a}$ | 2.93$^{a}$ | 2.64$^{b}$ | 2.62$^{b}$ | 0.000 |
| CEC | 16.02 | 16.76$^{a}$ | 16.68$^{a}$ | 16.80$^{a}$ | 0.564 | 15.65$^{d}$ | 18.05$^{a}$ | 17.20$^{b}$ | 16.09$^{c}$ | 0.000 |

OC : Organic Carbon; $N_{tot}$ : Total Nitrogen; $P_{avail}$: Available Phosphorus; CEC: Cation exchange capacity

Table 3. Soil chemical properties as affected by interaction of variety and fertilization in sandy clay soil

| | pH ($H_2O$) | pH (KCl) | OC | $N_{tot}$ | C/N | Ca | Mg | K | CEC | $P_{avail}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Cobra $F_1$ Control | 5.13$^{a}$ | 4.41$^{a}$ | 4.54$^{b}$ | 0.78$^{e}$ | 57$^{a}$ | 1.35$^{d}$ | 1.04$^{e}$ | 2.55$^{de}$ | 15.66$^{de}$ | 8.96$^{f}$ |
| Cobra $F_1$ NPK 20:10:10 | 4.96$^{a}$ | 4.70$^{a}$ | 4.53$^{b}$ | 1.73$^{a}$ | 53$^{bcd}$ | 1.47$^{ab}$ | 1.11$^{bcd}$ | 2.93$^{a}$ | 18.06$^{a}$ | 11.50$^{e}$ |
| Cobra $F_1$ Foliar NPK 20:10:10 | 5.01$^{a}$ | 4.72$^{a}$ | 4.60$^{b}$ | 0.90$^{d}$ | 51$^{def}$ | 1.50$^{ab}$ | 1.14$^{abc}$ | 2.64$^{bc}$ | 17.22$^{b}$ | 12.70$^{cd}$ |
| Cobra $F_1$ Poultry Manure | 5.50$^{a}$ | 4.77$^{a}$ | 5.24$^{a}$ | 1.02$^{bc}$ | 49$^{fg}$ | 1.53$^{ab}$ | 1.13$^{abc}$ | 2.62$^{bc}$ | 16.10$^{cd}$ | 14.70$^{ab}$ |
| Rio grande control | 5.10$^{a}$ | 4.41$^{a}$ | 4.50$^{b}$ | 0.73$^{e}$ | 58$^{a}$ | 1.32$^{d}$ | 1.02$^{e}$ | 2.52$^{e}$ | 15.58$^{e}$ | 8.77$^{f}$ |
| Rio grande NPK 20:10:10 | 4.97$^{a}$ | 4.70$^{a}$ | 4.50$^{b}$ | 1.70$^{a}$ | 54$^{bc}$ | 1.46$^{bc}$ | 1.09$^{cd}$ | 2.90$^{a}$ | 17.99$^{a}$ | 11.20$^{e}$ |
| Rio grande Foliar NPK 20:10:10 | 5.02$^{a}$ | 4.72$^{a}$ | 4.47$^{b}$ | 0.87$^{d}$ | 52$^{cde}$ | 1.49$^{ab}$ | 1.12$^{abc}$ | 2.62$^{bc}$ | 17.11$^{b}$ | 12.27$^{d}$ |
| Rio grande Poultry Manure | 5.50$^{a}$ | 4.77$^{a}$ | 5.14$^{a}$ | 1.00$^{bc}$ | 50$^{efg}$ | 1.51$^{ab}$ | 1.11$^{abc}$ | 2.60$^{bcd}$ | 16.03$^{cd}$ | 14.27$^{b}$ |
| Kiara Control | 5.13$^{a}$ | 4.41$^{a}$ | 4.47$^{b}$ | 0.71$^{e}$ | 56$^{ab}$ | 1.39$^{cd}$ | 1.06$^{de}$ | 2.58$^{cd}$ | 15.72$^{cd}$ | 9.11$^{f}$ |
| Kiara NPK 20:10:10 | 4.97$^{a}$ | 4.70$^{a}$ | 4.57$^{b}$ | 1.75$^{a}$ | 52$^{cde}$ | 1.49$^{ab}$ | 1.13$^{abc}$ | 2.96$^{a}$ | 18.10$^{a}$ | 11.73$^{e}$ |
| Kiara Foliar NPK 20:10:10 | 5.02$^{a}$ | 4.72$^{a}$ | 4.73$^{b}$ | 0.94$^{cd}$ | 50$^{efg}$ | 1.52$^{ab}$ | 1.16$^{a}$ | 2.66$^{b}$ | 17.26$^{b}$ | 12.90$^{c}$ |
| Kiara Poultry Manure | 5.50$^{a}$ | 4.77a | 5.27$^{a}$ | 1.04$^{b}$ | 48$^{g}$ | 1.55$^{a}$ | 1.15$^{ab}$ | 2.63$^{bc}$ | 16.14$^{c}$ | 14.93$^{a}$ |
| | 0.100 | 0.847 | 0.000 | 0.000 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

