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ORIGINAL RESEARCH

Growth performance, Calcium, Iron and Vitamin concentrations of two varieties of Kale (*Brassica oleracea var Acephala*) in Awka, Southeast Nigeria

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Abstract

Purpose: Soil nutrient depletion is an endemic factor that constitutes one of the greatest limitations to crop production in the tropics. Identifying high yielding kale varieties that thrive best with the most cost-effective fertilizer type can help meet the nutritional deficits of most families in Africa in line with WHO recommendations. The propose of this study was to determine the effect of fertilizer type and variety on growth, calcium (Ca), iron (Fe), and vitamin concentrations of kale.

Method: Two kale varieties, curly and lacinato, and three fertilizers, 200 kg ha^{-1} NPK 20:10:10 (NPK_{200}), 16 t ha^{-1} poultry manure (PM_{16}), and 100 kg ha^{-1} NPK 20:10:10 + 8 t ha^{-1} poultry manure (NPK_{100}+PM_8) were evaluated in a 2×3 factorial in randomized complete block design (RCBD) with 3 replications. Data collections were based on selected agronomic, vitamins, and minerals parameters.

Results: Fertilizer type, variety and their interaction significantly affected ($p<0.05$) agronomic traits, minerals, and vitamin contents of kale. PM_{16} influenced the most significant increases in plant height, leaf number, Ca, Fe, and vitamin-A concentrations whereas, NPK_{100}+PM_8 treated plants recorded higher leaf area and weight. Curly variety showed superiority in leaf area, leaf weight, Fe, and vitamin-A whereas, lacinato was higher in plant height, leaf number, Ca, vitamin D and E. Lacinato variety on NPK_{200} treatment was highest in Ca, vitamin D and E concentrations while curly variety on PM_{16} was highest in Fe and vitamin A.

Conclusion: PM_{16} and NPK_{100}+PM_8 best improved growth, mineral and vitamin concentrations in kale and were therefore recommended for use.

Keywords: Kale minerals, Vitamins in Kale, Fertilizer type, Varietal effect, Poultry manure

Introduction

Kale (*Brassica oleracea* var. Acephala) is grown as a leafy vegetable belonging to the *Brassicaceae* family with cabbage, cauliflower, broccoli and brussels sprouts (Rodriguez-Mendoza et al. 2021). Unlike cabbage that forms a regular component of household meals in Nigeria, kale is unknown in most parts of the country, limiting its production to only a few locations within the country.

The crop is loved by many because of its high nutritional and medicinal benefits. It is an excellent source of protein (11.67%), energy (58.46 k cal $^{-1}$100 g), fiber (3%) and carbohydrate (2.36%) (Emebu and Anyika 2012), and contains a preponderance of es-

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sential phytochemicals and antioxidants such as folic acids, flavonoids, panthothemic acid, glucosinolates, thiamine, vitamins A-K, carotenoids, and minerals like calcium, iron, magnesium and zinc (USDA 2016). It also plays an indispensable role in secondary metabolism (Reyes-Munguia et al. 2017).

Kale has been used in years past both as prophylactic and curative medicine in management of several health related conditions like obesity, yeast infections, breast engorgement, constipation, and rheumatism (Duma et al. 2014). Reduced risks of cardiovascular and cancerous diseases have also been correlated with high intake of green leafy vegetables (Sindesi et al. 2021).

Cabbage and Kale production in Africa is low accounting for only about 5.5% of global production (FAOSTAT 2020), necessitating a need to improve its production due to its enormous nutritional and health benefits with a view to providing alternative sources of plant derived minerals and vitamins to all.

However, one major limiting factor in Africa and in particular southeast Nigeria is the problem of soil fertility decline. Southeast Nigeria soils are known to be low in soil fertility (Nkwopara et al. 2020), with nitrogen, the most critical element in vegetable crop production (Aguilar et al. 2017), mostly falling below the critical level (Nkwopara et al. 2020). This low soil fertility status has been largely implicated on the leaching of basic cations, and accumulation of acidic radicals as a consequence of the characteristic coarse textured nature of its soils, in addition to the high rainfall amounts of the zone (Nkwopara et al. 2020).

The application of supplemental fertilizer has been used over time to raise the fertility status of the soil to a level that will enhance crop growth. However, literature searches on the growth performance, minerasl and vitamins concentration of kale because of organic and inorganic fertilizer types are non-existent within the region. Knowledge of the fertilizer management that could enhance growth and nutritional value of kale could be vital in combating nutrient deficiency syndromes in line with the WHO (WHO 2009) recommendations. The objective of this study was to investigate the effect of organic, inorganic, and combined fertilizer applications on growth performance, minerals and vitamin concentration of two kale varieties in Awka, tropical rainforest climate.

Studies conducted outside the region have reported significant improvement in growth, phytochemicals, and minerals concentration of the crop with supplemental fertilizer application. Gebre et al. (2018) reported significant increase in plant height, leaf number, leaf area, shoot weight, and beta carotene content of kale in Ethiopia with application of biofertilizer. Peireira et al. (2020) observed a significant improvement in plant height, stem diameter and leaf number of kale with combined application of 180 g bovine manure and 8 g rock powder, while 120 g bovine manure and 12 g rock powder favored the development of larger leaf sizes. In a related study, Rodriguez-Mendoza et al. (2021) found 13% higher leaf number production with soil and foliar application of vermicompost compared to soil and foliar application of mineral fertilizer. Emebu and Anyika (2012) reported comparatively higher levels of calcium in kale leaf than the recommended dietary allowance by FAO and WHO.

