

Assessing the resistance of soybean genotypes to *Callosobruchus chinensis* L. (Coleoptera: Chrysomelidae) in Ethiopia

Minyahil Kebede Earecho  and Seid Ahmed Seid

Department of Plant Protection Research, Assosa Agricultural Research Centre, Ethiopian Institute of Agricultural Research, Assosa, Ethiopia

Research Paper

Cite this article: Earecho MK, Seid SA (2026) Assessing the resistance of soybean genotypes to *Callosobruchus chinensis* L. (Coleoptera: Chrysomelidae) in Ethiopia. *Bulletin of Entomological Research* **116**, 572–581. <https://doi.org/10.1017/S0007485326100972>

Received: 23 April 2025
Revised: 10 March 2026
Accepted: 30 March 2026
First published online: 17 April 2026

Keywords:

adult emergence; bruchid resistance; Dobie's susceptibility index; oviposition rate; seed weight loss

Corresponding author:

Minyahil Kebede Earecho;
Email: minishkebe@gmail.com

Abstract

Soybean (*Glycine max* L.) is a globally significant crop, valued for its high protein content and vegetable oil, which serve vital roles in both food and industrial applications. However, the soybean bruchid (*Callosobruchus chinensis* L.) infests soybean seeds in Ethiopia, especially during storage, and this infestation threatens their post-harvest quality. This study evaluated the resistance of 50 soybean genotypes against *C. chinensis* by analysing oviposition rates, adult emergence, and seed weight loss. Results revealed substantial genetic variation among genotypes for their resistance. Two genotypes (G-44 and G-38) exhibited strong resistance, and 16 showed moderate resistance, while the rest were susceptible. The vulnerability of released cultivars in Ethiopia underscores the critical importance of integrating bruchid resistance into future breeding programmes. Addressing this challenge is critical for sustaining soybean productivity and ensuring post-harvest seed integrity in bruchid-prone regions.

Introduction

Soybean (*Glycine max* (L.) Merr.) is one of the most essential food crops, known for its high protein content and vegetable oil (Jiang *et al.*, 2023). It also provides essential omega-3 fatty acids (alpha-linolenic acid) and omega-6 fatty acids (linoleic acid) (Abdelghany *et al.*, 2019). These qualities make soybeans a promising solution to meet the caloric and protein demands of the growing global population. However, the crop is threatened by soybean bruchid (*Callosobruchus chinensis* L.), a major pest that infests dry seeds of leguminous plants (Porca, 2003; Rees, 2004; Onyido *et al.*, 2011), including cowpea (*Vigna unguiculata* L.), soybean (*Glycine 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.), and chickpea (*Cicer arietinum* L.).

Callosobruchus chinensis is commonly known as the adzuki bean weevil, pulse beetle, or cowpea bruchid and is a pervasive storage pest prevalent in tropical and subtropical regions (Spradbery, 2013; Chandra and Girish, 2014). It inflicts severe damage on pulse crops both in the field and during storage (Kananji, 2007), with soybean yield losses in sub-Saharan Africa reported to reach 60–100% in storage (Pawlowski *et al.*, 2021). Even low levels of infestation can lead to considerable damage, as one beetle alone may cause a 3.5% weight loss in cowpea seeds (Tembo *et al.*, 2016). Complete loss of cowpea and bean grains within 3–6 months of storage has been documented (Credland, 2000; Onyido *et al.*, 2011), while in Uganda, soybean losses of up to 27.18% have been recorded (Msiska *et al.*, 2018). The pest's rapid reproduction, short generation time, and reinfestation capacity make it particularly destructive (Yamane, 2013), resulting in reduced seed weight, viability, and nutritional quality due to contamination by frass, excreta, and insect remains.

In Ethiopia, *C. chinensis* is a major pest of chickpeas, field peas, cowpeas, and beans. Its impact on soybeans, though less studied, is increasingly evident. A recent trial in Jimma recorded weight loss as high as 91.71% after 6 months of storage in plastic bags, with further reports indicating seed damage rates of up to 99.54% across multiple soybean varieties (Shimales and Bidira, 2023). These findings highlight an urgent need for research and integrated storage pest management interventions.

Although chemical insecticides remain the most effective management strategy against *C. chinensis*, their widespread use is constrained due to risks of toxic residues, human health concerns, and environmental contamination (Odeyemi *et al.*, 2006). Genetic resistance is a cornerstone of long-term, cost-effective management (Zhou *et al.*, 2024). Therefore, the use of resistant cultivars may offer a safe and sustainable option for managing *C. chinensis*. Resistant soybean varieties may reduce dependency on external inputs and ensure consistent protection

in storage environments with limited infrastructure. Resistance mechanisms, such as reduced flavonoid content, enhanced antioxidant activity, and thicker seed coats, impede oviposition and larval development (Mbata, 2003; I.I.T.A., 2009; Shimala and Bidira, 2023). Given the severity of *C. chinensis*-induced damage and the vulnerability of local soybean varieties, this study aims to identify genotypes with inherent resistance under Ethiopian storage conditions.