## Effect of variety and fertilization on tomato growth performance

### Effect of variety and fertilization and their interaction on tomato growth

Variety significantly affected the growth of tomatoes (Table 4). Rio grande had the highest vegetative performance of all the varieties cultivated in the sandy clay soils of Kumba. Plant height was highest in Rio grande (71.2 cm), so was the number of leaves (180), leaf area (37.8 cm$^2$), number of branches (15), and the number of flowers (109), all significantly different from Cobra $F_1$ and Kiara varieties.

Table 4. Effect of variety and fertilization on tomato vegetative parameters

| | Plant height (cm) | Number of leaves | Leaf area (cm$^2$) | Number of branches | Number of flowers |
|---|---|---|---|---|---|
| Variety | | | | | |
| Cobra F1 | 67.5$^b$ | 170$^b$ | 34.5$^b$ | 14$^b$ | 95$^b$ |
| Rio grande | 71.2$^a$ | 180$^a$ | 37.8$^a$ | 15$^a$ | 109$^a$ |
| Kiara | 63.8$^c$ | 161$^c$ | 30.4$^c$ | 12$^c$ | 92$^b$ |
| Significance level | 0.01 | 0.000 | 0.000 | 0.000 | 0.000 |
| Fertilization | | | | | |
| Control | 58.9$^c$ | 142$^d$ | 24.2$^d$ | 9$^c$ | 71$^b$ |
| NPK 20:10:10 | 66.8$^b$ | 171$^c$ | 31.0$^c$ | 14$^b$ | 109$^a$ |
| Foliar NPK 20:10:10 | 70.5$^{ab}$ | 180$^b$ | 37.3$^b$ | 15$^{ab}$ | 105$^a$ |
| Poultry manure | 73.9$^a$ | 198$^a$ | 44.3$^a$ | 16$^a$ | 110$^a$ |
| Significance level | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

Applied fertilization significantly affected Tomato growth parameters (Table 4). Poultry manure had the highest plant height (73.9 cm), number of leaves (198), leaf area (44.3 cm$^2$), number of branches (16), and number of flowers (110), which was significantly different from the other treatments.

Factors interaction showed significantly different effects on tomato growth parameters across treatment combinations (Table 5). Rio grande poultry manure treatment had the highest plant height (77.3 cm), with the lowest in Kiara control treatment (55.7 cm). Most leaves (197) were counted in Rio grande poultry manure treatment, with the fewest leaves seen in the Kiara control treatment (131). Rio grande poultry manure treatment produced the largest leaf area (47.1 cm$^2$), while the Kiara control treatment produced the smallest leaf area. A similar trend was observed for the number of branches and flowers recorded.