Materials and methods

Experimental site

The research was conducted at the Department of Crop Science and Horticulture, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria between July 2019, and July 2020. The University is located between latitude 06°14'N and longitude 07°07'E with average temperature and rainfall of 30°C and 1828 mm per annum, respectively. Awka belongs to the tropical rainforest climate according to the Koppen-Gieger climate classification with predominantly sandy (28 – 98%) and clay (0 – 72%) soil types.

Treatments and experimental design

Treatments were comprised of two factors including, variety and fertilizer type. Two varieties of kale, curly and lacinato, and three fertilizer types, 200 kg ha^{-1} NPK 20:10:10 (NPK_{200}), 16 t ha^{-1} poultry manure (PM_{16}), and 100 kg ha^{-1} NPK 20:10:10 + 8 t ha^{-1} poultry manure (NPK_{100}+PM_8) were designed as a 2 × 3 factorial to give six treatment combinations. Seeds were sown under shade in seed trays containing a medium of topsoil, poultry manure and river sand in a 3:2:1 ratio for 3 weeks. Vigorous and uniform seedlings were then transplanted to the field on raised beds at a spacing of 0.5 × 0.5 m within each plot of size 3 m^2. The experimental design was a 2 × 3 factorial in randomized complete block design with three replications. The application of Fertilizers was 8 days after transplanting (DAT) and plots were kept away from pests using a combination of physical net and neem extract solution. Manual weeding with hoe was done to protect plots from weeds.

Analysis of soil and poultry manure

Soil particle size distribution, pH, organic matter, organic carbon, total nitrogen, exchangeable bases, exchangeable acidity and available phosphorus were determined following the standard procedures used by (Ihejiofor et al. 2020) as follows:

Determination of particle size distribution of soil

Particle size distribution was determined using Bouyoucus hydrometer method (Bouyoucos 1962). 50 g of the air-dry sieved soil was weighed into a dispersion cup, 20 ml of 5% sodium hexametaphosphate (calgon) and 200 ml of distilled water were added and the suspension was stirred for 5 minutes with a mechanical stirrer. The suspension was later transferred from the cup into the glass cylinder and made into the 1000 ml of distilled water. The top of the cylinder was covered with the hand and the suspension shaken from end to end 50 times. The cylinder was set down and after 40 seconds, the first reading on the hydrometer was taken. The temperature was also recorded. The second reading was taken after two hours. The percentages of sand, silt and clay were determined.

First hydrometer reading = concentration of silt + clay particles

Second hydrometer reading = concentration of clay particles

Temperature correction at 1 minute and 2 hours $= 0.3(T-20)°C = X_g\,L^{-1}$

$$\%\ \text{silt} + \%\ \text{clay} = (\text{Temperature correction factor} + \text{Conc. of silt and clay})/(50\ g)\ \times\ 100/1$$

$$\%\ \text{sand} = \frac{\text{weight of oven dry sand (g)}}{50\ g}\ \text{x}\ \frac{100}{1}$$

% sand + % silt + % clay = 100

The textural class of the soil was determined using the USDA textural triangle (NSSC 1995).

Soil pH determination

Soil pH was determined using the procedure of Black (1965). 10 g of air-dried soil (< 2 mm fraction) was weighed into 50 ml beaker while 10ml distilled water was added to form 1:1 ratio. The shaker was used to stir the mixture for 10 minutes. The electrode was inserted into the suspension and the reading was taken after the pH had been standardized.

Determination of exchangeable bases

Two grams of air-dried soil was included to 50 ml beaker. 20 ml of Neutral normal Ammonium acetate in **(**NH_4OAC**)** pH was added and shaken on the mechanical stirrer for 10 minutes and later filtered with filter paper. The filtrate was taken to the flame photometer to determine K and Na (Ford 1954); while Ca and Mg were determined using Atomic Absorption Spectrophotometer (AAS).

The calculation of exchangeable bases were as follows:

mg kg^{-1} in solution = R × gf

Where,

R is reading on flame photometer or absorption spectrophotometer; gf is graph factor; mg kg^{-1} in soil is mg kg^{-1} in solution × Ef × Df. Where,

Ef is Extraction Factor = $\frac{\text{Volume of final extractant}}{\text{Volume of extractant}}$

Exchangeable base (meq 100^{-1} g of soil) = mg kg^{-1} in soil x 10

Total exchangeable bases (TEB) = meq of Ca + Mg + Na + K

Determination of organic Carbon (OC)

Organic carbon was determined using the Walkey and Black procedure (Walkey and Black 1934). 0.5 g of air-dried soil was weighed into a 500 ml conical flask. 10 ml of 1.00 $NK_2Cr_20_7$ was added to the flask from a burette and mixed by swirling. 20 ml of concentrated H_2SO_4 was added and mixed vigorously for 1 minute and then allowed to stand for 30 minutes. The solution was diluted using 200 ml of distilled water, 3 drops of orthophennotroline indicator was then added. Blank solution was prepared following the same procedure but without the sample. The two solutions were titrated to a fine red end point with 0.5 N ferrous ammonium sulphate.

