



**Original Article**

**AGRO-MORPHOLOGICAL AND BIOCHEMICAL RESPONSE OF COWPEA (*Vigna unguiculata* L. walp.) GENOTYPES TO GAMMA IRRADIATION**

**\*Abdulmalik, M., Abdulhakeem A., Abdulsalami, H., Daudu, O. A. Y. and Mohammed, C. D.**

**Department of Plant Biology, Federal University of Technology, Minna, Nigeria**

Submitted: September 2025; Accepted: October 2025; Published: December 2025

**ABSTRACT**

Cowpea (*Vigna unguiculata* L. walp.) is one of the most widely adaptable grain consumed for its high-quality plant protein and low-fat content as well as favorable amino acid sequence. Despite these importances, its productivity in typical Sub-Sahara Africa farmers' fields is very low due to low diversity and narrow genetic base of the crop. Thus, the study was carried out assesses the impacts of gamma irradiation on the growth performance of cowpea plants. A total of three genotypes cowpea mostly consumed, designated as White, Black and Brown were irradiated with gamma ray at dosage of 100, 200, 300, and 400 Gy. The non-irradiated cowpea seeds served as the control. Three seeds each of the treated genotypes and their control were sown and laid out using a Randomised Completely Block Design (RCBD) with three replications. The germinated seedlings were thinned to two per stand at 2, 4, 6 and 8 weeks after emergence (WAE) and evaluated for morphology from two weeks after emergence till it reach maturity and biochemical parameters at 8 weeks. The results of morphological parameters decrease significantly with increasing irradiation doses. At 8WAE, 200Gy irradiated plant had significantly highest height of 96.59 cm and the lowest (90.34 cm) was recorded in 400Gy. Among the irradiated plants highest mean number of leaves per plant (54.11) and leaf area (193.8 cm<sup>2</sup>) were recorded in 100Gy plants at 8WAE. In terms of yield parameters, the highest number of pods, seed per plant, Weight of pod as well as weight of seed per plant and weight of 100 seed per plant with the mean values of 23.67g, 237.78, 27.67 g, 25.89 g and 22.16 g were recorded at 100Gy irradiated plant. These values were not significantly different from yield of the control but differed from that of all other irradiated plants. In contrast, biochemical assays revealed a positive trend, as irradiation enhanced the activities of superoxide dismutase (SOD), catalase (CAT), and peroxidase (POD), alongside increases in total soluble sugars (TSS) and proline content. Among the genotypes, the Brown cowpea recorded the highest enzyme activities with the value of 58.77u/gFW and metabolite accumulation, followed by White with 47.70u/gFW. while Black 49.79u/gFW exhibited the lowest biochemical response. Thus, gamma irradiation had a reduction effect on germination and yield traits of Cowpea plants, it simultaneously triggers strong antioxidants responses.

**Keywords:** Cowpea, Genotypes, Biochemical responses, Parameters and Irradiation.

**\*Corresponding author email:** abdulmalikmurjanatu@gmail.com, 08063832592.

## INTRODUCTION:

Cowpea (*Vigna unguiculata* [L.] Walp.) is one of the most important grain legumes cultivated across the tropics and subtropics, serving as a staple source of dietary protein, income, and food security, particularly in sub-Saharan Africa. Nigeria remains the largest producer and consumer of cowpea globally, accounting for over 45% of world production (1); (2). The crop plays a dual role, both as a subsistence food for rural communities and as a commercial crop with high market value. Its grains contain 20–35% protein, 50–60% carbohydrates, and essential vitamins and minerals, making it a cheap alternative to animal protein for low-income households (3). Beyond its nutritional value, cowpea contributes significantly to soil fertility through nitrogen fixation, thereby reducing the dependence on synthetic fertilizers (4). Despite its socioeconomic and nutritional significance, cowpea production is constrained by several challenges that limit yield potential and quality. Prominent among these constraints are viral diseases, insect pests, poor soil fertility, and limited genetic diversity in cultivated varieties (2).

Gamma irradiation is a physical mutagen widely used in crop improvement to induce heritable mutations that broaden genetic variability without compromising the integrity of the existing genome. It has been successfully employed in the improvement of several legumes, cereals, and vegetables, resulting in the release of high yielding, stress tolerant, and disease resistant varieties (5) (6). In cowpea, mutation breeding has been shown to induce beneficial variations in traits such as plant height, number of branches, pod characteristics, seed size, seed weight, and flowering time (7). However, these

challenges still linger due to continue cropping and inadequate conventional variety. Additionally, induced mutations can alter biochemical responses, including enzymatic antioxidant systems (superoxide dismutase [SOD], peroxidase [POD], catalase [CAT]) and metabolites (amino acids, soluble sugars), which play crucial roles in stress mitigation and pathogen defence, thus, study was carried out.

## MATERIALS AND METHODS

### Collection of seeds and irradiation of seeds

A total of three cowpea (*Vigna unguiculata*) genotypes used for the research were donated by local farmers in Minna, Niger State. The viable seed were grouped into five, of equal weights (100g) for irradiation at dosage of 100Gy, 200Gy, 300Gy, 400Gy using a cobalt-60 (<sup>60</sup>Co) and un-irradiated seeds (0Gy) serve as the control using Gamma rays' source at Centre for Energy and Research Training (CERT), Ahmadu Bello University Zaria, Nigeria.

### Experimental Treatments Design and layout

The factorial experiment consists of five (5) irradiation doses and three (3) cowpea genotypes and to give 15 experimental combinations of (5 × 3). The experimental set up was arranged in a Completely Randomized Design with three replications to total of 45 experimental pots. The experimental sets up were watered twice daily in absence of rainfall to ensure adequate soil moisture for growth.

### Growth Parameters:

*Plant height* (cm): Height of each plant was measured using measuring tape from the base to the tip of the main shoot

at two (2) week intervals, four times (at 2, 4, 6 and 8 weeks).

*Number of leaves per plant:* This was done by direct counting of the number of leaves produced per plant at two (2) weeks interval.

*Leaf area (cm<sup>2</sup>):* This estimated using a non-destructive method by measuring the length and breadth using measuring tape. The area is estimated as the product of length and breath as well as correction factor using the formula below;

Leaf area= Leaf length X Leaf width X 0.75

### Yield and Yield-Related Parameters

*Days to flowering:* Number of days from sowing to first flower appearance is being noted i.e at 40 days, the flowers start.

*Number of pods per plant;* This was determined by counting the total number of pods produced by each plant.

*Weight of pod per plant;* the weight (g) of the harvested pod per plant was determined by using sensitive weighing balance (Melter PM2000, England) after harvest.

Table 4.1: Effects of Gamma Irradiation on the Germination percentage (%) of Three Cowpea Genotypes

Doses (D)	W	BL	B
Control	100	100	95
100Gy	90	95	80
200Gy	85	70	75
300Gy	75	75	75
400Gy	70	85	70

Key: Dose (D), White(W); Black (BL); Brown(B)

The result revealed that gamma irradiation exerts a dose-dependent effect on cowpea growth, with low to moderate doses (100–200Gy) enhancing plant height, while higher doses (300–400Gy) are inhibitory. Significantly ( $p < 0.05$ ) highest plant height was recorded at 100Gy throughout the study period

*Total weight of seed per plant;* The weight (g) of the harvested seed per plant was determined using sensitive weighing balance (Melter PM2000, England) after harvest and peeling of the pod.

