



Assessment of the Agromorphological Performance of Gamma-Irradiated Mutant Cowpea [*Vigna unguiculata* (L.) Walp.] Lines in Burkina Faso

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Abstract

This study aimed to characterize mutation-induced genetic variability in cowpea to identify agronomically superior genotypes. The experiment was conducted in 2024 during the rainy season at the Kamboinsé Environmental, Agricultural Research, and Training Center using an alpha lattice design with three replicates. Mutant lines derived from K VX396-4-5-2D, MOUSSA Local, and TILIGRÉ were evaluated for qualitative and quantitative agro-morphological traits. Results revealed significant phenotypic variation between mutants and their parental lines. Early pod semi-maturity was observed in M5KA2-1-4-3 and M5KA2-1-4-4 (57 and 58 days), whereas M5M13-2-6-6, M5KA2-1-7-2, and K VX-Nike recorded the highest grain yields (1735.14, 1669.4, and 1667.13 kg/ha, respectively). Several lines also displayed morphological traits favorable for adaptation to local agro-climatic conditions. All mutants derived from MOUSSA Local retained the prostrate growth habit of the parent, while 20% of K VX396-4-5-2D mutants exhibited an erect habit. Principal component analysis structured the observed variability, distinguishing early-maturing, low-biomass genotypes from late-maturing, high-biomass types. The most promising mutants in terms of earliness, yield, and forage potential will undergo further evaluation

Keywords: Cowpea, phenotypic variability, mutants, agronomic traits, gamma rays

Introduction

Cowpea [*Vigna unguiculata* (L.) Walp.] is a highly important crop in sub-Saharan Africa due to its high nutritional value (23-28% protein), biological nitrogen fixation capacity, and resilience to poor soils (Mgula *et al.*, 2025; Nkurunziza *et al.*, 2024). It is a key plant in agroecological cropping systems, particularly in West Africa. Approximately 95.4% of global cowpea production originates from Africa, especially sub-Saharan Africa, namely Nigeria, Niger, and Burkina Faso (Kim *et al.*, 2025). In Burkina Faso, over 1.8 million households cultivate cowpea, primarily during the rainy season. It is the main legume crop and the fourth most important staple crop after maize, sorghum, and millet (Coulibaly *et al.*, 2020). The cowpea value chain generates about 18% of agricultural export revenues, with a dynamic regional market toward Ghana, Côte d'Ivoire, and Benin. It directly contributes to food security, accounting for 32% of the annual income of many rural households. Between 2018 and 2023, the area under cowpea cultivation increased from 720,000 ha to approximately 850,000 ha. Despite this expansion, production rose by only 15%, from 560,000 tons to 640,000 tons, with an average yield of 0.75 t/ha. This indicates that cowpea is not fully expressing its potential. Indeed, its production faces abiotic constraints (erratic rainfall, declining soil fertility) and biotic constraints (pests, diseases, parasitic weeds) exacerbated by climate change (Shevkani *et al.*, 2025). The

scarcity of high-yielding genotypes is also a barrier to the productivity of this legume (Raina *et al.*, 2020). In response to these challenges, innovative approaches are needed to enhance the physiological and agronomic performance of cowpea. Among them, induced mutagenesis represents a promising method for generating useful genetic variability for selecting improved genotypes (Chaudhary *et al.*, 2019; Nikiema *et al.*, 2023). This technique induces variations in key traits such as earliness, stress tolerance, and grain yield improvement. Mutagenesis has already enabled the development of sorghum mutant lines resistant to *Striga* (Nikiéma *et al.*, 2020), early-cycle cowpea mutant lines (Dabiré *et al.*, 2024), and water stress-tolerant cowpea mutant lines (Gnankambary *et al.*, 2020) in Burkina Faso.

Given the socio-economic importance of cowpea, it is crucial to develop varieties adapted to local agro-climatic constraints. This study fits within this framework and aims to identify mutant lines that are earlier maturing and more productive. This will enhance cowpea productivity through the agro-morphological characterization of cowpea mutant lines.

Materials and methods

Study area

Agromorphological characterization of the cowpea mutant lines was conducted at the research station of the Environmental, Agricultural and Training Research Center (CREAF) in Kamboinsé. The CREAF/Kamboinsé is located at 12°28' N latitude and 1°32' W longitude, at an altitude of 296 m, approximately 18 km north of the city center of Ouagadougou along National Road 22. Established on an area of approximately 166 hectares, this research station features ferruginous soil type and a Sudano-Sahelian climate.

Plant material

The plant material evaluated consisted of 20 genotypes: 15 mutant cowpea lines, their three parental varieties (KVX 396-4-5-2D, MOUSSA Local, and TILIGRÉ), and two check varieties YIPOUSSI and KOMCALLÉ. Seeds of the mutant lines and check varieties were provided by the breeding team at the Institute of Environment and Agricultural Research (INERA). Table 1 shows the distribution of the mutant lines by parental variety.