Equation of reaction:

$$2Cr_2O_7 + 3C + 16H^+ \longrightarrow HCr^{3+} + 3CO_2 + H_2O$$

% OC was calculated using: $Y = \frac{\text{Volume of } K_2Cr_2O_7}{\text{Blank value}} \times \frac{0.03 \times 100 \times 1.33}{\text{Weight of sample}}$

% OC = (Blank titre – Sample titre)

Organic matter of the soil was obtained from OC by multiplying with the conventional 'Van Bemmelar factor' of 1.724.

Determination of available Phosphorus

Available P was determined using Bray P-1 procedure (Bray and Kurtz 1945). 2.0 g of sample was weighed into each cup, 20 ml of Mehlich solution (extractant) was added and the suspension shaken for 10 minutes. The soil was filtered. 5 ml of the clear supernatant was pipetted into a 50 ml volumetric flask and 30 ml Reagent 'B' prepared by dissolving 1.50 g of ascorbic acid in 200 ml of Reagent 'A' which is a mixture of 12 g ammonium molydate in 250 ml distilled water and 0.29 g antimony phosphorus tartrate plus 1000 ml of 5N H_2SO_4. It was done until the blue color developed. The available phosphorus was determined with the aid of supertonic 70 on wavelength of 882 nm spectrophotometer.

Determination of Nitrogen (N)

Nitrogen was determined following Kirk (1950). 0.5 g of air-dried soil sample was weighed into a dry macro kjedahl flask, one selenium tablet was added, 10 ml of concentrated sulfuric acid was also added, and the samples were heated on the digestion stand for 5 hours until digestion was complete. Chemical decomposition of the sample was complete when the initially very dark colored medium had become clear and colorless. The samples were removed from the digestion stand and then left to cool. The digest was made up to 50 ml and then put into sample cups. Distillation: 5 ml of boric acid was weighed into Erlenmeyer flask and placed under the end of the condenser of the distillation apparatus. 5 ml of the digest solution was then distilled with 5 ml of sodium hydroxide in the distillation flask by opening the funnel stop-cork. The condenser was kept cool by allowing sufficient cold water to flow through and regulate heat to minimize frothing and prevent suck-back. The ammonium salt which converted to ammonia giving a green colored solution (distillate) was collected for each sample that was distilled.

Titration: 50 ml of distillate was titrated with 0.01M HCl. The ammonia reacted with acid. There was a colour change from green to pink. A blank sample was also provided using the same procedure but without soil sample.

Computation of nitrogen (%N) was as: % N = $\frac{(T-B) \times 14.01 \times 0.01N \times 100 \times 10}{\text{Weight of soil sample} \times 10000}$

Data collection

Data were collected on plant height, leaf number (Plate 1), leaf area, fresh leaf weight, calcium, iron, and vitamins A, B_3, C, D and E. Plant height and leaf number were determined following standard procedures according to (Ihejiofor et al. 2020, 2022). Leaf area was determined from 3-5 fully expanded leaves using Ll-3100 leaf area meter. Fresh leaf weight (FLW) was determined using TS200 electronic compact scale. Freshly harvested leaves were sorted, washed with clean water to remove dirt and other contaminants, rinsed with clean water, packaged in clean white polythene nylon, labeled, and taken to the laboratory for analysis. The leaves were crushed in a ceramics mortar to homogenize the sample and fresh sample were analyzed.

Determination of vitamins

Vitamin A, B_3, D and E were determined by calorimetric method according to the procedures used by (Okonwu et al. 2018a, 2018b). Vitamin C was determined by the titrimetric method following the procedures adopted by (Okwu 2004).

Statistical analysis

Data were assessed for significance using analysis of variance and significant means were separated using Duncan's multiple range test with the aid of Genstat discovery 10.3 DE. Graphs and charts were constructed using Graphpad prism 6.

Plate 1. Schematic representation of the growth stages of Kale Production

Results and discussion

Physicochemical properties of soil and poultry manure

The result of the particle size distribution of sample soil shows that the textural class of the soil is sandy loam (Fig. 1). Result of the chemical soil and poultry manure analysis is shown in Table 1. The soil pH and poultry manure were slightly acidic. Soil organic matter, organic carbon, total N, P and K were low, with N falling below the critical value (2.75%). In contrast, poultry manure contains high amounts of organic matter, organic carbon, Total N, P and K.