Materials and methods

Experimental site

The study was conducted at the Plant Protection Laboratory of the Assosa Agricultural Research Center (AsARC), located in Benishangul Gumuz, Ethiopia (latitude: 10°03' N, longitude: 34°59' E, altitude: 1553 m.a.s.l.). The site experiences an average annual rainfall of 1177 mm and a mean temperature of 26.79°C.

Insect colony maintenance

Third-generation adults of *C. chinensis* used for infestation trials were sourced from a laboratory colony maintained at the AsARC. The colony originated from bruchids recovered from infested soybean grain stores in Assosa and was sustained under controlled conditions using Gizo soybean seeds. Insects were reared in 2-L plastic containers covered with muslin cloth to allow air circulation while preventing escape. To ensure continuous breeding and avoid age bias, adults were periodically transferred to fresh seeds. Morphological identification of *C. chinensis* L. was conducted based on diagnostic criteria established by Farrell *et al.* (2015), confirming the species' identity prior to experimentation.

Soybean genotypes and experimental design

This study evaluated 50 soybean genotypes, including 48 genotypes from the Jimma Agricultural Research Center and 2 genotypes (Belesa-95 and Gishama) obtained from the AsARC (table 1). To ensure the exclusion of pre-existing insect contamination, all seed samples were oven-dried at 30°C for 24 h following the method described by Amusa *et al.* (2014). The dried seeds were then conditioned on laboratory shelves for 7 days at ambient temperature to equilibrate moisture levels before infestation (Kananji, 2007).

From each genotype, 50 seeds were randomly selected and weighed to establish initial seed mass. The 50 seeds were placed in plastic Petri dishes (9 cm diameter) and infested using the no-choice test protocol outlined by Somta *et al.* (2008). Each dish received one female and two to three male adult *C. chinensis* (1–2 days old), with sexes identified based on external morphological characteristics (Farrell *et al.*, 2015). The experiment followed a randomised complete block design with two replications per genotype. Infesting adults were removed after 10 days to prevent overlapping generations and ensure consistent pest pressure (Kananji, 2007).

Data collection and resistance indices

On the 11th day following infestation, the number of eggs deposited on the seeds was recorded, following the procedure outlined by Kananji (2007). Emerged adult insects were subsequently counted and removed daily until no emergence was observed for 5 consecutive days, as described by Lephale *et al.* (2012). Following

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

Code	Genotypes	Code	Genotypes
G-2	Pawe 03	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	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
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
G-30	PI423961A	G-63	Gishama

the final emergence assessment, the remaining seeds in each Petri dish were weighed to determine post-infestation weight:

- Grain weight loss percentage (GWL%): This represents the economic loss due to insect damage and was calculated using the formula proposed by Amusa *et al.* (2014):

Table 2. Soybean genotypes' response to *C. chinensis* in Assosa, Ethiopia (2023–2024)

Genotypes	No. of eggs	MDP (days)		Growth index		No. of adults emerged	% Adult emerged	
G-2	57.50	58.00	ab	0.60	abc	20.75	34.33	abcd
G-3	56.25	50.00	b	1.39	a	29.75	48.29	abcd
G-4	63.75	60.00	ab	0.38	bc	16.25	22.26	abcd
G-5	38.50	59.25	ab	0.30	bc	6.50	17.78	abcd
G-6	49.00	53.00	b	0.61	abc	14.50	31.91	abcd
G-7	34.75	57.25	ab	0.30	bc	6.00	16.25	abcd
G-8	43.50	61.75	ab	0.15	bc	3.50	9.56	bcd
G-9	37.50	52.00	b	0.60	abc	14.00	30.05	abcd
G-11	43.00	51.50	b	0.66	abc	14.75	30.16	abcd
G-12	35.25	59.75	ab	0.57	abc	11.50	32.00	abcd
G-13	37.00	55.75	ab	0.99	abc	22.50	54.30	ab
G-15	37.25	53.25	b	1.12	ab	19.75	57.71	a
G-16	49.50	53.25	b	0.74	abc	20.00	38.71	abcd
G-17	56.75	55.50	ab	0.56	abc	15.50	33.61	abcd
G-19	42.00	57.50	ab	0.61	abc	14.75	34.56	abcd
G-20	25.50	63.00	ab	0.46	abc	8.75	27.18	abcd
G-21	61.00	69.50	a	0.43	abc	20.75	29.51	abcd
G-22	51.75	57.25	ab	0.96	abc	24.00	52.28	abc
G-23	31.00	54.00	ab	0.51	abc	5.75	27.32	abcd
G-25	40.75	53.00	b	0.36	bc	8.75	19.35	abcd
G-26	53.00	52.00	b	0.62	abc	14.00	27.78	abcd
G-27	56.75	59.25	ab	0.29	bc	12.00	20.82	abcd
G-28	57.25	52.00	b	0.80	abc	30.75	42.05	abcd
G-29	40.75	56.00	ab	0.27	bc	6.00	15.29	abcd
G-30	38.75	57.25	ab	0.42	bc	8.75	23.77	abcd
G-31	58.50	57.50	ab	0.43	abc	10.75	24.22	abcd
G-32	54.50	58.75	ab	0.20	bc	6.00	11.55	bcd
G-33	60.25	58.00	ab	0.35	bc	13.50	20.28	abcd
G-34	64.75	58.25	ab	0.86	abc	32.75	48.16	abcd
G-35	60.00	55.00	ab	0.26	bc	8.75	14.42	abcd
G-36	48.75	52.50	b	0.62	abc	29.25	31.54	abcd
G-38	27.50	53.50	b	0.16	bc	2.25	8.61	cd
G-39	28.75	51.75	b	0.40	bc	5.50	20.57	abcd
G-40	35.75	53.25	b	0.33	bc	6.50	17.41	abcd
G-41	24.25	55.25	ab	0.32	bc	4.75	17.36	abcd
G-42	51.00	63.25	ab	0.63	abc	25.75	41.75	abcd
G-44	25.75	56.50	ab	0.14	c	2.25	7.33	d
G-45	37.25	60.25	ab	0.32	bc	8.00	21.94	abcd
G-46	45.50	55.00	ab	0.58	abc	15.00	31.64	abcd
G-48	39.75	54.50	ab	0.60	abc	12.00	32.18	abcd
G-49	75.50	53.00	b	0.76	abc	27.00	37.69	abcd
G-51	32.25	60.00	ab	0.48	abc	10.75	28.95	abcd