Table 1: List of evaluated genotypes

Plot number	Genotypes	Generation
1	KVX396-4-5-2D	M0 (parent)
2	M5KA1-4-0-3	M5
3	M5KA2-1-4-3	M5
4	M5KA2-1-4-4	M5
5	M5KA2-1-7-2	M5
6	M5KA-4-1-2-1	M5
7	M5KA57-6-3-2	M5
8	M5KA71-3-4-4	M5
9	M5KA80-1-6-1	M5
10	M5KA99-2-3-1	M5
11	M5KB12-3-0-1	M5
12	KVX-NIK	M5
13	MOUSSA Local	M0 (parent)
14	M5MA3-1-3-3	M5
15	M5M13-2-6-6-4	M5
16	TILIGRÉ	M0 (parent)
17	M5TA2-3-1-3	M5
18	M5TB2-1-4	M5
19	YIPOUSSI	M0 (check)
20	KOMCALLE	M0 (check)

Methods

Experimental design and trial management

The field was plowed two weeks prior to sowing using a tractor-mounted disc plow to ensure adequate soil pulverization and facilitate the decomposition of plant residues. Planting was carried out manually on July 22,

2024, along pre-marked rows, with a spacing of 0.5 m between hills and 0.8 m between rows. An alpha lattice design with three replications was adopted to account for field heterogeneity. Each replication comprised two blocks of ten elementary plots, with plots completely randomized within each block. Each elementary plot consisted of four rows, each 2 m in length. Five hills were established per row, resulting in a total of 20 hills per plot. Replications were separated by 1 m, and blocks by 0.8 m. The total experimental area covered 586.56 m². Two seeds were sown per hill, and thinning to one plant per hill was performed 14 days after sowing. This was followed by the application of NPK (14–23–14) fertilizer at a rate of 100 kg/ha using side-dressing. Weeding was conducted as necessary to minimize competition. Two phytosanitary treatments of Lambda-cyhalothrin (15 g/L) + Acetamiprid (10 g/L) at 40 mL per 16 L of water were applied at pod formation to control insect pests. Pods were harvested at full physiological maturity, row by row and hill by hill, to isolate the net plot yield. Pods were subsequently sun-dried and threshed.

Collection and data analysis

The parameters recorded and the methods of data collection are presented in Tables 2 and Table 3. Mean separation of the measured parameters was performed using Tukey's test at the 5% probability level with SAS software version 9.3, in order to distinguish high-performing genotypes from low-performing ones. Principal component analysis (PCA) was conducted using R software version 4.4.1 to assess the contribution of variables to trait variation.

Table 2: Qualitative traits recorded and data collection methods

Qualitative traits	Code	Data collection method
Plant growth habit	PltHabit	Recorded at flowering: prostrate, semi-erect, erect
Leaf color	LeafCol	Recorded at flowering: light green, medium green, dark green
Shape of distal part of leaf	LeafDistShape	Acute, acute to truncate, truncate
Flower color	FlwCol	White, purple
Wing petal color	WingPetCol	Purple, pinkish white, white
Branch pigmentation	BrPig	Recorded at maturity: green, brown, reddish
Intensity of green color	GreenInt	Recorded at semi-maturity: light, medium, dark, very dark
Anthocyanin pigmentation intensity (hypocotyl)	HypAnthInt	Absent, weak, medium, strong
Pod color	PodCol	Recorded at semi-maturity: whitish, yellow, brown, reddish
Degree of pod curvature	PodCurvDeg	Recorded at semi-maturity: slight, moderate, strong
Type of pod curvature	PodCurvType	Concave, convex, none
Secondary color	SecCol	Absent, present
Seed color	SeedCol	White, yellowish, brown
Seed shape	SeedShape	Circular, circular to elliptical, elliptical, kidney-shaped, rectangular
Hilum color	HilumCol	Light brown, dark brown, very dark brown, yellow-brown, black
Leaf color at harvest	LeafColHarv	Yellow, green

Table 3: Quantitative traits recorded and data collection methods

Quantitative traits	Code	Data collection method
Plant height (cm)	Height	Measured from ground level to the apex
Number of branches per plant	Bran-Num	Count of primary branches at flowering
Mean leaflet diameter (cm)	Leaf-Diam	Measured on three median leaflets
Mean leaflet length (cm)	Leaf-Len	Measured on three median leaflets
Mean petiole length (cm)	Pet-Len	Measured on three petioles

Days to 50% maturity	Mat-Dat	Number of days from sowing to when 50% of pods reach maturity
Mean peduncle length (cm)	Ped-Len	Measured at maturity on three randomly selected peduncles
Mean pod length	Pod-Len	Measured on six pods chosen at random from six plants.
Mean pod thickness (cm)	Pod-Thic	Measured with a caliper on six pods
Mean pod width (cm)	Pod-Wid	Measured with a caliper on six pods
Thousand seed weight (g)	TKW	Weighed using a precision balance
Mean yield per hectare	Yield (kg ha ⁻¹)	Yield (kg ha ⁻¹) = Seed weight (kg) × 10,000 / Plot area (m ²), where Plot area = NR × RL × DR

NR = number of rows; *RL* = row length (m); *DR* = distance between rows (m)

Results and discussion

Results

Frequency distribution of qualitative traits

Tables 4 and 5 present the frequency distribution of qualitative variables across the cowpea genotypes.