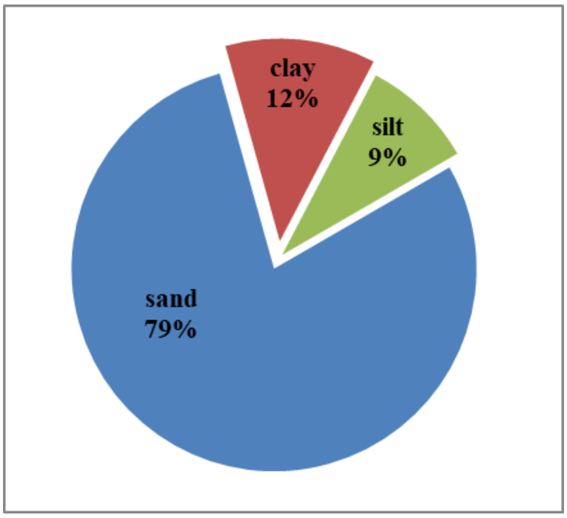

Fig. 1 Particle size distribution of soil

Table 1. Chemical properties of soil and poultry manure

Properties	Soil	PM
pH in H_2O	6.56	6.30
%Organic carbon	0.78	26.60
%Organic matter	1.34	45.75
%Total Nitrogen	0.07	3.89
Available P (mg kg^{-1})	3.63	2140.05
Exchangeable Bases (cmol kg^{-1})		
Sodium (Na)	0.14	0.63
Potassium (K)	0.18	0.80
Calcium (Ca)	2.40	125.00
Magnesium (Mg)	1.60	55.00

PM = poultry manure

Particle size distribution (PSD) is an important soil parameter affecting root growth and development since plants tend to grow well in well aerated and well-drained soil, with good water holding capacity and aggregate stability (Maselesele et al. 2022). The PSD of the soil showed that the soil textural class was sandy loam and suitable for kale production (Fig. 1). Pre-planting soil chemical analysis revealed very low amounts of organic matter, percent N, P and K. Soil nitrogen in particular was below the critical level which agrees with (Ihejiofor et al. 2020), however, the low nutrient status of the soil was adequately compensated for by the corresponding higher levels in the poultry manure (Table 1).

Main effect of fertilizer and variety on growth performance of Kale at 6 WAP

There was no significant effect ($p>0.05$) of fertilizer type on plant height and leaf number of kale (Fig. 2). However, leaf area and fresh leaf weight showed significant difference ($p<0.05$) (Fig. 3). Larger leaf area (248 cm^2) and weightier leaves (94 kg ha^{-1}) were recorded in plants that received a combination of poultry manure and NPK, followed by plants receiving only poultry manure.

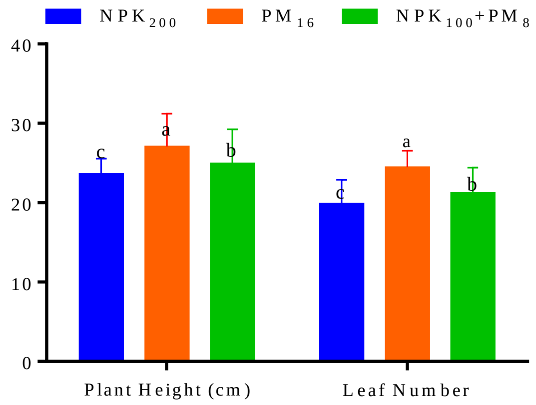

Fig. 2 Main effect of fertilizer on plant height and leaf number of Kale at 6 WAP

Columns are mean values and bars represent standard deviations. Bars with different alphabets are significantly different at $p<0.05$

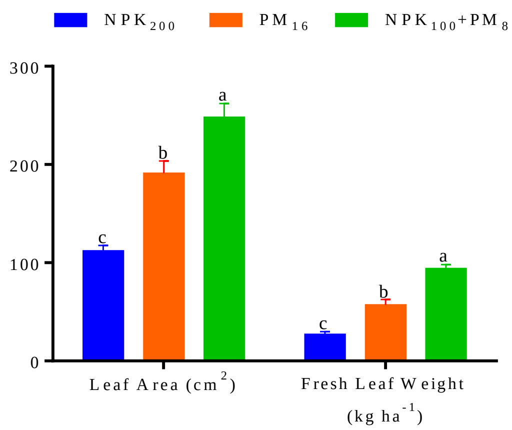

Fig. 3 Main effect of fertilizer on leaf area and fresh leaf weight of Kale at 6 WAP

Columns are mean values and bars represent standard deviations. Bars with different alphabets are significantly different at $p<0.05$

Plants receiving only NPK produced the least leaf area (112 cm^2) and leaf weight (27 kg ha^{-1}). Variety significantly affected plant height, leaf number and FLW (Fig.4). Lacinato variety produced the tallest plant (29.87 cm) and the highest leaf number (24.60). However, it was curly variety that produced the highest FLW (90.00). Variety did not affect the leaf area of kale.

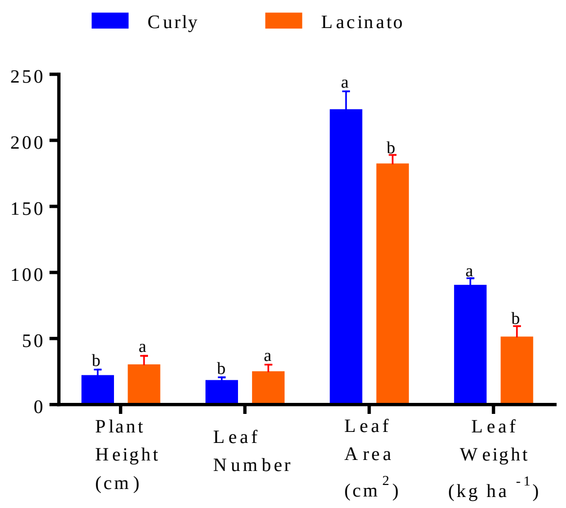

Fig. 4 Effect of variety on growth and leaf yield of kale

Columns are mean values while bars represent standard deviation. Bars with different alphabets are significantly different at $p<0.05$