Table 5. Interaction effect of variety and fertilization on tomato vegetative parameters

| Treatment | Plant height (cm) | Number of leaves | Leaf area (cm$^2$) | Number of branches | Number of flowers |
|---|---|---|---|---|---|
| Cobra $F_1$ Control | 59.0$^{de}$ | 140$^f$ | 24.6$^{fg}$ | 9$^f$ | 68$^f$ |
| Cobra $F_1$ NPK 20:10:10 | 66.1$^{cd}$ | 171$^{cd}$ | 30.3$^{de}$ | 15$^{bcd}$ | 108$^{bcd}$ |
| Cobra $F_1$ Foliar NPK 20:10:10 | 70.7$^{abc}$ | 180$^{bc}$ | 37.5$^{bc}$ | 15$^{bcd}$ | 100$^d$ |
| Cobra $F_1$ Poultry Manure | 74.3$^{ab}$ | 190$^{ab}$ | 45.9$^a$ | 16$^{abc}$ | 104$^{cd}$ |
| Rio grande Control | 62.1$^{de}$ | 155$^e$ | 27.3$^{ef}$ | 11$^e$ | 80$^e$ |
| Rio grande NPK 20:10:10 | 71.0$^{abc}$ | 179$^{bc}$ | 36.6$^{bc}$ | 16$^{abc}$ | 114$^{abc}$ |
| Rio grande Foliar NPK 20:10:10 | 74.3$^{ab}$ | 190$^{ab}$ | 40.2$^b$ | 17$^{ab}$ | 119$^{ab}$ |
| Rio grande Poultry Manure | 77.3$^a$ | 197$^a$ | 47.1$^a$ | 18$^a$ | 123$^a$ |
| Kiara Control | 55.7$^e$ | 131$^f$ | 20.7$^g$ | 7$^f$ | 64$^f$ |
| Kiara NPK 20:10:10 | 63.3$^{cde}$ | 163$^{de}$ | 26.2$^{ef}$ | 11$^e$ | 105$^{cd}$ |
| Kiara Foliar NPK 20:10:10 | 66.4$^{bcd}$ | 170$^{cd}$ | 34.2$^{cd}$ | 13$^{de}$ | 97$^d$ |
| Kiara Poultry Manure | 70.1$^{abc}$ | 180$^{bc}$ | 40.3$^b$ | 14$^{cd}$ | 102$^d$ |
| Significance level | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

### Effect of variety and fertilization on tomato fruit yield

Tomato fruit varied significantly ($P$ = 0.01) across the varieties. The Cobra $F_1$ variety had the highest fruit yield with 12.34 tha$^{-1}$, followed by Rio Grande with 11.82 tha$^{-1}$ and Kiara with 11.18 tha$^{-1}$ (Figure 2)

Fertilization treatments showed significant differences ($P$ = 0.001) in tomato fruit yield. The Poultry manure treatment produced the highest fruit yield with 13.13 tha$^{-1}$, followed by the foliar NPK 20:10:10 treatment with 12.85 tha$^{-1}$, and NPK 20:10:10 treatment with 12.29 tha$^{-1}$. The Control treatment had the lowest fruit yield with 8.72 tha$^{-1}$ (Figure 3)

Tomato fruit yield experienced a significant ($P$ =0.01) effect of the interaction between variety and fertilization (Figure 4). Cobra $F_1$ poultry manure treatment yielded the highest (13.56 tha$^{-1}$), followed by Cobra $F_1$ foliar NPK 20:10:10 treatment (13.42 tha$^{-1}$) with the least yield from the Kiara Control treatment (8.36 tha$^{-1}$).