*Number of seeds per pod;* this as determined by counting the total number of seeds per pods produced by each plant.

*Weight (g) of 100 seed per plant;* the weight (g) of the harvested of 100 seed per plant was determined by using sensitive weighing balance (Melter PM2000, England).

## RESULTS

The effect of gamma irradiation on the germination of the selected cowpea showed that at 100Gy dose had the highest percentage across all the cowpea seed types (Table 4.1). Gamma irradiation has a dose-dependent negative effect on cowpea germination, 100-200Gy has mild to moderate effects, 300-400Gy has strong inhibitory effects.

with the value of (23.00, 51.06, and 72.48) cm at 2, 4 and 6 WAE, respectively while the shortest plant was obtained in 300Gy with the height of 19.94 (2 WAE), 43.66 (4 WAE) and 71.22 (6 WAE). At 8 WAE, the tallest plant was due to 200Gy while the shortest was obtained in 400Gy with the value of 90.34 cm. These

values were significantly ( $p < 0.05$ ) different from one another and from the values of all other irradiated dose plants. Among the genotypes, the white genotype had the highest plant height throughout the experimental period with the value of 23.63, 51.15, 74.67 and 95.19 cm at 2, 4, 6 and 8 WAE, respectively. These highest heights at 2 and 4 WAE were not significantly ( $p > 0.05$ ) different from the value of 22.63 and 48.97 cm obtained in Brown genotype but differed significantly from that of black with the height of 19.53 and 38.87 cm, respectively. Similarly, highest height at 6 and 8 WAE were not significantly ( $p > 0.05$ ) different from the value of 72.45 and 94.52 cm recorded in Black genotype but differed significantly ( $p < 0.05$ ) from that of brown with the height of 67.26 and 88.33 cm, respectively.

The interaction of the doses and genotypes were significantly different ( $p < 0.05$ ) for all the treatments throughout the study period. The highest height (27.33cm) was produced by interaction of 100Gy and white genotype and the least height of 18.67cm recorded in interaction of both 200\*BL and 300\*BL at 2 WAE. At 4 WAE significant highest height (63.33cm) was due to the interaction of 100Gy and white genotype and the least height of 35.67cm recorded was due to 300\*BL interaction. Significant ( $p < 0.05$ ) highest height (78.33cm) at 6 WAE was due to the interaction of produce by 100Gy\*White and the least height of 63.53cm was obtained in interaction of control\*Br genotype. Similarly, interaction of 200Gy\*W had the highest height (99.43cm) and the least height of 84.93cm was due to the interaction 400Gy\*Br

Table 2: Effects of Gamma irradiation doses on Plant height (cm) of irradiated Cowpea genotype at different Weeks After Emergence (WAE)

	2WAE	4WAE	6WAE	8WAE
<b>Doses (D)</b>				
Control	22.72 <sup>ab</sup>	46.50 <sup>a</sup>	70.40 <sup>a</sup>	91.62 <sup>ab</sup>
100 Gy	23.00 <sup>b</sup>	51.06 <sup>a</sup>	72.48 <sup>a</sup>	93.66 <sup>b</sup>
200 Gy	21.56 <sup>ab</sup>	45.60 <sup>a</sup>	71.64 <sup>a</sup>	96.59 <sup>c</sup>
300 Gy	19.94 <sup>a</sup>	43.66 <sup>a</sup>	71.22 <sup>a</sup>	91.18 <sup>ab</sup>
400 Gy	22.44 <sup>ab</sup>	44.83 <sup>a</sup>	71.56 <sup>a</sup>	90.34 <sup>a</sup>
S.E (±)	0.91	2.36	1.16	1.03
<b>Variety (V)</b>				
W	23.63 <sup>b</sup>	51.15 <sup>b</sup>	74.67 <sup>b</sup>	95.19 <sup>b</sup>
BL	19.53 <sup>a</sup>	38.87 <sup>a</sup>	72.45 <sup>b</sup>	94.52 <sup>b</sup>
BR	22.63 <sup>b</sup>	48.97 <sup>b</sup>	67.26 <sup>a</sup>	88.33 <sup>a</sup>
S.E (±)	0.70	1.82	0.89	0.79
<b>Interaction (D*V)</b>				
Control*W	24.50 <sup>a</sup>	52.67 <sup>a</sup>	73.00 <sup>a</sup>	94.83 <sup>a</sup>
Control*BL	20.00 <sup>a</sup>	40.17 <sup>b</sup>	74.67 <sup>a</sup>	94.10 <sup>b</sup>
Control*BR	23.67 <sup>a</sup>	46.67 <sup>a</sup>	63.53 <sup>c</sup>	85.93 <sup>c</sup>
100*W	27.33 <sup>a</sup>	63.33 <sup>a</sup>	78.33 <sup>a</sup>	98.57 <sup>a</sup>
100*BL	20.00 <sup>a</sup>	42.17 <sup>b</sup>	72.83 <sup>a</sup>	93.43 <sup>b</sup>
100*BR	21.67 <sup>a</sup>	47.67 <sup>a</sup>	66.27 <sup>b</sup>	88.97 <sup>c</sup>
200*W	22.67 <sup>a</sup>	47.47 <sup>a</sup>	76.00 <sup>a</sup>	99.43 <sup>a</sup>
200*BL	18.67 <sup>b</sup>	39.17 <sup>b</sup>	71.43 <sup>a</sup>	97.17 <sup>a</sup>
200*BR	23.33 <sup>a</sup>	50.17 <sup>a</sup>	67.50 <sup>b</sup>	93.17 <sup>b</sup>
300*W	21.00 <sup>a</sup>	45.30 <sup>a</sup>	74.33 <sup>a</sup>	91.73 <sup>c</sup>
300*BL	18.67 <sup>b</sup>	35.67 <sup>b</sup>	69.17 <sup>b</sup>	93.17 <sup>b</sup>
300*BR	20.17 <sup>a</sup>	50.00 <sup>a</sup>	70.17 <sup>b</sup>	88.63 <sup>c</sup>
400*W	22.67 <sup>a</sup>	47.00 <sup>a</sup>	71.67 <sup>a</sup>	91.37 <sup>c</sup>
400*BL	20.33 <sup>a</sup>	37.17 <sup>b</sup>	74.17 <sup>a</sup>	94.73 <sup>a</sup>
400*BR	24.33 <sup>a</sup>	50.33 <sup>a</sup>	68.83 <sup>b</sup>	84.93 <sup>d</sup>
S.E (±)	1.57	4.09	2.01	1.78

Means with same letters along the column are not significantly ( $p < 0.05$ ) different using DMRT; S.E (Standard Error); WAE (Weeks After Emergence); W (White); BL (Black); BR (Brown).