Plant height, leaf number, leaf area and leaf weight are important phenotypic traits applied to discriminate between contrasting genotypes and environmental responses of plants. The effect of fertilizer type on plant height and leaf number followed a definite pattern. PM_{16} affected the tallest plant and the highest leaf number than $NPK_{100}+PM_8$ and NPK treatments (Fig. 2) which could be explained by the higher concentrations of N, P, and Ca in the poultry manure which could have resulted in better light absorption, faster root development and cell elongation in addition to the vital role of organic matter in improving soil physical conditions. Gebre et al. (2018) also reported significant increase in plant height and leaf number with application of biofertilizer in Ethiopia while Rodriguez-Mendoza et al. (2021) reported 13% increase in leaf number with supplemental application of vermicompost as against mineral fertilizer. Leaf area and FLW were significantly higher ($p<0.05$) in $NPK_{100}+PM_8$ than either of PM_{16} or NPK_{200} (Fig. 3).This trend might be attributed to the enhanced N concentration provided by the mix of poultry manure and NPK which influenced vigorous vegetative growth in contrast to sole applications. This finding is in agreement with Yeshiwas (2017) who reported increase in leaf length and width with application of N-fertilizer, and Mebrahtu and Solomon (2018) who found higher leaf number in plants that received combined application of 112.5 kg urea + 0.875 t of farm yard manure.

The effect of variety on growth performance of kale showed a sharp contrast between curly and lacinato variety. Plant height and leaf number were higher in lacinato than in curly. However, it was curly variety that recorded the largest leaf area and weightiest leaves (Fig. 4). The variation in growth performance of the two kale varieties suggests considerable genetic distance between them as a function of different ancestry. Similar findings have previously been reported in cassava by Ukwu and Olasanmi (2018).

Interaction effect of fertilizer and variety on growth performance of Kale at 6 WAP

There was no interaction between fertilizer and variety on growth and leaf yield of kale. Both curly and lacinato varieties responded in an equivalent way to the different fertilizer types. Interaction of PM_{16} and lacinato gave insignificantly the tallest plant (32.48 cm) and highest leaf number (27.80) (Fig. 5) but did not translate into the largest leaf sizes or weightiest leaves which was recorded by the interaction of $NPK_{100}+PM_8$ and curly variety with 285.45 cm^2 and 113.52 kg ha^{-1}, respectively (Fig. 6). The non-significant interaction effect of fertilizer type and variety as shown in Figs.5 and 6 indicated that the responses of the varieties were similar across the different fertilizer types which inferred stability. Varietal stability across environments is an indispensable parameter in plant breeding that guarantees against crop failure when a genotype is grown in contrasting environment.

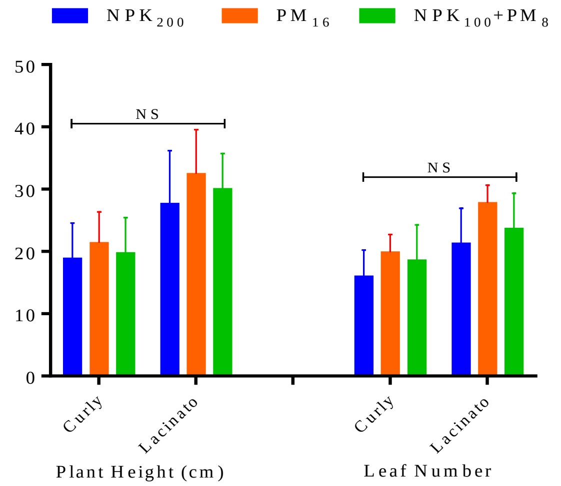

Fig. 5 Interaction effect fertilizer and variety on plant height and leaf number of Kale

Columns are mean values while bars represent standard deviation. NS = no significant difference

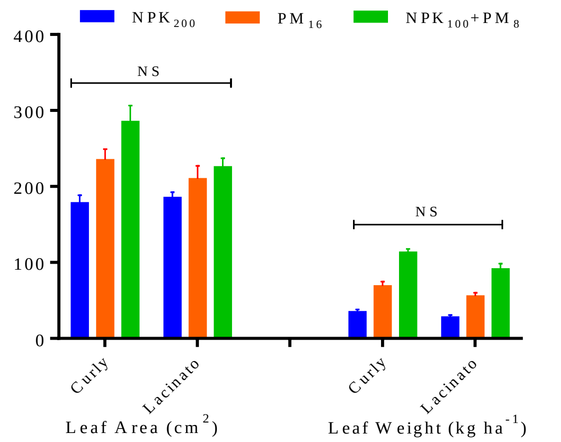

Fig. 6 Interaction effect fertilizer and variety on leaf area and fresh leaf weight of Kale

Columns are mean values while bars represent standard deviation. NS = no significant difference

Main effect of fertilizer and variety on calcium, iron and vitamin concentration of Kale