For K VX396-4-5-2D, the analysis indicates that 80% of the mutant lines exhibit a semi-erect growth habit, identical to that of the parent. In contrast, 20% of the mutant lines display an erect growth habit, distinct from the parental genotype. Regarding leaf color intensity, 30% of the mutant lines have dark green leaves, similar to the parent, while 40% show medium green coloration and the remaining 30% exhibit light green leaves. Branch pigmentation is relatively diverse: 30% of mutants show brown pigmentation, 30% reddish pigmentation, and 30% green pigmentation, compared to 10% with yellow pigmentation. For anthocyanic pigmentation of hypocotyls, 80% of mutants and the parent exhibit pigmentation, with 12.5% of low intensity and 87.5% of medium intensity. Twenty percent of mutants show no anthocyanic pigmentation. Flower color is predominantly violet (70% of mutants), while 30% have white flowers. However, wing petal color shows greater variation: 80% are violet, 10% pale pink, and 10% white. At semi-maturity, 70% of mutants have yellow to light brown pods with reddish spots. The remaining 30%, along with the parent, possess yellow pods. For pod curvature degree, 40% of mutants and the parent show a medium degree, 50% a low degree, and 10% a very low or absent degree. Regarding the shape of this curvature, 10% of mutants lack curvature and thus have no defined shape. The parent and 50% of mutants exhibit convex curvature, while the remaining 40% show concave curvature. Seed color is distributed as follows: 40% are yellowish, identical to the parent; 30% are white; and 30% are brown. Seed shape also varies between lines and the parent: 10% of mutants have circular seeds, 10% (including the parent) have circular to elliptical seeds, 30% have reniform seeds, and 50% have rectangular seeds.

In the MOUSSA Local population, both mutants and the parent exhibit a semi-erect growth habit. Leaf color is green to very dark across all genotypes. In contrast, branch pigmentation is evenly distributed among mutants: 50% show green pigmentation and 50% reddish pigmentation, while the parent is also reddish. The shape of the distal leaf portion is acute in all mutants, whereas the parent has an acute to truncated shape. Anthocyanic pigmentation of hypocotyls is absent in the parent but of medium intensity in the mutants. Flower color is uniform and white in the MOUSSA Local parent and 50% of mutants; the other 50% have violet flowers. However, variability is observed in wing petal color: 50% of mutants and the parent retain white coloration, while the others show violet pigmentation. Pod color is reddish in the parent, while 50% of lines are brown and the other 50% yellow. Pod curvature is strong in the parent and half of the mutant population and exclusively low in the other half. For the shape of this curvature, the parent shows convex form, while the mutants are concave. The MOUSSA Local variety and half of the mutants produce white seeds, while the other half have brown seeds. Seed shape is reniform in the parent and 50% of mutants, and elliptical in the other mutants. Regarding hilum color, the parent has a dark brown hilum, while the mutants display a light brown hilum. In the TILIGRE mutant population, the growth habit is semi-erect. Leaf green color is dark and identical across the parent and all mutants. Branch pigmentation shows some diversity: the parent exhibits reddish pigmentation, 50% show brown pigmentation, and 50% green pigmentation. For the distal leaf shape, the parent and 50% of mutants have an acute to truncated form, while the other half show an exclusively acute form. Anthocyanic hypocotyl pigmentation is absent in the parent and 50% of mutants but

present in the remaining 50%. Flower color varies among TILIGRE genotypes: the standard is violet in the parent and 50% of mutants but entirely white in the other 50%. Pod curvature degree is medium in the parent and half of the mutants but low in the other half. For curvature shape, it is convex in the parent and half of the mutants; the other half show concave form. Seeds are white in the parent and yellowish in the mutants. The parent and half of the mutants have circular to elliptical seeds, while the other mutants display reniform shape. For hilum color, the parent and 50% of mutants have a light brown hilum, and the other have a yellowish-brown hilum.

Table 4: Frequency of occurrence of qualitative traits (vegetative system) in mutant lines and their parents

Variables	Phenotypic variation	K VX 396-4-5-2D population		MOUSSA Local population		TILIGRE population	
		Parent	Frequency (%)	Parent	Frequency (%)	Parent	Frequency (%)
Plant growth habit	Semi-erect	Yes	80	Yes	100	Yes	100
	Erected	No	20	No	None	No	None
Anthocyanin pigmentation (hypocotyl)	Absent	No	20	Yes	None	Yes	50
	Light	No	12.50	No	None	No	50
	Average	Yes	67.50	No	100	No	None
Leaf color	Very dark green	No	None	Yes	100	No	None
	Dark green	Yes	30	No	None	Yes	100
	Medium green	No	40	No	None	No	None
	Light green	No	30	No	None	No	None
Distal leaf shape	Acute	No	20	No	100	No	50
	Acute truncated	Yes	60	Yes	None	Yes	50
	Truncated	No	20	No	None	No	None
Branch pigmentation	Green	No	30	No	100	No	50
	Brown	Yes	30	No	None	No	50
	Reddish	No	30	Yes	None	Yes	None
Flower color	Yellow	No	10	No	None	No	None
	Purple	Yes	70	No	50	Yes	50
	White	No	30	Yes	50	No	50
Color of floral wings	White	No	None	Yes	50	No	None
	Purple	Yes	80	No	50	Yes	100
	Pinkish	No	10	No	None	No	None