The results in (Table 3) of the number of leaves per plant showed that there were not significant differences in number of leaves among the different doses used throughout the study period. The number of leaves decreased with increase in dosages from 100Gy with 8.22 to 6.89 in 300Gy and subsequently increase at 200Gy (8.11) at 2 WAE (Weeks After Emergence). At 4WAE the control plant had the highest number of leaves of 16.33 and 300Gy produced the lowest height with the value 15.69 per plant. The highest and lowest were not significantly ( $p < 0.05$ ) different from one another and the number of leaves of all other treatment doses Similarly at 6WAE, 100Gy irradiated plant had the highest number of leaves of 39.00 and 300Gy produced the lowest height with the value 32.78 per plant. The white genotype had significantly highest mean number of leaves at 2 and 4 WAE with the value of 8.13 and 17.67 per plant, respectively while the least of 6.93 and 14.80 per plant was due to Black genotype. At 6 WAE, White genotype had highest number of leaves 37.07 per plant, followed by Brown (35.33 per plant) and the least of 35.33 per plant in the black genotype. This value of White and Black are not significantly different from one another but differed significantly ( $p < 0.05$ ) from that of brown genotype. At

8WAE 300Gy irradiated plant had the highest number of leaves of 55.56 and control produced the lowest height with the value 51.00. The highest and lowest were not significantly different from one another and from the number of leaves in all other treatment doses.

The interaction of doses and genotypes resulted in significantly ( $p < 0.05$ ) different mean number of leaves among the treatment; with highest number of leaves (9.00 per plant) produced by 100Gy\*W and the least of 6.00 per plant recorded in interaction 300\*BL at 2WAE. At 4WAE, the interaction 400\*W had the highest number of leaves (18.33 per plant) and the least mean number of leaves; 14.00 per plant was obtained in interaction of 200\*BL. The highest number of leaves (40.67 per plant) produced by 100Gy\*Br and the least number of leaves of 29.33 produced in interaction 200\*BL at 6WAE. Interaction of higher dose 300Gy and brown genotypes at 8WAE resulted in highest average number of leaves (57.67) and was due to Control\*BL genotype with the mean value of 48.67 per plant. This highest mean number of leaves was significantly ( $p < 0.05$ ) different from the number of leaves in all other treatment doses

Table 3: Number of leaves of Gamma Irradiated Cowpea at different Weeks After Emergence (WAE)

	2WAE	4WAE	6WAE	8WAE
<b>Doses (D)</b>				
Control	7.78 <sup>a</sup>	16.33 <sup>a</sup>	33.22 <sup>a</sup>	51.00 <sup>a</sup>
100 Gy	8.22 <sup>a</sup>	15.78 <sup>a</sup>	39.00 <sup>b</sup>	54.11 <sup>a</sup>
200 Gy	8.11 <sup>a</sup>	16.00 <sup>a</sup>	35.33 <sup>a</sup>	53.89 <sup>a</sup>
300 Gy	6.89 <sup>a</sup>	15.67 <sup>a</sup>	32.78 <sup>a</sup>	55.56 <sup>a</sup>
400 Gy	7.22 <sup>a</sup>	15.89 <sup>a</sup>	35.11 <sup>a</sup>	51.56 <sup>a</sup>
S.E ( $\pm$ )	0.44	0.58	0.87	1.71
<b>Variety (V)</b>				
W	8.13 <sup>b</sup>	17.67 <sup>b</sup>	37.07 <sup>b</sup>	52.80 <sup>a</sup>
BL	6.93 <sup>a</sup>	14.80 <sup>a</sup>	32.87 <sup>a</sup>	52.87 <sup>a</sup>
BR	7.87 <sup>ab</sup>	15.33 <sup>a</sup>	35.33 <sup>b</sup>	54.00 <sup>a</sup>
S.E ( $\pm$ )	0.34	0.45	0.67	1.33

Interaction (D*V)				
Control*W	8.33 <sup>a</sup>	17.33 <sup>a</sup>	36.67 <sup>a</sup>	52.33 <sup>b</sup>
Control*BL	6.67 <sup>b</sup>	14.67 <sup>b</sup>	30.33 <sup>b</sup>	48.67 <sup>c</sup>
Control*BR	8.33 <sup>a</sup>	17.00 <sup>a</sup>	32.67 <sup>b</sup>	52.00 <sup>b</sup>
100*W	9.00 <sup>a</sup>	17.67 <sup>a</sup>	37.33 <sup>a</sup>	52.67 <sup>b</sup>
100*BL	7.33 <sup>a</sup>	14.33 <sup>b</sup>	39.00 <sup>a</sup>	53.67 <sup>b</sup>
100*BR	8.33 <sup>a</sup>	15.33 <sup>a</sup>	40.67 <sup>a</sup>	56.00 <sup>b</sup>
200*W	8.67 <sup>a</sup>	18.00 <sup>a</sup>	37.33 <sup>a</sup>	52.33 <sup>b</sup>
200*BL	7.33 <sup>a</sup>	14.00 <sup>b</sup>	29.33 <sup>b</sup>	54.00 <sup>b</sup>
200*BR	8.33 <sup>a</sup>	16.00 <sup>a</sup>	39.33 <sup>a</sup>	55.33 <sup>b</sup>
300*W	7.67 <sup>a</sup>	17.00 <sup>a</sup>	36.00 <sup>a</sup>	53.67 <sup>b</sup>
300*BL	6.00 <sup>b</sup>	15.67 <sup>a</sup>	31.67 <sup>b</sup>	55.33 <sup>b</sup>
300*BR	7.00 <sup>a</sup>	14.33 <sup>b</sup>	30.67 <sup>b</sup>	57.67 <sup>a</sup>
400*W	7.00 <sup>a</sup>	18.33 <sup>a</sup>	38.00 <sup>a</sup>	53.00 <sup>b</sup>
400*BL	7.33 <sup>a</sup>	15.33 <sup>a</sup>	34.00 <sup>b</sup>	52.67 <sup>b</sup>
400*BR	7.33 <sup>a</sup>	14.00 <sup>b</sup>	33.33 <sup>b</sup>	49.00 <sup>c</sup>
S.E (±)	0.75	1.01	1.49	0.29

Means with same letters along the column are not significantly ( $p < 0.05$ ) different using DMRT; S.E (Standard Error); WAE (Weeks After Emergence); W (White); BL (Black); BR (Brown).

The results (Table 4) of the leaf area at 2 WAE (Weeks After Emergence) showed leaf area decreases with increase in dosages from 100Gy with the area of 37.50 cm<sup>2</sup> to 24.46 cm<sup>2</sup> in control and subsequently increase at 200Gy (35.64 cm<sup>2</sup>). The highest leaf area at 100Gy and the lowest height at control were significantly different from one another and from the value of other treatment doses. At 4WAE 100Gy irradiated plant had significantly highest leaf area of 79.21cm<sup>2</sup> and control produced the lowest area with the value 61.10 cm<sup>2</sup>. Similarly, the leaf area at 6WAE revealed that the control plant had the highest leaf area of 103.07 cm<sup>2</sup> and 200Gy produced the lowest area with the value 83.19 cm<sup>2</sup>. At 8WAE the control plant had the highest leaf area of 193.89 cm<sup>2</sup> and 400Gy produced the lowest area with the value 126.44 cm<sup>2</sup>. These values are significantly ( $p < 0.05$ ) different from one another and the number of leaves recorded in all other treatment doses.

