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Research Article

EVALUATION OF SOYBEAN GENOTYPES AGAINST CALLOSOBRUCHUS CHINENSIS (COLEOPTERA: CHRYSOMELIDAE) INFESTATION IN ETHIOPIA

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ABSTRACT. Soybean (*Glycine max* (L.) Merr.) is among the chief food and industrial crops grown globally for its high protein and vegetable oil content. This study investigates the resistance of various soybean genotypes to the infestation of soybean bruchid (*Callosobruchus chinensis* L.), a key pest affecting the storage of this critical crop in Ethiopia. This study evaluates 50 soybean genotypes' susceptibility to *C. chinensis* infestation through parameters such as egg oviposition, adult emergence, weight loss percentages, and growth index. Results indicate significant genetic variability among the genotypes about pest resistance, with two genotypes classified as resistant, sixteen as moderately resistant, and the majority as susceptible or highly susceptible. Notably, genotype JM-PI230970/PI635999-020-T14-S43 displayed the lowest susceptibility, showing exceptional resistance traits, and the other resistant genotype is JM-PI635999/F6LG04-5196-LG06-5920-020-T3-S5. Conversely, many released soybean varieties exhibited susceptibility, emphasizing the need for targeted breeding programs to enhance resistance traits and sustain soybean production in regions afflicted by *C. chinensis*.

Keywords: *Callosobruchus chinensis, Dobie susceptibility index, Growth index, grain weight loss*

INTRODUCTION

Soybean is one of the most vital food crops, rich in protein and vegetable oil [1]. In addition, it has ample amounts of essential omega-3 fatty acids, alpha-linolenic acid, and omega-6 fatty acid, linoleic acid [2]. This is why soybeans are hoped to fulfill the need for caloric and protein intake for the growing global population. However, this critical crop is threatened by soybean bruchid (*Callosobruchus chinensis* L.) infestation.

Callosobruchus chinensis is among the main storage insect pests that feed on dry seeds of leguminous plants [3-5]. It is commonly called adzuki bean weevil, pulse beetle, cowpea bruchid, or Chinese bruchid [6,7]. It feeds on pulses like cowpea (*Vigna unguiculata* L.), soybean (*G. max* L. Merr.), mung bean (*Vigna radiata* L.), pigeon pea (*Cajanus cajan* (L.) Huth), lablab (*Lablab purpureus* (L.) Sweet), faba bean (*Vicia faba* L.), field pea (*Pisum sativum* L.), chickpea (*Cicer arietinum* L.). It found in the tropics and subtropics of the world [6,7]. It causes irreversible and direct loss of pulse grains in the field and storage [8]. This pest causes 60-100% yield losses on soybeans in Sub-Saharan Africa [9]. Bruchids' high fertility, ability to re-infest, short generation times, and even low initial infestation rates can lead to tremendous damage [10].

The damage caused by this pest includes seed or grain weight loss, loss of seed viability, and altered nutritional quality due to the presence of insect frass, excrement, and dead insects in and on the seeds or grains. According to Tembo et al. [11], a single bruchid beetle can cause 3.5% weight loss in cowpea seeds. Likewise, *C. chinensis* caused up to 100% losses in cowpeas [5], beans [12] after 3-6 months of storage, and up to 27.18% in soybeans in Uganda [13]. *Callosobruchus chinensis* was a major storage pest of field peas, chickpeas, cowpeas, and beans in Ethiopia, but there is a lack of information regarding damage caused to soybeans. Recently, *C. chinensis* has been observed on different soybean varieties stored at Assosa, and some soybean seeds from the Jimma Agricultural Research Center have been severely damaged.

The management of *C. chinensis* can be effectively achieved through an integrated approach. Implementing proper sanitation practices, such as cleaning storage areas, removing infested seeds, and using airtight containers (Purdue Improved Crop Storage), can significantly reduce infestation [14,15]. Utilizing natural enemies of *C. chinensis*, such as ecto-parasites and egg predators, can help keep the beetle population in check [16,17]. Insecticides can control bruchid populations, but their use should be minimized due to potential health and environmental hazards [18]. Plant-based insecticides, such as neem oil, have shown promise in controlling bruchids [19].

Developing and planting soybean varieties resistant to *C. chinensis* is crucial to integrated pest management [20]. The resistance of some soybean varieties to the *C. chinensis* can be attributed to several biochemical factors. For instance, specific soybean genotypes have lower concentrations of flavonoids, which are linked to decreased susceptibility to the beetle, and higher concentrations of antioxidants, which protect the seeds from damage by the beetle. Higher tannins deter insect feeding, while higher peroxidase plays a role in the plant's defense mechanisms by prolonging the insect development period. These factors contribute to soybean resistance against the bruchids [21]. Also, soybean varieties with thicker seed coats and higher moisture content are more resistant to bruchid infestation [22,23]. Therefore, this investigation aimed to identify soybean genotypes resistant to *C. chinensis* damage in Ethiopia.

MATERIALS AND METHODS

Trial Site and C. chinensis Culture

The study was conducted in 2023 and 2024 at the Plant Protection Laboratory of the Assosa Agricultural Research Center (AsARC) in Benishangul Gumuz, Ethiopia. AsARC is located at 34°34.10" E longitude, 10° 02.55" N latitude, and an altitude of 1553 meters above sea level. The area receives an average annual rainfall of 1177 mm and has a mean temperature of 26.79 °C.

Adult *C. chinensis* for this study were sourced from a laboratory culture at AsARC. The initial culture was established using bruchids collected from infected soybean stores at the center. The culture was maintained by allowing these insects to oviposit on the Gizo variety. The insects were reared on 1 kg of seeds in 2-liter plastic buckets covered with muslin cloth to allow ventilation and prevent the insects from escaping. The bruchid populations were maintained by regularly transferring the insects to fresh soybean seeds. A sample of the reared bruchid population was confirmed as *Callosobruchus chinensis* L. (Fig. 1,2) following the diagnostic protocol described by Farrell et al. [24].

Soybean Genotypes and Trial Design

The study used 48 soybean genotypes from the Jimma Agricultural Research Center and two from AsARC. The seed samples were oven-dried at 30°C for 24 hours to kill any eggs or adult insects present [25]. They were then placed on laboratory shelves under room conditions for 7 days [8].

A sample of 50 soybean seeds was drawn from each of the 50 genotypes and weighed to obtain the initial weight of each soybean germplasm. Subsequently, samples of 50 soybean seeds were placed in separate plastic petri dishes. The seeds in each dish were artificially infested by a female and 2-3 male adult bruchids, 1-2 days old, randomly selected from the bruchid colony using the no-choice test method described by Somta et al. [26]. The Petri dishes were arranged in a randomized complete block design replicated twice. Bruchids were removed from the soybean samples after 10 days [8].

