

Profiling Maize Genotypes for Resistance to *Spodoptera frugiperda* under Artificial Infestation

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Abstract

Maize is increasingly affected by various biotic and abiotic stressors across growth stages. Among these, the fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith), has emerged as a serious threat to maize cultivation in India. Host plant resistance (HPR) offers an effective, economical and environmentally sustainable strategy for its management. In the present study, 31 maize inbred lines and 10 introgression lines (ILs) were screened for FAW resistance under artificial infestation. The experiment was conducted in a randomised block design with three replications during Kharif 2023 at Punjab Agricultural University, Ludhiana. Each genotype was infested with ten neonate larvae per plant at 14 days after germination. Leaf injury ratings were recorded at 7, 14, 21, 28 and 35 days after infestation (DAI), while ear damage was assessed at harvest using the 1 – 9 Davis scale. Maximum foliar damage was observed at 21 DAI (V6 stage), identifying it as the most appropriate stage for screening. Among inbreds, CML 46 showed the least damage, whereas LM 12 and LM 14 were highly susceptible. Hybrids derived from tolerant parents, particularly JH 23128 (CML 46 × CML 72), exhibited improved resistance, while JH 23135 showed the highest susceptibility. This indicates that the use of both tolerant parents is essential for developing resistant hybrids. A strong positive correlation between foliar and ear damage ($r = 0.84$ in inbreds; $r = 0.75$ in hybrids) indicated consistency in resistance expression. Among hybrids, JH 23136 recorded the highest grain yield (7.3 t ha^{-1}), followed by JH 23132 (7.0 t ha^{-1}). The inbreds CML 46, CML 71 and CML 72 were identified as promising sources for developing FAW-resistant maize hybrids suitable for sustainable cultivation.

Abbreviations

ANOVA – Analysis of variance

CD – Critical difference

CIMMYT – International Maize and Wheat Improvement Center

DAI – Days after infestation

DMRT – Duncan's multiple range test

FAW – Fall armyworm

IAS – Invasive alien species

ICAR-IIMR – Indian Institute of Maize Research

IL – Introgression line

IPM – Integrated pest management

PAU – Punjab Agricultural University

RBD – Randomised block design

Introduction

Maize (*Zea mays* L.), belonging to the Poaceae family, is a leading cereal and fodder crop worldwide. Owing to its exceptional yield potential and broad genetic variability, it is known as the “Queen of Cereals” and can be cultivated across a wide range of agro-ecological conditions (Azerefegne et al., 2002). Maize exhibits remarkable adaptability to various environmental stresses and insect infestations. However, biotic factors, particularly insect pests, pose significant challenges to maize production. The primary insect pests of maize include the spotted stem borer (*Chilo partellus*), shoot fly (*Atherigona* spp.), and pink stem borer (*Sesamia inferens*), which collectively have the potential to cause yield losses of up to 80% (Reddy, 2001).

Among the emerging threats to maize production is the fall armyworm (FAW), *Spodoptera frugiperda*, an invasive alien species (IAS) characterised by its polyphagous nature, high mobility, and destructive potential. As an IAS, it exemplifies the broader risks posed to agricultural productivity, native biodiversity, and ecosystem stability—risks that are expected to intensify with ongoing climate change and increased global trade, leading to significant economic losses (Pratt et al., 2017; Kumar and Singh, 2020). FAW, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), a species native to the tropical and subtropical regions of the Americas (Sparks, 1979), was first reported in West Africa (Goergen et al., 2016) and has since rapidly expanded its ran-

ge across sub-Saharan Africa (Stokstad, 2017) and the Asian subcontinent (Guo et al., 2018; Ullah et al., 2019; Keerthi et al., 2020). It is a highly polyphagous and invasive pest, with a documented host range exceeding 353 plant species across 76 families, predominantly within Poaceae (106 species), Asteraceae (31), and Fabaceae (31) (Dumas et al., 2015; Montezano et al., 2018). Infestations by FAW have been associated with significant reductions in maize yields, ranging from 15% to 73% (Guo et al., 2018). Given the pivotal role of maize in smallholder nutrition, infestations by FAW pose a substantial threat to global food security. Moreover, FAW-induced maize yield reductions may adversely impact associated industries, including bioethanol production, poultry, and livestock sectors (Guo et al., 2018).