(Continued)

Table 2. (Continued.)

Genotypes	No. of eggs	MDP (days)		Growth index		No. of adults emerged		% Adult emerged
G-53	63.75	48.00	b	0.52	abc	16.75	23.70	abcd
G-54	50.75	56.50	ab	0.59	abc	15.00	33.00	abcd
G-55	50.50	49.25	b	0.73	abc	18.75	35.78	abcd
G-56	37.25	54.75	ab	0.27	bc	6.00	14.55	abcd
G-58	52.25	56.00	ab	0.88	abc	25.25	47.69	abcd
G-61	36.00	56.50	ab	0.22	bc	4.50	12.26	bcd
G-62	54.50	60.50	ab	0.20	bc	6.25	11.52	bcd
G-63	77.25	58.25	ab	0.64	abc	34.00	34.21	abcd
Mean	46.61	56.14		0.52		14.34	28.10	
Tukey's HSD	80.09	15.93		0.97		46.35	44.82	
CV	58.88	9.72		63.29		110.77	54.65	
P value	0.7111	0.0009		<0.0001		0.2483	<0.0001	

CV is the coefficient of variance (%); HSD is the Tukey's minimum significant difference; P value is a probability value; and means with the same alphabet were not statistically different within the column.

$GWL\% = \frac{IGW - FGW}{IGW} \times 100$, where IGW is the initial grain weight (g) and FGW is the final grain weight (g).

- b. Growth index (GI): This reflects the suitability of each genotype for the development of *C. chinensis*, based on the formula by Régnière *et al.* (2012):

$$GI = \frac{\% \text{Adult emergence}}{\text{Median development period}}$$

The median development period (MDP) was defined as the number of days elapsed from the fifth day after oviposition to the emergence of the first adult, following Kananji (2007).

- c. Dobie's susceptibility index (DSI): This quantifies the susceptibility of seed samples to bruchid damage, incorporating both the number of emerged adults and the MDP, as defined by Dobie (1974):

$$DSI = \frac{\log_e (\text{Total adults emerged}) \times 100}{MDP}$$

A DSI score of 0 was assigned if no adult insects emerged (Derera *et al.*, 2001). Based on DSI values, soybean genotypes were classified into susceptibility categories as follows (Kananji, 2007; Radha and Susheela, 2014): resistant when DSI = 0–1, moderately resistant (DSI = 2–3), susceptible (DSI = 4–5), and highly susceptible (DSI = 6–9).

Data analysis

Statistical analyses were conducted to evaluate genotypic variation in resistance traits using a randomised complete block design model across 2 years as follows:

$$y_{ijk} = \mu + Y_i + B_{j(i)} + G_k + (GY)_{ik} + \varepsilon_{ijk},$$

where y_{ijk} is the observed resistance trait, μ is the overall mean, Y_i is the fixed effect of year i , $B_{j(i)}$ is the effect of replication j nested within year i , G_k is the fixed effect of genotype k , $(GY)_{ik}$ is the

genotype $\times$ year interaction, and ε_{ijk} is the random error. Analysis of variance was performed in R Statistical software (R Core Team, 2023) to determine the significance of differences among soybean genotypes for each resistance parameter. Treatment means were separated using Tukey's Honestly Significant Difference (HSD) at a 5% probability level. Based on the mean values of DSI, genotypes were classified into distinct resistance categories. To further investigate the relationships among measured traits, such as grain weight loss, adult emergence, MDP, and GI, regression and Pearson's correlation analyses were conducted, following the approach of Amusa *et al.* (2013).