Variability of growth parameters and leaf morphology of cowpea genotypes

The results in Table 6 show highly significant differences ($P < 0.0005$) between cowpea genotypes for vegetative growth parameters of the plants. Mean separation for parameters related to growth and foliar morphology indicates that TILIGRE achieved the greatest plant height (16.77 cm), followed by YIPOUSSI (15.77 cm), whose value was statistically identical to that of K VX396-4-5-2D, M5KA1-4-0-3, M5KA-4-1-2-1, M5KA71-3-4-4, M5KA80-1-6-1, and M5KB12-3-0-1. For branch number, all cowpea genotypes had statistically similar values except M5KA2-1-4-3, which averaged 5.38 branches. Genotypes with the longest peduncles were M5KA2-1-4-4 (31.63 cm), M5KA2-1-4-3 (29.27 cm), and K VX-NIK (25.08 cm). The longest petioles were observed in M5KA2-1-4-4 (14.55 cm), M5TB2-1-4 (13.94 cm), M5KA2-1-4-3 (13.58 cm), YIPOUSSI (13.66 cm), and TILIGRE (13.5 cm). The shortest leaflet length and diameter were recorded for M5KA1-4-0-3, M5KA-4-1-2-1, MOUSSA, M5MA3-1-3-3, and M5M13-2-6-6-4. The coefficients of variation are relatively moderate and range from 15.97% to 33.2%.

Table 5: Frequency of occurrence of qualitative traits (pods and seeds) in mutant lines and their parents

Variables	Phenotypic variation	K VX 396-4-5-2D population	MOUSSA Local population	TILIGRE population
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		Parent	Frequency (%)	Parent	Frequency (%)	Parent	Frequency (%)
Pods color (50 % maturity)	White	No	10	No	None	Yes	50
	Yellow	Yes	30	No	50	Yes	50
	Brown	No	70	No	None	No	None
	Reddish	No	None	Yes	None	No	None
Degree of pod curvature	Very light	No	10	No	None	No	None
	Light	No	50	No	50	No	50
	Average	Yes	40	No	None	Yes	50
	High	No	None	Yes	50	No	None
Shape of pods curvature	Straight	No	10	No	None	No	None
	Concave	No	40	No	100	No	50
	Convex	Yes	50	Yes	None	Yes	50
Seeds color	Yellowish	Yes	40	No	None	No	50
	White	No	30	Yes	50	Yes	None
	Brown	No	30	No	50	No	50
Seeds shape	Circular	No	10	No	None	No	None
	Elliptical curve	Yes	10	No	None	Yes	50
	Elliptical	No	None	No	50	No	None
	Renal	No	30	Yes	50	No	50
	Rectangular	No	50	No	None	No	None
Color of the seed hilum	Light brown	No	30	No	100	Yes	50
	Dark brown	No	40	Yes	None	No	None
	Yellow brown	No	None	No	None	No	50
	Black	Yes	20	No	None	No	None

Table 6: Comparison of the performance of cowpea genotypes based on height, number of branches, leaflet diameter, peduncle length, petiole length, and leaflet length

Genotypes	Height±SD (cm)	Bran-Num±SD	Ped-Len±SD (cm)	Pet-Len±SD (cm)	Leaf-len±SD (cm)	Leaf-Diam±SD (cm)
KVX396-4-5-2D	15.05±6.98 ^{abc}	6.27±2.27 ^{ab}	1.44±3.76 ^{cde}	10.11±1.27 ^{defg}	10.41±1.89 ^{abc}	5.88±0.83 ^{abcd}
M5KA1-4-0-3	13.61±2 ^{abcde}	7.17±1.20 ^a	17.16±4.96 ^{cde}	8.47±1.09 ^{fgh}	9.02±1.62 ^{cd}	4.66±0.70 ^{de}
M5KA2-1-4-3	10.61±2.17 ^{de}	5.38±0.69 ^b	29.27±9.34 ^{ab}	13.58±1.11 ^{abc}	12.13±1.60 ^a	6.83±2.59 ^a
M5KA2-1-4-4	9.83±2.91 ^{ef}	5.88±2.27 ^{ab}	31.63±12.90 ^a	14.55±2.39 ^a	11.55±2.16 ^a	6.83±0.89 ^a
M5KA2-1-7-2	12.22±2.83 ^{bcdef}	7.16±0.98 ^a	19.97±6.46 ^{cde}	10.77±2.91 ^{de}	10.63±1.38 ^{abc}	5.97±0.79 ^{abc}
M5KA-4-1-2-1	13.55±2.28 ^{abcde}	6.5±1.29 ^{ab}	19.05±5.29 ^{cde}	9.38±1.27 ^{efgh}	9.11±1.61 ^{bcd}	4.88±0.77 ^{cde}
M5KA57-6-3-2	12.5±3.45 ^{bcd}	6.33±1.23 ^{ab}	20.72±4.36 ^{cde}	10.3±1.84 ^{def}	10.38±1.46 ^{abc}	5.77±0.75 ^{abcd}
M5KA71-3-4-4	12.5±3.94 ^{abcdef}	6.94±0.99 ^{ab}	19±3.81 ^{cde}	10.69±1.38 ^{de}	10.61±1.40 ^{abc}	6.38±0.75 ^{ab}
M5KA80-1-6-1	13.72±2.37 ^{abcde}	6.72±0.89 ^{ab}	21.47±6.34 ^{bcd}	11.77±1.77 ^{cd}	10.33±1.42 ^{abc}	5.44±0.85 ^{bcd}
M5KA99-2-3-1	12.33±3.72 ^{bcdef}	6.83±1.20 ^{ab}	14.55±5.28 ^e	9.55±1.06 ^{efgh}	10.30±1.52 ^{abc}	5.86±0.81 ^{abcd}
M5KB12-3-0-1	14.5±2.09 ^{abc}	6.38±0.97 ^{ab}	21.05±3.98 ^{cde}	11.97±1.09 ^{bcd}	10.91±2.01 ^{abc}	6.11±0.97 ^{abc}
MOUSSA Local	11.55±2.99 ^{cd}	7.38±1.33 ^a	17.05±5.85 ^{de}	7.75±2.33 ^h	8.22±1.69 ^d	4.91±1.38 ^{cde}