Fertilizer type significantly affected ($p<0.05$) calcium, iron, and vitamins A, D and E concentrations of kale but did not affect vitamin B_3 and C concentrations (Table 2). PM_{16} resulted in the highest calcium (8.60), iron (0.52) and vitamin A (8.94) content of kale. Crops receiving combined NPK_{100}+PM_8 recorded similar vitamin A (8.84) with crops on PM_{16} treatment. Combined NPK_{100}+PM_8 recorded the least calcium (3.07) content while crops on the NPK_{16} treatment recorded the lowest amount in iron (0.18) and vitamin A (6.10). Vitamins D (21.37) and E (351.4) were indicated the highest level in crops receiving NPK_{16} in contrast to those receiving combined NPK_{100}+PM_8 which showed reduced amounts of vitamins D (9.84) and E (77.42). Iron and vitamin A were higher in curly variety (0.31 and 8.15, respectively) while calcium and vitamins D and E were higher in lacinato variety (7.35, 17.68 and 254.91 respectively). There was no significant difference ($p>0.05$) in vitamins B_3 and C concentration of both varieties.

Interaction effect of fertilizer type and variety on calcium, iron and vitamin concentration of Kale

The responses of curly and lacinato varieties to different fertilizer types are shown in Table 3. Significantly higher ($p<0.05$) levels of calcium (9.86), vitamin D (32.40) and vitamin E (609.89) were reported in curly crops receiving NPK_{200} than the rest whereas, it was curly crops on PM_{16} that recorded the highest iron (0.58) and vitamin A (10.54) concentrations. The responses of both varieties across fertilizer types were similar for vitamins B_3 and C.

The significant increase in Ca and Fe concentrations of kale as a function of PM_{16} relative to NPK_{100}+PM_8 and NPK_{200} could be implicated on high calcium amount of the poultry manure used which released adequate quantities for plant uptake through the roots. The amount of Ca in PM_{16} treated plants (8.60 mg kg^{-1}) was higher than what was earlier reported (0.41 mg kg^{-1}) by Emebu and Anyika (2012), but Fe (0.52 mg kg^{-1}) was lower (0.89 mg kg^{-1}), respectively. Ca and Fe are important minerals for health and wellbeing (Agogbua et al. 2022). Ca is an essential component in the formation of bones and teeth while Fe plays vital roles in oxygen circulation within the body, normal brain functioning and building a formidable immune system. The substantive high concentration of Ca in kale could be of therapeutic benefit especially in patients suffering from osteoporosis (Emebu and Anyika 2012). Variation in vitamins concentration of kale as a function of fertilizer types was significant ($p<0.05$) (Table 2).

PM_{16} and NPK_{100}+PM_8 comparably increased vitamin A concentration relative to NPK_{200}. However, it was NPK_{200} that influenced the highest concentration of vitamin D and E. Vitamin B3 and C were unaffected by fertilizer type or variety.

Table 2. Main effect of fertilizer and variety on calcium, iron and vitamin concentration of Kale

Treatment	Minerals (mg kg^{-1})		Vitamins (mg kg^{-1})				
	Calcium	Iron	A	B_3	C	D	E
Fertilizer							
NPK	8.27±0.71b	0.18±0.35c	6.01±1.06b	0.03±0.07a	2182.40±212.1a	21.37±2.12a	351.40±14.12a
PM	8.60±0.71a	0.52±0.35a	8.84±1.06a	0.03±0.07a	2190.20±212.1a	11.68±2.12b	126.96±14.12b
Combined	3.07±0.71c	0.19±0.35b	8.94±1.06a	0.03±0.07a	2183.30±212.1a	9.84±2.12c	77.42±14.12c
Variety							
Curly	5.94±0.58b	0.31±0.03a	8.15±0.87a	0.03±0.006a	2180.40±173.2a	10.94±1.73b	115.61±11.55b
Lacinato	7.35±0.58a	0.29±0.03b	7.71±0.87b	0.03±0.006a	2184.20±173.2a	17.68±1.73a	254.91±11.55a

Three fertilizer types (NPK = 400 kg ha-1 of NPK 20:10:10; PM = 8 t ha-1 of poultry manure; Combined = 200 kg ha-1 of NPK 20:10:10 + 4 t ha^{-1} of poultry manure). Means and standard errors are shown. Means with different alphabets in corresponding columns are significantly different at $p<0.05$

Table 3. Interaction effect of fertilizer types and variety on calcium, iron and vitamin concentration of Kale

Treatments		Minerals (mg kg^{-1})		Vitamins (mg kg^{-1})				
Fertilizer	Variety	Calcium	Iron	A	B3	C	D	E
NPK	Curly	6.69±1.0d	0.33±0.49e	5.14±1.5f	0.03±0.01a	2190.10±300a	10.34±3.0d	92.91±20c
NPK	Lacinato	9.86±1.0a	0.04±0.49d	6.88±1.5e	0.03±0.01a	2174.80±300a	32.40±3.0a	609.89±20a
PM	Curly	9.85±1.0b	0.58±0.49a	10.54±1.5a	0.03±0.01a	2187.90±300a	14.02±3.0b	191.43±20b
PM	Lacinato	7.34±1.0c	0.45±0.49b	7.14±1.5d	0.04±0.01a	2192.40±300a	9.34±3.0e	62.50±20d
Combined	Curly	1.27±1.0f	0.01±0.49f	8.76±1.5c	0.03±0.01a	2181.10±300a	8.45±3.0f	62.50±20d
Combined	Lacinato	4.85±1.0e	0.38±0.49c	9.11±1.5b	0.03±0.01a	2185.60±300a	11.23±3.0c	92.35±20c

