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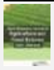

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Assessment of Mutation Induced Bruchid (*Callosobruchus spp.*) Resistance in Cowpea

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ABSTRACT

A study was carried out at the Joseph Sarwuan Tarka University, Makurdi located at latitude 7.41⁰ N and longitude 8.39⁰ E. The laboratory experiment was carried out in the Plant Breeding and Seed Science laboratory of the University. The objective of the study was to assess the cowpea induced mutants for bruchid resistance. This is to mitigate the post-harvest losses experienced by farmers to bruchids. Genotypes used in the study were Fuampea 1, IFE BROWN and Sampea 14. The seeds were subjected to mutagenic treatment using experimental grade Ethyl Methane Sulphonate (EMS), Sodium Azide (SA), Hydroxylamine Hydrochloride (HH) at 0.01%, 0.05% and 0.1. The seeds obtained from this mutagenesis experiment in the fourth mutant generation were used to test for bruchid resistance. Bruchids were cultured and subsequent treatment of the mutant cowpea genotypes were carried out and data recorded. Results from Analysis of Variance showed that there was significant (P<0.01) genotype effect only for holes in seeds and mean development period. Mutagen effect was significant (P<0.01 and P<0.05) for only holes in seeds and number of eggs. Dose effect was also significant (P<0.01 and P<0.05) for holes in seeds. Genotype x Mutagen x Dose had significant (P<0.01 and P<0.05) variation in all the measured traits except for percentage bruchid emergence, percentage pest tolerance and growth index. From the present study it can be concluded that; EMS induced the only above susceptible resistance on the Dobie's Index among the genotypes studied. EMS could potentially be used to induce bruchid resistance in cowpea.

Keywords: *Resistance, Mutation, Bruchids, Susceptibility-index, Callosobruchus, Cowpea*

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INTRODUCTION

Cowpea (2n=22) (Horn and Shimelis, 2020) is an annual herbaceous grain crop classified under the family Fabaceae. It is a significant legume (Omoigui et al., 2018), recognized for its high-quality protein content and comparatively low fat levels (Jayathilake et al., 2018). Cowpea holds particular importance in traditional agricultural systems due to its notable adaptation to heat and water stress, alongside its ability to fix atmospheric nitrogen (Molosiwa and Makwala, 2020). West- Africa is the epicentre of cowpea production which accounts for about 60% of the world production (Nkomo et al., 2021) with Nigeria producing about a third of the world's production with approximately 2.14 million metric tonnes (Horn and Shimelis, 2020). It is cultivated and thrives under rain-fed but also in drier and drought prone conditions. This makes it the crop of choice for food security and breeding efforts aimed at handling the environmental effects of climate change.

The role of mutation breeding in increasing food production and providing sustainable nutrition is well established (Khan and Wani, 2005). It is a fundamental and highly successful tool in the global effort to increase agricultural output. The use of induced mutants in plant breeding programmes across the world has led to the official release of over 2,300 plant mutant varieties (Jain, 2005) and the inadequate variability in cowpea imposed by a narrow genetic base (Raina et al., 2023) requires the use of other solutions. The surging demand for cowpea especially in Africa has necessitated the use of genetic mutation methods that can break and surpass the genetically imposed limits for yield, earliness and pest resistance. Point mutations which are characteristic of chemical mutagenesis can result in the production of polymorphic variations in a given character as well as the up regulation of traits which increases their intensity may be the most feasible route for the improvement of resistance in cowpea. Bruchid resistance will be studied in terms of the capacity of the mutagenic process to confer the characters as well as improve already existing characters of interest in the selected genotypes. The present experiment was conducted to evaluate the development of Bruchid (*Callosobruchus spp*) resistance in mutant cowpea.

The use of chemicals such as Aluminium phosphate in the preservation of cowpea raises issues with the health and safety of the consumers. The development of effective resistance to bruchids will eliminate the need for these dangerous chemicals. The results of this study will contribute to reducing the irreversible damage caused by this pest which has resulted in significant economic loss for the farmer. Increase in the capacity for yield in cowpea will favour farmers who would be able to meet their production quota while cultivating less land area.
Scarce Bruchid (*Callosobruchus spp.*) tolerance or resistance to be induced in the course of this study will further the breeding efforts aimed at containing the most damaging pest of post-harvest cowpea (Ofuya et al., 2010) by providing effective and cheaper breeding alternatives.

MATERIALS AND METHODS

A bruchid resistance assessment experiment was carried out at the Plant Breeding and Seed Science Laboratory of the Federal University of Agriculture, Makurdi. It was a 3x3x4 factorial experiment laid out in a Randomized Block Design with 3 replications.Three Genotypes were used in the study. FUAMPEA 1, IFE BROWN and SAMPEA 14 which were all products of the fourth mutant generation of a previous mutation experiment using Ethylmathane Sulphonate, Sodium Azide and Hydroxylamine Hydrochloride as mutants at 0.01%, 0.05%, 0.1% and a control. The bruchid resistance assessment experiment therefore had three genotypes, three mutagen and four doses for a total of thirty-six treatment combinations. Culture, screening of Bruchids and treatment of the cowpea seeds were done according to (Lephale et al., 2012) with little modifications.

Observation and data collections

Parameters measured were; number of eggs laid, mean development period: this feature was evaluated by the formula;

$$\text{Mean development period} = \frac{X_1 + X_2 + X_3}{3}$$

Where X = Development period of adult insects in each replicate

Percentage bruchid emergence (%), this was estimated by the formula;

$$\text{Percentage bruchid emergence (\%)} = \frac{\text{Number of emerged adult bruchids}}{\text{Total number of eggs}} \times 00$$

Percentage seed damage (%) This was estimated by the formula;

$$\text{Percentage seed damage (\%)} = \frac{\text{Number of damaged seeds}}{\text{Number of undamaged seeds}} \times 100$$

Percentage pest tolerance (%): This was estimated by the formula;

$$\frac{\text{Total number of initial seeds} - \text{Number of damaged seeds}}{\text{Total number of initial seeds}} \times 100$$

Growth index (GI): This was estimated by the formula;

$$\text{Growth index (GI)} = \frac{\text{Percentage adult emergence}}{\text{Mean development period}}$$

Susceptibility index: The susceptibility index was calculated using the equation of (Dobie, (1977) as follows;

$$\text{Susceptibility index} = \text{Log}_e \frac{F \times 100}{MDP}$$

Where
F = Total number of emerged adults
Log_e = Natural logarithm
MDP = Median Development Period estimated as time from the middle of the oviposition period to the emergence of 50 % of the bruchids.

Dobies index of susceptibility: The Dobies index of susceptibility will be used to classify the cowpea genotypes into different resistance and susceptibility groups Dobie, 1977) using the following scale.
Scale index of <4.1 as highly resistance,
Scale index of 4.1 -6.0 as moderately resistance
Scale index of 6.1 -8.0 as moderately susceptible
Scale index of 8.1 -10.0 as susceptible
Scale index of >10.0 as highly susceptible

Table 1: Analysis of Variance (ANOVA) for Bruchid Traits.

Source of Variation	DF	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percentage Seed Damage	Growth Index	Holes in Seeds	Mean Dev. Period (Days)	Number of Eggs	Susceptibility Index
Rep	2	536.30	3.70	77.80	1.43	1236.60	34.09	4678.20	10.61
Genotype	2	345.0ns	267.60ns	202.80ns	0.10ns	1226.30**	43.59**	804.60ns	4.28ns
Mutagen	2	120.10ns	70.40ns	144.40ns	0.21ns	1570.10**	11.14ns	1471.30*	4.30ns
Dose	4	56.60ns	440.40ns	440.4ns	0.03ns	511.40**	3.93ns	845.30ns	8.71ns
Genotype*Mutagen	4	317.40ns	214.80ns	455.60ns	0.72ns	1175.60**	14.32*	3501.80**	17.74**
Genotype*Dose	6	175.50ns	347.80ns	653.40**	0.27ns	300.80*	11.98*	1104.40**	6.02ns
Mutagen*Dose	6	409.00ns	413.60*	784.00**	0.75ns	1190.70**	12.12*	3521.40**	29.63**
Genotype*Mutagen*Dose	12	189.30ns	293.20ns	496.90**	0.34ns	796.10**	12.72**	1912.10**	10.57**
Error	70	306.60	178.9	195.90	0.48	132.40	5.21	327.50	3.97
Total	107								

Key: ** and * significant at 0.01% and 0.05%, ns: not significant.

Table 2: Effect of genotype on bruchid traits

Genotype	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percentage Seed Damage	Growth Index	Holes in Seeds	Mean Dev. Period Days	Number of Eggs	Susceptibility Index
FUAMPEA 1	77.23a	3.89a	93.33a	2.70a	37.28a	28.74b	55.69a	12.03a
IFE BROWN	72.61a	8.61a	91.39a	2.62a	29.51b	28.39b	47.44a	11.34a
SAMPEA 14	78.49a	3.89a	96.11a	2.61a	40.94a	30.44a	55.57a	11.72a

Means with the same letter are not significant different. The susceptibility index, ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and ≥10 = highly susceptible (Dobie, 1977).

All the traits were evaluated in the Fourth Mutant Generation (M4).