Data Collection

On the 11th day, the eggs on each of the 50 seeds were counted [8]. Once adult emergence began, the emerged insects were counted and removed daily until no new insects appeared for five consecutive days [27]. After that, the final weight of the seeds in each Petri dish was recorded. The total number of eggs laid indicated oviposition [25], while the number of bruchid emergences indicated the degree of infestation [28]. These data were used to derive the following variables:

Grain weight loss percentage (Eqn.1), an economic loss indicator [25], was calculated as follows:

$$Grain\ weight\ loss\ (\%) = \frac{Initial\ grain\ weight\ (g) - final\ grain\ weight\ (g)}{Initial\ grain\ weight\ (g)}\ x\ 100$$

Eqn. 1

Growth index, an indicator of genotype suitability for insect development [29], was calculated as described in Eqn. 2:

$$Growth\ index = \frac{\%\ adult\ emergence}{Median\ development\ period}$$

Eqn. 2

The median development period was calculated as the number of days from the middle of oviposition (day five) to the first progeny emergence [8]. The percent adult emergence (Eqn. 3) was calculated as:

$$Adult\ emergence\ (\%) = \frac{Total\ number\ of\ adults\ emerged}{Total\ number\ of\ eggs\ laid}\ x\ 100$$

Eqn. 3

Dobie susceptibility index (DSI) was calculated using the data on the number of adult bruchids that emerged and the median development period for each genotype [30]. The Equ. 4 used was:

$$DSI = \frac{Log_e Y\ x\ 100}{t}$$

Eqn. 4

Where Y is the total number of adult bruchids that emerged, and t is the median development period.

Table 1. *List of 50 soybean genotypes used in this study*

Code	Genotypes	Code	Genotypes
G-2	Pawe 03 or TGX-1987-62F	G-31	JM-SCS-1/PI605891B-020-T5-S4
G-3	S1180/5/54	G-32	PI471904
G-4	Dundee	G-33	JM-PI230970/PI635999-020-T14-S37
G-5	5002T or PI634193	G-34	JM-PI230970/PI635999-020-T14-S11
G-6	SC STATUS	G-35	JM-PI230970/PI635999-020-T14-S15
G-7	JM-CLK/CRFD-15-SD	G-36	JM-PI230970/PI635999-020-T14-S18
G-8	TGX 2014-49FZ	G-38	JM-PI635999/F6LG04-5196-LG06-5920-020-T3-S5
G-9	TGX 2021-03FZ	G-39	JM-PI230970/PI635999-020-T14-S26
G-11	JM-PI230970/PI635999-020-T14-S45	G-40	JM-PI230970/PI635999-020-T14-S36
G-12	Lukanga	G-41	JM-PI230970/PI635999-020-T14-S23
G-13	MAKSOY 4N	G-42	JM-PI230970/PI635999-020-T14-S16
G-15	MAKSOY 6N	G-44	JM-PI230970/PI635999-020-T14-S43
G-16	S1146/5/25	G-45	JM-PI230970/PI635999-020-T14-S30
G-17	S1150/5/22	G-46	JM-PI230970/PI635999-020-T14-S20
G-19	SC Squire	G-48	JM-PI230970/PI635999-020-T14-S27
G-20	SCS-1	G-49	JM-PI230970/PI635999-020-T14-S22
G-21	SNKGM001	G-51	JM-PI230970/PI635999-020-T14-S10
G-22	SNKGM004	G-53	Guda
G-23	TGX 2001-13DM	G-54	JM-PI230970/PI635999-020-T14-S42
G-25	TGX 2014-19FM	G-55	Afgat or TGX-1892-10F
G-26	Gazala	G-56	JM-PI230970/PI635999-020-T14-S21
G-27	JM-PI230970/PI635999-020-T14-S33	G-58	JM-PI230970/Clark-63K-020-T15-S1
G-28	PI594796	G-61	JM-PI230970/PI635999-020-T14-S40
G-29	PI423958	G-62	Belesa-95 or PR-149
G-30	PI423961A	G-63	Gishama or PR-143-(26)

If no insects emerged over the test period, the DSI value was equal to zero [31]. The modified susceptibility index, ranging from 0 to 9, was used to classify the soybean genotypes: 0-1 = resistant; 2-3 = moderately resistant; 4-5 = susceptible; 6-9 = highly susceptible. This modification differs from Dobie's original range of 0-11 [30]. DSI was also modified by Kananji [8] and Radha and Susheela [32] to fit the crops they studied. Genotypes with high DSI were considered susceptible, while those with low DSI were deemed resistant. This classification assumed that fewer insect progenies would emerge from a resistant genotype, and insect progeny development would take longer in a resistant genotype than in a susceptible one [8].

Data Analysis

Data were analysed using the R Statistical Package [33]. Where assumptions of Analysis of Variance (ANOVA) were violated, data transformations were applied. Genotypes were categorized into four groups based on DSI means: resistant, moderately resistant, susceptible, and highly susceptible. Frequency distributions and correlation coefficients (r) were calculated to determine relationships [34].

RESULTS AND DISCUSSION

Analysis of Variances for Resistance Parameters

The analysis of variance results for the parameters used to assess soybean resistance to *C. chinensis* is presented in Table 2. Genotypes showed highly significant effects on percent adult emergence, median development period, growth index, Dobie susceptibility index, and substantial (P<0.05) effects on percent weight loss. This highlights the genetic variability among the studied genotypes in resistance to *C. chinensis* infestation. Msiska et al. [13] identified significant differences among soybean genotypes in their resistance to *C. chinensis*, particularly regarding biochemical factors (total antioxidants, tannins, peroxidase, and flavonoids). These biochemical markers are crucial for developing resistant soybean cultivars, as they directly impact the pest's ability to infest and damage the seeds.

Table 2. *Mean squares for variables used to assess soybean resistance to C. chinensis in Assosa, Ethiopia, during 2023 and 2024*

Source of variation	Df	Number of eggs	Percent adult emergence	Adult emerged	Percent weight loss	Median development period	Growth index	Dobie susceptibility index
Year	1	710.65	1972.86**	367.21	490.78***	112.50*	1.26***	4.87
Rep	1	489.85	538.28	483.61	80.77*	28.88	0.23	0.03
Genotypes	49	650.58	618.85***	296.08	27.22*	62.78***	0.28***	6.77**
Year*Genotype	49	959.17	254.95	295.88	33.25**	47.75*	0.16*	3.52
Residuals	99	887.19	233.65	250.67	19.44	31.48	0.11	3.45
Mean		46.61	28.10	14.34	6.22	56.14	0.52	3.96
CV		63.91	54.39	110.45	70.92	9.99	63.45	46.93

Df degree of freedom; *** Significant at P< 0.001; ** significant at P<0.01; * significant at P<0.05

The year had highly significant effects (P<0.001) on percent weight loss and growth index, percent adult emergence, and median development period (Table 2). This emphasizes the importance of environmental condition, such as temperature, which play a critical role in the infestation dynamics of bruchids [35]. During the experimentaion period, the average maximum and minimum temperatures at Assosa in 2023 (from September to December) were 22.93 °C and 11.25 °C, respectively, while in 2024 (from February to May), they increased to 23.95 °C and 14.00 °C, respectively. Ouedraogo et al. [35] reported that higher temperatures tend to accelerate the reproductive cycle and increase the population density of bruchids. Lale and Vidal [36] also reporetd that temperature is the most crucial factor in infulencing oviposition and progeny development of bruchids. This is why the year showed a highly significant effect in the study. The interaction between year and genotype further highlights the importance of considering both genetic and environmental factors in breeding programs.

