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Research Article

Effects of Colchicine-Induced Polyploidy on the Nutritional Composition of Selected Okra (*Abelmoschus esculentus*) Varieties

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ABSTRACT
Okra is a nutritionally important vegetable. There is limited information on the effect of colchicine on the nutritional composition of okra varieties. This study aimed to determine the varying concentration of colchicine on the nutritional composition of selected *okra (Abelmoschus esculentus) varieties' capsules*. Materials and Methods: Okra seeds were treated with five different concentrations of colchicine (0.0, 0.1, 0.5, 1.0, and 2.0mM) for five hours. Seeds were washed and air dried for 24 hours, and then sown in a Completely Randomised Design with three replications in polythene bags and then raised to the maturity stage. Fresh okra capsules of each variety were harvested from varying concentrations of colchicine, and they were processed into fine powder. Mineral elements and proximate composition were determined using standard procedures. Data were analysed using Analysis of Variance (ANOVA), and Duncan's Multiple Range Test was applied to separate the means. Results: Colchicine (0.1mM) treatment significantly ($p \leq 0.05$) increased mineral elements of capsules (P:20527.67mg/kg, Ca: 4632.81mg/kg, Mg: 2996.72mg/kg, Na: 5733.33 mg/kg and Fe: 847.27 mg/kg) and proximate composition except carbohydrate. Clemson Spinless recorded the highest Mg (12,680.39 mg/kg), Na (10,881.33 mg/kg), Zn (27.43 mg/kg), crude protein (24.51%) and carbohydrate (44.83%). Yar'Balla had the highest P content (3,376.56 mg/kg), Ash content (7.55%) and Crude fibre (19.38%). While Yar'Sumaila recorded the highest Ca (4,260.90 mg/kg), K (32,307.33 mg/kg), Fe (964.80 mg/kg), moisture (3.72%), and crude lipid content (8.20%). Conclusion: The study demonstrated that colchicine-induced variation can improve mineral (P, Ca, Mg, Na, and Fe) and all proximate parameters except carbohydrate.

Keywords: Capsule; Colchicine; Mineral; Mutation breeding; Okra; Proximate content

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INTRODUCTION

Okra (*Abelmoschus esculentus* [L.] (Moench) (2n=58)) is a vegetable crop that belongs to the family Malvaceae and the genus Abelmoschus. Commonly known as Ladies' finger or Gumbo in the United States, while in Nigeria, it is called 'Kubewa,' 'Ila,' and 'Olewele' in Hausa, Yoruba, and Igbo, respectively. It is widely cultivated in tropical and subtropical parts of the world in both rain-fed and irrigated areas (Singh & Pandey, 2024). The whole part of the okra plant, such as fresh leaves, buds, flowers, pods, stems, and seeds, has significant value (Swamy, 2023). Okra is regarded as a powerhouse of essential minerals (such as calcium, iron, potassium, zinc, and magnesium), vitamins (such as A, B, C, D, and K), proteins, carbohydrates, fats, unsaturated fatty acids, and alpha-tocopherol, which are vital for human health (Romdhane *et al.,* 2020). It is the third most cultivated vegetable in Nigeria after pepper and tomato, in terms of area and consumption (Tijani & Kehinde, 2022).

In recent years, okra has garnered increasing recognition and acceptance as a global crop, attributed to the growing appreciation for its nutritional benefits among consumers (Iliasu *et al.,* 2025). Food insecurity and nutrient deficiencies remain major public health concerns in Nigeria, driven by population growth and economic instability (United Nations, 2024). Nigeria ranks first in Africa and second globally for malnourished children, with five of the top ten risk factors for disability and premature mortality are diet-related (GAINS, 2023). Deficiencies of essential micronutrients such as iron, calcium, and zinc are widely contributed to anaemia, impaired growth, blindness, and poor bone health (Senbanjo *et al.,* 2022). These nutritional challenges also impose significant economic losses, estimated at over 15% of national gross domestic product annually (UNICEF, 2019; GAINS, 2023). Therefore, nutrient rich vegetables such as okra could play an important role in improving dietary quality and reducing hidden hunger.