Results

Oviposition preference

This study revealed substantial genotypic variation in response to *C. chinensis* oviposition and infestation dynamics. Egg counts ranged from 24.50 to 77.25 across genotypes (table 2), with Gishama (G-63) – a widely cultivated variety in Assosa – recording the highest oviposition. In contrast, genotypes SCS-1 (G-20), TGX 2001-13DM (G-23), JM-PI230970/PI635999-020-T14-S43 (G-44), and JM-PI635999/F6LG04-5196-LG06-5920-020-T3-S5 (G-38) demonstrated significantly lower egg deposition, indicating resistance.

Adult emergence

Adult emergence followed a similar trend to egg loads, ranging from 2.25 to 34.00 individuals (table 2). Gishama (G-63) again showed the highest emergence, while JM-PI635999/F6LG04-5196-LG06-5920-020-T3-S5 (G-38) and JM-PI230970/PI635999-020-T14-S43 (G-44) recorded the lowest, reinforcing their resistant profiles. Notably, genotypes G-8 (TGX 2014-49FZ), G-62 (Belesa-95), and G-32 (PI471904) also exhibited reduced emergence percentages, supporting their potential as resistant lines.

Table 3. Soybean weight loss due to *C. chinensis* infestation at Assosa, Ethiopia (2023–2024)

Genotypes	Per cent weight loss			Genotypes	Per cent 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
Mean		6.22				6.22	
Tukey's HSD		12.93				12.93	
CV		71.26				71.26	
P value		0.05				0.05	

CV is the coefficient of variance (%); HSD is the Tukey's minimum significant difference; P value is a probability value; and means with the same alphabet were not statistically different within the column.

Developmental timing

The MDP varied significantly ($P < 0.001$), spanning from 48.00 to 69.50 days (table 2). Longer development durations were observed in genotypes G-21 (SNKGM001), G-20, G-8, G-62, G-45, G-4, and G-51, suggesting enhanced resistance.

Growth potential

GI values also varied, with G-3 (S1180/5/54) recording the highest (table 2), indicating high susceptibility. Conversely, G-44, G-38, G-8, G-62, and G-32 displayed lower GI values, consistent with their reduced pest proliferation potential.

Weight loss and DSI

Infestation-induced weight loss ranged from 0.12% to 39.04% ($P < 0.05$). Genotypes G-8, G-32, G-44, and G-5 exhibited the lowest losses, while G-4, G-3, G-36, G-28, G-34, and G-63 showed the highest losses (table 3). Based on DSI classification (table 4), genotypes G-44 and G-38 were classified as resistant. Sixteen genotypes showed moderate resistance, 21 were susceptible, and 11 highly susceptible, underscoring wide genetic variability.

Association of resistance traits in soybean genotypes

Correlation analysis (table 5) revealed that egg count positively correlated with adult emergence, weight loss, GI, and DSI, indicating that high oviposition contributes to greater infestation severity.

Table 4. Dobie's susceptibility indexes and resistance responses of soybean genotypes to *C. chinensis* infestation in Assosa, Ethiopia (2023–2024)

Genotypes	DSI		Response	Genotypes	DSI		Response
G-44 (fig. 1)	0.81	b	R	G-31	4.02	ab	S
G-38	1.05	b	R	G-26	4.20	ab	S
G-8	1.86	ab	MR	G-27	4.23	ab	S
G-41	2.07	ab	MR	G-9	4.25	ab	S
G-56	2.17	ab	MR	G-46	4.39	ab	S
G-61	2.39	ab	MR	G-19	4.47	ab	S
G-20	2.43	ab	MR	G-42	4.52	ab	S
G-29	2.61	ab	MR	G-48	4.54	ab	S
G-32	2.67	ab	MR	G-11	4.62	ab	S
G-7	2.95	ab	MR	G-54	4.77	ab	S
G-23	3.06	ab	MR	G-63	4.84	ab	S
G-30	3.07	ab	MR	G-2	4.88	ab	S
G-62	3.07	ab	MR	G-17	4.94	ab	S
G-51	3.15	ab	MR	G-6	5.05	ab	S
G-39	3.23	ab	MR	G-13	5.18	ab	HS
G-40	3.28	ab	MR	G-22 (fig. 2)	5.37	ab	HS
G-5	3.33	ab	MR	G-53	5.40	ab	HS
G-45	3.38	ab	MR	G-16	5.42	ab	HS
G-25	3.50	ab	S	G-34	5.47	ab	HS
G-35	3.55	ab	S	G-15	5.48	ab	HS
G-36	3.60	ab	S	G-28	5.51	ab	HS
G-4	3.70	ab	S	G-58	5.61	ab	HS
G-12	3.73	ab	S	G-55	5.66	ab	HS
G-33	3.73	ab	S	G-49	6.34	a	HS
G-21	3.85	ab	S	G-3	6.50	a	HS
Mean	3.96			Mean	3.96		
Tukey's HSD	5.01			Tukey's HSD	5.01		
CV	43.36			CV	43.36		
P value	<0.001			P value	<0.001		

CV is the coefficient of variance (%); HSD is the Tukey's minimum significant difference; P value is a probability value; means with the same alphabets were not statistically different within the column.