The FAW, *Spodoptera frugiperda*, was first detected in India in May 2018, with its initial occurrence reported in the Shivamogga district of Karnataka (Sharanabasappa et al., 2018). Since then, the pest has rapidly expanded across various agro-climatic zones of the country, largely due to its high reproductive and dispersal capacity (Suby et al., 2020). In Punjab, one of the major maize-producing states in India, FAW was first identified in grain maize fields by the Indian Council of Agricultural Research – Indian Institute of Maize Research (ICAR-IIMR) (Rakshit et al., 2019). Subsequently, infestations were also reported in fodder maize crops in Hoshiarpur district (Cheema et al., 2021). Reports indicate that inadequate pest management strategies have resulted in substantial yield losses across India (Day et al., 2017). Efforts to manage FAW in Punjab and across India include integrated pest management (IPM) strategies combining cultural practices, biological control agents, and judicious use of chemical insecticides. Ongoing research aims to develop resistant maize varieties and improve early detection and monitoring systems to mitigate the pest's impact and safeguard maize productivity in the region. Host plant resistance has the potential to serve as an important tool for successful FAW management (Day et al., 2017). The adoption of resistant cultivars as part of IPM is an economical, safe, and reliable approach to reduce insect damage (Rasool et al., 2017). Therefore, screening maize genotypes for resistance to FAW is essential and forms the basis for effective IPM strategies. Germplasm pools, including landraces, improved cultivars, open-pollinated varieties, and synthetic lines, provide valuable resources for such screening. The identification of resistant maize genotypes not only supports the development of robust breeding strategies but also aids farmers in selecting cultivars suitable for effective pest management (Kasoma et al., 2020).

Previous studies have identified maize genotypes with resistance to FAW, such as Antigua 2D (B10 × B14)

and Hybrid 6417, with Latin American varieties like Cuba Honduras 46-J exhibiting lower levels of damage (Wiseman et al., 1967). Building on this work, Wiseman et al. (1981) developed inbred lines resistant to FAW derived from the Antigua Gpo.2 genotype. Since then, institutions such as CIMMYT and USDA-ARS have continued efforts to develop resistant inbred lines. However, no commercially released maize cultivars in sub-Saharan Africa have yet demonstrated effective resistance to FAW (Matova et al., 2022; Kasoma et al., 2020). In the present study, a set of maize inbred lines was screened for tolerance to FAW, leading to the identification of several tolerant genotypes. These tolerant inbreds were subsequently used to develop hybrids, which were evaluated for key agronomic traits along with their resistance to FAW. The findings reinforce the potential of integrating biophysical and biochemical resistance traits through targeted breeding to develop cultivars with enhanced FAW tolerance. Such approaches offer a sustainable alternative to chemical control, contributing to environmentally sound and economically viable maize production systems.

Materials and methods

Plant materials

For the present study, a total of 31 inbred lines and 10 introgression lines (ILs) of maize (*Zea mays*) were selected from the germplasm repository of Punjab Agricultural University (PAU). The inbred lines, previously stabilized through successive generations of selfing, are currently maintained via selfing or sib-mating. The detailed pedigree information of these lines is provided in Annexure 1 (Supplementary). The introgression lines (ILs) utilized in this study were developed using *Zea mays* spp. *parviglumis* (teosinte) as the donor parent, followed by five backcrosses and advancement to the BC₅F₅ generation in diverse genetic backgrounds {LM × *Zea mays* spp. *parviglumis*/LM line *5(BC₅)-1....-f, namely IL 1 to IL 3 from LM 24; IL 4 and 5 from LM 13; IL 6 - 9 from LM 16 and IL 10 from CM 139}. Field experiments were carried out in Kharif (rainy season) 2023-24 at Maize Experimental Area, Department of Plant Breeding and Genetics, PAU, Ludhiana, India. Artificial inoculation cultures were prepared in the Maize Entomology Laboratory, Department of Plant Breeding and Genetics, PAU.