M5MA3-1-3-3	12.11±3.67 ^{bc def}	7.38±2.17 ^a	16.72±5.68 ^{de}	8.11±1.64 ^{gh}	7.77±1.42 ^d	4.5±0.85 ^e
M5M13-2-6-6-4	9.44±2.03 ^f	6.88±1.49 ^{ab}	15.86±8.21 ^{de}	8.33±1.91 ^{fgh}	8.05±1.10 ^d	4.44±0.53 ^e
TILIGRÉ	16.77±4.58 ^a	6.5±1.20 ^{ab}	20.22±4.69 ^{cde}	13.5±1.42 ^{abc}	11.16±1.58 ^a	6.61±0.94 ^{ab}
M5TA2-3-1-3	12.05±3.17 ^{bc def}	6.05±1.55 ^{ab}	19.05±6.55 ^{cde}	11.27±1.52 ^{de}	10.36±1.47 ^{abc}	5.97±0.93 ^{abc}
M5TB2-1-4	12±1.37 ^{bcdef}	6.27±1.17 ^{ab}	18.05±7.96 ^{cde}	13.94±2.42 ^{ab}	10.83±1.36 ^{abc}	6.13±0.92 ^{abc}
YIPOUSSI	15.77±4.26 ^{ab}	6.61±1.03 ^{ab}	22.63±7.59 ^{bcd}	13.66±2.05 ^{abc}	11.02±1.69 ^{ab}	6.61±1.02 ^{ab}
KOMCALL E	12.16±2.89 ^{bc def}	6.22±1.11 ^{ab}	18.38±7.89 ^{cde}	11±1.50 ^{de}	11.36±1.89 ^a	6.38±1.51 ^{ab}
KVX-NIK	10.77±2.43 ^{de f}	6.27±0.82 ^{ab}	25.08±6.57 ^{abc}	10.8±1.38 ^{de}	9±1.74 ^{cd}	5.38±0.73 ^{bcde}
Moyenne	12.652	6.55	20.26	10.97	10.15	5.77
CV (%)	26.27	20.89	33.2	16.24	15.97	18.5
Pr > F	<0.0001	0.0005	<0.0001	<0.0001	<0.0001	<0.0001

Height: plant height; Bran-Num: branch number; Ped-Len: peduncle length; Pet-Len: petiole length; Leaf-len: leaf length; Leaf-Diam: leaf diameter; CV (%): coefficient of variation, Pr > F: probability; ±SD: standard deviation.

Means with the same letter are not significantly different at the 5% level according to Tukey's test.

Phenological variability, yield components, and yield of cowpea genotypes

Table 7 highlights promising cowpea genotypes based on earliness, pod morphology, and grain yield. A very highly significant difference ($P < 0.0005$) is observed among genotypes for the measured parameters. The period to semi-maturity ranges from 57.33 days (M5KA2-1-4-3) to 68.66 days (MOUSSA Local, M5M13-2-6-6-4). The longest pods are recorded in M5TB2-1-4 (18.48 cm) and M5KA2-1-4-3 (18.13 cm), whereas the shortest pods occur in M5KA-4-1-2-1 (13.6 cm) and M5KA1-4-0-3 (13.69 cm). Pod width varies little, but thickness shows marked variation, reaching up to 9.03 mm in TILIGRÉ, 8.67 mm in YIPOUSSI, and 8.62 mm in MOUSSA. The 1000-seed weight ranges from 113.88 g (M5KA80-1-6-1) to 179.95 g (TILIGRÉ). In addition to TILIGRÉ, M5TB2-1-4 (174.33 g), YIPOUSSI (169.63 g), KOMCALLE (162.26 g), MOUSSA Local (163.58 g), M5M13-2-6-6-4 (161.16 g), and KVX-NIK (160.10 g) show high seed weights. Grain yields range from 1068.42 kg/ha to 1735.14 kg/ha. The highest yields are recorded in lines M5M13-2-6-6-4 (1735.14 kg/ha), M5KA2-1-7-2 (1669.40 kg/ha), KVX-NIK (1667.13 kg/ha), and M5KA57-6-3-2 (1632.16 kg/ha), which are statistically similar to TILIGRÉ, M5KA71-3-4-4, and KOMCALLE. The coefficients of variation are low and range from 1.72% to 10.98%.