R, resistant; MR, moderately resistant; S, susceptible; HS, highly susceptible.

Adult emergence was strongly associated with GI ($r = 0.57$), DSI ($r = 0.54$), and weight loss ($r = 0.62$), while negatively correlated with MDP ($r = -0.43$), reinforcing its importance in pest impact evaluation.

Weight loss correlated positively with GI ($r = 0.28$) and DSI ($r = -0.30$) but showed minimal association with MDP ($r = -0.05$). MDP, however, negatively correlated with both GI ($r = -0.40$) and DSI ($r = -0.42$), affirming the role of delayed development in resistance.

Predictive insights from regression analysis

Regression analysis further confirmed adult emergence as a significant predictor of weight loss, accounting for 38.78% of its variation (fig. 3). Each additional emerged adult corresponded to a 0.2%

increase in seed weight loss, highlighting the direct contribution of pest survival to post-harvest deterioration.

Discussion

This study revealed substantial variation in oviposition preference, developmental performance, and infestation outcomes of *C. chinensis* across tested soybean genotypes (table 6). These results are consistent with Msiska *et al.* (2018), who reported genotype-dependent resistance to *C. chinensis*.

Oviposition preference

Genotype Gishama (G-63), a widely cultivated variety in Assosa, exhibited the highest oviposition rates, indicating high

Table 5. Pearson's correlation coefficients (*r*) for experimental traits in *C. chinensis* no-choice assays

	%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						-

ns, not significant; NE, number of eggs; %AE, per cent adult emergence; NAE, number of adults emerged; %WL, per cent weight loss; MDP, median development period; GI, growth index; DSI, Dobie's susceptibility index.

***Significant at $P < 0.001$.

**Significant at $P < 0.01$.

**Figure 1.** The most resistant genotype JM-PI230970/PI635999-020-T14-S43 (G-44).

susceptibility. This preference is likely due to physical traits such as large seed size, smooth surface texture, and thin seed coats (Msiska *et al.*, 2018; Elsayy *et al.*, 2024), which favour bruchid attachment and egg deposition. The elevated risk of pest outbreak associated with Gishama highlights the need for targeted management in regions where this variety dominates. In contrast, genotypes JM-PI230970/PI635999-020-T14-S23 (G-41), SCS-1 (G-20), JM-PI230970/PI635999-020-T14-S43 (G-44), and JM-PI635999/F6LG04-5196-LG06-5920-020-T3-S5 (G-38) recorded significantly lower egg loads, suggesting resistance traits. These may be attributed to defensive compounds, such as tannins and antioxidants (Cope and Fox, 2003; Sharma and Thakur, 2014; Msiska *et al.*, 2018), or physical barriers like thicker seed coats (Naseri *et al.*, 2022; Ventury *et al.*, 2022).

**Figure 2.** The highly susceptible genotype SNKGM004 (G-22).

Adult emergence

Gishama (G-63) also recorded the highest adult emergence (34.00), aligning with its oviposition rates and confirming its susceptibility (Msiska *et al.*, 2018; Mukuze *et al.*, 2023). Conversely, G-38 and G-44 exhibited the lowest emergence (2.25), reinforcing their resistance to bruchids. Resistant varieties typically possess traits such as tough or rough seed coats, which impair larval development and survival (Pessu and Umeozor, 2004; Vishwakarma, 2013).

Developmental timing

Significant differences in MDP among genotypes indicate varied resistance levels. Eight genotypes exhibited extended MDPs, likely due to harder seed textures and elevated tannin and antioxidant levels, which suppress larval progression and reduce emergence (Msiska *et al.*, 2018; Mukuze *et al.*, 2023). The observed influence on MDP and GI points to underlying biochemical variation, specifically, reduced flavonoid concentrations and increased defensive compounds (Msiska *et al.*, 2018). Negative correlations between MDP, GI, and DSI (table 4) further affirm that prolonged pest development is associated with enhanced resistance.

Growth potential

Lower GI values were observed in genotypes JM-PI230970/PI635999-020-T14-S43 (G-44), JM-PI635999/F6LG04-5196-LG06-5920-020-T3-S5 (G-38), TGX-2014-49FZ (G-8), Belesa-95 (G-62), and PI471904 (G-32), indicating limited support for *C. chinensis* population growth (Ouedraogo *et al.*, 1996; Msiska *et al.*, 2018; Mukuze *et al.*, 2023). These genotypes likely lack nutritional or structural characteristics conducive to rapid pest proliferation and represent strong candidates for resistance breeding.