Three fertilizer types (NPK = 400 kg ha-1 of NPK 20:10:10; PM = 8 t ha-1 of poultry manure; Combined = 200 kg ha-1 of NPK 20:10:10 + 4 t ha^{-1} of poultry manure). Means and standard errors are shown. Means with different alphabets in corresponding columns are significantly different at $p<0.05$

The relatively high amount of vitamin A in kale could be a viable alternative to combating vitamin A deficiency in Nigeria by encouraging incorporation of kale in Nigerians diet, which corroborated the report of Aniedu and Omodamiro (2012). Vitamin D is essential for the development of strong bones and teeth while vitamin E is an integral part of the cell antioxidant defense mechanism, playing an important role in preventing disease conditions such as cataracts, cancer, arthritis and aging (Rizvi et al. 2014). Curly and lacinato varieties varied in minerals and vitamins concentration. Curly variety showed superiority for Fe and vitamin A while lacinato was superior in Ca, and vitamins D and E. This variation could be implicated on premise that the varieties are distant relatives, hence, genetically variable (Ukwu and Olasanmi 2018). The interaction between fertilizer type and variety revealed that lacinato variety on NPK_{200} treatment was highest in Ca, and vitamin D and E concentrations while curly variety on PM_{16} was highest in Fe and vitamin A, thus suggesting that the two varieties have different fertilizer preferences for specific traits.

Conclusion

This study was able to ascertain that fertilizer type, variety and interaction of fertilizer and variety affected growth performance, leaf weight, minerals, and vitamin concentrations of kale vegetables. PM_{16} treated plants recorded the tallest plants, highest leaf number, Ca, Fe, and vitamin A concentrations. NPK_{100}+PM_8 treated plants recorded the largest leaf area and leaf weight while plants on NPK_{200} were superior in vitamins D and E. Curly variety showed superiority in leaf area, leaf weight, Fe and vitamin A whereas lacinato was higher in plant height, leaf number, Ca, vitamin D and E. Vitamins B_3 and C concentrations were unaffected by fertilizer or variety. The interaction effect of fertilizer type and variety revealed that lacinato variety on NPK_{200} treatment was highest in Ca, and vitamin D and E concentration while curly variety on PM_{16} was highest in Fe and vitamin A. The confirmation of substantive amounts of Ca and Fe minerals, and vitamins A, B_3, C, D and E in kale give credence to earlier reports on its capacity to combat diverse health related diseases such as obesity, yeast infections, breast engorgement, constipation, rheumatism cancer, cataracts, osteoporosis, arthritis, and night blindness through a buffered immune system. The variation in the nutritional composition of the two varieties is a call for improvement through hybridization or gene introgression.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

References

Agogbua JU, Okonwu K, Akonye LA, Mensah SI (2022) Studies on nutrient and mineral contents of fluted pumpkin grown in NPK solution. European J Agric Food Sci 4(2):52-57. https://doi.org/10.24018/ejfood.2022.4.2.470

Aguilar AS, Silva AC, Oliveira RC, Silva JER, Luz JMQ, Luz LHS (2017) Uso de fertilizantes e reguladores de crescimento na produção de mudas de brócolis.Pesq. Agropec. Pern. (22):1-4. https://doi.org/10.12661/PAP.2017.012

Aniedu C, Omodamiro RM (2012) Use of newly bred β-carotene cassava in production of value- added products: Implication for food security in Nigeria. Global J Sci Frontier Res Agri Vet Sci 12(10):1-7

Black CA (1965) Methods of soil analysis. American Society of Agronomy: Madison, Wisconsin, USA. 1572 p

Bouyoucos GJ (1962) Hydrometer method improved for making particle size analysis of soils. Agronomy J 54 (5):464-465

Bray RH, Kurtz LT (1945) Determination of total, organic, and available forms of phosphorus in soils. Soil Science 59:39-45

Duma M, Alsina J, Zeipina S, Lepse L, Duboua L (2014) Leaf vegetables as source of phytochemicals. Proceedings of the 9th Baltic Conference on Food Science and Technology, FOODBALT 2014, pp 262–265

Emebu PK, Anyika JU (2012) Proximate and mineral concentration of kale (*Brassica oleracea*) grown in Delta State Nigeria. Pakistan J Nutr 10(2):190-194. https://doi.org/10.3923/pjn.2011.190.194

FAOSTAT (2020) Food and Agriculture Organization Statistical Database. https://www.fao.org/faostat/en/#home. Accessed August 2022

Ford CL (1954) Flame photometric determination of sodium and potassium. Analytical Chemistry 26 (10):1578-1581. https://doi.org/10.1021/ac60094a013