Msiska et al. [13] also found that higher concentrations of total antioxidants and tannins can slow down the pest's development and reduce its growth rate, resulted in increased resistance to *C. chinensis.* The significant genotype effects on median development period and growth index observed in Table 2 suggest that genotypes might have higher levels of antioxidants and tannins, and lower levels of flavonoids, a protective biochemical [13].

Number of Eggs (Oviposition)

Our findings revealed that the oviposition preferences of *C. chinensis* on various soybean genotypes were significantly varied with mean eggs of 24.50 to 77.25 (Table 3). The highest mean numbers of eggs (77.25) were laid on the Gishama variety, indicating the most preferred soybean genotype for oviposition. Scholars reported that *C. chinensis* mostly preferred soybean seeds with larger size, smooth surfaces, thin and weak seed coats for oviposition [13, 37]. It might be due to these charactersitics that Gishama variety; the most popularly grown variety in Assosa, was perefered for oviposition.

In contrast, few egg loads was recorded on genotypes JM-PI230970/PI635999-020-T14-S23, SCS-1, JM-PI230970/PI635999-020-T14-S43, and JM-PI635999/F6LG04-5196-LG06-5920-020-T3-S5. Soybean genotypes with fewer eggs were reported as resistant to *C.*

chinensis compared to moderate and susceptible ones [13]. The lower egg load on resistant genotypes might be due to biochemicals (tannins and antioxidants) that detere oviposition [13, 38, 39]. In addition, *C. Chinensis* laid fewer eggs on soybean genotypes with thick seed coat [40, 41]. The positive correlation between the number of eggs and the percentage of adult emergence and the number of emerged adults further supports the idea that initial egg-laying preferences significantly impact subsequent developmental stages.

Number of Adults Emerged

In this investigation, the number of emerged adults ranged from 2.25 to 34.00 (Table3). Gishama (G-63) had the highest number of emerged adults (34.00), which correlates with its high egg count and emergence percentage. In contrast, genotypes JM-PI635999/F6LG04-5196-LG06-5920-020-T3-S5 and JM-PI230970/PI635999-020-T14-S43 had the lowest number of emerged adults (2.25), indicating strong resistance. According to Msiska et al. [13], susceptible soybean varieties exhibited higher numbers of *C. chinensis* adult emergence, while resistant varieties showed fewer. The number of emerged adults was directly related to the reproductive success of *C. chinensis* and impact of the pest on soybean storage. Studies have shown that genotypes with more adults often have physical and biochemical traits that make them more susceptible to infestation. For instance, Singha and Rajkumari [42] reported that seeds with smoother surfaces and higher nutritional contents were more susceptible to *C. chinensis* infestation.

On the other hand, resistant soybean genotypes possess traits that deter oviposition or reduce larval survival, resulting in lower adult emergence [42]. The larval survival might be reduced due to seed coat thickness, roughness, and hardness that hinder the penetration of larvae [43, 44]. Additionally, high fat content in soybean seeds was reported as a trait that reduces bruchid attacks on soybeans [45].

Percentage of Adult Emergence

Genotype MAKSOY 6N had the highest percentage of adult emergence (57.72%), indicating it provides a favourable environment for larval development. This aligns with findings that certain genotypes with specific biochemical properties, such as lower levels of defensive compounds, can enhance insect development [13, 46]. According to Msiska et al. [13], susceptible soybean varieties exhibited higher number of *C. chinensis* adult emergence, while resistant varieties showed fewer. Our investigation found that genotypes JM-PI230970/PI635999-020-T14-S43, JM-PI635999/F6LG04-5196-LG06-5920-020-T3-S5, TGX 2014-49FZ, Belesa-95, and PI471904 had the lowest percentage of adult emergence, indicating strong resistance. The strong positive correlation between the percentage of adult emergence and the growth index (Table 6) suggests that genotypes supporting higher adult emergence also promote faster growth, which is crucial for understanding pest dynamics.

Table 3. *Effects of soybean genotypes on C. chinensis eggs, MDP, % adult emergence, growth index, and number of adults emerged in 2023 and 2024 at Assosa, Ethiopia*