RESULTS

Analysis of Variance (ANOVA) for Bruchid Traits

Table 1 showed that there was significant (P<0.01) genotype effect on holes in seeds and mean development period whereas no significant variation was observed on percentage bruchid emergence, percentage pest tolerance, percentage seed damage, growth index, number of eggs. The mutagen effect was significant (P<0.01 and P<0.05) for only holes in seeds and number of eggs. Dose effect was also significant (P<0.01 and P<0.05) for holes in seeds. The result also showed that Genotype x Mutagen had significant (P<0.01 and P<0.05) variation on holes in seeds, mean development period and number of eggs. Genotype x Dose had significant (P<0.01 and P<0.05) effect on percentage seed damage, holes in seeds, mean development period and number of eggs. Mutagen x Dose had significant (P<0.01 and P<0.05) variation in percentage pest tolerance, percentage seed damage, holes in seeds, mean development period and number of eggs. Genotype x Mutagen x Dose had significant (P<0.01 and P<0.05) variation in all the measured traits except for percentage bruchid emergence, percentage pest tolerance and growth index on the Dobie's scale.

The effect of genotype on bruchid traits

Table 2 showed the effect on bruchid traits. The result showed no significant variation among the genotypes for percentage bruchid emergence. However, SAMPEA 14 had higher percentage of bruchid emergence (78.49 %) followed by FUAMPEA 1 with 77.23 % while IFE BROWN had lower bruchid emergence (72.61 %). Percentage pest tolerance was observed to be highest in IFE BROWN (8.61 %) while FUAMPEA 1 and SAMPEA 14 had the least percentage pest tolerance (3.89 %). Percentage seed damage was observed to be higher in SAMPEA 14 (96.11 %) followed by FUAMPEA 1 (93.33%) while IFE BROWN had the least percentage seed damage (91.39 %). Although there were no significant variations among the genotypes. Growth index showed non-significant but higher value for FUAMPEA 1 (2.70) followed by IFE BROWN (2.62) while SAMPEA 14 had lower growth index (2.61). FUAMPEA 1 and IFE BROWN were not significantly different from each other for Mean development period as they had 28.74 and 28.39 days respectively. SAMPEA 14 had the longest Mean development period of 30.44 days. The number of eggs laid by the bruchids was 47.44 for IFE BROWN, 55.69 for FUAMPEA 1 and 55.57 for SAMPEA 14. The genotypes all read above 10 on the susceptibility index on the Dobie's scale.

Effect of Mutagen on Bruchid Traits

Table 3 showed the effect of Mutagen on Bruchid traits. Result revealed no significant difference among the mutagens for percentage bruchid emergence. Non-significant but higher percentage pest tolerance was observed on Hydroxylamine hydroxide (6.94 %) this was followed by Ethyl Methane sulphonate (5.28 %) while Sodium Azide had lower percentage pest tolerance (4.17 %). No significant variation was observed among the mutagens for growth index. Significant higher Holes in seeds were recorded by Sodium Azide (43.39), this was significantly higher than that of Hydroxylamine hydroxide (33.47) and Ethyl methane sulphonate (30.88). Higher number of eggs was recorded by Sodium Azide (59.50 %) this was followed by Hydroxylamine hydroxide (52.47)

Table 3: Effect of mutagen on bruchid traits.

Mutagen	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percentage Seed Damage	Growth Index	Holes in Seeds	Mean Dev. Period (Days)	Number of Eggs	Susceptibility Index
Sodium Azide	77.14a	4.17a	95.83a	2.61a	43.39a	29.79a	59.50a	12.02a
Hydroxylamine Hydroxide	74.00a	6.94a	93.06a	2.59a	33.47b	28.69a	52.47ab	11.73a
Ethyl Methane Sulphonate	77.19a	5.28a	91.94a	2.73a	30.88b	29.08a	46.74b	11.33a

Means with the same letter are not significant different. The susceptibility index, ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and ≥10 = highly susceptible (Dobie, 1977).

Table 4: Effect of dose on bruchid traits

Dose	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percentage Seed Damage	Growth Index	Holes in Seeds	Mean Dev. Period Days	Number of Eggs	Susceptibility Index
Control	75.52a	1.11b	98.89a	2.63a	39.81a	28.94a	57.76a	12.45a
0.01	74.58a	5.93ab	94.07ab	2.63a	30.72b	28.81a	46.19b	11.30b
0.05	76.36a	10.74a	89.26b	2.62a	33.93ab	29.65a	50.41ab	11.22b
0.10	77.99a	4.07ab	92.22ab	2.69a	39.19a	29.35a	57.26a	11.82ab

Means with the same letter are not significant different. The susceptibility index, ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and ≥10 = highly susceptible (Dobie, 1977).

Table 5: Effect of Genotype x Mutagen Interaction on Bruchid Traits

Genotype * Mutagen	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percentage Seed Damage	Growth Index	Holes in Seeds	Mean Dev. Period (Days)	Number of Eggs	Susceptibility Index
FUAMPEA 1 * SA	78.05a	0.00a	100.00a	2.64a	46.17ab	29.79bc	66.25a	12.58ab
IFE BROWN * SA	78.19a	12.50a	87.50ab	2.72a	31.58c	29.08bcd	45.67bcd	11.13bc
SAMPEA 14 * SA	75.18a	0.00a	100.00a	2.48a	52.42a	30.50ab	66.58a	12.35ab
FUAMPEA 1 * HH	73.66a	5.00a	95.00ab	2.60a	44.08ab	28.42bcd	70.58a	13.25a
IFE BROWN * HH	65.89a	9.17a	90.83ab	2.31a	27.25c	28.58bcd	47.83bc	11.21bc
SAMPEA 14 * HH	82.46a	6.67a	93.33ab	2.85a	29.08c	29.08bcd	39.00cd	10.74bc
FUAMPEA 1 * EMS	79.98a	6.67a	85.00b	2.87a	21.58c	28.00cd	30.25d	10.25c
IFE BROWN * EMS	73.76a	4.17a	95.83ab	2.81a	29.71c	27.50d	48.83bc	12.08abc
SAMPEA 14 * EMS	77.84a	5.00a	95.00ab	2.50a	41.33b	31.75a	61.12ab	12.08abc

Means with the same letter are not significant different. The susceptibility index, ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and ≥10 = highly susceptible (Dobie, 1977).

while Ethyl methane sulphonate had least number of eggs (46.74). The result showed a range of 41.74 (Ethyl methane sulphonate) to 43.60 (Sodium Azide). Each genotype posted susceptibility index values of above 10 on the Dobie's scale.

Effect of dose on bruchid traits

Table 4 showed that doses didn't have any effect on Percentage bruchid emergence, Growth index and Mean development period. Percentage pest tolerance was at 1.1% for control and 10.74% for dose 0.05. Other performances were 5.93% for dose 0.01 and 4.07% for dose 0.1. On the other hand, Percentage seed damage had 98.89% for the control dose, 89.26% for dose 0.05, 94.07% for dose 0.01 and 92.22% for dose 0.1. Holes in seeds were 39.81 in the control and 39.19 at the dose 0.1 which were not significantly different from each other. Holes in the seeds were also observed to be 30.72 and 33.93 at dose 0.01 and 0.05 respectively. The eggs laid in the control were 57.76 and 57.26 at dose 0.1 between which there was no significant difference while 46.19 and 50.41eggs were laid at 0.01 and 0.05. Each dose posted susceptibility index values of above 10 on the Dobie's scale.

Effect of Genotype x Mutagen Interaction on Bruchid Traits

Table 5 showed that there were no significant interactions for Percentage Bruchid Emergence, Percentage pest tolerance and Growth Index. Percentage seed damage had significant differences among the means for Genotype x SA and Genotype x EMS interactions with FUAMPEA 1 x SA and SAMPEA 14 x SA interactions both producing 100% seed damage. IFE BROWN x EMS and SAMPEA 14 x EMS were also both observed to produce 95.83 and 95.00 seed damage while IFE BROWN x SA had 87.50% seed damage.
FUAMPEA 1 x SA had 46.17 holes, IFE BROWN x SA had 31.56 holes while SAMPEA 14 x SA produced 52.42 holes in the seeds. IFE BROWN x HH was also observed to have 31.58 holes while IFE BROWN x EMS produced 29.71 holes. FUAMPEA 1 x SA, IFE BROWN x SA and SAMPEA 14 x EMS had 29.79, 29.08 and 30.50 holes respectively. FUAMPEA 1 had 66.25 eggs in its interaction with SA, 70.58 in its interaction with HH and 30.25 in its interaction with EMS. IFE BROWN x SA on the other hand had 45.67 eggs, IFE BROWN x HH had 47.83 eggs and IFE BROWN x EMS had 48.83 eggs. SAMPEA 14 x SA, SAMPEA 14 x HH and SAMPEA 14 x EMS had 66.58, 39.00 and 61.12 eggs respectively were significantly different from each other. Each interaction posted susceptibility index values of above 10 on the Dobie's scale.

Effect of genotype x dose interaction on bruchid traits

Table 6 reveal that, SAMPEA 14 x 0.1 Dose interactions

Table 6: Effect of genotype x dose interaction on bruchid traits.