Gebre E, Degefu T, Wolde-Meskel E, Lelago A, Davis J (2018) Response of Kale (*Brassica Oleracea* L) crop to cyanobacterial biofertilizer in Ziway area, Ethiopia. J Biol Agri Healthcare 8(13):40-45

Ihejiofor PN, Ukwu UN, Adeoye GO (2020) Comparative effects of different levels of kolgrace organic fertilizer on growth and yield of green gram (*Vigna radiata* (L) wilczek) in the screen house. Asian J Res Agric For 6(3):1-7. https://doi.org/10.9734/AJRAF/2020/v6i330104

Ihejiofor PN, Ukwu UN, Adeoye G (2022) Determination of Kolgrace bio-fertilizer rate for optimum greengram (*Vigna radiata* L. Wilczek) production in Ibadan, Southwest Nigeria. Agro-Science 21(1):82-8. https://doi.org/10.4314/as.v21i1.13

Kirk PL (1950) Kjeldahl method for total nitrogen. Analytical Chemistry 22(2):354-358. https://doi.org/10.1021/ac60038a038

Maselesele D, Ogola JBO, Murovhi RN (2022) Nutrient uptake and yield of Chinese cabbage (*Brassica rapa* L. *Chinensis*) increased with application of macadamia husk compost. Horticulturae 8:196. https://doi.org/10.3390/horticulturae8030196

Mebrahtu M, Solomon M (2018) The combined effect of organic and inorganic fertilizer on yield and yield component of cabbage (*Brassica oleracea*) at Dedebit Central Tigray, Ethiopia. J Plant Sci Crop Protection 1(2):1-6

NSSC: National Soil Service Centre (1995) Soil survey information manual; Soil Survey Report 45(1): 305

Nkwopara UN, Osita AF, Nzube ET, Onwudike SU, Inem EE (2020) Fertility status of soils under selected land use types in Orlu, Imo State, South Eastern Nigeria. Academic J 12(1):1-9. https://doi.org/10.5897/JSSEM2020.0835

Okonwu K, Akonye LA, Mensah SI (2018a) Comparative studies on bioactive components of fluted pumpkin, *Telfairia occidentalis* Hook F. grown in three selected solid media. J Exp Agric Int 20(2):1–10. http://dx.doi.org/10.9734/JEAI/2018/38334

Okonwu K, Akonye LA, Mensah SI (2018b) Nutritional composition of *Telfairia occidentalis* leaf grown in hydroponic and geoponic media. J Appl Sci Environ Mgt 22(2):153-159. https://doi.org/10.4314/JASEM.V22I2.18

Okwu DE (2004) Phytochemicals and vitamin content of indigenous spices of South-Eastern Nigeria. J Sustain Agric Environ 6(1):30-37

Peireira MB, Dias TJ, Lima NR, Justino ES, Oliveira DS, Martins-Veras ML (2020) Plant growth and yield of butter kale (*Brassica olerácea* L. var. acephala), as influenced by the combined application of bovine manure and rock powder. Acta Agronómica 69(1):38-45. https://doi.org/10.15446/acag.v69n1.75174

Reyes-Munguia A, Rosas-Trejo L, Camos-Montiel R, Quintero-Lira A, Carrillo-Inungaray ML (2017) Propiedades antioxidantis del extracto acuoso de Brassica oleracea var. Sabellica. Revista de Ciencias Ambientales y Recursos. Naturales 3 (8):30-34

Rizvi S, Raza ST, Ahmed F, Ahmad A, Abbas S, Mahdi F (2014) The role of vitamin e in human health and some diseases. Sultan Qaboos University Medical. J 14(2):157-165

Rodriguez-Mendoza MN, Mora-Bautista MA, Garcia-Cue JL, Sanchez-Escudero J, Etchevers-Barra JD (2021) Field production of kale (*Brassica oleracea* var Acephala) with different nutrition sources. Agro productividad. https://doi.org/10.32854/agrop.v14i10.1954

Sindesi OA, Lewu MN, Ncube B, Mulidzi R, Lewu F(2021) Mineral concentration of potted cabbage (*Brassica oleracea* var. *capitata* L.) grown in zeolite amended sandy soil. Agriculture (Poľnohospodárstvo) 67(3):103-112. https://org/10.2478/agri-2021-0010

Ukwu NU, Olasanmi B (2018) Crossability among five Cassava (*Manihot esculenta* Crantz) Varieties. Modern Concepts and Development in Agronomy 2(4):1-6. https://doi.org/10.31031/mcda.2018.02.000543

USDA (2016) United State Department of Agriculture and National Database for standard reference. https://data.nal.usda.gov/dataset/usda-national-nutrient-database-standard-reference-legacy-release. Accessed August, 2022

Walkey A, Black IA (1934) An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science 37:29-38. https://doi.org/10.1097/00010694-193401000-00003

WHO (2009) Vitamin and Mineral Nutrition Information System (VMNIS). Micronutrients database. http://www.who.int/vmnis/database/en/. Accessed July 2022

Yeshiwas Y (2017) Effect of different rates if nitrogen fertilizer on the growth and yield of cabbage (*Brassica oleracea*) at Debre Markos, North West Ethiopia. Afri J Plant Sci 11(7):276-289. https://doi.org/10.5897/AJPS2015.1330