Colchicine is a natural alkaloid compound obtained from *Colchicum autumnale*, a member of the family Liliaceae (Alam *et al.,* 2022). It is widely used as a chromosome-doubling agent in plant breeding and cytogenetic studies. It interferes with cell division by disrupting spindle fiber formation during metaphase, preventing chromosome segregation. This leads to the formation of cells with doubled chromosome numbers, which give rise to polyploidy plants (Yousef *et al.,* 2020). Mutagens affect plant growth and development by inducing morphological, biochemical, physiological, cytological, and genetic changes in the plant germplasm (Din *et al.,* 2023). Adekiya *et al.* (2020) focused on the use of organic and inorganic fertilizers to enhance the nutritional content of okra. However, these approaches are expensive, labor-intensive, and require routine fertilizer application, which may not directly enhance nutritional traits genetically. Although colchicine has been used to improve yield and growth traits in several crops, limited studies have evaluated the effect of different colchicine concentrations on the mineral and proximate composition of okra capsules. The aim of the study is to assess the effects of Colchicine-Induced Polyploidy on the Nutritional Composition of Selected Okra (*Abelmoschus esculentus*) Varieties

MATERIALS AND METHODS

Sources of Seed

Seed of three okra (Clemon spinless, 'Yar Balla and 'Yar Sumaila) variety was collected from department of agronomic Institute for Agricultural Research, Ahmadu Bello University Zaria, Kaduna State

Experimental site and soil analysis

Topsoil was collected from the Botanical Garden of Ahmadu Bello University, Zaria, Nigeria (latitude 11 ° 11 'N, longitude 07 ° 38`E, and altitude of 660m above sea level) and was transferred for sterilization and physico-chemical analysis at the General Laboratory Department of Soil Science, Institute for Agricultural Research, Zaria. Soil particle size distribution, soil textural class, soil pH in 1:1, soil: water ratio, and 1:2 soil: 0.01 $CaCl_2$ ratio, available phosphorus was determined following the procedure described by Okalebo *et al.* (1993). Organic carbon and Total nitrogen were determined following the Jackson (1967) method. Exchangeable base was determined using the method described by Sparks (1996).

Treatments and Experimental Design

Seeds of each variety were pre-soaked in distilled water for four hours, and then immersed in four different concentrations of colchicine (0.1 mM, 0.5 mM, 1.0 mM, and 2.0 mM) for five hours at room temperature. The controls (0.0mM) were soaked in distilled water for the same duration. After treatment, they were washed thoroughly in tap water and allowed to dry overnight on Whatman No. 1 filter paper.

The treated seeds and controls were sown in polythene bags and maintained for 120 days,

arranged in a Completely Randomised Design (CRD) with three replications in a factorial arrangement. All cultural practices followed the protocols described by Vikash *et al.* (2019). Furthermore, 1kg of NPK 15:15:15 fertilizer was applied monthly to supply adequate nutrients for plant growth.

Harvesting of okra

Five days immature okra capsules were harvested, sliced into smaller pieces, sun-dried, and ground into a fine powder.

Mineral element

Mineral elements (phosphorus [P], calcium [Ca], magnesium [Mg], potassium [K], sodium [Na], zinc [Zn], and iron [Fe]) were determined following the procedures of AOAC (2019). A gram of ash content of mutant okra was weighed and placed in a 100 mL conical flask. Thereafter, 5 mL of nitric acid (HNO3) was added to the flask, and it was left for 8 hours. After pre-digestion, 10 mL of di-acid mixture (6.1 mL of HNO3 and 3.1 mL of perchloric acid (HClO4)) was added to the flask. The contents in the flask were heated (180-200 °C) on a hot plate until dense white fumes evolved and transparent white contents remained. The solution was cooled, and then 25 mL of double-distilled water was added to the flask. The solution was filtered into a 100 mL volumetric flask, and the volume was made to the mark using distilled water. The digestion was done simultaneously in three replicates, including one blank digestion for each okra sample, and elemental analysis, such as Ca, Mg, Zn, and Fe, was carried out by an Agilent 240 FS flame atomic absorption spectrophotometer (Agilent Technologies, USA), K and Na with a flame photometer, and P with a colorimeter, after calibration with appropriate standard solutions. All other chemicals used for analysis were of analytical grade and used without further purification.