Genotypes	# of eggs		% adult emerged		MDP (days)		Growth index		# of adult emerged	
G-63	77.25	a	34.21	b-i	58.25	b-h	0.64	c-k	34.00	a
G-49	75.50	ab	37.69	a-h	53.00	e-k	0.76	b-h	27.00	a-e
G-34	64.75	a-c	48.16	a-d	58.25	b-h	0.86	b-f	32.75	ab
G-4	63.75	a-c	22.26	e-o	60.00	b-f	0.38	g-m	16.25	a-h
G-53	63.75	a-c	23.70	e-o	48.00	k	0.52	d-m	16.75	a-h
G-21	61.00	a-c	29.51	d-n	69.50	a	0.43	e-m	20.75	a-h
G-33	60.25	a-c	20.27	g-o	58.00	b-h	0.35	g-m	13.50	a-h
G-35	60.00	a-c	14.42	i-o	55.00	d-k	0.26	k-m	8.75	c-h
G-31	58.50	a-c	24.22	e-o	57.50	b-i	0.43	e-m	10.75	b-h
G-2	57.50	a-c	34.33	b-i	58.00	b-h	0.60	c-m	20.75	a-h
G-28	57.25	a-c	42.05	a-e	52.00	g-k	0.80	b-g	30.75	a-c
G-27	56.75	a-c	20.82	e-o	59.25	b-h	0.29	i-m	12.00	a-h
G-17	56.75	a-c	33.61	b-j	55.50	b-k	0.56	c-m	15.50	a-h
G-3	56.25	a-c	48.29	a-d	50.00	i-k	1.39	a	29.75	a-d
G-62	54.50	a-c	11.52	l-o	60.50	b-e	0.20	k-m	6.25	e-h
G-32	54.50	a-c	11.55	k-o	58.75	b-h	0.20	k-m	6.00	e-h
G-26	53.00	a-c	27.78	d-o	52.00	g-k	0.62	c-l	14.00	a-h
G-58	52.25	a-c	47.69	a-d	56.00	b-j	0.88	b-e	25.25	a-g
G-22	51.75	a-c	52.29	a-c	57.25	b-i	0.96	a-d	24.00	a-h
G-42	51.00	a-c	41.75	a-f	63.25	ab	0.63	c-k	25.75	a-f
G-54	50.75	a-c	33.00	b-k	56.50	b-j	0.60	c-m	15.00	a-h
G-55	50.50	a-c	35.78	b-i	49.25	jk	0.73	b-j	18.75	a-h
G-16	49.50	a-c	38.72	a-g	53.25	e-k	0.74	b-i	20.00	a-h
G-6	49.00	a-c	31.92	c-l	53.00	e-k	0.62	c-l	14.50	a-h
G-36	48.75	a-c	31.54	c-l	52.50	f-k	0.61	c-l	29.25	a-d
G-46	45.50	a-c	31.64	c-l	55.00	d-k	0.58	c-m	15.00	a-h
G-8	43.50	a-c	9.56	m-o	61.75	a-d	0.15	lm	3.50	gh
G-11	43.00	a-c	30.16	d-m	51.50	h-k	0.66	b-k	14.75	a-h
G-19	42.00	a-c	34.56	b-i	57.50	b-i	0.61	c-l	14.75	a-h
G-29	40.75	a-c	15.29	i-o	56.00	b-j	0.27	j-m	6.00	e-h
G-25	40.75	a-c	19.35	g-o	53.00	e-k	0.36	g-m	8.75	c-h
G-48	39.75	a-c	32.19	c-l	54.50	d-k	0.60	c-l	12.00	a-h
G-30	38.75	a-c	23.77	e-o	57.25	b-i	0.42	e-m	8.75	c-h
G-5	38.50	a-c	17.79	g-o	59.25	b-h	0.30	h-m	6.50	e-h
G-9	37.50	a-c	30.05	d-n	52.00	g-k	0.61	c-l	14.00	a-h
G-56	37.25	a-c	14.56	i-o	54.75	d-k	0.27	j-m	6.00	e-h
G-45	37.25	a-c	21.94	e-o	60.25	b-f	0.32	h-m	8.00	d-h
G-15	37.25	a-c	57.72	a	53.25	e-k	1.12	ab	19.75	a-h
G-13	37.00	a-c	54.30	ab	55.75	b-k	0.99	a-c	22.50	a-h
G-61	36.00	a-c	12.26	l-o	56.50	b-j	0.22	k-m	4.50	f-h
G-40	35.75	a-c	17.41	g-o	53.25	e-k	0.33	h-m	6.50	e-h
G-12	35.25	bc	32.00	c-l	59.75	b-g	0.58	c-m	11.50	b-h
G-7	34.75	bc	16.25	h-o	57.25	b-i	0.30	h-m	6.00	e-h
G-51	32.25	c	28.95	d-n	60.00	b-f	0.48	e-m	10.75	b-h
G-23	31.00	c	27.33	d-o	54.00	d-k	0.51	d-m	5.75	e-h
G-39	28.75	c	20.57	f-0	51.75	h-k	0.40	f-m	5.50	e-h
G-38	27.50	c	8.61	no	53.50	e-k	0.16	lm	2.25	h
G-44	25.75	c	7.33	o	56.50	b-j	0.14	m	2.25	h
G-20	25.50	c	27.18	d-o	63.00	a-c	0.46	e-m	8.75	c-h
G-41	24.25	c	17.36	g-o	55.25	c-k	0.32	h-m	4.75	f-h
LSD	41.79		21.45		7.87		0.47		22.21	

LSD is least significant difference; means with the same alphabets were not statistically different within the column.

Median Development Period (in Days)

The median development period (MDP) is a crucial parameter for assessing the resistance of soybean genotypes to *C. chinensis*. Our study revealed that there was a significant (P<0.001) variation in MDP among soybean genotypes (Table 3), which aligns with the findings of Msiska et al. [13] and Mukuze et al. [46]. In this study, genotypes SNKGM001, JM-PI230970/PI635999-020-T14-S16, SCS-1, TGX-2014-49FZ, Belesa-95, JM-PI230970/PI635999-020-T14-S30, Dundee, and JM-PI230970/PI635999-020-T14-S10 had the longest MDP of 69.50, 63.25, 63.00, 61.75, 60.50, 60.00, 60.00 days, respectively. Long development periods are often associated with higher resistance, as they can delay the life cycle of *C. chinensis* and reduce its reproductive success. These genotypes may possess traits that make them less suitable for larval development, such as a hard seed texture[13, 46]. Additionally, biochemical factors such as tannins and antioxidants are crucial in resistance. Genotypes with higher levels of these compounds tend to have more extended development periods and lower adult emergence rates [13]. Further, the negative correlation between MDP GI and DSI (Table 6) supports the idea that extended development times are linked to increased resistance. Scholars should use marker-assisted selection to identify and select genetic markers associated with longer MDP and other resistance traits to improve soybean resistance against *C. chinensis*.

Growth Index

The growth index parameter is also crucial for understanding the potential for rapid population growth of *C. chinensis*. The result of this study showed that genotype S1180/5/54 (G-3) had the highest growth index (Table 3). According to Mukuze et al. [46], genotypes with higher growth indices often have favourable nutritional or physical properties that support faster development. In contrast, genotypes JM-PI230970/PI635999-020-T14-S43, TGX-2014-49FZ, JM-PI635999/F6LG04-5196-LG06-5920-020-T3-S5, Belesa-95, and PI471904 showed lower growth indices (Table 3), indicating their least suitability for *C. chinensis* development [13, 35].

Fig. 1. *Female C. chinensis*

Fig. 2. *Male C. chinensis*

Percentage of Weight Loss

Weight loss is a direct measure of the damage caused by *C. chinensis* to soybean. The percentage seed-weight loss varies significantly (P<0.05) among different genotypes, ranging from as low as 0.12% to as high as 39.04% (Table 3). The lowest mean weight losses were recorded for genotypes TGX 2014-49FZ (G-8), PI471904 (G-32), JM-PI230970/PI635999-020-T14-S43 (G-44), and 5002T (G-5). Similar findings were reported by Msiska [47] that revealed resistant soybean varieties exhibited lower weight loss. Besides, genotypes with higher weight loss tend to have lower levels of defensive compounds, making them more vulnerable to pest attacks [13, 46]. In contrast, genotypes Dundee (G-4), S1180/5/54 (G-3), JM-PI230970/PI635999-020-T14-S18 (G-36), PI594796 (G-28), JM-PI230970/PI635999-020-T14-S11 (G-34), and Gishama (G-63) exhibited the highest mean weight losses, indicating high susceptibility to *C. chinensis* infestation (Table 4). Our study showed that high weight losses were associated with high percentage of adult emergence and number of emerged adult.

Further, genotype JM-PI230970/PI635999-020-T14-S18 showed a wide range of percent weight loss (2.56% to 28.88%), suggesting that environmental factors or genetic variability might influence susceptibility within the same genotype [48, 42]. Genotypes showing a wide range of weight loss percentages within the same genotype indicate the need for further research to stabilize resistance traits. The interaction between genotype and environment is evident in the variability of weight loss, suggesting that certain genotypes may perform differently under varying environmental conditions, emphasizing the need for multi-environment trials.

Indeed, genotype TGX 2014-49FZ had a narrower range (2.36% to 3.61%), suggesting more consistent resistance across different conditions. Utilizing genotypes such as TGX 2014-49FZ, PI471904, and JM-PI230970/PI635999-020-T14-S43 can aid in developing new soybean varieties that are less affected by *C. chinensis*, thereby reducing economic losses. High weight loss percentages directly translate to economic losses for farmers, making varieties with high susceptibility (like Dundee) less desirable for cultivation in regions prone to bruchid infestation.