Genotype*Dose	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percentage Seed Damage	Growth Index	Holes in Seeds	Mean Dev. Period (Days)	Number of Eggs	Susceptibility Index
FUAMPEA 1 * Control	72.28a	1.11c	98.89ab	2.51a	40.67ab	29.06bcd	62.22abc	12.32ab
IFE BROWN * Control	73.97a	2.22bc	97.78abc	2.68a	30.11bc	27.67cd	43.56cd	12.40ab
SAMPEA 14 * Control	80.31a	0.00c	100.00a	2.68a	48.67a	30.11abc	67.50a	12.63ab
FUAMPEA 1 * 0.01	81.46a	5.56abc	94.44abcd	2.83a	33.67bc	28.72bcd	46.00bcd	11.85ab
IFE BROWN * 0.01	71.36a	12.22abc	87.78abcd	2.64a	27.06c	28.11bcd	51.89abcd	11.85ab
SAMPEA 14 * 0.01	70.91a	0.00c	100.00a	2.41a	31.44bc	29.61abcd	40.67d	11.22ab
FUAMPEA 1 * 0.05	78.45a	0.00c	100.00a	2.80a	34.89bc	27.94cd	50.56abcd	12.63ab
IFE BROWN * 0.05	70.91a	16.67a	83.33cd	2.38a	33.78bc	30.50ab	55.00abcd	10.52b
SAMPEA 14 * 0.05	79.70a	15.56ab	84.44bcd	2.66a	33.11bc	30.50ab	45.67bcd	10.58b
FUAMPEA 1 * 0.1	76.73a	8.89abc	80.00d	2.65a	39.89ab	29.22abcd	64.00ab	11.85ab
IFE BROWN * 0.1	74.20a	3.33abc	96.67abc	2.75a	27.11c	27.28d	39.33d	11.22ab
SAMPEA 14 * 0.1	83.04a	0.00c	100.00a	2.66a	50.56a	31.56a	68.44a	12.87a

Means with the same letter are not significant different. The susceptibility index, ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and ≥10 = highly susceptible (Dobie, 1977).

Table 7: Effect of Mutagen x Dose Interaction on Bruchid Traits.

Mutagen * Dose	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percentage Seed Damage	Growth Index	Holes in Seeds	Mean Dev. Period (Days)	Number of Eggs	Susceptibility Index
SA * Control	78.69a	0.00b	100.00a	2.57a	58.44a	31.11a	81.44a	13.68a
SA * 0.01	66.26a	12.22ab	87.78abc	2.26a	27.44de	29.33abc	34.11ef	9.28d
S A* 0.05	81.29a	4.44b	95.56ab	2.83a	36.56cd	29.06abc	50.33cde	11.88abc
S A* 0.1	82.32a	0.00b	100.00a	2.78a	51.11ab	29.67abc	72.11ab	13.68a
H H* Control	71.53a	3.33b	96.67a	2.54a	29.00de	28.17c	44.44cdef	11.61abc
H H* 0.01	73.85a	5.56ab	94.44ab	2.59a	32.44de	28.61abc	56.33bcd	12.49ab
H H* 0.05	78.07a	18.89a	81.11bc	2.72a	26.78de	28.89abc	37.78def	10.31cd
H H* 0.1	72.57a	0.00b	100.00a	2.50a	45.67bc	29.11abc	71.33ab	12.73ab
EMS * Control	76.35a	0.00b	100.00a	2.78a	32.00de	27.56c	47.39cde	12.49ab
EMS * 0.01	83.63a	0.00b	100.00a	3.04a	32.28de	28.50bc	48.11cde	12.33abc
EMS * 0.05	69.70a	8.89ab	91.11ab	2.30a	38.44cd	31.00ab	63.11abc	11.47bc
EMS * 0.1	79.08a	12.22ab	76.67c	2.80a	20.78e	29.28abc	28.33f	9.05d

Means with the same letter are not significant different. The susceptibility index, ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and ≥10 = highly susceptible (Dobie, 1977).

produced higher but non-significant percentage bruchid emergence of 83.04 % this was followed by FUAMPEA 1 x 0.01 dose interactions with the value of 81.46 % while SAMPEA 14 x 0.01 and IFE BROWN x 0.05 dose interaction had lower percentage of bruchid emergence (70.91 % respectively). Significant and highest percentage pest tolerance were observed between IFE BROWN x 0.05 dose interaction (16.67 %) followed by SAMPE 14 x 0.05 dose interaction with the value of 15.56 % while SAMPE 14 x control interaction, SAMPEA 14 x 0.01, FUAMPEA 1 x 0.05 and SAMPEA 14 x 0.1 had least percentage pest tolerance (0.00 % respectively). Significant higher variation was observed for percentage seed damage in SAMPEA 14 x control, SAMPEA 14 x 0.01, FUAMPEA 1 x 0.05 and SAMPEA 14 x 0.1 (100 % respectively) this was followed by IFE BROWN x control (97.78 %) while FUAMPEA 1 x 0.1 had lower percentage seed damage (80.00 %).

No significant variation was observed on Growth index. Significantly higher holes in seeds were observed in SAMPEA 14 x 0.1 (50.56) followed by SAMPEA 14 x control (48.67) whereas IFE BROWN x 0.01 had lower holes in seeds (27.06Mean development period was observed to be higher in SAMPEA 14 x 0.1 (31.56) this was followed by IFE BROWN x 0.05 and SAMPEA 14 x 0.05 interactions with a value of 30.50 respectively while least mean development period was observed in IFE BROWN x 0.1 (27.28). Significant higher number of eggs were observed in SAMPEA 14 x 0.01 (68.44). This was followed by SAMPEA 14 x control with 67.50 eggs while IFE BROWN x 0.1 had least number of eggs (39.33). Each interaction posted susceptibility index values of above 10 on the Dobie's scale.

Effect of mutagen x dose interaction on bruchid traits

Table 7 showed that, EMS x 0.01 interactions produced higher but non-significant percentage bruchid emergence of 83.63 % which was followed by SA x 0.1 interaction with a value of 82.32 % while SA x 0.01 interaction had lower percentage of bruchid emergence (66.26 %). Significant and higher percentage pest tolerance were observed between HH x 0.05 interaction (18.89 %) followed by SA x 0.01 and EMS x 0.1 interactions with the value of 12.22 % while SA x control, SA x 0.1, HH x 0.1, EMS x control interactions had lower percentage pest tolerance (0.00 % respectively).

Percentage seed damage in SA x control, SA x 0.1, HH x 0.01, EMS x control and EMS x 0.01 yielded 100 % respectively, followed by HH x control (96.67 %) while EMS x 0.1 had lower percentage seed damage (76.67 %). Significant higher holes in seeds were observed in SA x control (58.44) followed by SA x 0.1 (51.11) whereas EMS x 0.1 had lower holes in seeds (20.78). Mean development period was observed in SA x control as 31.11, this was followed by EMS x 0.05 interaction with a value of 31.00 while lower mean development period was observed in EMS x control (27.56).

Number of eggs was observed in SA x control as 81.44 which was followed by SA x 0.1 with 72.11 while EMS x

Table 8a: Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits.

Genotype	Mutagen Dose	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percentage Seed Damage	Growth Index	Holes in Seeds	Mean Development Period (Days)	Number of Eggs	Susceptibility Index
FUAMPEA1	SA Control	72.15ab	0.00e	100.00a	2.26ab	69.00a	32.50abc	103.00ab	13.26abcdef
FUAMPEA1	SA 0.01	78.72ab	0.00e	100.00a	2.70ab	26.67fghijk	29.00bcde	32.33ghijkl	9.95defghi
FUAMPEA 1	SA 0.05	76.53ab	0.00e	100.00a	2.68ab	37.33defghi	28.33cde	58.33cdefghi	13.20abcdef
FUAMPEA1	SA 0.1	84.80a	0.00e	100.00a	2.90ab	51.67abcde	29.33bcde	71.33bcdef	13.91abcd

Means with the same letter are not significant different. The susceptibility index, ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and ≥10 = highly susceptible (Dobie, 1977).

Table 8b: Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits (Cont'd)

Genotype	Mutagen Dose	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percentage Seed Damage	Growth Index	Holes in Seeds	Mean Development Period (Days)	Number of Eggs	Susceptibility Index
IFE BROWN	SA Control	81.61ab	0.00cde	100.00a	2.87ab	37.33deffghi	28.50cde	52.00efghij	13.12abcdef
IFE BROWN	SA 0.01	72.55ab	36.67a	63.33c	2.55ab	15.33ijk	28.33cde	20.00jkl	8.35hij
IFE BROWN	SA 0.05	79.73ab	13.333abcde	86.67abc	2.84ab	22.33hijk	29.50bcde	38.33fghijkl	9.66fghi
IFE BROWN	SA 0.1	78.89ab	0.00cde	100.00a	2.64ab	51.33abcde	30.00bcde	72.33bcdef	13.40abcdef

Means with the same letter are not significant different. The susceptibility index, ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and ≥10 = highly susceptible (Dobie, 1977).

0.1 had least number of eggs (28.33). Result for percentage weight loss showed that SA x 0.1 weighed higher (54.91 %) this was followed by SA x 0.01 and HH x 0.01 (49.09 %) while SA x 0.05 weighed lower (31.27 %). Susceptibility index values ranged from 9.05 to 13.68 on the Dobie's scale.

Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits

The result showed that FUAMPEA 1 x SA x 0.1 produced higher percentage of bruchid emergence (84.80%) followed by FUAMPEA 1 x SA x 0.01 (78.72%) while least percentage bruchid emergence was recorded by FUAMPEA 1 x SA x control (72.15%). Result for growth index were variable and ranges from 2.26 (FUAMPEA 1 x SA x control) to 2.90 (FUAMPEA 1 x SA x 0.1). Higher growth index was observed in FUAMPEA 1 x SA x 0.1 (2.90) followed by FUAMPEA 1 x SA x 0.01 (2.70) while the least growth index was recorded by FUAMPEA 1 x SA x control (2.26). The higher number of holes in seeds was observed in FUAMPEA 1 x SA x control (69.00) which was significantly greater than FUAMPEA 1 x SA x 0.1 (51.67), FUAMPEA 1 x SA x 0.05 (37.33) and FUAMPEA 1 x SA x 0.01 (26.67).

Mean development period (days) was observed to be highest in FUAMPEA 1 x SA x control with 32.50 days followed by FUAMPEA 1 x SA x 0.1 (29.33 days) while FUAMPEA 1 x SA x 0.05 interaction had lower mean development period (28.33 days). The varied number of eggs showed that FUAMPEA 1 x SA x control had significant higher number of eggs (103.00) this was followed by FUAMPEA 1 x SA x 0.1 (71.33) while FUAMPEA 1 x SA x 0.01 had the least number of eggs (32.33). Susceptibility index values ranged from 9.95 to 13.91 on the Dobie's scale.

Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits

IFE BROWN x SA x Dose interaction induced variation results revealed that IFE BROWN x SA x control produced significant higher percentage of bruchid emergence (81.61 %) this was followed by IFE BROWN x SA x 0.05 (79.73 %) while the least percentage bruchid emergence was recorded by IFE BROWN x SA x 0.01 (72.55 %). Significant higher percentage pest tolerance was observed in IFE BROWN x SA x 0.01 (36.67 %) followed by IFE BROWN x SA x 0.05 (13.33 %) while IFE BROWN x SA x control and IFE BROWN x SA x 0.1 interactions produced lower percentage pest tolerance value of 0.00 %. Significant higher percentage seed damage was recorded by IFE BROWN x SA x control and IFE BROWN x SA x 0.1 (100.00 % respectively) while IFE BROWN x SA x 0.01 had lower percentage seed damage (63.33 %).

Result for growth index were variable and ranges from 2.55 (IFE BROWN x SA x 0.01) to 2.87 (IFE BROWN x SA x control). Meanwhile, higher growth index was observed in IFE BROWN x SA x 0.01 (2.87 %) followed by IFE BROWN x SA x 0.05 (2.84) while the least growth index was recorded by IFE BROWN x SA x 0.01 (2.55 %). Significant higher number of holes in seeds was observed in IFE BROWN x SA x 0.1 (51.33) this was followed by IFE BROWN x SA x 0.01 (37.33) while IFE BROWN x SA x 0.01 had the least number of holes in seeds (15.33). Mean development period (days) was observed to be highest in IFE BROWN x SA x 0.1 with 30.00 days followed by IFE BROWN x SA x 0.05 (29.50 days) while IFE BROWN x SA x 0.01 interaction had lower mean development period (28.33 days). Number of eggs showed that IFE BROWN x SA x 0.1 had significant higher number of eggs (72.33 days) this was followed by IFE BROWN x SA x control (52.00) while IFE BROWN x SA x 0.01 had the least number of eggs (20.00). Susceptibility index values ranged from 8.35 to 13.40 on the Dobie's scale.

Effect of genotype x mutagen x dose interaction on bruchid traits

SAMPEA 14 x SA x 0.05 recorded higher percentage of

Table 8c: Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits (Cont'd)

Genotype	Mutagen	Dose	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percentage Seed Damage	Growth Index	Holes in Seeds	Mean Development Period (Days)	Number of Eggs	Susceptibility Index
SAMPEA 14	SA	Control	82.31ab	0.00cde	100.00a	2.59ab	69.00a	32.33abc	89.33abcd	13.36abcdef
SAMPEA 14	SA	0.01	47.50b	0.00e	100.00a	1.54b	40.33cdefgh	30.67bcd	50.00efghijk	9.55 fghij
SAMPEA 14	SA	0.05	87.62a	0.00cde	100.00a	2.97a	50.00abcde	29.33bcde	54.33defghij	12.78abcdef
SAMPEA 14	SA	0.1	83.28a	0.00cde	100.00a	2.81ab	50.33abcde	29.67bcde	72.67bcdef	13.73 abcde

Means with the same letter are not significant different. The susceptibility index, ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and ≥10 = highly susceptible (Dobie, 1977).

Table 8d: Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits (Cont'd)

Genotype	Mutagen	Dose	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percentage Seed Damage	Growth Index	Holes in Seeds	Mean Develop-ment Period (Days)	Number of Eggs	Susceptibility Index
FUAMPEA1	**HH**	**Control**	64.64ab	3.33cde	96.69ab	2.40ab	32.67efghij	27.00ef	55.00defghij	12.41abcdefg
FUAMPEA 1	**HH**	**0.01**	80.56ab	16.67abcde	83.33abc	2.81ab	34.33defghi	28.67cde	50.00efghijk	12.25 abcdefgh
FUAMPEA 1	**HH**	**0.05**	83.23a	0.00e	100.00a	2.99a	47.33abcdef	28.00cde	66.33bcdef	14.11 abc
FUAMPEA 1	**HH**	**0.1**	66.22ab	0.00cde	100.00a	2.21ab	62.00abc	30.00bcde	111.00a	14.24 ab

Means with the same letter are not significant different. The susceptibility index, ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and ≥10 = highly susceptible (Dobie, 1977).

bruchid emergence (87.62 %) this was followed by SAMPEA 14 x SA x 0.1 (83.28 %) while least percentage bruchid emergence was recorded by SAMPEA 14 x SA x 0.01 (47.50 %). Result for percentage pest tolerance revealed no significant difference among the treatments, same trend was observed in percentage seed damage. Result for growth index were variable and ranged from 1.54 (SAMPEA 14 x SA x 0.01) to 2.97 (SAMPEA 14 x SA x 0.05). Higher growth index was observed in SAMPEA 14 x SA x 0.05 (2.97) this was followed by SAMPEA 14 x SA x 0.1 (2.81) while the least growth index was recorded by SAMPEA 14 x SA x 0.01 (1.54). The higher number of holes in seeds was observed in SAMPEA 14 x SA x control (69.00) which was significantly greater than SAMPEA 14 x SA x 0.1 (50.33) and SAMPEA 14 x SA x 0.05 (50.00) while SAMPEA 14 x SA x 0.01 had the least number of holes in seeds (40.33). Mean development period (days) was observed to be highest in SAMPEA 14 x SA x control with 32.33 days followed by SAMPEA 14 x SA x 0.01 (30.67 days) while SAMPEA 14 x SA x 0.05 interaction had lower mean development period of 29.33 days. The result for number of eggs showed that SAMPEA 14 x SA x control had significant higher number of eggs (89.33) this was followed SAMPEA 14 x SA x 0.1 (72.67) while SAMPEA 14 x SA x 0.01 had the least number of eggs (50.00). Susceptibility index values ranged from 9.55 to 13.73 on the Dobie's scale.

Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits

FUAMPEA 1 x HH x Dose interaction induced significant variation in all the Bruchid traits. The results revealed that FUAMPEA 1 x HH x 0.05 produced significant higher percentage of bruchid emergence (83.23 %) compared to FUAMPEA 1 x HH x 0.01 (80.56 %), FUAMPEA 1 x HH x 0.1 (66.22 %) and FUAMPEA 1 x HH x control (64.64 %). Significant higher percentage pest tolerance was observed in FUAMPEA 1 x HH x 0.01 (16.67 %) followed by FUAMPEA 1 x HH x control (3.33 %) while FUAMPEA 1 x HH x 0.05 and FUAMPEA 1 x HH x 0.1 interactions produced lower percentage pest tolerance value of 0.00 %. Significantly higher percentage seed damage was recorded by FUAMPEA 1 x HH x 0.05 and FUAMPEA 1 x HH x 0.1 (100.00 % respectively) while FUAMPEA 1 x HH x 0.01 had lower percentage seed damage (83.33 %). Result for growth index were variable and ranges from 2.21 (FUAMPEA 1 x HH x 0.1) to 2.99 (FUAMPEA 1 x HH x 0.05). Higher growth index was recorded by FUAMPEA 1 x HH x 0.05 (2.99 %) this was followed by FUAMPEA 1 x HH x 0.01 (2.81) while lower growth index was recorded by FUAMPEA 1 x HH x 0.1 (2.21 %). Significant higher number of holes in seeds was observed in FUAMPEA 1 x HH x 0.1 (62.00) this was followed by FUAMPEA 1 x HH x 0.05 (47.33) while FUAMPEA 1 x HH x control had the least number of holes in seeds (32.67). Mean development period (days) was observed to be highest in FUAMPEA 1 x HH x 0.1 with 30.00 days followed by FUAMPEA 1 x HH x 0.01 (28.67 days) while FUAMPEA 1 x HH x control interaction had lower mean development period (27.00 days). The results on number of eggs showed that FUAMPEA 1 x HH x 0.1 had significant higher number of eggs (111.00 days) this was followed by FUAMPEA 1 x HH x 0.05 (66.33) while FUAMPEA 1 x HH x control and FUAMPEA 1 x HH x 0.01 had the least number of eggs (50.00). Susceptibility index values were above 10 on the Dobie's scale.

Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits

Percentage pest tolerance was higher in IFE BROWN x HH x 0.05 (30.00 %) while IFE BROWN x HH x 0.01 and IFE BROWN x HH x 0.1 recorded lower percentage pest tolerance (0.00 %). Percentage seed damage was higher in IFE BROWN x HH x 0.01 and IFE BROWN x HH x 0.1

Table 8e: Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits (Cont'd).

Genotype	Mutagen	Dose	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percentage Seed Damage	Growth Index	Holes in Seeds	Mean Development Period (Days)	Number of Eggs	Susceptibility Index
IFE BROWN	HH	Control	63.38ab	6.67bcde	93.33ab	2.30ab	29.00efghij	28.00cde	45.67efghijk	11.90abcdefghi
IFE BROWN	HH	0.01	66.29ab	0.00e	100.00a	2.38ab	45.00bcdefg	28.00cde	91.33abc	14.46a
IFE BROWN	HH	0.05	66.31ab	30.00ab	70.00bc	2.20ab	16.00ijk	30.00bcde	23.67ijkl	8.60ghij
IFE BROWN	HH	0.1	67.56ab	0.00cde	100.00a	2.38ab	19.00hijk	28.33cde	30.67ghijkl	9.88efghi

Means with the same letter are not significant different. The susceptibility index, ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and ≥10 = highly susceptible (Dobie, 1977).

Table 8f: Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits (Cont'd).

Genotype	Mutagen	Dose	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percentage Seed Damage	Growth Index	Holes in Seeds	Mean Development Period (Days)	Number of Eggs	Susceptibility Index
SAMPEA 14	*HH*	Control	86.55a	0.00cde	100.00a	2.94ab	25.33fghijk	29.50bcde	32.67ghijkl	10.52abcdefghi
SAMPEA 14	*HH*	0.01	4.70ab	0.00cde	100.00a	2.58ab	18.00hijk	29.17bcde	27.67hijkl	10.14cdefghi
SAMPEA 14	*HH*	0.05	84.67a	26.67abc	73.33abc	2.97a	17.00ijk	28.67cde	23.33ijkl	8.24ij
SAMPEA 14	*HH*	0.1	83.91a	0.00cde	100.00a	2.89ab	56.00abcd	29.00bcde	72.33bcdef	14.06 abc

Means with the same letter are not significant different. The susceptibility index, ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and ≥10 = highly susceptible (Dobie, 1977).

(100.00 %) this was followed by IFE BROWN x HH x control (93.33 %) while IFE BROWN x HH x 0.05 had lower percentage seed damage (70.00 %).Growth index was highest at IFE BROWN x HH x 0.01 and IFE BROWN x HH x 0.1 (2.38) followed by IFE BROWN x HH x control (2.30) while the least growth index was recorded by IFE BROWN x HH x 0.05 (2.20). Higher number of holes in seeds was recorded by IFE BROWN x HH x 0.01 (45.00) which was significantly greater than that of IFE BROWN x HH x control (29.00) while IFE BROWN x HH x 0.05 had the least number of holes in seeds (16.00). Result for initial seed weight showed that IFE BROWN x HH x 0.05 had significant higher initial seed weight (1.65) followed by IFE BROWN x HH x 0.01 (1.60) while IFE BROWN x HH x control had least initial seed weight (1.50). Mean development period (days) was observed to be highest in IFE BROWN x HH x 0.05 with 30.00 days followed by IFE BROWN x HH x 0.1 (28.33 days) while IFE BROWN x HH x control and IFE BROWN x HH x 0.01 interactions had lower mean development period (28.00 days). The varied number of eggs revealed that IFE BROWN x HH x 0.01 had significant higher number of eggs (91.33) this was followed by IFE BROWN x HH x control (45.67) while IFE BROWN x HH x 0.05 had the least number of eggs (23.67). Susceptibility index values ranged from 8.60 to 11.90 on the Dobie's scale.

Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits

The findings revealed that SAMPEA 14 x HH x control interaction produced a higher percentage of bruchid emergence (86.55 %) compared to SAMPEA 14 x HH x 0.05 (84.67 %), SAMPEA 14 x HH x 0.1 (83.91 %) and SAMPEA 14 x HH x 0.01 (74.70 %). Significant higher percentage pest tolerance was observed in SAMPEA 14 x HH x 0.05 (26.67 %) while SAMPEA 14 x HH x control, SAMPEA 14 x HH x 0.01 and SAMPEA 14 x HH x 0.1 both with the least value of percentage pest tolerance (0.00 %). Significant higher percentage seed damage was recorded by SAMPEA 14 x HH x control, SAMPEA 14 x HH x 0.01 and SAMPEA 14 x HH x 0.1 (100.00 % respectively) while SAMPEA 14 x HH x 0.05 had lower percentage seed damage (73.33 %). Higher growth index was recorded by SAMPEA 14 x HH x 0.05 (2.97 %) this was followed by SAMPEA 14 x HH x control (2.94) while lower growth index was recorded by SAMPEA 14 x HH x 0.01 (2.58 %). Significant higher number of holes in seeds was observed in SAMPEA 14 x HH x 0.1 (56.00) this was followed by SAMPEA 14 x HH x control (25.33) while SAMPEA 14 x HH x 0.05 had the least number of holes in seeds (17.00). Mean development period (days) was observed to be highest in SAMPEA 14 x HH x control with 29.50 days followed by SAMPEA 14 x HH x 0.01 (29.17 days) while SAMPEA 14 x HH x 0.05 interaction had lower mean development period (28.67 days). The varied number of eggs showed that SAMPEA 14 x HH x 0.1 had significant higher number of eggs (72.33 days) which was significantly higher than that of SAMPEA 14 x HH x control (32.67), SAMPEA 14 x HH x 0.01 (27.67) and SAMPEA 14 x HH x 0.05 (23.33). Susceptibility index values ranged from 8.24 to 14.06 on the Dobie's scale.

Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits (Cont'd)

FUAMPEA 1 x EMS x 0.01 recorded higher percentage of bruchid emergence (85.10 %). This was followed by FUAMPEA 1 x EMS x control (80.05 %) while least percentage bruchid emergence was recorded by FUAMPEA 1 x EMS x 0.05 (75.60 %). Result for percentage pest tolerance revealed significant higher percentage pest tolerance (26.67) in FUAMPEA 1 x EMS x 0.1 compared to others. Percentage seed damage showed non-significant differences in FUAMPEA 1 x

Table 8g: Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits (Cont'd).

Genotype	Mutagen	Dose	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percentage Seed Damage	Growth Index	Holes in Seeds	Mean Development Period (Days)	Number of Eggs	Susceptibility Index
FUAM PEA 1	EMS	Control	80.05ab	0.00e	100.00a	2.90ab	20.33hijk	27.67de	28.67hijkl	11.29abcdefghi
FUAMPEA 1	EMS	0.01	85.10a	0.00e	100.00a	2.99a	40.00cdefgh	28.50cde	55.67defghij	13.36 abcdef
FUAMPEA 1	EMS	0.05	75.60ab	0.00cde	100.00a	2.75ab	20.00hijk	27.50def	27.00hijkl	10.39bcdefghi
FUAMPEA 1	EMS	0.1	79.17ab	26.67abcd	40.00d	2.86ab	6.00k	28.33cde	9.67l	5.96 j

Means with the same letter are not significant different. The susceptibility index, ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and ≥10 = highly susceptible (Dobie, 1977).

Table 8h: Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits (Cont'd).

Genotype Dose		Mutagen	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percen-tage Seed Damage	Growth Index	Holes in Seeds	Mean Development Period (Days)	Number of Eggs	Susceptibility Index
IFE BROWN	EMS	Control	76.92ab	0.00cde	100.00a	2.90ab	24.00ghijk	26.50ef	33.00ghijkl	12.18abcdefghi
IFE BROWN	EMS	0.01	75.25ab	0.00cde	100.00a	3.00a	20.83hijk	28.00cde	44.33fghijkl	10.85abcdefghi
IFE BROWN	EMS	0.05	66.70ab	6.67bcde	93.33ab	2.11ab	63.00ab	32.00abcd	103.00ab	13.30abcdef
IFE BROWN	EMS	0.1	76.15ab	10.00bcde	90.00ab	3.24a	11.00jk	23.50f	15.00kl	10.38bcdefghi

Means with the same letter are not significant different. The susceptibility index, ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and ≥10 = highly susceptible (Dobie, 1977).

EMS x control, FUAMPEA 1 x EMS x 0.01 and FUAMPEA 1 x EMS x 0.05 both with a high value of 100.00 % respectively while least value was observed in FUAMPEA 1 x EMS x 0.1 (40.00 %).