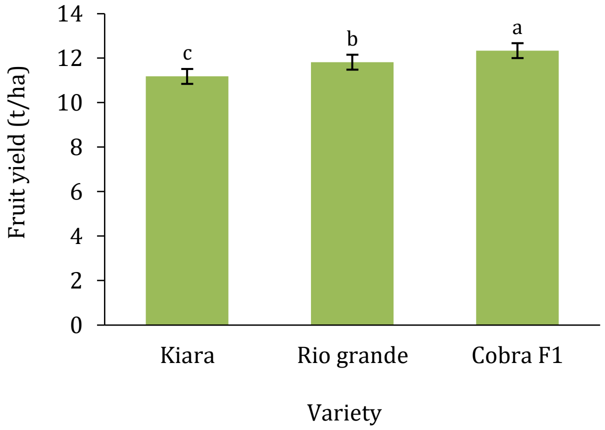


Figure 2. Effect of variety on fruit yield

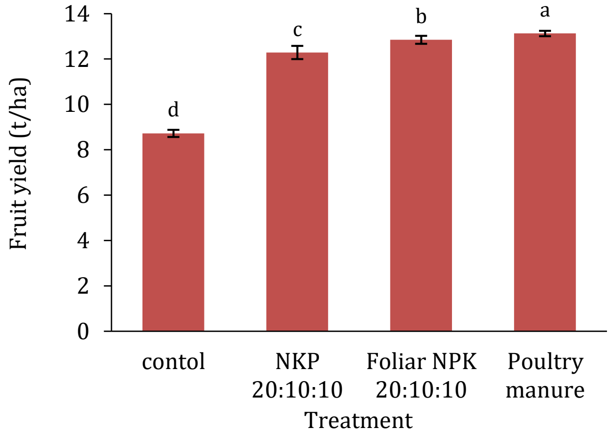


Figure 3. Effect of fertilization on fruit yield

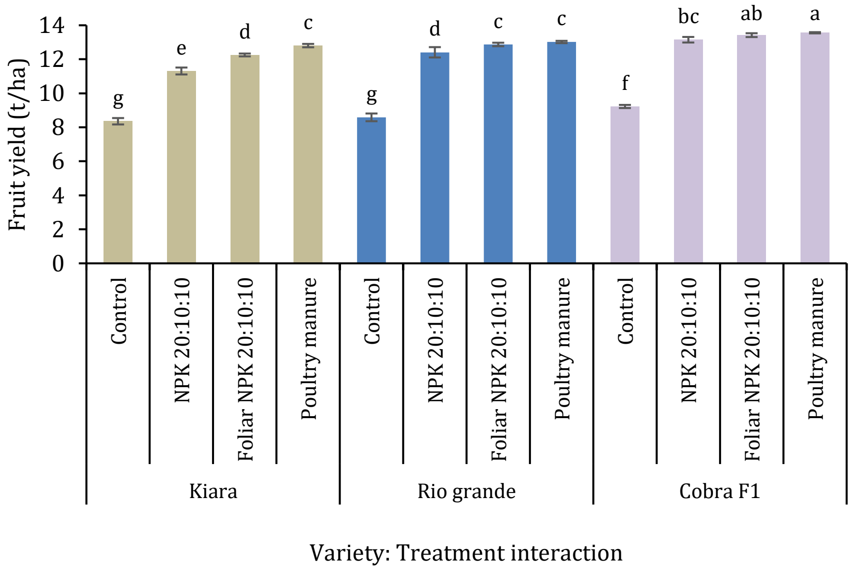


Figure 4. Interaction effect of variety and fertilization on number of tomato fruits

# Discussion

## Response of tomato varieties and fertilization on soil chemical properties

Generally, there was little effect on soil chemical properties by tomato varieties, as shown by the results. This is because the performance of varieties is a function of phenotypic and environmental factors combined with agronomic practices. Thus under the experimental setting, the agronomic and phenotypic factors enhance variety growth while the environmental factor was favored by better management (Healy et al., 2017; Ketema and Beyene, 2021). On the other hand, fertilization significantly affects the soil's chemical properties, with poultry manure showcasing prowess in enhancing soil chemical properties (Hasnain et al., 2020; Alaboz et al., 2022). The poultry manure buffered the soil pH positively, which makes more nutrients available, whereas NPK 20:10:10 further dampens the acidic pH under which nutrients like phosphorus are fixed to the metallic ions and become less available (Brunetti et al., 2019).