Establishing the Insect culture

To establish a culture of *Spodoptera frugiperda*, egg clusters and larvae were collected from maize fields and maintained under laboratory conditions at 25 ± 2°C and 70 % relative humidity. Neonates were reared on

Table 1 - Foliar and ear damage in different maize genotypes under artificial infestation of fall armyworm (*Spodoptera frugiperda*)

S. No.	Genotype	Foliar damage#					Ear damage
		Days after infestation					
		7	14	21	28	35	
2	CML 71	2.93 ± 0.02	3.33 ± 0.06	4.13 ± 0.06	4.07 ± 0.03	3.43 ± 0.07	2.25 ± 0.09
3	CML 72	3.17 ± 0.03	3.63 ± 0.05	4.33 ± 0.06	4.14 ± 0.03	3.37 ± 0.06	2.73 ± 0.06
4	CML139	2.83 ± 0.06	3.47 ± 0.07	4.27 ± 0.02	4.17 ± 0.09	3.47 ± 0.01	2.57 ± 0.03
5	CML 313	3.47 ± 0.01	4.33 ± 0.01	4.80 ± 0.04	4.33 ± 0.09	4.53 ± 0.02	3.66 ± 0.07
6	CML 332	3.53 ± 0.08	4.33 ± 0.03	5.13 ± 0.09	4.97 ± 0.04	5.03 ± 0.11	4.43 ± 0.09
7	CML 574	3.23 ± 0.05	4.27 ± 0.02	4.93 ± 0.04	4.47 ± 0.07	4.13 ± 0.04	3.43 ± 0.06
8	CML 579	3.37 ± 0.06	4.37 ± 0.09	5.63 ± 0.09	4.63 ± 0.02	4.77 ± 0.01	4.23 ± 0.02
9	LM 5	3.17 ± 0.03	4.73 ± 0.10	5.27 ± 0.02	4.47 ± 0.07	4.27 ± 0.07	4.34 ± 0.05
10	LM 11	3.13 ± 0.07	4.37 ± 0.03	5.17 ± 0.03	4.17 ± 0.08	4.47 ± 0.10	4.15 ± 0.03
11	LM 12	3.77 ± 0.03	4.83 ± 0.08	5.97 ± 0.09	5.27 ± 0.01	4.57 ± 0.05	3.56 ± 0.00
12	LM 13	3.07 ± 0.05	4.57 ± 0.01	5.53 ± 0.13	4.83 ± 0.03	4.47 ± 0.11	4.53 ± 0.01
13	LM 14	3.33 ± 0.03	4.33 ± 0.06	5.93 ± 0.02	4.67 ± 0.01	4.93 ± 0.09	3.86 ± 0.06
14	LM 16	3.63 ± 0.03	4.13 ± 0.01	5.43 ± 0.04	4.97 ± 0.07	4.33 ± 0.01	3.50 ± 0.05
15	LM 24	3.47 ± 0.07	4.23 ± 0.03	5.37 ± 0.05	4.77 ± 0.03	4.17 ± 0.02	3.80 ± 0.01
16	PML 896	3.37 ± 0.04	4.93 ± 0.02	5.93 ± 0.10	5.13 ± 0.12	4.93 ± 0.07	4.13 ± 0.03
17	PML 898	3.53 ± 0.05	4.93 ± 0.03	5.87 ± 0.01	5.23 ± 0.09	3.53 ± 0.01	3.24 ± 0.07
18	PML 912	3.47 ± 0.01	5.03 ± 0.12	5.63 ± 0.13	4.97 ± 0.11	3.67 ± 0.05	3.46 ± 0.07
19	PML 915	3.07 ± 0.03	4.80 ± 0.06	5.73 ± 0.03	5.57 ± 0.05	4.43 ± 0.01	3.64 ± 0.06
20	PML 923	3.47 ± 0.08	4.83 ± 0.04	5.43 ± 0.01	5.13 ± 0.03	4.67 ± 0.03	3.76 ± 0.01
21	PML 1115	3.57 ± 0.02	4.67 ± 0.01	5.73 ± 0.03	4.63 ± 0.07	4.53 ± 0.10	3.31 ± 0.04