Tableau 7: Comparison of phenological parameters, yield, and yield components of cowpea genotypes

Genotypes	Mat-Dat±SD (JAS)	Pod-Len±SD (cm)	Pod-Wid±SD (cm)	Pod-Thic±SD (cm)	TKW±SD (g)	Yield±SD (kg/ha)
KVX 396-4-5-2D	63±0 ^{bc}	17.58±0.72 ^{abc d}	5.84±0.63 ^{abc}	8.16±0.37 ^{bcdef}	130.35±2.71 ^{fg}	1478.26±102.57 ^{bcde}
M5KA1-4-0-3	62.33±1.52 ^{bc}	13.69±0.85 ⁱ	5.74±0.72 ^{abc}	7.61±0.50 ^f	138.42±29.56 ^{defg}	1369.23±20.10 ^{def}
M5KA2-1-4-3	57.33±0.57 ^c	18.13±1.08 ^{ab}	5.56±0.57 ^{abc}	7.82±0.43 ^{ef}	158.62±4.34 ^{abcde}	1232.71±159.04 ^{efgh}
M5KA2-1-4-4	58.33±0.57 ^{de}	17.76±1.18 ^{abc}	5.45±1.21 ^{bc}	8.09±0.47 ^{bcdef}	143.73±14.50 ^{cdef}	1630.05±20.54 ^{abc}
M5KA2-1-7-2	60±1 ^{cde}	17.18±0.67 ^{bcd}	6.25±0.38 ^a	8.22±0.50 ^{bcdef}	141.69±3.94 ^{cdefg}	1669.40±86.59 ^{ab}
M5KA-4-1-2-1	60.33±1.15 ^{bcde}	13.60±0.85 ⁱ	5.62±0.44 ^{abc}	7.96±0.59 ^{cdef}	133.10±0.54 ^{efg}	1063.9±73.76 ^a
M5KA57-6-3-2	61.33±1.52 ^{bcd}	16.78±0.70 ^{cde f}	5.75±0.34 ^{abc}	7.82±0.37 ^{ef}	137.14±11.46 ^{defg}	1632.16±16.32 ^{abc}

M5KA71-3-4-4	60.66±0.57 ^{bcd}	16.77±0.91 ^{cde} _f	5.82±0.69 ^{abc}	7.95±0.60 ^{def}	141.49±3.9 ^{2defg}	1485.87±49.6 ^{3abcde}
M5KA80-1-6-1	63±0 ^{bc}	14.65±1.32 ^{hi}	5.53±0.62 ^{abc}	7.71±0.57 ^{ef}	113.88±8.8 ^{9g}	1403.97±33.8 ^{8cde}
M5KA99-2-3-1	63.33±0.57 ^b	17.00±0.84 ^{bcd}	5.69±0.60 ^{abc}	7.85±0.49 ^{ef}	135.62±6.7 ^{8defg}	1079.76±77.7 ^{6gh}
M5KB12-3-0-1	61.33±1.52 ^{bcd}	17.50±0.86 ^{abcd}	6.07±0.55 ^{ab}	8.06±0.50 ^{bcd}	146.49±5.4 ^{1bcd}	1609.4±63.65 ^{bcd}
MOUSSA Local	68.66±0.57 ^a	15.61±1.30 ^{fg}	6.29±0.56 ^a	8.62±0.49 ^{abc}	163.58±4.5 ^{7abcd}	1129.61±144.3 ^{7fgh}
M5MA3-1-3-3	68.33±0.57 ^a	16.37± ^{defg}	6.06±0.80 ^{ab}	8.24±0.43 ^{bcd}	148.21±3.3 ^{7bcd}	1327.64±6.71 ^{defg}
M5M13-2-6-6-4	68.66±2.30 ^a	15.34±1.04 ^{fgh}	6.01±0.59 ^{ab}	8.00±0.35 ^{cdef}	160.16±6.8 ^{4abcde}	1735.14±35.0 ^{6^a}
TILIGRÉ	62±1 ^{bc}	17.78±1.67 ^{abc}	5.94±0.58 ^{ab}	9.03±0.88 ^a	179.95±3.7 ^{6^a}	1546.10±113.99 ^{abcd}
M5TA2-3-1-3	61.33±1.52 ^{bcd}	16.37± ^{defg}	6.25±0.49 ^a	8.32±0.54 ^{bcd}	141.85±5.5 ^{2cdefg}	1068.42±142.90 ^h
M5TB2-1-4	61.66±1.15 ^{bc}	18.48± ^a	6.04±0.70 ^{ab}	8.58±0.85 ^{abcd}	174.33±2.5 ^{9ab}	1393.17±97.6 ^{1cde}
YIPOUSSI	61±0 ^{bcd}	17.50±0.93 ^{abcd}	6.05±0.60 ^{ab}	8.67±0.69 ^{ab}	169.63±5.9 ^{0abc}	1435.62±49.1 ^{3cde}
KOMCALL E	62.33±1.15 ^{bc}	15.75±1.61 ^{efg} _h	5.15±0.62 ^c	8.26±0.70 ^{bcd}	162.26±7.1 ^{8abcd}	1485.22±14.6 ^{6abcde}
KVX-NIK	61.66±0.57 ^{bc}	16.93±1.09 ^{bcd}	5.81±0.60 ^{abc}	8.35±0.37 ^{bcd}	160.10±2.83 ^{abcde}	1667.13±55.4 ^{7ab}
Mean	62.36	16.54	5.85	6.85	149.03	1414.49
CV (%)	1.72	6.42	10.98	8.17	6.1	5.79
Pr > F	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<.0001

Mat-Dat: maturity date; Pod-Len : pod length; Pod-Wid : pod width; Pod-Thic : pod thickness; TKW : thousand kernels weight; Yield: grain yield; SD: standard deviation; CV (%): coefficient of variation, Pr > F: probability; ±SD: standard deviation

Means with the same letter are not significantly different at the 5% level according to Tukey's test.