Among the varieties, at 2 and 4 WAE the black genotype had the highest leaf area with the area value of 37.20 cm<sup>2</sup> and 76.87 cm<sup>2</sup>, respectively while the white had the least area of 29.97 cm<sup>2</sup> at 2 WAE and Brown at 4 WAE with the value of 58.51 cm<sup>2</sup>. The highest leaf area on black

genotype is significantly ( $p < 0.05$ ) different from the leaf area of the least and all other treatment doses. Similarly, significant highest leaf area of 108.72 cm was obtained in black genotype at 6 WAE while the brown had the least with the area of 72.85 cm. At 8WAE, the highest leaf area with the area value of 194cm was recorded in the white genotype while the brown had the least area of 100.67cm. The highest leaf area on White genotype is significantly ( $p < 0.05$ ) different from the area of the least and all other treatment doses.

The interaction of the doses and genotypes also revealed great variability for all the treatment with significantly ( $p < 0.05$ ) highest leaf area of 43.47 cm<sup>2</sup> produced by 300Gy\*BL and the least leaf area of 18.47 cm<sup>2</sup> recorded in Control\*Br at 2 WAE. Significantly highest ( $p < 0.05$ ) leaf area of 88.40 cm<sup>2</sup> was obtained in 200Gy\*BL while least leaf area of 43.47 cm<sup>2</sup> produced by interaction of Control and Brown genotype. At 6 WAE interaction of Control\*White resulted in significantly ( $p < 0.05$ ) highest of leaf area of 120.50 cm<sup>2</sup> and the least leaf area of 62.37cm<sup>2</sup> was recorded in 200Gy\*Br. Also, control\*BL produced significantly ( $p < 0.05$ ) highest leaf area of 279.67cm<sup>2</sup> at 8 WAE and the least leaf area of 79.00 cm<sup>2</sup> was obtained 200Gy\*Br.

Table 4: Effects of Gamma irradiation doses on Leaf area (cm<sup>2</sup>) at different Weeks After Emergence (WAE)

	2WAE	4WAE	6WAE	8WAE
<b>Doses (D)</b>				
Control	24.46 <sup>a</sup>	61.10 <sup>a</sup>	103.07 <sup>d</sup>	193.89 <sup>c</sup>
100Gy	37.50 <sup>b</sup>	79.21 <sup>d</sup>	101.23 <sup>d</sup>	184.33 <sup>c</sup>
200Gy	35.63 <sup>b</sup>	66.27 <sup>c</sup>	83.19 <sup>a</sup>	131.00 <sup>a</sup>
300Gy	35.64 <sup>b</sup>	64.01 <sup>b</sup>	95.51 <sup>c</sup>	157.00 <sup>b</sup>
400Gy	35.58 <sup>b</sup>	64.37 <sup>bc</sup>	90.36 <sup>b</sup>	126.44 <sup>a</sup>
S.E (±)	0.64	0.69	0.66	6.02
<b>Variety (V)</b>				
W	29.97 <sup>a</sup>	65.59 <sup>b</sup>	102.44 <sup>b</sup>	194.87 <sup>c</sup>
BL	37.20 <sup>c</sup>	76.87 <sup>c</sup>	108.72 <sup>c</sup>	180.07 <sup>b</sup>
BR	34.12 <sup>b</sup>	58.51 <sup>a</sup>	72.85 <sup>a</sup>	100.67 <sup>a</sup>
S.E (±)	0.49	0.53	0.51	4.66
<b>Interaction (D*V)</b>				
Control*W	20.77 <sup>b</sup>	69.70 <sup>b</sup>	120.50 <sup>a</sup>	168.67 <sup>b</sup>
Control*BL	34.13 <sup>a</sup>	70.13 <sup>b</sup>	106.17 <sup>a</sup>	279.67 <sup>a</sup>
Control*BR	18.47 <sup>b</sup>	43.47 <sup>d</sup>	82.53 <sup>c</sup>	133.33 <sup>c</sup>
100*W	34.33 <sup>a</sup>	88.27 <sup>a</sup>	106.33 <sup>a</sup>	266.67 <sup>a</sup>
100*BL	39.80 <sup>a</sup>	78.30 <sup>b</sup>	118.47 <sup>a</sup>	172.67 <sup>b</sup>
100*BR	38.37 <sup>a</sup>	71.07 <sup>b</sup>	78.90 <sup>c</sup>	113.67 <sup>d</sup>
200*W	36.27 <sup>a</sup>	72.27 <sup>b</sup>	81.00 <sup>c</sup>	145.33 <sup>b</sup>
200*BL	34.47 <sup>a</sup>	80.40 <sup>b</sup>	106.20 <sup>a</sup>	168.67 <sup>b</sup>
200*BR	36.17 <sup>a</sup>	46.13 <sup>d</sup>	62.37 <sup>c</sup>	79.00 <sup>d</sup>
300*W	20.27 <sup>b</sup>	35.67 <sup>d</sup>	110.07 <sup>a</sup>	238.33 <sup>a</sup>
300*BL	43.47 <sup>a</sup>	88.20 <sup>a</sup>	106.30 <sup>a</sup>	145.33 <sup>b</sup>
300*BR	43.20 <sup>a</sup>	68.17 <sup>b</sup>	70.17 <sup>c</sup>	87.33 <sup>d</sup>
400*W	38.20 <sup>a</sup>	62.07 <sup>c</sup>	94.30 <sup>b</sup>	155.33 <sup>b</sup>
400*BL	34.13 <sup>a</sup>	67.33 <sup>b</sup>	106.47 <sup>a</sup>	134.00 <sup>c</sup>
400*BR	34.40 <sup>a</sup>	63.70 <sup>c</sup>	70.30 <sup>c</sup>	90.00 <sup>d</sup>
S.E (±)	1.11	1.19	1.14	10.42

Means with same letters along the column are not significantly ( $p < 0.05$ ) different using DMRT; S.E (Standard Error); WAE (Weeks After Emergence); W (White); BL (Black); BR (Brown).

The results of the yield parameters showed that there was reduction in yield and yield traits with increase in the irradiation dosage. The plant of seed irradiated at 100Gy had the highest number of pods per plant, seed per plant, weight of pod and weight of seed per plant as well as weight of 100 seed per plant with the mean value of 23.67 pods, 237.78 seeds, 27.67 g, 25.89 g and 22.16 g, respectively. These yield traits values differed significantly ( $p < 0.05$ ) from the value obtained in all other treatments except for weight of 100 seed that was not significant to that of the control treatment with the value of 21.22 g.

Among the genotypes, the white genotype had the highest mean number of pods per plant (18.60 pods) and weight of pod per plant (20.82 g) which is not significantly different ( $p > 0.05$ ) from that of black genotype with the value of 18.53 pods and 20.35 g, respectively. The highest means number of seeds per plant (182.07 seeds) and weight of seeds per plant (20.35 g) were obtained in Black genotypes which differed significantly ( $p < 0.05$ ) from the values obtained in the Brown genotype but not significantly different ( $p > 0.05$ ) from that of White black genotype with the value of 181.20 seeds and 19.97 g, respectively. Highest

weight of 100 seeds per plant was obtained in White genotype (19.79 g) followed by 18.60 g in black genotype and the least of 18.10 g was recorded in Brown genotype.