Proximate composition

Proximate analysis of mutant okra was determined according to AOAC Official Methods of Analysis (2019).

Moisture content

The moisture content was determined by the oven drying method. The crucible was weighed and recorded. Exactly 3.00 g of each mutant okra variety was weighed into a previously weighed crucible and dried in an oven set at 105°C overnight. The samples were removed from the oven and placed in a desiccator with a partially covered lid for 30 minutes to allow for cooling at room temperature, then weighed again. The amount of moisture was expressed as a weight loss.

$$\text{Moisture content (\%)} = \frac{W1-W2}{W1}\times 100$$

W1: The weight of the sample before drying, W2: The weight of the sample after drying to a constant weight.

Total ash

The crucible was cleaned, dried, and ignited at 550°C for 1 hour and weighed. Exactly 10 g of okra was placed in a pre-weighed dry crucible. The crucible and the sample were placed in the muffle furnace set at 550°C for 12 hours to ensure that impurities on the surface of the crucible were burned off. The crucible and ash were cooled in a desiccator at room temperature and weighed. Percentage ash was calculated using the following equation:

$$\textbf{Ash\%} = \frac{\text{weigh of ash}}{\text{weigh of sample}}\times 100$$

Crude fat

A round-bottomed flask was dried for 30 minutes. and weighed. After, 5 g of mutant okra was weighed on a paper filter and wrapped to form a thimble. The sample was taken into the extraction thimble and transferred into the Soxhlet. Thereafter, the round-bottomed flask was filled with 250 mL of petroleum ether and then placed on the heating mantle. The Soxhlet apparatus was connected. After that, the heating mantle was switched on. The sample was heated for 1 hr. The solvent (petroleum ether) was evaporated using the vacuum condenser. Thereafter, the bottle was incubated at 80-90 °C until the petroleum ether completely evaporated and the bottle was completely dry. After drying, the bottle was transferred to the desiccator to cool. The bottle and its dried contents were weighed on the balance. Fat content was determined using the formula:

$$\textbf{Fat \%} = \frac{\text{weight of fat}}{\text{weigh of the sample}}\times 100$$

Crude fibre

Exactly 2 g of the mutant okra was transferred into a 500 mL conical flask, followed by 200 mL of boiled 1.25% sulfuric acid (H2SO4) solution. The mixture was boiled for 30 min under reflux. The digest was filtered through a Whatman filter paper. The residue was washed with boiling water until it was free from acid. The acid-free residue was quantitatively transferred into the refluxing flask, followed by exactly 200 mL of 1.25% sodium hydroxide (NaOH) solution and refluxed for 30 minutes. The digest was filtered, washed with boiling water, then alcohol and diethyl ether before being dried at 100°C for 1 hour. The dried residue was transferred into a porcelain crucible and incinerated for 1 h at 500°C using a muffle furnace. The crucibles were removed from the furnace and allow to cool in the desiccator,

immediately transferred and weighed. The percentage fibre was calculated using the following equation:

$$\%\text{Crude fibre} = \frac{\text{weigh of residual after oven drying}}{\text{weigh of the sample used}} \times 100$$

Crude protein

Exactly 1.00 g of pre–dried mutant okra was weighed and quantitatively transferred into Kjeldahl digestion flasks followed by addition of mixed catalyst (1.00 g of CuSO4 and 5.00 g of K2SO4 and 0.50 g of selenium powder and 25 mL of concentrated H2SO4). The contents of the flask were digested by heating in a fume chamber at 420 °C until the colour of the solution changed from black to a clear green-blue. The contents of the flask were cooled to room temperature and diluted to exactly 100 mL with distilled water. Exactly 10 mL of the aliquot of the digested solution quantitatively transferred into a distilling flask and mixed with 15 mL of 40% NaOH to neutralize the acid and make the solution slightly alkaline. The mixture was distilled, and the distillate was transferred to a receiving flask containing 50 mL of 4% boric acid mixed indicator solution. After collecting 80 mL of the distillate, the mixture was titrated against 0.1N Hydrochloric acid (HCl) using methyl red indicator until the colour changed from blue to green-orange, marking the endpoint. The percentage of protein nitrogen was calculated using the following formula:

$$(\%)\ \text{Nitrogen} = \frac{VHClA - VHClB \times NHCl \times 0.014077}{W\ Sample} \times 100$$

% protein=6.25×nitrogen%

Carbohydrate content: The carbohydrate content was calculated by subtracting the sum of percentage of moisture, fat, protein, fibre and ash contents from 100% as follows:

Carbohydrate content = 100% – [% crude protein+% fat content+% moisture content+%fibre+%ash].