Result for growth index were variable and ranged from 2.75 (FUAMPEA 1 x EMS x 0.05) to 2.99 (FUAMPEA 1 x EMS x 0.01). Higher growth index was observed in FUAMPEA 1 x EMS x 0.01 (2.99) this was followed by FUAMPEA 1 x EMS x control (2.90) while the least growth index was recorded by FUAMPEA 1 x EMS x 0.05 (2.75).

The higher number of holes in seeds was observed in FUAMPEA 1 x EMS x 0.01 (40.00) which was significantly greater than FUAMPEA 1 x EMS x control (20.33), FUAMPEA 1 x EMS x 0.05 (20.00) and FUAMPEA 1 x EMS x 0.01 (6.00).

Mean development period (days) was observed to be highest in FUAMPEA 1 x EMS x 0.01 with 28.50 days followed by FUAMPEA 1 x EMS x 0.1 (28.33 days) while FUAMPEA 1 x EMS x control interaction had lower mean development period of 27.67 days. The result for number of eggs showed that FUAMPEA 1 x EMS x 0.01 had significant higher number of eggs (55.67) this was followed by FUAMPEA 1 x EMS x control (28.67) while FUAMPEA 1 x EMS x 0.1 had the least number of eggs (9.67). Susceptibility index values ranged from 5.96 in FUAMPEA 1 x EMS x 0.1 to 13.36 on the Dobie's scale.

Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits

The result revealed that IFE BROWN x EMS x control interaction produced non-significant but higher percentage of bruchid emergence (76.92 %) compared to IFE BROWN x EMS x 0.1 (76.15 %), IFE BROWN x EMS x 0.01 (75.25 %) and IFE BROWN x EMS x 0.05 (66.70 %). Non-significant higher percentage pest tolerance was observed in IFE BROWN x EMS x 0.1 (10.00 %) followed by IFE BROWN x EMS x 0.05 (6.67 %) while IFE BROWN x EMS x control and IFE BROWN x EMS x 0.01 recorded the least value of percentage pest tolerance (0.00 %). Significant higher percentage seed damage was recorded by IFE BROWN x EMS x control and IFE BROWN x EMS x 0.01 (100.00 % respectively) while IFE BROWN x EMS x 0.1 had lower percentage seed damage (90.00 %). Higher growth index was recorded by IFE BROWN x EMS x 0.1 (3.24 %) this was followed by IFE BROWN x EMS x 0.01 (3.00) while lower growth index was recorded by IFE BROWN x EMS x 0.05 (2.11 %). Significant higher number of holes in seeds was observed in IFE BROWN x EMS x 0.05 (63.00) this was followed by IFE BROWN x EMS x control (24.90) while IFE BROWN x EMS x 0.1 had the least number of holes in seeds (11.00).

Mean development period (days) was observed to be highest in IFE BROWN x EMS x 0.05 with 32.00 days followed by IFE BROWN x EMS x 0.01 (28.00 days) while IFE BROWN x EMS x 0.1 interaction had lower mean development period (23.50 days). The varied number of eggs showed that IFE BROWN x EMS x 0.05 had significant higher number of eggs (103.00 days) which was significantly higher than that of IFE BROWN x EMS x 0.01 (44.33), IFE BROWN x EMS x control (33.00) and IFE BROWN x EMS x 0.1 (15.00). Susceptibility index values ranged from 10.38 to 13.30 on the Dobie's scale.

Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits

The results showed that SAMPEA 14 x EMS x 0.01 recorded higher percentage of bruchid emergence (90.54 %) followed by SAMPEA 14 x EMS x 0.1 (81.92 %) while least percentage bruchid emergence was recorded by SAMPEA 14 x EMS x 0.05 (66.81 %). Result for percentage pest tolerance revealed higher value at SAMPEA 14 x EMS x 0.05 (20.00 %) while SAMPEA 14 x EMS x control, SAMPEA 14 x EMS x 0.01 and SAMPEA 14 x EMS x 0.1 had lower value of 0.00%. Higher percentage seed damage was recorded by

Table 8i: Effect of Genotype x Mutagen x Dose Interaction on Bruchid Traits (Cont'd).

Genotype	Mutagen	Dose	Percentage Bruchid Emergence	Percentage Pest Tolerance	Percentage Seed Damage	Growth Index	Holes in Seeds	Mean Development Period Days)	Number of Eggs	Susceptibility Index
SAMPEA 14	EMS	Control	72.07ab	0.00cde	100.00a	2.54ab	51.67abcde	28.50cde	80.50abcde	14.00abc
SAMPEA 14	EMS	0.01	90.54a	0.00cde	100.00a	3.13a	36.00defghi	29.00bcde	44.33fghijkl	12.77abcdef
SAMPEA 14	EMS	0.05	66.81ab	20.00abcde	80.00abc	2.10ab	32.33efghij	33.50ab	59.33cdefgh	10.73abcdefghi
SAMPEA 14	EMS	0.1	81.92ab	0.00cde	100.00a	2.28ab	45.33bcdefg	36.00a	60.33cdefgh	10.81abcdefghi

Means with the same letter are not significant different. The susceptibility index, ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and ≥10 = highly susceptible (Dobie, 1977).

SAMPEA 14 x EMS x control, SAMPEA 14 x EMS x 0.01 and SAMPEA 14 x EMS x 0.1 (100.00 % respectively) while least was recorded by SAMPEA 14 x EMS x 0.05 (80.00 %). Result for growth index were variable and ranges from 2.10 (SAMPEA 14 x EMS x 0.05) to 3.13 (SAMPEA 14 x EMS x 0.01). Higher growth index was observed in SAMPEA 14 x EMS x 0.01 (3.13) this was followed by SAMPEA 14 x EMS x 0.1 (2.28) while the least growth index was recorded by SAMPEA 14 x EMS x 0.05 (2.10). The higher number of holes in seeds was observed in SAMPEA 14 x EMS x control (51.67) which was significantly greater than SAMPEA 14 x EMS x 0.1 (45.33), SAMPEA 14 x EMS x 0.01 (36.00) and SAMPEA 14 x EMS x 0.05 (32.33).

Mean development period (days) was observed to be highest in SAMPEA 14 x EMS x 0.1 with 36.00 days followed by SAMPEA 14 x EMS x 0.05 (33.50 days) while SAMPEA 14 x EMS x control interaction had lower mean development period of 28.50 days. The result for number of eggs showed that SAMPEA 14 x EMS x control had significant higher number of eggs (80.50) this was followed by SAMPEA 14 x EMS x 0.1 (60.33) while SAMPEA 14 x EMS x 0.01 had the least number of eggs (44.33). Susceptibility index values ranged from 10.73 to 14.00 on the Dobie's scale.

DISCUSSION

The effect of genotype on bruchid traits

The results have indicated that there is no significant difference in the percentage of bruchid emergence among the three varieties of cowpea used in the study namely FUAMPEA 1, IFE BROWN and SAMPEA 14 which is also strongly indicative of a natural susceptibility to bruchids that is within the same range. The genotypes can thus be thought of being uniformly susceptible to bruchids with no significant advantage of one over the other. Percentage pest tolerance, percentage seed damage, Growth index, number of eggs, percentage weight loss and residual seed weight were all statistically not significant after the bruchid infestation experiment. This result indicates that the bruchid infestation did not have a statistically significant effect on the six variables that were measured. In other words, there was no significant difference in the mean values of the genotypes. This makes the genotypes suitable for bruchid culture in in the laboratory in efforts to find resistance to this pest. It would be observed that pest tolerance showed dismal values of below 10 percent for all the genotypes studied. Also clearly obvious is the very strong percentage seed damage which were over 90 percent for all the genotypes studied. It is expected that cowpea hosts that provide conducive incubation, food and maturity conditions for bruchids cannot escape the high percentage seed damage observed in the results as indicated by the number of eggs laid, growth index and mean development period which showed that the genotypes provided good and fairly equal environments that fostered the growth and development of the bruchids.

The effect of mutagen on bruchid traits

The mean number of eggs laid on the seeds treated with the three mutagens used in this study was significantly different from each other, each in a class of its own. Sodium Azide had the greatest number of bruchid eggs laid on its seeds than any other group of treated seeds. Antinutrients which amounts have been proven to be altered in the upward direction by Sodium Azide can have an effect on the number of eggs bruchids can lay on cowpea seeds (Amenu et al., 2022). Antinutrients are naturally occurring compounds in plants that can interfere with the digestion and absorption of nutrients by insects. Antinutrients can bind to essential nutrients, making them unavailable to the bruchids. This can lead to reduced growth, development, and egg production. These antinutrients can inhibit the enzyme trypsin, which is needed for protein digestion. Lectins can bind to carbohydrates in the gut of bruchids, preventing them from absorbing nutrients. Tannins can bind to proteins and prevent them from being digested. Phytates can bind to minerals such as iron, zinc, and calcium, making them unavailable to bruchids (Amenu et al., 2022) found a positive correlation between higher levels of antinutritional factors and lower bruchid egg laying and adult emergence. The current study has however found that Sodium Azide treated seeds performed in the opposite direction by accommodating more bruchid eggs than the seeds of Ethyl methane sulphonate and other mutagens used. Sodium Azide treated seeds had 43.9 mean number of holes which were significantly higher than those in the seeds treated with Hydroxylamine hydrochloride and Ethyl Methane Sulphonate. Holes indicate damage to the embryo or endosperm, resulting in lower germination rates, seedling vigor, and crop yields. Sodium Azide's significantly higher hole count suggests greater damage to the seeds compared to the other two mutagens. This translates to reduced seed quality and potentially lower crop yields. Hydroxylamine hydroxide and Ethyl methane sulphonate appear not to support harmful changes that predispose the seeds, inducing fewer holes and potentially preserving seed viability and seedling vigor.