Principal Component Analysis (PCA) of measured quantitative variables

Principal Component Analysis (PCA) allows the principal components to be broken down into several dimensions. The first two dimensions (Dim 1 = 43.3% and Dim 2 = 20.6%) along the principal axes (horizontal and vertical axes) explain 63.9% of the total variance. The first principal component (Dim 1) is strongly positively correlated with mean leaflet length ($r = 0.92$), mean leaflet diameter ($r = 0.89$), mean petiole length ($r = 0.87$), and mean peduncle length ($r = 0.77$), and negatively correlated with the mean number of branches ($r = -0.83$) and the date of 50% maturity ($r = -0.91$). As for Dimension 2, it is strongly positively correlated with mean pod thickness ($r = 0.94$) and mean 1000-seed weight ($r = 0.84$), and moderately correlated with mean pod width ($r = 0.48$) and mean plant height ($r = 0.36$). It is negatively correlated with seed yield ($r = -0.4$). This dimension distinguishes traits related to pod and seed quality, particularly pod thickness, mean 1000-seed weight, and pod width. Dimension 2 reflects seed size and quality more specifically and could be considered the productivity axis. The color of the segments indicates the contribution level of each variable. Green represents the variables that contribute most, while blue indicates the variables that contribute least to the overall character variation (Figure 1). Accordingly, pod thickness, petiole length, leaflet length, and leaflet diameter are the variables that contribute most to the observed variation.

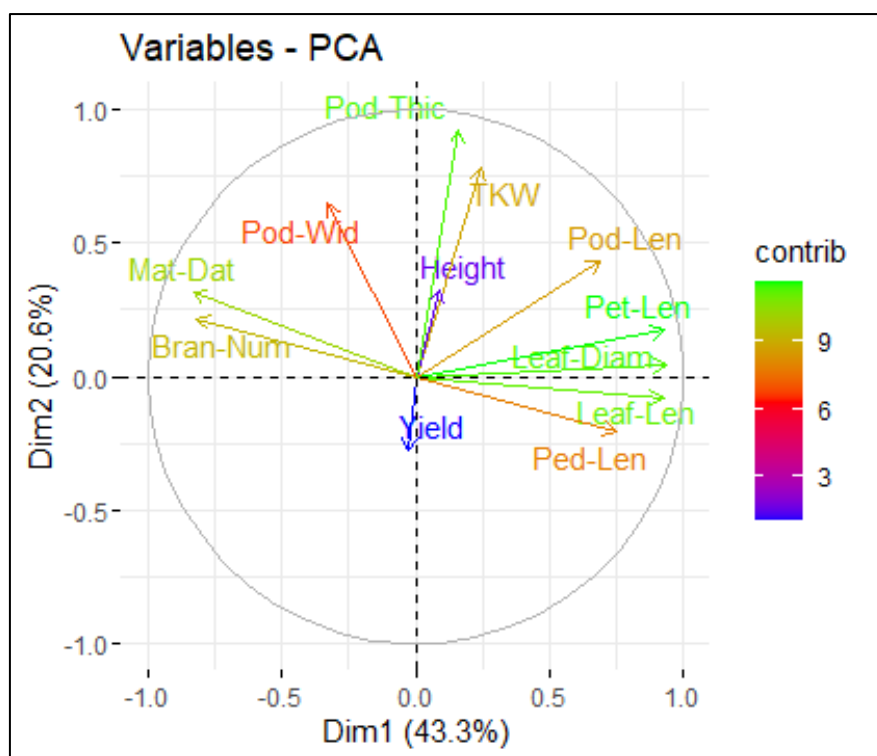


Figure 1: Factorial plan showing the associations between quantitative traits in cowpea genotypes

Height: plant height at semi-maturity; *Bran-Num:* number of branches per plant at maturity; *Ped-Len:* peduncle length (cm); *Pet-Len:* petiole length (cm); *Leaf-Len:* leaflet length (cm); *Leaf-Diam:* leaflet diameter (cm); *Mat-Dat:* date of 50% maturity; *Pod-Len:* pod length (cm); *Pod-Wid:* pod width (cm); *Pod-Thic:* pod thickness (cm); *TKW:* thousand kernel weight (g); *Yield:* grain yield (kg/ha).

Discussion

The agro-morphological evaluation of cowpea genotypes revealed significant genetic variability between mutant lines and their parental genotypes, affecting both quantitative and qualitative traits. Qualitative traits, in particular, showed variations in seed color, hilum color, pod color, and leaf shape, which can be attributed to mutations induced by gamma irradiation. Similar modifications have been reported in other species exposed to mutagenic agents (Raina *et al.*, 2022; Diouf *et al.*, 2021). Seed color, a key selection trait closely linked to consumer preferences, is generally associated with loci involved in anthocyanin biosynthesis (Herniter *et al.*, 2018). In certain mutants derived from MOUSSA Local, the transition from reddish branch pigmentation to a greenish coloration suggests a disruption in this metabolic pathway. Likewise, the diversification of flower color, particularly the emergence of purple flowers in mutant M5M13-2-6-6-4, indicates a mutation affecting the flavonoid biosynthetic pathway (Ntswane *et al.*, 2023; Dabiré *et al.*, 2024).

Furthermore, pod shape and curvature, as well as plant growth habit, were modified, with a predominance of the semi-erect growth habit among mutants of K VX 396-4-5-2D and a prostrate habit among those derived from MOUSSA Local. Some genotypes exhibited an erect growth habit associated with determinate growth, which facilitates mechanization, harvesting, canopy aeration, and reduction of post-harvest losses. This represents a major agronomic advantage in intensive production systems.