Table 4. *Percent weight losses in soybean due to C. chinensis at Assosa, Ethiopia (2023-2024)*

Genotypes	**Percent weight loss**			**Genotypes**	**Percent weight loss**		
	Range	**Mean**			**Range**	**Mean**	
G-8	2.36 – 3.61	2.78	h	G-17	2.17 – 7.45	5.28	c-h
G-32	0.91 – 6.00	3.03	h	G-12	2.48 – 8.32	5.35	c-h
G-44	0.12 – 6.14	3.24	h	G-13	2.92 – 7.54	5.38	c-h
G-5	0.55 – 6.96	3.41	h	G-16	3.42 – 7.06	5.51	c-h
G-61	2.53 – 4.05	3.46	h	G-41	2.07 – 13.26	5.86	b-h
G-56	2.09 – 4.56	3.46	h	G-11	2.44 – 13.33	6.19	b-h
G-2	3.16 – 4.62	3.81	gh	G-51	2.62 – 8.72	6.35	a-h
G-23	1.87 – 8.14	3.83	gh	G-55	4.06 – 11.59	6.95	a-h
G-29	1.41 – 8.62	3.96	gh	G-42	2.06 – 12.60	7.11	a-h
G-7	2.56 – 7.40	4.34	f-h	G-6	4.39 – 9.25	7.13	a-h
G-35	2.13 – 5.38	4.41	f-h	G-21	2.72 – 17.50	7.27	a-h
G-40	2.23 – 7.44	4.43	e-h	G-30	2.26 – 16.75	7.28	a-h
G-31	2.64 – 7.36	4.46	e-h	G-22	5.51 – 8.56	7.44	a-h
G-15	2.93 – 5.50	4.47	e-h	G-62	2.83 – 12.16	7.76	a-h
G-45	2.19 – 10.17	4.47	e-h	G-49	3.90 – 11.14	7.79	a-h
G-48	2.18 – 7.98	4.50	e-h	G-54	5.79 – 8.91	7.86	a-h
G-53	2.62 – 7.84	4.53	e-h	G-26	2.74 – 21.36	8.92	a-h
G-9	2.17 – 8.20	4.73	d-h	G-58	7.37 – 11.16	9.88	a-g
G-25	2.60 – 7.34	4.76	d-h	G-33	3.53 – 13.08	10.18	a-f
G-20	1.18 – 9.63	4.77	d-h	G-63	1.29 – 15.96	10.60	a-e
G-27	2.32 – 9.97	4.94	c-h	G-34	3.93 – 16.46	10.78	a-d
G-39	2.92 – 8.25	4.96	c-h	G-28	2.95 – 32.48	11.07	a-c
G-19	3.58 – 7.01	5.07	c-h	G-36	2.56 – 28.88	11.71	ab
G-46	2.33 – 6.52	5.22	c-h	G-3	1.37 – 27.30	12.44	a
G-38	3.78 – 7.04	5.26	c-h	G-4	2.00 – 39.04	12.52	a
LSD		6.19				6.19	

LSD is least significant difference; means with the same alphabets were not statistically different within the column.

Dobie Susceptibility Index

The Dobie Susceptibility Index is a comprehensive measure of the susceptibility of soybean genotypes to *C. chinensis*. Based on DSI, two genotypes were resistant, 16 showed moderate resistance, 21 were susceptible, and 11 were highly susceptible (Fig. 5). This variability is crucial for enhancing resistance to *C. chinensis*. As indicated int Table 5 and Fig. 5, genotype JM-PI230970/PI635999-020-T14-S43 (G-44) had the lowest DSI, followed by JM-PI635999/F6LG04-5196-LG06-5920-020-T3-S5 (G-38), demonstrate strong resistance and are valuable resources for developing new resistant soybean varieties. In contrast, genotype S1180/5/54 (G-3), with a high GI, also had a high DSI, indicating high susceptibility. These might be due to lower levels of defensive compounds [46]. İn addition, genotypes with high DSI values are less desirable for cultivation in regions prone to bruchid infestation.

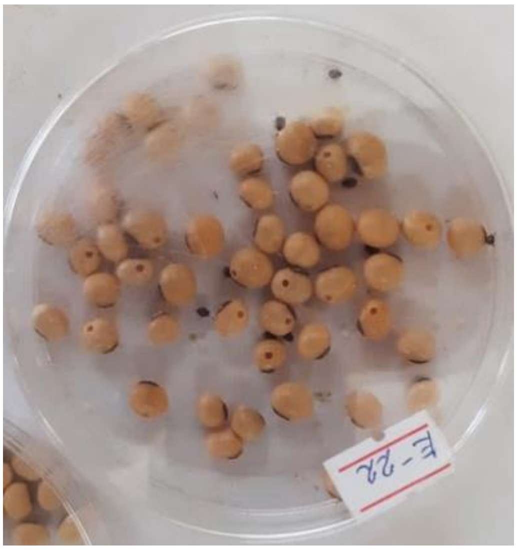

Fig. 3. *The highly susceptible genotype SNKGM004*

Fig. 4. *The most resistant genotype JM-PI230970/PI635999-020-T14-S43*

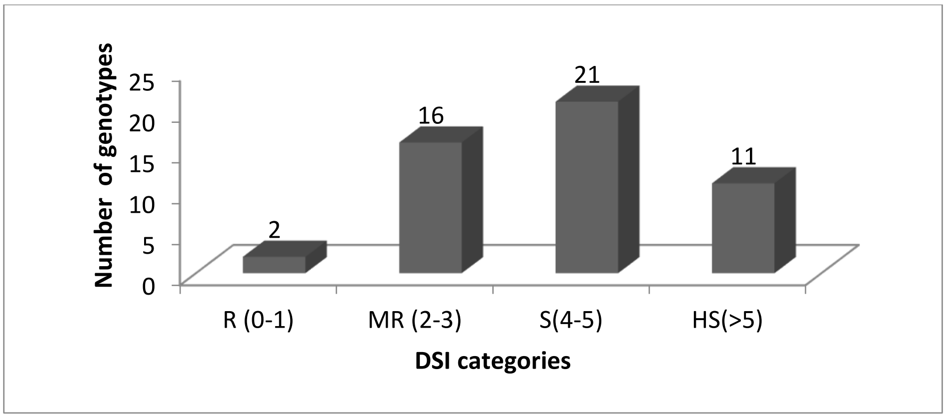

Fig. 5. *Response of soybean genotypes against C. chinensis based on the DSI categories in Ethiopia. R = resistant, MR = moderately resistant, S = susceptible, HS = highly susceptible, DSI = Dobie susceptibility indexes*

Table 5. *Dobie susceptibility indexes and corresponding responses of soybean genotypes to C. chinensis infestation at Assosa, Ethiopia (2023-2024)*