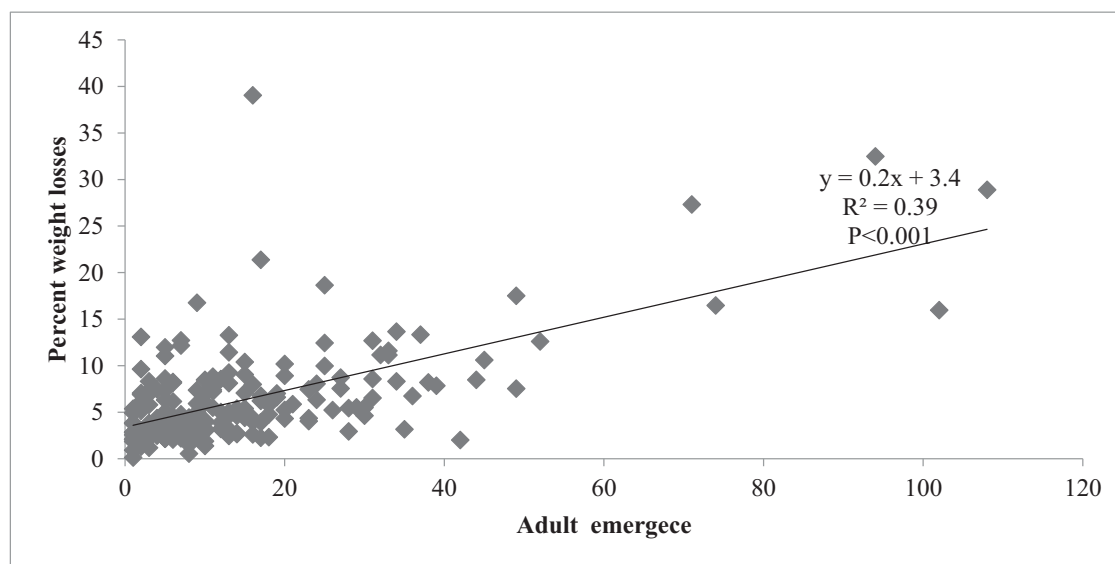


Figure 3. Regression of per cent weight loss in soybean seeds against adult bruchid emergence for 50 genotypes.

Table 6. Analysis of variance for key variables assessing soybean resistance to *C. chinensis* in Assosa, Ethiopia (2023–2024)

Source of variation	DF	Number of eggs	Per cent adult emergence	Adult emergence	Per cent weight loss	MDP (days)	GI	DSI
Year	1	710.65	1973.12**	367.21	490.86***	112.50	1.28***	4.87
Replication (Year)	2	7258.98***	277.75	294.37	40.98	112.45	0.20	26.58***
Genotypes	49	650.58	618.83***	296.08	27.22	62.68***	0.28***	6.76***
Genotype × Year	49	959.17	254.96	295.88	33.25**	47.75	0.16	3.52
Residuals	99	753.10	235.83	252.15	19.63	29.80	0.11	2.95
Mean		46.61	28.10	14.34	6.22	56.14	0.52	
CV		58.88	54.65	110.77	71.26	9.72	63.29	
Tukey's HSD		80.09	44.82	46.35	12.93	15.93	0.97	5.01

DF, degrees of freedom; DSI, Dobie's susceptibility index; GI, growth index; MDP, median development period (days).

***Significant at $P < 0.001$.

**Significant at $P < 0.01$.

Weight loss and DSI

Weight loss variation among genotypes was considerable, with G-8, G-32, G-44, and G-5 showing the lowest mean values, reflecting superior resistance (Msiska *et al.*, 2018; Msiska, 2019; Mukuze *et al.*, 2023). Genotypes such as G-3, G-21, G-26, G-28, and G-36 exhibited broader ranges (1.37–39.40%), suggesting underlying genetic diversity and environmental effects on pest susceptibility (Maharjan *et al.*, 2019; Singha and Rajkumari, 2021). However, the consistent performance of G-8, G-32, and G-44 across conditions underscores their stability and value for bruchid-resistant breeding. DSI analysis identified G-44 as the most resistant genotype, followed closely by G-38. These entries likely possess elevated levels of defensive compounds or physical barriers (Mukuze *et al.*, 2023). Their consistent performance across infestation metrics affirms their suitability for incorporation into breeding programmes aimed at mitigating bruchid damage and enhancing the sustainability of soybean production in vulnerable regions.