Data analysis

The data obtained from nutritional composition were subjected to Multivariate Analysis of Variance (MANOVA) with SAS version 9.1 (SAS, 2012). Duncan's New Multiple Range Test (DNMRT) used to separate significant means (p≤0.05).

RESULTS

The result of table 1 showed the physicochemical parameters of the soil. The soil texture class used is sandy loam. The soil pH measured in water and $CaCl_2$ is 6.40 and 5.70. Organic carbon of the soil is 0.84% while organic matter is 1.44% and total nitrogen is 0.14%, available phosphorus (3.09 mg/kg), calcium (2.40 cmol/kg), magnesium (0.65 cmol/kg), potassium (0.25 cmol/kg), and sodium (0.13 cmol/kg), Exchangeable acidity ($H^+ + Al^{3+}$) is 0.80 cmol/kg. Particle size distribution shows 56% sand, 33% silt, and 11% clay.

The result of Table 2 showed the effects of colchicine concentration on the mineral element content of okra capsules. In Clemson Spineless, 0.1 mM colchicine produced the highest Ca (4343.16±6.98mg/kg), Mg (27470.00± 210.13mg/kg), K(20527.67±9.62mg/kg), P (514.22±5.76mg/kg), Na (5733.33±10.84mg/kg), Zn (29.22mg/kg), and Fe (847.27± 2.77mg/kg) contents which all differed significantly ($p \leq 0.05$) among treatments expect P and Zn**.**

The same pattern was observed in **'**Yar Balla, where 0.1 mM colchicine had the highest Ca (3503.54± 20.56mg/kg), K (18500.00± 0.00mg/kg), and Mg (2996.72±1.40 mg/kg) exceeded the control values. P (3504.23±10.13 mg/kg) and Na **(**4446.67**±**10.84mg/kg) were highest at 0.5 mM colchicine and differed significantly ($p \leq 0.05$) from the control except Mg. However, 1.0 mM concentration has the highest accumulation of Zn (31.00±0.72 mg/kg) and Fe (1138.50±16.46 mg/kg), which differed significantly ($p \leq 0.05$) from the control except Zn**.**

In **'**Yar Sumaila, 0.1 mM colchicine treatment produced the highest Ca (4632.81±2.47mg/kg), Mg (2954.67± 12.47mg/kg), K (84200.00±148.17mg/kg), Fe (1134.33± 1.91 mg/kg), and Zn (23.32±±0.04) contents, which were all significantly ($p \leq 0.05$) higher than the control except Zn**.** However, the highest P (3757.52±7.03 mg/kg) and Na (5208.33± 2.13 mg/kg) were recorded at 2.0 mM, which exceeded the control which differed significantly ($p \leq 0.05$) among treatment except P.

Table 3 showed the comparison of varieties that responded to the effects of colchicine on the mineral element content of okra varieties. In Yar'Sumaila, accumulate the highest Ca (4260.90±146.45mg/kg), K (32307.33±22.68mg/kg), and Fe (964.80±25.46 mg/kg) contents, which are significantly (p≤0.05) higher than Clemson spineless and Yar'Balla. While Clemson Spineless had the highest Mg (12680.39 ±3184mg/kg) and Zn (27.34 ±0.33 mg/kg), which differed significantly (p≤0.05) higher than Yar'Sumaila and Yar'Balla, except Zn. However, Yar'Balla mutant has highest P (3376.56 ±72.90mg/kg) and Na (4245.33±63.04) content which differed significantly (p≤0.05) higher Yar'Sumaila and Clemson Spineless except Na.

Table 4 showed that colchicine concentration significantly ($p \leq 0.05$) influenced all proximate components across the three okra varieties. In

Clemson Spineless, 0.1 mM produced the highest moisture (3.77±0.03%), ash (7.36±0.01%), and crude fibre (13.78±0.06%), which differed significantly ($p \leq 0.05$) from the control. The maximum crude lipid (6.29±0.05%) and crude protein (24.71±0.03%) were observed at 2mM colchicine, which was significantly ($p \leq 0.05$) higher than the control. However, control has the highest carbohydrate (45.29±0.13%), which exceeded all colchicine treatments.