Genotypes	Dobie susceptibility indexes		Response
JM-PI230970/PI635999-020-T14-S43 (Fig. 4)	0.82	k	R
JM-PI635999/F6LG04-5196-LG06-5920-020-T3-S5	1.05	jk	R
TGX 2014-49FZ	1.86	i-k	MR
JM-PI230970/PI635999-020-T14-S23	2.07	h-k	MR
JM-PI230970/PI635999-020-T14-S21	2.17	g-k	MR
JM-PI230970/PI635999-020-T14-S40	2.39	f-k	MR
SCS-1	2.43	f-k	MR
PI423958	2.61	e-k	MR
PI471904	2.67	e-k	MR
JM-CLK/CRFD-15-SD	2.95	d-k	MR
TGX 2001-13DM	3.06	c-k	MR
PI423961A	3.07	c-k	MR
Belesa-95	3.08	c-k	MR
JM-PI230970/PI635999-020-T14-S10	3.16	c-k	MR
JM-PI230970/PI635999-020-T14-S26	3.23	c-k	MR
JM-PI230970/PI635999-020-T14-S36	3.28	c-k	MR
5002T	3.33	c-k	MR
JM-PI230970/PI635999-020-T14-S30	3.38	c-k	MR
TGX 2014-19FM	3.50	c-j	S
JM-PI230970/PI635999-020-T14-S15	3.55	c-j	S
JM-PI230970/PI635999-020-T14-S18	3.60	c-j	S
Dundee	3.70	c-i	S
Lukanga	3.73	c-i	S
JM-PI230970/PI635999-020-T14-S37	3.73	c-i	S
SNKGM001	3.86	b-i	S
JM-SCS-1/PI605891B-020-T5-S4	4.02	a-i	S
Gazela	4.19	a-i	S
JM-PI230970/PI635999-020-T14-S33	4.23	a-i	S
TGX 2021-03FZ	4.25	a-i	S
JM-PI230970/PI635999-020-T14-S20	4.39	a-i	S
SC Squire	4.47	a-i	S
JM-PI230970/PI635999-020-T14-S16	4.52	a-h	S
JM-PI230970/PI635999-020-T14-S27	4.53	a-h	S
JM-PI230970/PI635999-020-T14-S45	4.62	a-h	S
JM-PI230970/PI635999-020-T14-S42	4.77	a-g	S
Gishama	4.84	a-f	S
PAWE3	4.88	a-f	S
S1150/5/22	4.94	a-f	S
SC STATUS	5.05	a-e	S
MAKSOY 4N	5.18	a-e	HS
SNKGM004 (Fig. 3)	5.37	a-d	HS
Guda	5.40	a-d	HS
S1146/5/25	5.42	a-d	HS
JM-PI230970/PI635999-020-T14-S11	5.47	a-d	HS
MAKSOY 6N	5.48	a-d	HS
PI594796	5.51	a-d	HS
JM-PI230970/Clark-63K-020-T15-S1	5.62	a-c	HS
Afgat	5.66	a-c	HS
JM-PI230970/PI635999-020-T14-S22	6.34	ab	HS
S1180/5/54	6.50	a	HS
LSD	2.61		

CV is the coefficient of variation; LSD is the least significant difference, which means that the same alphabets were not statistically different within the column; R is resistant; MR is moderately resistant; S is susceptible; HS is highly susceptible.

Association among C. chinensis Resistance Parameters

Table 6 presents the relationships between different parameters and their significance in assessing soybean resistance to C. chinensis. The mean number of eggs had a highly significant and positive correlation with the number of adults emerged, DSI, percent weight loss, and growth index. This means that more eggs laid lead to more adults emerging, higher DSI, greater weight loss, and a higher growth index. The mean number of adult emergencies had a highly significant and positive correlation with DSI, growth index, and percent weight loss, but it was significantly negatively correlated with MDP. More adults emerging increase weight loss, which correlates with a higher growth index and DSI, but shorter development periods.

The percent weight loss positively correlates with the growth index (r=0.28), and DSI (r=0.30), but not significantly with MDP (r=-0.05). Higher weight loss relates to higher growth index and DSI, but it does not significantly impact the MDP.

Table 6. *Person's correlation coefficients (r) for experimental parameters, under C. chinensis no-choice*

	%AE	NAE	%WL	MDP	GI	DSI
NE	0.23***	0.70***	0.26***	-0.05^{ns}	0.22***	0.64***
%AE	-	0.75***	0.26***	-0.26***	0.91***	0.77***
NAE		-	0.62***	-0.20**	0.69***	0.81***
%WL			-	-0.05^{ns}	0.28***	0.30***
MDP				-	-0.40***	-0.42***
GI					-	0.75***
DSI						-

*** Significant at P<0.001; ** significant at P<0.01; * significant at P<0.05; ns is not significant; NE is number of eggs; %AE is percent adult emergence; NAE is number of adult emerged; %WL is percent weight loss; MDP is median development period; GI is growth index; DSI is Dobie susceptibility index.

The MDP was negatively correlated with all other variables, notably with DSI (r = -0.42) and Growth Index (r = -0.40), suggesting that more extended development periods relate to lower values in other traits. The growth index had a strongly positive correlation with DSI (r=0.75), suggesting that higher growth rates correspond with higher susceptibility.

The regression model showed that the variable number of adults explained 38.78% of the variance from the variable percent weight loss (Fig. 6). In this model, the number of adult *C. chinensis* emerged has the most significant influence on the percent weight loss of soybean seeds as illustrated in Fig. 6, when the number of adults emerged changed by one unit, the value of the percent weight loss changed by 0.2. The p-value for the coefficient of adult C. chinensis emerged is <0.00, indicating that the coefficient for the number of adult C. chinensis that emerged in the population differs from zero.