Interaction of varieties and fertilizer types showed that poultry manure in combination with variety achieved better results, which falls in line with other studies (Hassnain et al., 2020). This is not only emanating from the rich nature of the poultry manure as the best livestock manure but also because it supplies more energy, carbon source, and suitable pH to the soil, which enables beneficial microorganisms to thrive, leading to the solubilization and fixation of nutrients (Lin et al., 2019). Granular NPK 20:10:10 unveiled the second best result after poultry manure. This is because synthetic fertilizer makes the nutrients available momentarily and may lead to leaching. Also, it negatively affects pH, as disclosed by this study which translates to less nutrient availability due to fixation to metallic ions. Foliar NPK 20:10:10 leads to more nutrient-used efficiency as demonstrated by other studies which is reflected in this research results (Schütz et al., 2018). Control in combination with variety, least affected soil chemical properties, the values obtained were less than those of pre-soil as the was an output of nutrients by varieties without any input (Farjana et al., 2019).

**Performance of tomato in response to variety, fertilization, and their interaction**

The growth parameters were positively affected by the variety and fertilizer factors. Rio grande tomato variety had the best growth, showing that vegetatively, it is more adapted to the Kumba area of Cameroon. Perhaps, due to its ability to better use the nutrient in the sandy clay soils, its genetic makeup may also align with the area's environmental component, leading to more growth performance (Shushay et al., 2013). Cobra $F_1$ variety is known for its outstanding growth performance in the volcanic soils of Buea; thus, being second best in Kumba is not surprising as the two areas are neighbors with some similarities (Ngosong et al., 2018). Kiara variety was the least adaptive and thus is not a good variety to adopt for this area as revealed by this study (Saleem et al., 2013; Healy et al., 2017). Like the varieties, fertilization enhanced tomato performance by supplying adequate nutrients. Control had the least performance as no input means less growth. Poultry manure resulted in the best growth result, followed by foliar NPK 20:10:10, due to the high nutrient content in poultry manure and efficiency of nutrients utilization in foliar NPK 20:10:10 (Mesallam et al., 2017; Fan et al., 2023). Granular NPK 20:10:10 came third, which may have been affected by nutrient volatilization due to high solarisation, leaching due to high rainfall, and other factors (Bilalis et al. ,2018; Naz et al., 2018).

Cobra $F_1$ variety had the best fruit yield compared to the other varieties as a variety and in interaction with fertilization. This is due to low flower abortion compared to the other varieties. Also, different tomato varieties possess genetic variations that influence their fruiting characteristics, such as fruit size and yield potential (Lippman et al., 2007). Thus Cobra $F_1$ variety possessed genetic traits that were more adapted to the environment than the other varieties, this result is supported by Ngosong et al. (2018) who stated Cobra $F_1$ variety as adapted variety in Sahelian and Tropical areas. Poultry manure yielded the best fruit yield compared to the other fertilizations as fertilization and in interaction with the varieties as reveal by this study, which is in line with Shehata (2018). This is due to the nutrient slow release nature of poultry manure, ensuring sufficient nutrients for plant uptake at all stages of growth, unlike synthetic fertilizers, which are fast in nutrient releasing, and the plants can be lacking in nutrients at some stages (Naz et al., 2018; Chatzistathis et al., 2020). Despite the high flower production of the Rio grande variety, less fruit yield was recorded due to the high rate of flower abortion, maybe due to little pollination and shrinking of immature fruits (Agbor et al., 2022b). Kiara had the least fruit yield, which is in line with less growth performance (Healy et al., 2017).

## Conclusion

The result of this study shows that Cobra $F_1$ is the most performing variety given the best yield shown. All the fertilization except control successfully increased the yield of tomato varieties, but poultry manures produced the most desired outcome, considering that it is eco-friendly. Although the inorganic fertilizers increase fruit yield, their adverse effect on the soil, like decreasing soil pH, makes them not sustainable options for crop production, especially for the sandy clay acidic soils of Kumba. Thus for optimal and eco-friendly tomato production in Kumba, the farmers should adopt organic fertilization in combination with the Cobra $F_1$ variety. Rio grande variety has good vegetative growth but experiences a lot of flower abortion, and fruits shrink before maturity, while the Kiara variety is not well adapted to the environment.

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