There are other effects of Sodium Azide on cowpea seeds that are also worth considering as they can encourage the activity of bruchids. Sodium Azide is a mutagen known to induce genetic mutations in plants. At higher concentrations, it can damage DNA and metabolic processes within the cowpea seed which are necessary for defence against pest (Hu et al., 2023). This translates to weaker cell walls and seed tissues, making the seeds more susceptible to bruchid infestation and easier for them to create holes (Wang et al., 2022). Sodium Azide can also affect the chemical composition of the cowpea seeds. It can disrupt the synthesis of essential nutrients and secondary metabolites that contribute to seed defenses against pests such as the production of defence enzymes and anti-microbial compounds (Hassan et al., 2021). This alteration in chemical composition can attract bruchids more readily and provide them with a more favorable environment for feeding and reproduction. Sodium Azide treatment can also alter the structure of the seed coat, which is the outer protective layer of the seed. This can lead to cracks and weaknesses in the coat, providing easier access for bruchids to penetrate the seed and reach the nutritious inner core (Liu et al., 2019). Sodium Azide may not be the ideal mutagen for cowpea breeding programs focused on improving seed quality and crop yields. Hydroxylamine hydroxide and Ethyl methane sulphonate appear to be better options in this regard, inducing more desired mutations the seeds which lead to a smaller number of holes.

Effect of dose on bruchid traits

The number of eggs laid by the bruchids showed no statistical difference between the control and dose 0.1%. Reductions in the number of eggs laid on the cowpea seeds were observed at dose 0.01% and 0.05% with the most reduction taking place at dose 0.01%. These doses could be indicative of doses at which the egg laying process of bruchids could be interrupted or deterred. Higher doses of mutagens can significantly influence oviposition behavior in bruchid beetles, particularly through effects on fecundity and egg viability. Sometimes Bruchids exhibit adaptability which allows females to optimize their reproductive output in certain unfavourable conditions, which makes the female bruchid increase oviposition to ensure survival of the young. This is known as compensatory oviposition (Horng et al., 1999).

Percentage pest tolerance produced a better performance for all the doses as they performed above the control. The ability of the doses to induce better pest tolerance on the seeds was clearly demonstrated by dose 0.05% which was also the best performance for the trait. A performance of 10.74% as the apex result could be considered as low, but compared to the performance of the control could be seen as a significant improvement. The percentage seed damage perfectly reflected the percentage pest tolerance results as the dose 0.05% which induced the best result also had the best result for percentage seed damage (89.26%) as all other doses provided higher percentage seed damage. Percentage pest tolerance and percentage seed damage both peaked at dose 0.05. It seems effective in reducing cowpea pest tolerance for bruchids across all tested doses. This is suggestive that the active ingredient in the treatment needs to reach a certain concentration to effectively deter bruchids. Dose 0.05% yielded the most significant positive impact in this regard, demonstrating the most likely potential for protecting cowpea crops from bruchid damage.

The Effect of genotype x mutagen interaction on bruchid traits

The relationship between Fuampea 1 and the mutagens were observed in the significantly high number eggs deposited on the seeds in Sodium Azide and Hydroxylamine hydrochloride treated seeds. It is then indicative of a better relationship between Fuampea 1 and Ethyl methane sulphonate as statistically less number of eggs were deposited on the seeds. It therefore means that Fuampea 1 may respond better when treated with Ethyl methane sulphonate with respect to deterring the egg laying capacities of bruchids on its seeds than IFE BROWN and Sampea 14. The closest any other interaction got to Fuampea 1 x EMS was 39 eggs on Sampea 14 x HH.

Similar performances were observed for IFE BROWN irrespective of the mutagen treatment as they ranged from 45 to 48 eggs for all the three interactions. This value range specifically for IFE BROWN x SA and IFE BROWN x HH were not as high as Fuampea 1 x SA and Fuampea 1 x HH interactions as they had far less eggs but were not as low as to come close to the minimum values provided by Fuampea 1 x EMS and Sampea 14 x HH. The resulting holes in the seeds produced by the hatching bruchid eggs were uniform for IFE BROWN as they ranged from 27 to 31 holes which was the best outcome for any of the genotype mutagen groups.

This was also indicative that an IFE BROWN mutagen combination might work better to reduce the incidence of holes in cowpea seeds better than any other genotype x mutagen interaction. Percentage seed damage was 100% for two out of three Genotype x SA interactions further stressing the role SA plays in worsening seed damage by the bruchids. Interactions with 46.17 holes and above produced a percentage seed damage of 100% while the interaction with the least number of holes (Fuampea 1 x EMS) also produced the least percentage seed damage (85%). It is therefore reasonable to expect dismal percentage pest tolerance for interactions with high percentage seed damage as observed in the current study.

The effect of genotype x dose interaction on bruchid traits

The best naturally expressed variation in terms of the non-suitability of the seeds of the various genotypes for bruchid egg laying was observed to be in IFE BROWN as it seemed to suppress the egg laying capacity of the bruchids. At the dose 0.01% and 0.05%, IFE BROWN had the highest number of eggs. This dropped to the lowest number of bruchid eggs laid at dose 0.1% which was also the lowest number of bruchid eggs laid for any treatment in the Genotype x dose interaction. FUAMPEA 1 interaction with the doses indicated a dose dependent increase in the number of bruchid eggs laid with an increase in dose. The greatest number of eggs were observed at the highest dose. There could therefore be indications that the factors which repel bruchids from laying their eggs on FUAMPEA 1 could reduce with an increase in mutagen dose. On the other hand, it could very well be compensatory oviposition at work (Horng et al., 1999).

Usually, the number of holes in the seeds should exhibit some kind of proportionality with the number of eggs laid which is to say, the increase in the number of eggs laid should translate into more holes in the seeds. This was not the case observed with IFE BROWN x dose interactions. There turned out to be fewer number of holes in the seeds for IFE BROWN x dose interactions even though there were more bruchid eggs laid on the seeds. This interaction even produced the lowest number of holes at two of the three mutagen doses namely 0.01% and 0.1%, but at dose 0.05% it was not significantly different from the other Genotype x dose interactions.

The percentage seed damage and the percentage pest tolerance have an inverse relationship. SAMPEA 14 x dose interactions all had 100 percent seed damage except for SAMPEA 14 x 0.05% which disobeyed this rule and indicated one of the strongest pest tolerances. The mean development period of the bruchids was lower at lower doses for FUAMPEA 1 x Dose interactions and took up to 29.22 days at FUAMPEA 1 x 0.1 which took significantly longer than the control. The mean developmental period for the bruchids took 27.67 days in the IFE BROWN x Control and was further reduced to 27.28days in IFE BROWN x 0.1 which display a statistical difference with the control. IFE BROWN x 0.05 however also had the highest value for the character at 30.50 days which is indicative of a wide variation. SAMPEA 14 x 0.1 extended the mean developmental period by more than 24 hours with an indicated value of 31.56 days. From the general observation of the character, IFE BROWN x Dose interactions carries the requisite variation that could contribute to breeding efforts to alter the mean developmental period of the bruchids.

The Effect of Mutagen x Dose Interaction on Bruchid Traits

The number of eggs laid on the seeds varied significantly among the Mutagen x Dose interactions as SA x Dose interactions produced its best result at SA x 0.01 with 34.11 eggs which was less than half of the eggs laid on the control. The HH x 0.05 interaction produced the least number of eggs among the HH x Dose interactions indicating that at this dose, factors which contribute towards the reduction of eggs through the enhancement of the unsuitability of the surface area of the seeds for bruchid eggs. For the EMS x Dose interactions, this was observed at EMS x 0.1 with a total number of 28.33 bruchid eggs which was the overall best expression for this character. Inspite of the genotypes, the interaction with the doses did not produce any particular patterns either reducing or increasing the number of eggs laid on the seeds. The interaction (SA x Control) with statistically the highest number of eggs (58.44) also was the interaction with the most holes (58.44) which was closely followed by SA x 0.1 with 51.11 holes The SA x Dose interactions alone produced both the highest and one of the lowest number of holes observed among all the interactions for the character. This is indicative of a wide range of possibilities for the character when the SA x Dose combinations are used. The least number of holes on the seeds was shown by EMS x 0.1 which also had the least number of bruchid eggs laid on the seeds with the number of eggs character seemingly predicting the number of holes in this case at least for the highest and lowest observations for both characters. While the mean developmental period for SA x Control also followed the already observed pattern as it had the highest value for the character as it did for number of eggs and number of holes while the lowest values were observed mostly among HH x Dose interactions.