Similarly, treand was observed in Yar' Balla, where 0.1 mM colchicine had the highest moisture (3.72±0.02%), ash (8.16±0.01%), crude protein (23.62±0.02%), and crude lipid (7.30±0.02%), which differed significantly ($p \leq 0.05$) from the control. While, the maximum crude fibre (32.15%) was recorded at 2mM significantly ($p \leq 0.05$) from control. The control has the highest carbohydrate content (45.41±0.09%), which exceeds all colchicine treatments.

In 'Yar Sumaila, 0.1mM colchicine had the highest moisture (3.87±0.01%), Ash (7.54±0.02%), Crude protein (24.34±0.01%), Crude lipid (10.28±0.15%), Crude fiber (14.83±0.03%), which all differed significantly ($p \leq 0.05$) from control. The control has the highest carbohydrate content (56.42±0.10%), which exceeds all colchicine treatments.

Results of Table 5 showed the varietal responses of okra to colchicine treatments on the proximate composition. Yar'Sumaila had the highest moisture (3.72±0.03%) and crude lipid content (8.20±0.29%), which are significantly ($p \leq 0.05$) higher than Clemson spineless and Yar'Balla. While in Yar Balla has the highest Ash content (7.55±0.08%) and Crude fiber (19.38±0.71%), which differed significantly ($p \leq 0.05$) from Clemson spineless and Yarsumaila. However, Clemson spineless produced highest crude protein (24.51±0.06%) and carbohydrate (44.83±0.11%) which differed significantly ($p \leq 0.05$) from Yarballa and YarSumaila

Table 1: Soil parameters and their values

Soil parameter	**Values**
pH ratio 1:2:5 in H_2O	6.40
pH ratio 1:2:5 in 0.01M$CaCl_2$	5.70
Organic Carbon	0.84
Organic matter	1.44
Total Nitrogen	0.143
Available Phosphorous (mg/kg)	3.09
Exchangeable base	**Value**
K	0.25
Na	0.13
Ca	2.40
Mg	0.65
Exchange acidity	Value
$H^+ + Al^{3+}$	0.80
Soil particle size	**Value**
Clay %	11
Sily %	33
Sand %	56
Soil texture	Sand-loam

Table 2: Effects of colchicine concentration on mineral element content of okra capsules