The interactive effects of dosage-genotype showed that significant ( $p > 0.05$ ) highest mean pods per plant was obtained in 100\*White genotype (24.33 seeds) while the least of 11.00 seeds was obtained in 400\*Brown. Similar trend

was recorded for seed per plant, weight of pod per plant, weight of seed per plant and weight of 100 seed per plant with the highest mean value of 243.33 seeds, 28.24 g, 25.91 g and 23.41 g, respectively for 100\*White genotype. However, significantly ( $p > 0.05$ ) least interaction of seed per plant (108.33 seeds), weight of pod per plant (13.55 g), weight of seed per plant (13.34 g) and weight of 100 seed per plant (13.39 g) were obtained in 400\*Brown

**Table 5: Effects of Gamma irradiation on Yield parameters of Cowpea Genotypes**

	No. pod/plant	No. of seed/plant	Weight of pod/plant (g)	Weight of seed/plant (g)	Weight of 100 seed/plant (g)
<b>Doses (D)</b>					
Control	20.33 <sup>d</sup>	203.33 <sup>d</sup>	23.77 <sup>d</sup>	23.44 <sup>d</sup>	21.27 <sup>d</sup>
100Gy	23.67 <sup>e</sup>	237.78 <sup>e</sup>	27.67 <sup>e</sup>	25.89 <sup>e</sup>	22.16 <sup>d</sup>
200Gy	17.89 <sup>c</sup>	171.33 <sup>c</sup>	19.31 <sup>c</sup>	19.31 <sup>c</sup>	19.25 <sup>c</sup>
300Gy	14.89 <sup>b</sup>	141.22 <sup>b</sup>	16.99 <sup>b</sup>	16.99 <sup>b</sup>	16.35 <sup>b</sup>
400Gy	12.67 <sup>a</sup>	122.22 <sup>a</sup>	14.37 <sup>a</sup>	13.62 <sup>a</sup>	15.12 <sup>a</sup>
S.E (±)	0.37	4.07	0.52	0.38	0.40
<b>Variety (V)</b>					
W	18.60 <sup>b</sup>	181.20 <sup>b</sup>	20.91 <sup>b</sup>	19.97 <sup>ab</sup>	19.79 <sup>b</sup>
BL	18.53 <sup>b</sup>	182.07 <sup>b</sup>	20.82 <sup>b</sup>	20.35 <sup>b</sup>	18.60 <sup>a</sup>
BR	16.53 <sup>a</sup>	162.27 <sup>a</sup>	19.54 <sup>a</sup>	19.23 <sup>a</sup>	18.10 <sup>a</sup>
S.E (±)	0.28	3.15	0.40	0.29	0.31
<b>Interaction (D*V)</b>					
Control*W	20.33 <sup>bc</sup>	203.33 <sup>b</sup>	24.33 <sup>b</sup>	23.33 <sup>b</sup>	21.14 <sup>b</sup>
Control*BL	21.00 <sup>bc</sup>	210.00 <sup>b</sup>	22.49 <sup>bc</sup>	22.49 <sup>bc</sup>	21.06 <sup>b</sup>
Control*BR	19.67 <sup>bc</sup>	196.67 <sup>b</sup>	24.51 <sup>b</sup>	24.51 <sup>b</sup>	21.61 <sup>b</sup>
100*W	24.33 <sup>a</sup>	243.33 <sup>a</sup>	28.24 <sup>a</sup>	25.91 <sup>a</sup>	23.41 <sup>a</sup>
100*BL	23.33 <sup>ab</sup>	236.67 <sup>a</sup>	27.57 <sup>ab</sup>	25.91 <sup>a</sup>	21.39 <sup>b</sup>
100*BR	23.33 <sup>ab</sup>	233.33 <sup>a</sup>	27.18 <sup>ab</sup>	25.85 <sup>a</sup>	21.69 <sup>b</sup>
200*W	17.67 <sup>cd</sup>	170.00 <sup>c</sup>	20.66 <sup>cd</sup>	20.66 <sup>cd</sup>	19.94 <sup>c</sup>
200*BL	19.33 <sup>bc</sup>	182.67 <sup>c</sup>	20.49 <sup>cd</sup>	20.49 <sup>cd</sup>	19.16 <sup>c</sup>
200*BR	16.67 <sup>d</sup>	161.33 <sup>cd</sup>	16.77 <sup>de</sup>	16.77 <sup>de</sup>	18.65 <sup>cd</sup>
300*W	16.33 <sup>d</sup>	156.00 <sup>cd</sup>	16.66 <sup>de</sup>	16.66 <sup>de</sup>	17.96 <sup>cd</sup>
300*BL	16.33 <sup>d</sup>	156.00 <sup>cd</sup>	18.64 <sup>d</sup>	18.64 <sup>d</sup>	15.93 <sup>d</sup>
300*BR	12.00 <sup>e</sup>	111.67 <sup>d</sup>	15.68 <sup>e</sup>	15.68 <sup>e</sup>	15.16 <sup>d</sup>
400*W	14.33 <sup>e</sup>	133.33 <sup>d</sup>	14.65 <sup>ef</sup>	13.29 <sup>f</sup>	16.50 <sup>cd</sup>
400*BL	12.67 <sup>e</sup>	125.00 <sup>d</sup>	14.91 <sup>ef</sup>	14.23 <sup>ef</sup>	15.47 <sup>d</sup>
400*BR	11.00 <sup>e</sup>	108.33 <sup>d</sup>	13.55 <sup>f</sup>	13.34 <sup>f</sup>	13.39 <sup>e</sup>
S.E (±)	0.63	7.05	0.90	0.65	0.70

Means with same letters along the column are not significantly ( $p < 0.05$ ) different using DMRT; S.E (Standard Error); W (White); BL (Black); BR (Brown).

Biochemical response to gamma irradiation is presented in table six (6) SOD showed that there was significant ( $p < 0.05$ ) different among the doses used the SOD decreases with increase in dosage from 200Gy (2.88) to 2.10 in control and subsequently increase at 400Gy (2.83). The highest SOD at 200Gy and the lowest SOD at control were

significantly different from one another. Among the genotypes, the Brown genotype had the highest SOD with the value of 3.33 while the black had the least SOD of 1.93. The SOD brown genotype is significantly different from the SOD of the least genotype. The interaction of the doses and genotypes was significantly ( $p < 0.05$ ) different for all the treatment

with the highest SOD (3.97) produce by 100\*Br and the SOD of 1.41 recorded in interaction 300\*Br.

The results of catalase (CAT) showed that the 300Gy plant had the highest CAT of 14.76 and control produced the lowest CAT with the value of 8.41. The highest in 300Gy is not significantly ( $p > 0.05$ ) different from the catalase recorded in 100, 200 and 400Gy with the value of 12.67, 12.69 respectively. Among the genotypes, the Brown genotype had the highest CAT with the value of 15.85 while the black had the least with the CAT of 9.18. The highest CAT in brown genotype is significantly different ( $p < 0.05$ ) from the CAT recorded in all other genotypes. The interaction of the doses and genotypes was significantly different for all the treatment with the highest CAT (19.62) produce by 300\*Br and the least CAT of 6.66 recorded in interaction control\*Bl.

The results of POD showed that the 200Gy plant had the highest POD of 1.27 and control produced the lowest POD with the value 0.86. The highest and lowest was significantly different from one another and from POD of all other treatment doses. Among the genotypes, the Brown genotype had the highest POD with the value of 1.38cm while the white had the least POD of 0.86. The POD recorded brown genotype is significantly different ( $p < 0.05$ ) from the POD Obtained in all other genotypes. The interaction of the doses and genotypes was significantly different for all the treatment with the highest POD (1.74)

produce by 400\*Br and the least POD of 0.69 recorded in interaction 100Gy\*W.