Quantitative data reveal high variability (CV > 20%) for traits such as plant height, physiological maturity, peduncle length, and mean number of branches per plant. This phenotypic heterogeneity reflects the genetic diversity induced by mutagenesis within cowpea genotypes derived from the parental varieties.

Some morphological traits, including peduncle length, leaflet length, and leaflet diameter, exhibited high variability between mutants and parents, with mutants displaying values significantly higher or lower than those of their parents. Mutants such as M5KA2-1-4-3 and M5KA2-1-4-4 stand out significantly from the parents due to their long peduncles. This phenotypic trait could enhance pollination through better flower exposure, thereby potentially improving yield.

Comparative analysis of plant height among mutants shows a significant reduction in some genotypes compared to the parents. This decrease may result from a mutation affecting vegetative development, particularly through a reduction in the number of internodes or overall plant vigor (Nair *et al.*, 2025). Such morphological variations are likely induced by chromosomal or physiological alterations linked to irradiation (Raina *et al.*, 2022).

Other mutants exhibited plant height comparable to that of their parental genotypes, suggesting variability in mutagenic effects. Gamma irradiation may exert either positive or negative effects on plant morphology, particularly plant height, by modulating the activity of growth hormones such as auxin, thereby promoting cell elongation through osmotic mechanisms (Jayawardhane *et al.*, 2022). Mutants M5MA-3-1-3-3, M5KA1-4-0-3, and M5KA2-1-7-2 displayed pronounced branching, likely associated with enhanced meristematic activity or hormone-mediated alterations (auxin and cytokinin) induced by mutagenesis. Increased branching is generally correlated with greater yield potential through the expansion of reproductive sites, as reported in other mutant lines (Adu-Gyamfi *et al.*, 2017; Sheidu and Igyuve, 2023).

Leaves play a central role in photosynthesis and carbohydrate accumulation, which constitute the primary carbon reserves of seeds; thus, enhanced branching may contribute to yield improvement. However, excessive foliage may lead to intra-plant competition and exacerbate water stress under severe moisture-deficit conditions (Adeniyi *et al.*, 2022; Olorunwa *et al.*, 2021). Conversely, weakly branched mutants (≤ 6 branches), such as M5KA2-1-4-3, M5KA2-4-4, and M5KA2-3-1-3, may promote earliness and prove better adapted to Sudano-Sahelian environments.

Date to 50% maturity is a critical trait for adaptation to erratic rainfall patterns. Early-maturing genotypes such as M5KA2-1-4-3 and M5KA2-1-4-4 offer a distinct advantage by enabling escape from terminal drought stress and facilitating relay or catch cropping an adaptive strategy increasingly advocated in the context of climate change (Kim *et al.*, 2025). This earliness also constitutes a significant asset in regions characterized by short growing seasons, notably the Sahelian zones. In a country such as Burkina Faso, early-maturing genotypes ensure a swift harvest, which is essential for vulnerable households facing depleted grain reserves. These genotypes are also capable of completing their life cycle prior to the cessation of rains, thereby mitigating yield losses associated with terminal drought. Furthermore, by vacating fields earlier, early-maturing cowpea genotypes allow for the cultivation of a subsequent crop or the establishment of forage crops post-harvest. Conversely, certain late-maturing mutants namely M5M13-2-6-6-4, M5KA2-1-7-2, and M5KA2-1-4-4 nevertheless exhibit satisfactory yield levels, illustrating the existence of divergent adaptive strategies. Genotypes TILIGRE, M5TB2-1-4, and YIPOUSSI produced the heaviest seeds, a trait highly sought after in local markets. However, the correlation between 1000-seed weight and grain yield is not systematically positive, as evidenced by the case of TILIGRÉ.

The first dimension of the principal component analysis contrasts characteristics related to the cycle and branching (negatively correlated) with those associated with leaf area (positively correlated), revealing a tension between vegetative vigor and short cycle, a phenomenon also observed in cowpea (Simova-Stoilova *et al.*, 2025; Danso *et al.*, 2025). The second dimension mainly groups variables related to pod and seed morphology, such as 1000-seed weight, pod width, and pod thickness. This dimension would constitute the productivity axis. These results indicate that it is possible to select genotypes combining several traits such as earliness, branching, and high seed weight.

Conclusion

The present study highlighted the effectiveness of gamma irradiation-induced mutagenesis as a tool for broadening genetic variability in cowpea in Burkina Faso. The agro-morphological evaluation of mutant lines derived from the varieties K VX 396-4-5-2D, MOUSSA Local, and TILIGRÉ revealed significant phenotypic diversity, affecting both qualitative and quantitative traits. This variability translated into notable modifications in plant morphology, growth habit, earliness, branching, and yield components, confirming the impact of induced mutations on the expression of agronomically important traits. Several mutants stood out for their superior or specific performance, notably exhibiting enhanced earliness, high seed yield, and plant architectures conducive to adaptation to local agro-climatic conditions. Genotypes M5KA2-1-4-3 and M5KA2-1-4-4 were distinguished by their earlier maturity, while M5M13-2-6-6, M5KA2-1-7-2, and K VX-Nike displayed the highest seed yields. Furthermore, the emergence of an erect growth habit in certain

mutants of K VX 396-4-5-2D represents a significant agronomic asset, facilitating cultural practices and harvest operations, while also reducing post-harvest losses.

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