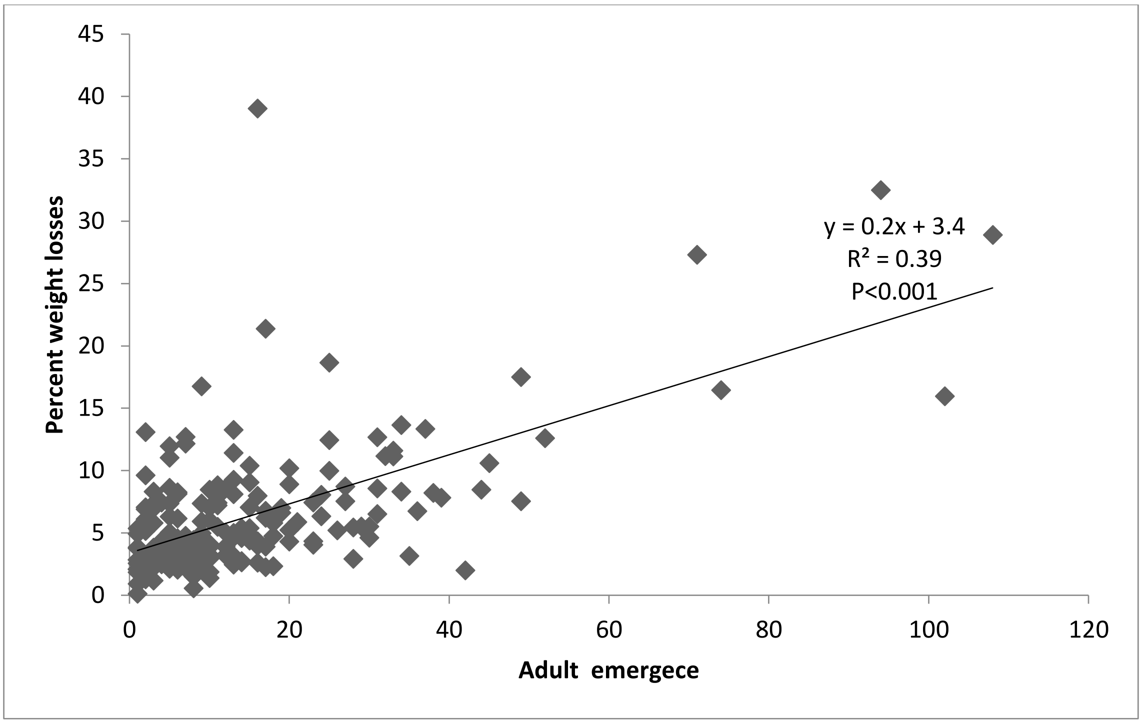

Fig. 6. *Regression of percent weight loss of soybean seeds against adult bruchid insect emergence for the 50 genotypes.*

CONCLUSION

In conclusion, this study revealed significant genetic variability among the 50 examined soybean genotypes, with some exhibiting strong resistance to *C. chinensis* while others demonstrated high susceptibility. Key findings indicate that the genotype JM-PI230970/PI635999-020-T14-S43 and JM-PI635999/F6LG04-5196-LG06-5920-020-T3-S5 showed the lowest adult emergence and Dobie susceptibility index, marking it as promising candidates for resistance breeding to mitigate the economic losses caused by this pest infestation, ultimately enhancing agricultural sustainability. The analysis also underscored the importance of environmental factors, as interactions between year and genotype significantly influenced *C. chinensis* resistance parameters. Furthermore, our findings confirmed that genotypes with lower egg counts and adult emergence rates, long development periods, and lower growth indices exhibit better resistance traits. Lastly, more research is needed for understand the genetic basis of resistance, identify resistance genes, and understand the uderlying resistance mechanisms to *C. chinensis* in Ethiopia.

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REFERENCES

[1] Jiang, G. L., Rajcan, I., Zhang, Y. M., Han, T., Mian, R. (2023): Editorial: Soybean molecular breeding and genetics. Frontiers in Plant Science 14: 1157632.

[2] Abdelghany, A. M., Zhang, S., Azam, M., Shaibu, A. S., Feng, Y., Qi, J., Li, Y., Tian, Y., Hong, H., Li, B., Sun, J. (2020): Natural variation in fatty acid composition of diverse world soybean germplasms grown in China. Agronomy 10(1) 24: 1-18.

[3] Porca, M. (2003): The actual stage the knowledge about the damages bruchids. Journal of Central European Agriculture 4(3): 2001

[4] Rees, D.P. (2004): Insects of Stored Products; CSIRO Publishing: Melbourne, Australia, pp. 39-46.

[5] Onyido, A. E., Zeibe, C. C., Okonkwo, N. J., Ezugbo-Nwobi, I. K., Egbuche, C. M., Udemezue, O. I., Ezeanya, L. C. (2011): Damage Caused By the Bean Bruchid, *Callosobruchus maculatus* (Fabricius) on Different Legume Seeds on Sale in Awka and Onitsha Markets, Anambra State, South Eastern Nigeria. African Research Review 5(21): 116-123.

[6] Chandra, G., Girish, S. (2014): *Callosobruchus chinensis*, The pulse beetle cowpea bruchid. IAS Zoology. com.

[7] Spradbery, P. (2013): Invasive species compendium. Xcsconsulting.Com.Au 4066.

[8] Kananji, G. A. D. (2007): A study of bruchid resistance and its inheritance in Malawian dry bean germplasm (Doctoral dissertation, University of KwaZulu-Natal, Pietermaritzburg).

[9] Pawlowski, M. L., Lagos-Kutz, D. M., da Fonseca Santos, M., Lee, N., Chigeza, G., Nachilima, C., Francischini, J. H., Hartman, G. L. (2021): Potential Threat of Bruchids on Soybean Production in Sub-Saharan Africa. Plant Health Progress 22(2):86–91.

[10] Yamane, T. (2013): Biorational control methods for protection of stored grain legumes against bruchid beetles. Agricultural Sciences 4(12): 762-766.

[11] Tembo, L., Pungulani, L., Mataa, J., Sohati, P. H., Munyinda, K. (2016): Developing cowpea and bean genotypes with tolerance to bruchid beetle. RUFORUM Working Document Series 14(1): 879-883.

[12] Credland, P. F. (2000): Bioassays with bruchid beetles: problems and (some) solution. Proceedings of the 6th International Working Conference on Seed Product Protection.

[13] Msiska, U. M., Odong, T. L., Hailay, M., Miesho, B., Kyamanywa, S., Rubaihayo, P. R., Tukamuhabwa, P. (2018): Resistance of Uganda soybean germplasm to adzuki bean bruchid. African Crop Science Journal 26(3): 399-415.

[14] Baributsa, D., Baoua, I., Bakoye, O. N., Murdock, L. L. (2010): Purdue Improved Crop Storage (PICS) bags: A new technology for reducing post-harvest cowpea storage losses. Journal of Stored Products Research 45(1): 1-2.

[15] Haines, C. P. (1991): Insects and arachnids of tropical stored products: Their biology and identification (2nd eds.). Natural Resources Institute.

[16] Baker, J. E. (2018): Biological control of stored-product insect pests. Annual Review of Entomology 35(1): 333-364.

[17] Damte, T. (2024): Natural occurrence of ectoparasitoids of Adzuki bean beetle (*Callosobruchus chinensis* L.) in stored chickpea (*Cicer arietinum* L.). International Journal of Tropical Insect Science 44(3): 1349-1354.

[18] Odeyemi, O., Daramola, A. M., Ogungbemi, T. (2006): Studies on the efficacy of some plant oils for the control of cowpea weevil, *Callosobruchus maculatus* (F.). Journal of Stored Products Research 42(1): 89-96.

[19] Isman, M. B. (2006): Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annual Review of Entomology 51: 45-66.

[20] Zhou, Z., Koiwa, H., Satoh, H. (2012): Breeding for resistance to soybean pests. In Soybean - Pest Resistance, pp. 141-159.

[21] Shimales, T., Bidira, T. (2023): Bean Weevil *Callosobruchus chinensis* in Stored Soybean and Its Management at Jimma, Ethiopia. International Journal of Nutrition and Food Sciences 12(6): 180-183.

[22] IITA (2009): Soybean bruchids: Biology and control strategies. International Institute of Tropical Agriculture.

[23] Mbata, G. N. (2003): Effect of relative humidity and seed moisture content on the development of *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) in cowpea seeds. International Journal of Pest Management 49(1): 95-98.