The results of TSS showed that the 400Gy plant had the highest of 59.36 and control produced the lowest TSS with the value 41.19. The highest and lowest were significantly different from one another and from the value of all other treatment doses. Among the genotypes, the Brown genotype had the highest TSS with the value of 58.77 while the white had the least with the TSS of 47.70. The TSS brown genotype is significantly different ( $p < 0.05$ ) from the TSS of all other genotypes. The interaction of the doses and genotypes was significantly different for all the treatment with the highest TSS (67.48) produce by 400\*Br and the least TSS of 37.52 recorded in interaction control\*W.

The results of Proline showed that the control plant had the highest Proline value of 16.51 and 300Gy produced the lowest Proline with the value 14.77. The highest and lowest was not significantly different ( $p > 0.05$ ) from one another and proline value of all other treatment doses. Among the varieties, the Brown genotype had the highest Proline with the value of 16.87 while the white had the least with the Proline of 14.42. The Proline brown genotype is significantly different from the Proline value of both other genotypes. The interaction of the doses and genotypes were significantly different for all the treatment with the highest Proline (20.24) produce by control\*Br and the least Proline of 12.24 recorded in interaction 300Gy\*W.

**Table 6: Biochemical response of cowpea Genotypes to Gamma irradiation**

	SOD (U/ g FW)	CAT (U/ g FW)	POD (U/ g FW)	TSS ( $\mu$ mol/g FW)	Proline (U/ g FW)
<b>Doses (D)</b>					
Control	2.10 <sup>a</sup>	8.41 <sup>a</sup>	0.86 <sup>a</sup>	41.19 <sup>a</sup>	16.51 <sup>a</sup>
100Gy	2.61 <sup>b</sup>	12.67 <sup>b</sup>	1.03 <sup>b</sup>	57.08 <sup>d</sup>	15.46 <sup>a</sup>
200Gy	2.88 <sup>b</sup>	13.49 <sup>b</sup>	1.27 <sup>d</sup>	52.48 <sup>c</sup>	15.62 <sup>a</sup>
300Gy	2.76 <sup>b</sup>	14.78 <sup>b</sup>	1.09 <sup>bc</sup>	50.18 <sup>b</sup>	14.77 <sup>a</sup>
400Gy	2.83 <sup>b</sup>	12.69 <sup>b</sup>	1.23 <sup>cd</sup>	59.36 <sup>e</sup>	15.55 <sup>a</sup>
S.E ( $\pm$ )	0.16	0.97	0.07	0.70	0.60
<b>Variety (V)</b>					

W	2.64 <sup>b</sup>	12.20 <sup>b</sup>	0.86 <sup>a</sup>	47.70 <sup>a</sup>	14.42 <sup>a</sup>
BL	1.93 <sup>a</sup>	9.18 <sup>a</sup>	1.05 <sup>b</sup>	49.71 <sup>b</sup>	15.46 <sup>a</sup>
BR	3.33 <sup>c</sup>	15.85 <sup>c</sup>	1.38 <sup>c</sup>	58.77 <sup>c</sup>	16.87 <sup>b</sup>
S.E (±)	0.13	0.73	0.04	0.54	0.47
<b>Interaction (D*V)</b>					
Control*W	2.75 <sup>b</sup>	11.72 <sup>c</sup>	0.93 <sup>b</sup>	37.52 <sup>c</sup>	14.66 <sup>c</sup>
Control*BL	1.62 <sup>c</sup>	6.66 <sup>c</sup>	0.84 <sup>c</sup>	40.65 <sup>c</sup>	14.62 <sup>c</sup>
Control*BR	1.92 <sup>c</sup>	6.86 <sup>c</sup>	0.82 <sup>c</sup>	45.41 <sup>c</sup>	20.24 <sup>a</sup>
100*W	2.22 <sup>b</sup>	8.24 <sup>c</sup>	0.69 <sup>c</sup>	51.81 <sup>b</sup>	15.31 <sup>c</sup>
100*BL	1.60 <sup>c</sup>	7.88 <sup>c</sup>	0.84 <sup>c</sup>	54.69 <sup>b</sup>	17.22 <sup>b</sup>
100*BR	3.97 <sup>a</sup>	21.90 <sup>a</sup>	1.56 <sup>a</sup>	64.74 <sup>a</sup>	13.85 <sup>c</sup>
200*W	2.38 <sup>b</sup>	10.16 <sup>c</sup>	0.84 <sup>c</sup>	48.13 <sup>c</sup>	13.85 <sup>c</sup>
200*BL	3.11 <sup>a</sup>	14.15 <sup>b</sup>	1.65 <sup>a</sup>	51.53 <sup>b</sup>	16.06 <sup>b</sup>
200*BR	3.17 <sup>a</sup>	16.17 <sup>b</sup>	1.33 <sup>a</sup>	57.78 <sup>b</sup>	16.95 <sup>b</sup>
300*W	3.07 <sup>a</sup>	16.98 <sup>b</sup>	0.96 <sup>b</sup>	47.08 <sup>c</sup>	12.24 <sup>c</sup>
300*BL	1.41 <sup>c</sup>	7.73 <sup>c</sup>	0.87 <sup>b</sup>	45.01 <sup>c</sup>	12.89 <sup>c</sup>
300*BR	3.82 <sup>a</sup>	19.62 <sup>a</sup>	1.46 <sup>a</sup>	58.43 <sup>b</sup>	19.17 <sup>a</sup>
400*W	2.81 <sup>b</sup>	13.91 <sup>b</sup>	0.87 <sup>b</sup>	53.98 <sup>b</sup>	16.02 <sup>b</sup>
400*BL	1.90 <sup>c</sup>	9.49 <sup>c</sup>	1.07 <sup>b</sup>	56.61 <sup>b</sup>	16.51 <sup>b</sup>
400*BR	3.78 <sup>a</sup>	14.68 <sup>b</sup>	1.74 <sup>a</sup>	67.48 <sup>a</sup>	14.13 <sup>c</sup>
S.E (±)	0.28	1.68	0.09	1.22	1.04

Means with same letters along the column are not significantly ( $p < 0.05$ ) different using DMRT; S.E (Standard Error); W (White); BL (Black); BR (Brown).

## DISCUSSION

The plant height of the cowpea genotypes was greatly influenced by the gamma irradiation across different growth stages (2–8 WAE). At early growth (2 WAE) stages, the enhancement of seedling vigor by the moderate doses (100Gy and 200Gy) and reduction at higher doses (300–400Gy) compared to the control could be attributed to the hermosis effects of gamma irradiation doses, on the cells of plant. The concept of radiation hormesis revealed that small doses stimulate growth, while excessive exposure causes detrimental effects (8). This observation aligns with reports that low to moderate gamma irradiation stimulates cell division and elongation, whereas higher doses impose physiological stress that limits growth (9)(10). Similar to the findings of (11), who observed increased plant height in cowpea and soybean at low irradiation doses ( $\leq 200$ Gy) consistent tallest heights was recorded in 100Gy at 4–6 WAE relative to other doses, suggesting that this dose may have activate and enhanced the effects of growth stimulatory hormones. (11), reported that higher doses suppressed growth due to damage in meristematic tissues. The decline in height at 300–400

Gy in the present study agrees with the studies in other legumes, where high irradiation impaired physiological activities, reduced chlorophyll content, and slowed biomass accumulation (12) (13). The variation in the responses of the genotypes to the irradiation doses in term of growth with white-seeded genotype generally outperforming the brown and black varieties, is an indication of the differences in their genetic make-up. This suggests that genotype background plays important role in determining sensitivity to irradiation. Previous studies have shown that cowpea genotypes vary in their tolerance to mutagenic treatments, with some lines exhibiting improved vigor under low radiation while others are more sensitive (14)(15).