The effect of genotype x mutagen x dose interaction on bruchid traits

In the Fuampea 1 x SA x Dose interactions, number of eggs produced in the treatments performed under the control which bear indications of potential genetically altered reductions in the number of eggs the bruchids can lay on Fuampea 1 seeds. This pattern was also reflected in the number of holes in the seeds as they all indicated reduction in number of holes. It is therefore plain to see by deductive reasoning that reduced number of eggs can also reduce the number of holes on the seeds. There was however no pest tolerance and there was one hundred percent seed damage which meant the number of eggs laid and the emerging bruchids were sufficient to cause maximum damage and therefore the reductions in the number of eggs laid by the bruchids were not sufficient to alter pest tolerance or seed damage. Percentage bruchid emergence were all above 70% and greater than the control. This means that Sodium Azide and the doses utilized in this study may not have any positive impact on Fuampea 1 with respect to increasing pest tolerance and reducing seed damage. Therefore, while a reduction in eggs and holes is a positive indicator, it may not necessarily guarantee endow pest tolerance or prevent 100% seed damage.

Bruchids can harm cowpea seeds even without laying eggs through various non-ovipositional activities (Akullo, 2023). This could be in form of chewing damage as adult bruchids have strong mandibles and can chew on the seed coat, creating small punctures or larger gouges. These wounds compromise the seed's protective barrier, making it vulnerable to moisture loss, fungal infections, and other pests (Adedire and Ajayi, 2024). IFE BROWN seeds treated with SA doses had only IFE BROWN x SA x 0.1 performing worse than the control as it had more bruchid eggs laid on it than the control. This pattern was replicated in the holes in the seeds character with IFE BROWN x SA x 0.1 still having the worst damage with mean developmental period and percentage pest tolerance.

SAMPEA 14 did not respond to SA differently from the pattern observed in IFE BROWN x SA x Dose interactions and were expressed in characters such as number of eggs, holes in seeds and growth index. Exceptions were found in percentage pest tolerance and percentage seeds damage with zero percent and 100% respectively. The number of eggs laid on FUAMPEA 1 seeds treated with Hydroxylamine Hydrochloride doses had its best expression at FUAMPEA 1 x HH x 0.01 as this was the only dose that seemed to reduce the number of eggs laid. The number of holes in the seeds however had a dose related increase as the number of holes increased with an increase in dose. This also should have been the case for the number of eggs character but for the decrease at FUAMPEA 1 x HH x 0.01. The presence of unfavorable conditions can cause the bruchids to increase oviposition. This is so as to increase the likelihood of survival just as the presence of certain compounds can cause bruchids to increase their oviposition (Gupta and Pandey, 2009). FUAMPEA 1 x EMS x 0.1 was exceptional in a number of traits. It had the least number of eggs laid for all the treatment combinations in this source. It also had the least number of holes in the seeds. Even though bruchid emergence was not low compared to other treatments, pest tolerance was appreciably high and Percentage seed damage was comparatively the lowest observed for any of the treatments. This means that even in the presence of newly emerged bruchids, there were indications that the damage traditionally caused by bruchids was to an extent contained. This could be explained by mutations of both physical and chemical barriers on the seeds enhancing it non-attractive to bruchid egg laying.

Susceptibility index

All the genotypes, mutagens and doses deployed in the experiment as main effects were assessed to be highly susceptible as they all presented values above 11 on the Dobie's index. FUAMPEA 1 x EMS x 0.1 scored 5.96 on the Dobie's index which indicates that it is moderately resistant. This result portends that in the bid to induce bruchid resistance, success is much more likely using the genotype FUAMPEA 1 and the mutagen Ethyl Methane Sulphonate (EMS) at 0.1%.

Conclusion

FUAMPEA 1 created the best responses for bruchid related character improvements. EMS and HH were more effective in reducing the number of eggs laid by the bruchids as well as bruchid emergence. SA on the other hand increased eggs laid on the cowpea seeds, bruchid emerged as well as holes in the seeds and is deemed unsuitable for breeding bruchid resistance in to the cowpea genotypes studied. EMS induced the only above susceptible resistance on the Dobie's Index among the genotypes studied. It therefore holds the most promise in the efforts to induce bruchid resistance in cowpea through chemical mutagenesis.

Recommendations

i. The use of EMS should be optimized by further research for better results in mutation breeding efforts for the improvement of bruchid resistance in cowpea.
ii. FUAMPEA 1 should be used more in attempts to induce resistance to bruchids as it shows more favourable responses in line with the trait.

REFERENCES

Adedire, C. O. and Ajayi, T. T. (2024). "Impact of bruchid feeding and frass contamination on the nutritional quality and marketability of stored cowpea seeds." Food Science and Nutrition, 12(1): 178-185.
Akullo, J. B. L. (2023). "Non-ovipositional damage by bruchid beetles

(Callosobruchus maculatus) reduces germination and seedling vigor of cowpea (Vigna unguiculata) seeds." Journal of Stored Products Research, 100:102-110.

Amenu, S.G., Wei, N., Wu, L., Oyebanji, O., Hu, G., Yadong, Z and Wang, Q. (2022). Phylogenomic and comparative analyses of coffeeae alliance (Rubiaceae): deep insights into phytogenetic relationships and plastome evolution. Plant Biology, 22(88):1-13.

Dobie, P. (1977). The contribution of the Tropical Stored Products Centre to the study of insect resistance in stored maize. Tropical Stored Products Information, 34, 7-22.

Gupta D.S., and Pandey I.D. (2009). Bioassay for bruchid resistance in cowpea. Journal of Food Legumes, 22(1):43-45.

Hassan, M. M., El-Sheshtawy, H. A., El-Aal, H. A., and El-Sayed, M. A. (2021). Effect of Sodium Azide on the chemical composition and antioxidant activity of some medicinal plants. Journal of Medicinal Plants Research, 15(2), 77-84.

Horn, L.N. and Shimelis, H. (2020). Production Constraints and Breeding Approaches for Cowpea Improvement for Drought Prone Agro-Ecologies in Sub-Saharan Africa. Annals of Agricultural Sciences, 65: 83-91.

Horng S, H., C., Lin., W., J., Wu., H., C., J., Godfray. (1999). Behavioral processes and egg-laying decisions of the bean weevil, Callosobruchus maculatus. Population Ecology, 41(3):283-290.

Hu, J., Zhang, X., Wang, H., Li, R., and Xu, C. (2023). Mechanisms and applications of Sodium Azide in controlling plant diseases. Frontiers in Plant Science, 14:836475-836480.

Jain, S.M. (2005). Major mutation-assisted plant breeding programs supported by FAO/IAEA. Plant Cell Tissue Organ Culture, 82: 113–123

Jayathilake, C., Visvanathan, R., Deen, A., Bangamuwage, R., Jayawardana, B. C., Nammi, S., & Liyanage, R. (2018). Cowpea: An overview on its nutritional facts and health benefits. Journal of the Science of Food and Agriculture, 98(13), 4793-4806.

Khan, S. and Wani, M.R. (2005) Quantitative assessments on induced high yielding mutant lines in Vigna radiata L. Legume Research, 2005, Volume 28, Issue 1, Pages 31-35.

Lephale, S., Abraham, A.B., & Victoria, A. (2012). Susceptibility of seven cowpea cultivars (Vigna unguiculata) to cowpea beetle (Callosobruchus maculatus). Agricultural Science Research Journal, 2(2), 65-69.

Liu, J., Cao, J., Zhang, Y., & Jiang, P. (2019). Effect of Sodium Azide on seed coat structure and germination of maize seeds. Journal of the Science of Food and Agriculture, 99(13): 6122-6128.

Molosiwa, O. O. and Makwala, B. C. (2020). Field evaluation of introduced and local cowpea genotypes performance in Botswana. African Journal of Agricultural Research, 16(9), 1317-1324.

Nkomo, G. V., Sedibe, M. M., & Mofokeng, M. A. (2021). Production Constraints and Improvement Strategies of Cowpea (Vigna unguiculata L. Walp.) Genotypes for Drought Tolerance. International Journal of Agronomy, 2021, Article ID 5536417, 9 pages. https://doi.org/10.1155/2021/5536417

Ofuya T.I., Olotuah, O.F. and Ogunsola, O.J. (2010). Fumigant toxicity of crushed bulbs of two allium species to Callosobruchus maculatus (fabricius) (COLEOPTERA: BRUCHIDAE). Chilean Journal of Agricultural Research. 70(3):510-514.

Omoigui, L.O., Kamara, A.Y., Batieno, J., Iorlamen, T., Kouyate, Z., Yirzagla, J. and Diallo. S. 2018. Guide to cowpea production in West Africa. Ibadan, Nigeria: IITA, (60 p.).

Raina, A., Younas R., and Tantray, S.K. (2023) Assessment of Bio-physiological Damages and Cytological Aberrations in Cowpea Varieties Treated with Gamma Rays and Sodium Azide. PLoS One. 18(7). Article Number: e0288590. PMID: 37471405. PMCID: MC10358960.

Wang, X., Liu, Y., Zhang, J., Chen, H., & Li, Q. (2022). Insecticidal, residual, and sub-lethal effects of some plant essential oils against bruchids. Journal of Pest Science, 95(3), 789-799.