[24] Farrell, J., Brier, H., Colins, P. (2015): Diagnostic protocols: Diagnostic methods for cowpea weevil or cowpea bruchid (*Callosobruchus maculatus*). Queensland Primary Industries and Fisheries. Kingaroy, Queensland.

[25] Amusa, O. D., Ogunkanmi, L. A., Adetunbi, J. A., Akinyosoye, S. T., Bolarinwa, K. A., Ogundipe, O. T. (2014): Assessment of bruchid (*Callosobruchus maculatus*) tolerance of some elite cowpea (*Vigna unguiculata*) varieties. Journal of Agriculture and Sustainability 6(2): 164-178.

[26] Somta, C., Somta, P., Tomooka, N., Ooi, P. A. C., Vaughan, D. A., Srinives, P. (2008): Characterization of new sources of mungbean (*Vigna radiata* (L.) Wilczek) resistance to bruchids, *Callosobruchus* spp. (Coleoptera: Bruchidae). Journal of Stored Products Research 44(4): 316–321.

[27] Lephale, S., Addo-Bediako, A., Ayodele, V. (2012): Susceptibility of seven cowpea cultivars (*Vigna unguiculatus*) to cowpea beetle (*Callosobruchus maculates*). Agricultural Science Research Journals 2(2): 65-69.

[28] Emeka, R. (2010): The effects of different infestation levels of *Callosobruchus maculates* F. on stored Cowpea. Retrieved from http:ssrn.com

[29] Régnière, J., Powell, J., Bentz, B., Nealis, V. (2012): Effects of temperature on development, survival and reproduction of insects: Experimental design, data analysis and modelling. Journal of Insect Physiology 58: 634-647.

[30] Dobie, P. (1974): The laboratory assessment of the inherent susceptibility of maize varieties to post harvest infestations by *Sitophilus zeamais* Mots. (Coleoptera: Curculionidae). Journal of Stored Products Research 10: 183-197.

[31] Derera, J., Giga, D. P., Pixley, K. V. (2001): Resistance of maize to the maize weevil: II. Non-preference. African Crop Science Journal 9(2): 441-450.

[32] Radha, R., Susheela, P. (2014): Studies on the life history and Ovipositional preference of Callosobruchus maculatus reared on different pulses. Research Journal of Animal, Veterinary and Fishery Sciences 2(6): 1-5.

[33] R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

[34] Amusa, O. D., Adebayo, L. O., Kehinde, B., Omoche, O. (2013): Evaluation of four cowpea lines for bruchid (*Callosobruchus maculatus*) tolerance. Journal of Natural Sciences Research 3(13): 2225-3186.

[35] Ouedraogo, P. A., Sou, S., Sanon, A., Monge, J. P., Huignard, J., Tran, B. E., Credland, P. F. (1996): Influence of temperature and humidity on populations of *Callosobruchus maculatus* (Coleoptera: Bruchidae) and its parasitoid *Dinarmus basalis* (Pteromalidae) in two climatic zones of Burkina Faso. Bulletin of entomological research 86(6): 695-702.

[36] Lale, N. E. S., Vidal, S. (2003): Effect of constant temperature and humidity on oviposition and development of *Callosobruchus maculatus* (F.) and *Callosobruchus subinnotatus* (Pic) on bambara groundnut, *Vigna subterranea* (L.) Verdcourt. Journal of Stored Products Research 39(5): 459-470.

[37] Elsawy, I. A., El-Talpanty, M. D., Mohamed, A. M., Morsy, A. R. (2024). Resistance of some soybean genotypes to Bruchids: Callosobruchus chinensis L. as Influenced by different biochemical and seed quality traits. J. of Plant production 15(4): 153-160.

[38] Cope, J. M., Fox, C. W. (2003): Oviposition decisions in the seed beetle, *Callosobruchus maculatus* (Coleoptera: Bruchidae): effects of seed size on superparasitism. Journal of Stored Products Research 39(4): 355-365.

[39] Sharma, S., Thakur, D. R. (2014): Studies on the varietal preference of *Callosobruchus maculatus* no soybean genotypes. Asian Journal of Biological Sciences 7(5): 233-237.

[40] Naseri, B., Ebadollahi, A., Hamzavi, F. (2022): Oviposition preference and life-history parameters of *Callosobruchus maculatus* (Coleoptera: Chrysomelidae) on different soybean (Glycine max) cultivars. Pest Management Science 78(11): 4882-4891.

[41] Ventury, K. E., Ferreira, S. R., De Moura Rocha, M., Do Amaral Gravina, G., Da Silva Ferreira, A. T., Perales, J., Fernandes, K. V. S., Oliveira, A. E. A. (2022): Performance of cowpea weevil *Callosobruchus maculatus* (F.) infesting seeds of different *Vigna unguiculata* (L.) Walpers genotypes: The association between bruchid resistance and chitin binding proteins. Journal of Stored Products Research 95:101925.

[42] Singha, T. A., Rajkumari, P. (2021): Ovipositional behaviour of *Callosobruchus chinensis* (L) in different pulses: A review. Journal of Entomology and Zoology Studies 9(1): 105-109.

[43] Pessu, P. O., Umeozor, A. C. (2004): Relative Susceptibility of Stored Cowpea, *Vigna unguiculata* Walp and Soybean, *Glycine Max* (L.) Merrill, to Infestation by the Cowpea Seed Beetle, *Callosobruchus maculatus* (Fab.) (Coleoptera: Bruchidae). Indian Journal of Agricultural Research 38(2): 101-105.

[44] Vishwakarma, A. (2013): Screening of Some Soybean Germplasm against Pulse Beetle, *Callosobruchus chinensis* (Linnaeus). Master of Science in Agriculture. G.B. Pant University of Agriculture & Technology Pantnagar – 263 145, U.S. Nagar, Uttarakhand, India.

[45] Mphuru, A. N. (1981): Comparative biological and ecological studies of *Callosobruchus chinensis* (L). Ph.D. Thesis. Faculty of Agriculture, University of Dares Salaam, Tanzania.

[46] Mukuze, C., Msiska, U. M., Badji, A., Obua, T., Kweyu, S. V., Nghituwamhata, S. N., Rono, E. C., Maphosa, M., Kasule, F., Tukamuhabwa, P. (2023): Genome-wide association mapping of bruchid resistance loci in soybean.bioRxiv 09.

[47] Msiska, M. U. (2019): Genetic resistance to adzuki bean bruchid (*Callosobruchus chinensis*) in soybean (Doctoral dissertation, Ph. D Dissertation), Makerere University, Uganda.

[48] Maharjan, R., Yi, H., Ahn, J., Roh, G. H., Park, C., Yoon, Y., Jang, Y., Baek, I., Kim, Y., Bae, S. (2019): Effects of radiofrequency on the development and performance of *Callosobruchus chinensis* (Coleoptera: Chrysomelidae: Bruchinae) on three different leguminous seeds. Applied entomology and zoology 54: 255-266.