Varieties	Concentration (mM)	Calcium (mg/kg)	Magnesium (mg/kg)	Potassium (mg/kg)	Phosphorus (mg/kg)	Sodium (mg/kg)	Zinc (mg/kg)	Iron (mg/kg)
Clemson spineless	0.0	4007.51±3.02^{d}	3068.62±23.25^{b}	19900.00±0.00^{c}	500.19±4.83^{a}	4500.00±47.14^{b}	26.00±0.12^{a}	700.63±0.37^{d}
	0.1	4343.16±6.98^{a}	27470.00±210.13^{a}	20527.67±9.62^{a}	514.22±5.76^{a}	5733.33±10.84^{a}	29.22±0.22^{a}	847.27±2.77^{a}
	0.5	4322.11±10.65^{a}	27070.00±53.12^{a}	20527.67±4.719^{a}	517.17±0.14^{a}	5336.67±38.80^{b}	28.13±0.07^{a}	834.19±1.68^{b}
	1.0	4203.71±7.33^{b}	2836.67±53.97^{b}	20510.00±47.14^{a}	503.40±2.74^{a}	4510.00±4.71^{b}	26.23±0.07^{a}	803.74±2.61^{c}
	2.0	4117.54±7.61^{c}	2956.67±22.28^{b}	20100.00±47.14^{b}	500.19±10.13^{a}	4326.67±11.86^{b}	27.13±0.00^{a}	700.33±0.20^{d}
	p-value	0.00	0.00	0.00	0.12	0.00	0.87	0.00
'Yar Balla	0.0	3264.20±0.00^{b}	2940.75±15.12^{a}	18100.00±94.28^{b}	2831.83±0.00^{b}	4000.00±0.00^{b}	24.00±0.00^{a}	789.90±5.30^{cd}
	0.1	3503.54±20.56^{a}	2996.72±1.40^{a}	18500.00±0.00^{a}	3504.23±10.13^{a}	4440.00±24.94^{ab}	27.00±0.47^{a}	821.20±0.00^{bc}
	0.5	3500.18±27.59^{a}	2890.24±4.69^{a}	18401.33±61.29^{ab}	3531.53±5.41^{a}	4446.67±25.96^{a}	26.33±0.94^{a}	837.30±0.09^{b}
	1.0	3477.22±27.59^{a}	2852.81±20.51^{a}	18111.33±86.85^{b}	3503.50±1.69^{a}	4306.67±127.40^{ab}	31.00±0.72^{a}	1138.50±16.46^{a}
	2.0	3456.85±47.24^{a}	2903.51±66.13^{a}	18273.33±30.31^{ab}	3511.69±2.70^{a}	4033.33±112.97^{ab}	28.00±0.47^{a}	769.51±4.40^{d}
	p-value	0.00	0.06	0.00	0.00	0.00	0.87	0.00
'Yar Sumaila	0.0	3178.92±8.68^{e}	2738.67±13.65^{c}	10670.00±273.54^{a}	2533.51±0.21^{c}	3003.33±2.72^{d}	22.52±0.05^{a}	856.67±23.25^{c}
	0.1	4632.81±2.47^{a}	2954.67±12.47^{a}	84200.00±148.17^{a}	2513.99±61.49^{c}	5005.00±3.60^{c}	23.32±0.04^{a}	1134.33±1.91^{a}
	0.5	4522.02±8.95^{c}	2913.33±4.71^{a}	21236.67±28.67^{a}	2681.23±25.79c	5094.67±3.60^{b}	20.23±0.21^{a}	953.00±1.25^{b}
	1.0	4378.60±3.62^{d}	2919.67±15.85^{a}	22070.00±14.34^{a}	3117.12±4.29^{b}	5108.33±2.36^{b}	20.10±0.03^{a}	910.00±4.71^{c}
	2.0	4592.16±1.42^{b}	2839.00±17.15^{b}	23360.00±19.05^{a}	3757.52±7.03^{a}	5208.33±2.13^{a}	21.83±0.05^{a}	970.00±4.71^{b}
	p-value	0.00	0.00	0.07	0.00	0.00	0.87	0.00

N.B: Means ± standard error with the same superscript(s) down a column for each variety are NOT significantly different ($p \leq 0.05$)

Table 3: Compares the effects of colchicine and diethyl sulphonate on the mineral content of okra varieties

Varieties	Calcium (mg/kg)	Magnesium (mg/kg)	Potassium (mg/kg)	Phosphorus (mg/kg)	Sodium (mg/kg)	Zinc (mg/kg)	Iron (mg/kg)
Clemson spineless	4198.81±33.83^{a}	12680.39±3184^{a}	20313.07±71.80^{b}	507.03±2.41^{c}	4881.33±217.28^{a}	27.34±0.33^{a}	777.23±17.19^{c}
Yar 'Balla	3440.40±27.14^{b}	2916.81±19.25^{b}	18277.20±51.78^{c}	3376.56±72.90^{a}	4245.33±63.04^{a}	27.27±0.67^{a}	871.28±36.45^{b}
Yar' Sumaila	4260.90±146.45^{a}	2873.07±21.24^{b}	32307.33±22.68^{a}	2920.67±126.78^{b}	4683.93±225.24^{a}	21.60±0.34^{a}	964.80±25.46^{a}
p-value	0.00	0.00	0.00	0.00	0.67	0.59	0.00

N.B: Means ± standard error with the same superscript(s) down a column for each mutagen are NOT significantly different ($p \leq 0.05$)

Table 4: Effects of varying concentrations of colchicine on the proximate composition of okra capsules varieties