Association of resistance traits in soybean genotypes

Correlation analysis revealed strong positive relationships among oviposition rate, adult emergence, GI, DSI, and seed weight

loss (table 5). Genotypes with higher egg counts exhibited greater adult emergence, which in turn was associated with raised GI and DSI values. These ultimately resulted in elevated seed weight loss, indicating the direct link between reproductive success and storage damage (Vishwakarma, 2013; Adams *et al.*, 2018; Msiska *et al.*, 2018; Singha and Rajkumari, 2021; Mukuze *et al.*, 2023; Elsayy *et al.*, 2024). Furthermore, the MDP exhibited negative correlations with both DSI and GI. Genotypes with longer MDP tended to show reduced seed damage and slow population growth. This inverse relationship suggests that delayed development functions as a resistance mechanism, likely mediated by biochemical defences or physical barriers such as seed coat thickness and hardness (Msiska *et al.*, 2018; Naseri *et al.*, 2022; Ventury *et al.*, 2022).

Predictive insights from regression analysis

The regression analysis revealed adult emergence as a statistically significant determinant of seed weight loss, explaining 38.78% of the observed variation. Specifically, each additional emerged adult was associated with an estimated 0.2% increase in weight loss. These findings align with Mphuru (1981), who linked higher adult emergence to intensive larval feeding and accelerated seed damage,

and with Pessu and Umeozor (2004), who reported that reproductive success in *C. chinensis* significantly exacerbates seed vulnerability. This relationship underscores the importance of selecting genotypes that suppress adult emergence through physical and biochemical resistance traits. As noted by Singha and Rajkumari (2021), smoother seed surfaces and richer nutrient content promote oviposition and larval development, while harder seed textures and elevated tannin levels function as protective barriers (Msiska *et al.*, 2018; Naseri *et al.*, 2022). Thus, breeding strategies aimed at reducing pest survival, especially emergence rates, hold strong predictive and practical value in mitigating infestation severity.

Conclusions

This study reveals important insights into the variability of resistance to *C. chinensis* among soybean genotypes. Genotypes JM-PI230970/PI635999-020-T14-S43 (G-44) and JM-PI635999/F6LG04-5196-LG06-5920-020-T3-S5 (G-38) showed resistance against *C. chinensis*. These resistant genotypes could be ideal candidates for breeding bruchid-resistant soybeans. Moreover, the correlation and regression analyses confirm that adult emergence significantly contributes to storage weight losses, with each additional emerged adult leading to measurable weight loss. Consequently, selecting genotypes with low susceptibility indices is paramount for mitigating losses, enhancing storage potential, and advancing sustainable soybean production. Further work can be conducted to determine the resistance mechanisms in the resistant genotypes and more research to identify additional resistant genotypes against *C. chinensis*. These can minimise the use of insecticides and provide healthier soybean to consumers.

Acknowledgements. The authors express their gratitude to the Ethiopian Institute of Agricultural Research for financial support and to the Jimma Agricultural Research Center for providing the soybean genotypes used in this study.

Competing interests. All authors declare that they have no conflict of interest.