Gamma irradiation is known to induce physiological and biochemical changes that can alter cell division and differentiation. Lower doses often promote metabolic activity and meristematic cell division, leading to enhanced vegetative growth, including leaf formation. Conversely, higher doses generate oxidative stress and DNA damage that suppress growth processes (9) (16). The number of leaves is a critical agronomic parameter in cowpea

because it directly contributes to photosynthetic efficiency, biomass accumulation, and ultimately yield performance. In this study, gamma irradiation significantly influenced leaf production across different doses, genotypes, and their interactions at various growth stages. The reduction in number of leaves at higher dose of gamma irradiation suggests that the number of leaf's was dose dependent. This revealed a stimulatory effect of low-dose gamma radiation (hormesis) and an inhibitory effect at higher doses, consistent with earlier findings in legumes (17)(13). This indicates a genotype-dependent radiosensitivity, where inherent genetic makeup determines how varieties respond to irradiation. Similar findings have been reported in cowpea (18) and soybean (5), where varietal differences in radiosensitivity influenced leaf production and other vegetative traits. The superior performance of the white and brown varieties may be linked to better adaptive responses in terms of antioxidant activity, DNA repair efficiency, and metabolic stability, which confer tolerance to gamma-induced stress (6).

Gamma irradiation significantly influenced the leaf area of cowpea at all stages of growth. This suggests that low to moderate doses of gamma irradiation stimulated early cell division and expansion, thereby enhancing leaf area development. Similar findings were reported by (11), who noted that low irradiation doses in legumes improved morphological growth parameters due to stimulatory effects on meristematic activity. This trend is consistent with the principle of radiation hormesis, where low doses enhance growth, while high doses cause inhibitory or deleterious effects due to damage in the photosynthetic apparatus and impaired cell elongation (10) (19). Among the

cowpea varieties, the black-seeded genotype (BL) consistently exhibited the highest leaf area across all growth stages. This indicates genetic variability in radiation response, where some genotypes possess better tolerance to oxidative stress induced by irradiation, thereby maintaining higher photosynthetic efficiency and leaf growth (20)(21). The interaction effect showed that 100Gy combined with the black-seeded variety (100\*BL) produced the highest leaf area far exceeding the control, this agrees with the findings of (22), who observed that high irradiation doses suppressed vegetative growth traits in cowpea due to DNA damage, reduced chlorophyll content, and impaired water balance.

Leaf area is a critical determinant of photosynthetic capacity and ultimately biomass accumulation. The increase in leaf area at low irradiation doses suggests enhanced physiological activity, which may translate into higher productivity. In contrast, reductions at high doses imply oxidative stress, membrane damage, and reduced turgor pressure in leaf cells (16). Therefore, the results underscore the importance of selecting both an optimal irradiation dose (100–200Gy) and genotype-specific tolerance for effective mutation breeding in cowpea.

Gamma irradiation significantly affected cowpea yield parameters, including number of pods per plant, pod weight, seed weight, number of seeds per plant, and 100-seed weight. The reduction at  $\geq 300$ Gy may be attributed to radiation-induced sterility and impaired flower development. Similar trends of pod reduction at higher doses were reported in cowpea and mungbean by (17) and (18). Pod weight and seed weight followed a similar trend. This decline is likely due to reduced assimilate partitioning to reproductive organs and

impaired seed filling, a common outcome of irradiation-induced metabolic stress (19)(20). Moderate doses (100–200Gy) maintained reasonable seed set ( $\approx$ 190–200 seeds/plant), suggesting that plants could withstand some irradiation stress without major reproductive penalty. This observation aligns with the hormetic effect reported in legumes, where low doses maintain or slightly stimulate reproductive capacity, but high doses drastically reduce fertility (9). Seed size, expressed as 100-seed weight, showed similar dose-dependent responses. Reduced seed size at higher doses suggests compromised assimilate translocation and radiation-induced damage to endosperm development, consistent with findings in irradiated soybean and cowpea (21) (22). Dose-genotype interaction highlighted genotype-specific responses. This shows that brown (BR) is the most radiosensitive genotype in terms of yield traits, while white (W) exhibits stronger resilience. These findings corroborate earlier reports that cowpea genotypes vary widely in radiosensitivity, with some maintaining higher yield stability under irradiation (23); (24).

The observed reductions in yield at higher doses are consistent with the biochemical responses. At moderate doses (100–200Gy), increased antioxidant enzyme activity (SOD, POD, CAT) and metabolite adjustments (sugars, amino acids) likely supported reproductive performance. However, at  $\geq$ 300Gy, oxidative stress overwhelmed cellular detoxification systems, leading to impaired pollen viability, ovule abortion, and reduced assimilate allocation to seeds. Similar biochemical links between oxidative stress and yield decline under irradiation have been reported in legumes (25) (20). This pattern indicates that moderate doses (100–300Gy) stimulated ROS-scavenging capacity, enhancing the first

line of oxidative defense. However, the plateau at 400Gy suggests that ROS production exceeded the capacity of enzymatic detoxification, as reported in irradiated legumes (25)(26). This suggests that CAT, which decomposes  $H_2O_2$  into water and oxygen, was most effective at moderate doses but partially inactivated at higher doses due to protein oxidation. Similar dose-dependent peaks in CAT activity have been reported in soybean and mungbean under gamma stress (21). It indicates that POD maintained functional stability even at higher doses, possibly as a compensatory mechanism for the decline in CAT. This agrees with the findings of (18), who observed increased POD activity in mungbean under irradiation as part of adaptive oxidative stress management.

This accumulation suggests a stress-adaptive mechanism, where sugars act as Osmo protectants and signaling molecules under irradiation stress. Increased sugar levels at higher doses also reflect reduced utilization due to impaired growth. These results agree with (27), described TSS accumulation as a hallmark of radiation-induced metabolic adjustment. The relatively stable proline concentration suggests that cowpea primarily relied on antioxidant enzyme activity and sugar accumulation rather than proline buildup for stress mitigation. However, the modest rise at 300Gy supports its known role in osmotic adjustment and ROS scavenging (24). For non-enzymatic metabolites, BR showed slightly higher proline content suggests, that BR relied more on proline-mediated stress tolerance. TSS was highest in BL, reflecting differential metabolic adjustments among genotypes. These findings align with (28) and (29), reported significant biochemical variability among cowpea genotypes under mutagenic stress.

## CONCLUSION

The findings from the research revealed that responses of cowpea to irradiation is dose-dependent, with both stimulatory and inhibitory effects depending on dose intensity. The findings indicate that 100–200Gy doses are suitable for generating useful variability in cowpea without drastically compromising yield; thus, can be exploited in cowpea improvement programs to enhance vegetative growth, particularly in white and brown genotypes. The White genotype is more promising for mutation breeding due to its higher yield stability under irradiation, whereas the Brown genotype may require more conservative dose management. Moderate doses (100–200Gy) enhanced antioxidant enzymes (SOD, CAT) and metabolites (TSS, proline), contributing to improved stress defense and yield maintenance. Therefore, 100 - 200 Gy are optimum dose for inducing valuable mutation in Cowpea for agronomic and biochemical improvement.