Varieties	Concentration (mM)	Moisture Content (%)	Ash content (%)	Crude Lipid (%)	Crude Protein (%)	Crude Fibre (%)	Carbohydrates (%)
Clemson spineless	0.0	3.43±0.04^{c}	7.34±0.02^{b}	6.05±0.03^{d}	24.27±0.07^{b}	13.62±0.02^{b}	45.29±0.13^{a}
	0.1	3.77±0.03^{a}	7.36±0.01^{a}	6.16±0.02^{b}	24.6±0.02c	13.78±0.06^{a}	44.33±0.013^{b}
	0.5	3.77±0.03^{a}	7.32±0.01^{b}	6.10±0.01^{c}	24.34±0.01^{c}	13.41±0.02^{c}	45.06±0.17^{a}
	1.0	3.62±0.02^{b}	7.25±0.02^{c}	6.24±0.02^{b}	24.61±0.02^{c}	13.56±0.02^{c}	44.72±0.02^{b}
	2.0	3.45±0.03^{c}	7.25±0.02^{c}	6.29±0.05^{a}	24.71±0.03^{a}	13.57±0.04^{c}	44.73±0.04^{b}
	p-value	0.00	0.00	0.00	0.00	0.00	0.00
'Yarballa	0.0	3.54±0.02^{b}	7.38±0.02^{b}	5.5±0.12^{b}	22.03±0.01^{c}	16.14±0.06^{b}	45.41±0.09^{a}
	0.1	3.72±0.02^{a}	8.16±0.01^{a}	7.30±0.02^{a}	23.62±0.02^{a}	16.14±0.02^{b}	41.06±0.04^{b}
	0.5	3.66±0.01^{a}	7.43±0.03^{b}	7.04±0.06^{a}	23.58±0.02^{a}	16.20±0.02^{b}	42.09±0.08^{b}
	1.0	3.65±0.02^{a}	7.33±0.02^{b}	7.18±0.06^{a}	23.58±0.01^{a}	16.25±0.00^{b}	42.01±0.10^{b}
	2.0	3.47±0.01^{b}	7.44±0.02^{b}	6.96±0.05^{a}	23.43±0.01^{b}	32.15±0.02^{a}	26.55±0.07^{c}
	p-value	0.00	0.00	0.00	0.00	0.00	0.00
'Yar Sumaila	0.0	3.59±0.01^{d}	2.41±0.03^{c}	7.40±0.11^{d}	21.51±0.01^{b}	8.67±0.01^{c}	56.42±0.10^{a}
	0.1	3.87±0.01^{a}	7.54±0.02^{a}	10.28±0.15^{a}	24.34±0.01^{a}	14.83±0.03^{a}	39.15±0.19^{c}
	0.5	3.77±0.03^{b}	7.03±0.01^{b}	8.1±0.03^{b}	24.26±0.03^{a}	14.75±0.02^{a}	42.09±0.06^{b}
	1.0	3.71±0.01^{b}	7.390.04±^{a}	7.60±0.05^{c}	24.14±0.05^{a}	14.590.01±^{b}	42.57±0.06^{b}
	2.0	3.66±0.04^{c}	7.53±0.11^{a}	7.60±0.12^{c}	24.18±0.05^{a}	14.75±0.02^{a}	42.27±0.11^{b}
	p-value	0.00	0.00	0.00	0.00	0.00	0.00

N.B: Means ± standard error with the same superscript(s) down a column for each variety are NOT significantly different ($p \leq 0.05$)

Table 5: Varietal responses of okra to colchicine and diethyl sulphonate treatments on proximate composition

Varieties	Moisture content (%)	Ash content (%)	Crude Lipid (%)	Crude Protein (%)	Crude Fibre (%)	Carbohydrates (%)
Clemson spineless	3.61±0.04[b]	7.30±0.01[a]	6.17±0.03[b]	24.51±0.06[a]	13.59±0.03[b]	44.83±0.11[a]
Yar 'Balla	3.61±0.03[b]	7.55±0.08[a]	6.80±0.18[b]	23.25±0.16[b]	19.38±0.71[a]	39.42±1.94[b]
Yar 'Sumaila	3.72±0.03[a]	6.38±0.19[b]	8.20±0.29[a]	23.69±0.29[b]	13.52±0.62[b]	44.50±1.63[a]
p-value	0.00	0.00	0.00	0.00	0.00	0.00

N.B: Means ± standard error with the same superscript(s) down a column for each mutagen are NOT significantly different ($p \leq 0.05$)