References

- Abdelghany AM, Zhang S, Azam M, Shaibu AS, Feng Y, Qi J, Li Y, Tian Y, Hong H, Li B and Sun J (2019) Natural variation in fatty acid composition of diverse world soybean germplasms grown in China. *Agronomy* **10**(1), 24.
- Adams B, Osekere E and Amoah S (2018) Evaluation of cowpea (*Vigna unguiculata* L.) genotypes' growth and yield performance and resistance to the cowpea seed beetle, *Callosobruchus maculatus* F. *Journal of Experimental Agriculture International* **19**(5), 1–9.
- Amusa OD, Ogunkanmi LA, Adetunbi JA, Akinyosoye ST, Bolarinwa KA and Ogundipe OT (2014) Assessment of bruchid (*Callosobruchus maculatus*) tolerance of some elite cowpea (*Vigna unguiculata*) varieties. *Journal of Agriculture and Sustainability* **6**(2), 164–178.
- Amusa OD, Ogunkanmi LA, Bolarinwa KA and Ojobo O (2013) Evaluation of four cowpea lines for bruchid (*Callosobruchus maculatus*) tolerance. *Journal of Natural Sciences Research* **3**(13), 2225–3186.
- Chandra G and Girish S (2014) *Callosobruchus chinensis*, The pulse beetle cowpea bruchid. *IASZoology.com*. <https://www.iaszoology.com/callosobruchus-chinensis/> (accessed 1 April 2025).
- Cope JM and Fox CW (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.
- Credland PF (2000) Bioassays with bruchid beetles: Problems and (some) solution. In *Proceedings of the 6th International Working Conference on Seed Product Protection*.
- Derera J, Giga DP and Pixley KV (2001) Resistance of maize to the maize weevil: II. Non-preference. *African Crop Science Journal* **9**(2), 441–450.
- 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.
- Elsawy IA, El-Talpanty MD, Mohamed AM and Morsy AR (2024) Resistance of some soybean genotypes to Bruchids: *Callosobruchus chinensis* L. as Influenced by different biochemical and seed quality traits. *Journal of Plant Production* **15**(4), 153–160.
- Farrell J, Brier H and Colins P (2015) *Diagnostic Protocols: Diagnostic Methods for Cowpea Weevil or Cowpea Bruchid (Callosobruchus Maculatus)*. Kingaroy, Queensland: Queensland Primary Industries and Fisheries.
- I.I.T.A. (2009) *Soybean Bruchids: Biology and Control Strategies*. International Institute of Tropical Agriculture.
- Jiang GL, Rajcan I, Zhang YM, Han T and Mian R (2023) Editorial: Soybean molecular breeding and genetics. *Frontiers in Plant Science* **14**, 1157632.
- Kananji GAD (2007) A study of bruchid resistance and its inheritance in Malawian dry bean germplasm Doctoral dissertation, University of KwaZulu-Natal, Pietermaritzburg.
- Lephale S, Addo-Bediako A and Ayodele V (2012) Susceptibility of seven cowpea cultivars (*Vigna unguiculata*) to cowpea beetle (*Callosobruchus maculatus*). *Agricultural Science Research Journals* **2**(2), 65–69.
- Maharjan R, Yi H, Ahn J, Roh GH, Park C, Yoon Y, Jang Y, Baek I, Kim Y and 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.
- Mbata GN (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.
- Mphuru AN (1981) Comparative biological and ecological studies of *Callosobruchus chinensis* (L.). Ph.D. Thesis. Faculty of Agriculture, University of Dares Salaam, Tanzania.
- Msiska MU (2019) Genetic resistance to adzuki bean bruchid (*Callosobruchus chinensis*) in soybean. Doctoral dissertation, PhD Dissertation, Makerere University, Uganda.
- Msiska UM, Odong TL, Hailay M, Miesho B, Kyamanywa S, Rubaihayo PR and Tukamuhabwa P (2018) Resistance of Uganda soybean germplasm to adzuki bean bruchid. *African Crop Science Journal* **26**(3), 399–415.
- Mukuze C, Msiska UM, Badji A, Obua T, Kweyu SV, Nghituwamhata SN, Rono EC, Maphosa M, Kasule F and Tukamuhabwa P (2023) Genome-wide association mapping of bruchid resistance loci in soybean. *bioRxiv* 09.
- Naseri B, Ebadollahi A and 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.
- Odeyemi O, Daramola AM and 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.
- Onyido AE, Zeibe CC, Okonkwo NJ, Ezugbo-Nwobi IK, Egbuche CM, Udemezue OI and Ezeanya LC (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.
- Ouedraogo PA, Sou S, Sanon A, Monge JP, Huignard J, Tran BE and Credland PF (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.
- Pawlowski ML, Lagos-Kutz DM, da Fonseca Santos M, Lee N, Chigeza G, Nachilima C, Francischini JH and Hartman GL (2021) Potential threat of bruchids on soybean production in Sub-Saharan Africa. *Plant Health Progress* **22**(2), 86–91.

- Pessu PO and Umeozor AC** (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.
- Porca M** (2003) The actual stage the knowledge about the damages bruchids. *Journal of Central European Agriculture* **4**(3), 2001.
- R Core Team** (2023) *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. <https://www.R-project.org/>.
- Radha R and 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.
- Rees DP** (2004) *Insects of Stored Products*. Melbourne, Australia: CSIRO Publishing, pp. 39–46.
- Régnière J, Powell J, Bentz B and 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.
- Sharma S and Thakur DR** (2014) Studies on the varietal preference of *Callosobruchus maculatus* on soybean genotypes. *Asian Journal of Biological Sciences* **7**(5), 233–237.
- Shimales T and 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.
- Singha TA and Rajkumari P** (2021) Ovipositional behaviour of *Callosobruchus chinensis* (L) in different pulses: A review. *Journal of Entomology and Zoology Studies* **9**(1), 105–109.
- Somta C, Somta P, Tomooka N, Ooi PA-C, Vaughan DA and 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.
- Spradbery P** (2013) Invasive species compendium. *Xcsconsulting.Com.Au* 4066.
- Tembo L, Pungulani L, Mataa J, Sohathi PH and Munyinda K** (2016) Developing cowpea and bean genotypes with tolerance to bruchid beetle. *RUFORUM Working Document Series* **14**(1), 879–883.
- Ventury KE, Ferreira SR, De Moura Rocha M, Do Amaral Gravina G, Da Silva Ferreira AT, Perales J, Fernandes KVS and Oliveira AEA** (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.
- Vishwakarma A** (2013) *Screening of Some Soybean Germplasm against Pulse Beetle, Callosobruchus chinensis* (Linnaeus). U.S. Nagar, Uttarakhand, India: Master of Science in Agriculture. G.B. Pant University of Agriculture & Technology Pantnagar, pp. 263145.
- Yamane T** (2013) Biorational control methods for protection of stored grain legumes against bruchid beetles. *Agricultural Sciences* **4**(12), 762–766.
- Zhou W, Arcot Y, Medina RF, Bernal J, Cisneros-Zevallos L and Akbulut ME** (2024) Integrated pest management: an update on the sustainability approach to crop protection. *ACS omega* **9**(40), 41130–41147.