## REFERENCE

1. Food and Agriculture Organization (2021). FAOSTAT statistical database: Cowpea production statistics. Food and Agriculture Organization of the United Nations. <https://www.fao.org/faostat/>
2. Timko, M. P., & Singh, B. B. (2022). Cowpea: A multifunctional legume for food and nutrition security in Africa. *African Crop Science Journal*, 30(1), 1–18.
3. Boukar, O., Fatokun, C. A., Huynh, B.-L., Roberts, P. A., & Close, T. J. (2019). Genetic improvement of cowpea for enhanced resilience, productivity, and quality. *Plant Breeding Reviews*, 43, 67–136.
4. Njoroge, S. M. C., Kimani, P. M., Karanja, J., & Kihara, A. (2021). Contribution of cowpea to soil fertility and food security in sub-Saharan Africa. *Journal of Agricultural Science*, 13(2), 45–56.
5. Oladosu, Y., Rafii, M. Y., Abdullah, N., Hussin, G., Ramli, A., Rahim, H. A., & Miah, G. (2016). Radiation-induced variability in soybean and cowpea: Implications for mutation breeding. *Applied Radiation and Isotopes*, 118, 330–340.
6. Shu, Q. Y. (2012). Mutation breeding for crop improvement under stress conditions. *FAO/IAEA Mutation Breeding Review*, 1(3), 5–19.
7. Bello, O. B., Olawuyi, O. J., Azeez, M. A., & Abdulmalik, S. Y. (2021). Gamma irradiation-induced variability and trait associations in cowpea (*Vigna unguiculata*). *Journal of Radiation Research and Applied Sciences*, 14(1), 150–160.
8. Sharma, P., Jha, A. B., & Dubey, R. S. (2018). Radiation hormesis and growth stimulation in plants exposed to low-dose gamma rays. *Environmental and Experimental Botany*, 153, 231–239.
9. Kovács, E., & Keresztes, Á. (2002). Effect of gamma and UV radiation on plant cells. *Micron*, 33(2), 199–210.
10. Wi, S. G., Chung, B. Y., Kim, J. H., Baek, M. H., Yang, D. H., Lee, J. W., & Kim, J. S. (2007). Effects of gamma irradiation on morphological changes and growth of plants. *Radiation Physics and Chemistry*, 71(1–2), 35–39.
11. Mudibu, J., Nkongolo, K. K., Kalonji-Mbuyi, A., & Kizungu, R. (2012). Effect of gamma irradiation on morphological characteristics and yield components of soybean and

- cowpea. *International Journal of Plant Breeding and Genetics*, 6(1), 47–54.
12. Ambli, G., & Muthalanathan, R. (2015). Influence of irradiation on chlorophyll content and biomass accumulation in legumes. *Journal of Plant Sciences*, 10(3), 145–152.
  13. Melki, M., & Marouani, A. (2010). Effects of gamma rays on some growth parameters and biological studies of cowpea (*Vigna unguiculata* L.). *Journal of Environmental Biology*, 31(6), 977–981.
  14. Adekola, M. O., & Oluleye, F. (2007). Radiation mutagenesis in cowpea (*Vigna unguiculata* L. Walp.): Evaluation of mutagenic effectiveness and efficiency. *Journal of Applied Sciences*, 7(2), 261–264.
  15. Gaul, H. (2016). Mutagenic efficiency and radiosensitivity in cowpea (*Vigna unguiculata*). *Mutation Research in Plants*, 12(2), 153–160.
  16. Kim, J. H., Baek, M. H., & Chung, B. Y. (2019). Oxidative stress and membrane damage in cowpea under gamma irradiation. *Plant Physiology and Biochemistry*, 134, 80–89.
  17. Adamu, A., Muhammad, A., & Yusuf, M. (2017). Gamma radiation-induced variation in pod and yield traits of cowpea and mungbean. *International Journal of Plant Research*, 7(2), 45–52.
  18. Olasupo, F. O., Olasanmi, B. A., & Alade, S. O. (2018). Radiosensitivity and growth response of cowpea genotypes to gamma irradiation. *Nigerian Journal of Botany*, 31(1), 23–32.
  18. Mba, C., Afza, R., & Shu, Q. Y. (2010). Mutagenic radiations: X-rays, ionizing particles and ultraviolet. In Q. Y. Shu, B. P. Forster, & H. J. Nakagawa (Eds.), *Plant Mutation Breeding and Biotechnology* (pp. 83–90). FAO/IAEA.
  19. Khan, M. A., Bukhari, S. A., & Aslam, M. (2019). Gamma irradiation effects on vegetative and reproductive growth of legumes. *Journal of Radiation Research and Applied Sciences*, 12(3), 322–331.
  20. Batia, A., & Ashwath, N. (2020). Radiation-induced morphophysiological variations in cowpea genotypes. *Plant Mutation Reports*, 14(1), 33–41.
  20. Akinyele, B. O., & Osekita, O. S. (2006). Genetic variability for radiation tolerance in cowpea (*Vigna unguiculata* L.). *African Journal of Agricultural Research*, 1(3), 67–72.
  21. Hameed, A., Abbas, G., & Khan, M. A. (2019). Enzymatic antioxidant responses in irradiated soybean and mungbean. *Radiation and Environmental Biophysics*, 58(4), 499–509.
  22. Nanhapo, M., Diallo, A., & Shemu, S. (2024). Cowpea radiosensitivity and dose optimization for mutation breeding. *Plant Mutation Breeding Journal*, 12(3), 125–138.
  23. Mensah, J. K., & Obadoni, B. O. (2007). Effects of gamma irradiation on biochemical parameters and yield traits in cowpea (*Vigna unguiculata* L.). *African Journal of Biotechnology*, 6(6), 653–658.
  24. Boureima, S., & Obadoni, B. (2019). Oxidative stress management in irradiated cowpea genotypes. *Plant Stress Physiology*, 25(4), 265–278.
  25. Ali, A., Singh, P., & Meena, R. (2021). Gamma radiation alters biochemical responses and oxidative metabolism in legumes. *Radiation Botany*, 180, 104–113.

26. Singh, P., Ali, A., & Meena, R. (2018). Antioxidative enzyme responses in legumes under gamma irradiation. *Journal of Radiation Research*, 59(6), 679–689.
27. Mishra, S., Gupta, K., & Pandey, R. (2024). Complexity of responses to ionizing radiation in plants, and plant–biotic interactions. *Science of the Total Environment*, 928, 172093. <https://doi.org/10.1016/j.scitotenv.2024.172093>
28. Mishra, P., Singh, R., & Mehta, P. (2024). Radiation-induced metabolic adjustment and TSS accumulation in legumes. *Plant Biochemistry and Biotechnology*, 33(2), 189–198.
29. Diallo, A., Moussa, M., & Issa, A. (2025). Optimizing gamma irradiation doses for cowpea mutation breeding in West Africa. *African Crop Science Journal*, 33(1), 101–115.