DISCUSSION

Okra capsules are widely consumed in their fresh or dried form, which are composed of important nutrients that are beneficial to humans. Mineral elements play a significant role in fruit quality and help maintain normal physiological functions in the body, as reported by Huang *et al.* (2022). The increased mineral element contents observed in the present study suggest that colchicine treatment enhanced nutrient accumulation in okra capsules. This response may be associated with colchicine-induced polyploidy, which can modify plant physiology through increased cell size, improved root growth, enhanced metabolic activity, and greater capacity for nutrient uptake and translocation. The finding agreed with several crop species, such as *Piper nigrum* (Abu *et al.,* 2019), reported improved mineral accumulation following mutagenic treatment. In addition, Tossi *et al.* (2022) noted that colchicine may improve root efficiency and nutrient absorption, particularly under environmental stress conditions.

Similarly, Wang *et al.* (2022) reported that ethyl methane sulphate increased the specific mineral content of *Oryza sativa*. The notable improvement of mineral elements such as Ca, Na, Mg, K, P and Fe at the lowest colchicine concentration. This may be due to mild colchicine, successfully inducing chromosome doubling without causing severe cellular damage, while excessive concentrations may disrupt spindle formation, inhibit mitosis, reduce root vigour, and impair nutrient uptake. Similar reductions in mineral content under high mutagen doses were reported by Osman *et al.* (2014) in *Glycyrrhiza glabra*

This finding contradicts the report of Abd El-Latif *et al.* (2018), who observed an increase in zinc accumulation in the leaves of *Carica papaya* treated with benzyl adenine and ethyl methane sulphate, possibly due to differences in mutagen type, dosage or species-specific nutrient uptake mechanism.

Colchicine treatments also significantly influenced the proximate composition of okra, including moisture, protein, lipid, fibre, ash, and carbohydrate contents. The highest ash content observed in treated samples may be directly related to the increased mineral accumulation recorded in this study, since ash represents the total inorganic residue remaining after combustion. Enhanced ash values may therefore reflect improved uptake and storage of mineral nutrients such as potassium, calcium, magnesium, phosphorus, and iron. This agrees with the work of Zhang *et al.* (2024) who found that induced polyploidy promoted nutrient uptake and assimilate storage.

The increase in moisture content may be a result of enlargement of vacuoles in the ploidy cell, which help improved water retention capacity. Similar observations were made by Rosskopf *et al.* (2021). Polyploid plants often exhibit thicker tissues and altered stomatal behaviour, which may reduce transpiration loss and improve water retention. This agreed with Trojak-Goluch *et al.* (2021), who reported that colchicine increases cell size affects a great number of key physiological processes in plants, such as water holding capacity, transport of gasses and solutes. However, this differs from the report of Hassan *et al.* (2009), who observed reduced moisture content under gamma irradiation, suggesting that different mutagens may exert contrasting physiological effects.

The increased crude lipid content may be linked to stimulation of lipid biosynthesis pathways and improved carbon allocation in treated plants. This agrees with the findings of Wijekoon *et al.* (2020) in alfalfa. Likewise, the higher protein content may reflect improved nitrogen assimilation, enhanced

amino acid metabolism, and upregulation of storage protein synthesis as previously reported by Fathurrahman and Mardaleni (2023), who observed that mutagens increased organic matter and total cellular protein. The crude fibre content observed supports Wijekoon *et al.* (2020), who linked it to altered cell wall biosynthesis, though it contrasts with findings of Hassan *et al.* (2009), who recorded decreased in crude fibre content under irradiation.

The variation observed among the okra varieties indicates genotype-dependent responses to colchicine treatment. Genetic background strongly influences chromosome stability, nutrient transport efficiency, metabolic regulation, and tolerance to mutagen exposure. Similar genotype-specific responses have been reported by Abu *et al.* (2019) and Hassan *et al.* (2019). Comparable results were reported Ahmad *et al.* (2023) confirming that genetic background governs biochemical trait expression.

CONCLUSION

Colchicine treatment significantly affected the mineral and proximate composition of okra capsules, with lower concentrations producing the most favourable nutritional responses. Therefore, selected mutants from these treatments could be valuable parental lines for future okra improvement programmes.

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