22	PML 1145	3.43 ± 0.09	4.83 ± 0.03	5.33 ± 0.01	5.03 ± 0.07	4.93 ± 0.03	3.75 ± 0.08
23	PML 1230	3.47 ± 0.05	4.73 ± 0.06	5.17 ± 0.11	4.67 ± 0.05	4.83 ± 0.11	3.58 ± 0.01
24	PML 1249	3.57 ± 0.09	4.67 ± 0.08	5.37 ± 0.05	4.87 ± 0.11	4.43 ± 0.01	4.63 ± 0.07
25	PML 1275	3.47 ± 0.07	4.23 ± 0.07	5.33 ± 0.09	4.43 ± 0.09	4.17 ± 0.07	4.16 ± 0.03
26	PML 1276	3.47 ± 0.02	4.63 ± 0.07	5.37 ± 0.04	4.47 ± 0.05	5.13 ± 0.12	3.93 ± 0.07
27	PML 1277	3.27 ± 0.05	4.67 ± 0.08	5.87 ± 0.12	5.47 ± 0.03	4.73 ± 0.02	4.11 ± 0.03
28	PML 1278	3.53 ± 0.08	5.03 ± 0.10	5.93 ± 0.05	4.73 ± 0.05	3.97 ± 0.03	3.46 ± 0.01
29	PML 1279	2.97 ± 0.07	4.43 ± 0.03	5.37 ± 0.03	4.53 ± 0.03	4.13 ± 0.07	3.56 ± 0.09
30	VL 21948	3.73 ± 0.07	4.53 ± 0.08	4.77 ± 0.07	5.47 ± 0.05	5.17 ± 0.03	4.20 ± 0.03
31	VL181545	3.87 ± 0.08	4.73 ± 0.08	5.47 ± 0.03	5.13 ± 0.01	4.73 ± 0.03	3.40 ± 0.03
32	IL 1*	3.33 ± 0.05	4.93 ± 0.06	5.27 ± 0.06	4.37 ± 0.03	4.13 ± 0.04	3.51 ± 0.01
33	IL 2	3.27 ± 0.04	4.23 ± 0.08	4.47 ± 0.04	4.17 ± 0.04	3.33 ± 0.08	2.95 ± 0.06
34	IL 3	3.47 ± 0.01	3.57 ± 0.05	4.37 ± 0.10	4.27 ± 0.03	3.23 ± 0.03	3.18 ± 0.06
35	IL 4	3.43 ± 0.04	5.27 ± 0.05	5.87 ± 0.05	5.43 ± 0.05	3.87 ± 0.01	3.21 ± 0.06
36	IL 5	3.33 ± 0.04	4.63 ± 0.08	5.83 ± 0.03	5.00 ± 0.06	4.97 ± 0.11	4.23 ± 0.02
37	IL 6	3.00 ± 0.06	3.53 ± 0.04	4.47 ± 0.06	4.17 ± 0.07	4.03 ± 0.04	3.14 ± 0.01
38	IL 7	3.47 ± 0.03	4.87 ± 0.02	5.37 ± 0.05	4.63 ± 0.01	3.53 ± 0.03	2.87 ± 0.06
39	IL 8	3.63 ± 0.03	5.43 ± 0.04	5.83 ± 0.10	4.67 ± 0.03	4.33 ± 0.05	3.86 ± 0.05
40	IL 9	3.57 ± 0.09	4.73 ± 0.11	5.47 ± 0.07	4.87 ± 0.12	4.43 ± 0.03	3.65 ± 0.04
41	IL 10	3.53 ± 0.02	4.33 ± 0.03	5.73 ± 0.01	5.17 ± 0.05	4.33 ± 0.03	3.27 ± 0.03
	Mean	3.32 ± 0.08	4.49 ± 0.01	5.24 ± 0.01	4.68 ± 0.03	4.28 ± 0.01	3.60 ± 0.08
	C.D. (p<0.05)	0.139	0.185	0.186	0.177	0.172	0.145
	SE(m)	0.049	0.066	0.066	0.063	0.061	0.051

IL* – Introgression line Data presented as Mean ± SE of three replicates. Foliar Damage scale #1=highly resistance, 2-3=resistance, 4-5=moderately resistance, 6-7=susceptible, 8-9 = highly susceptible Ear Damage Scale 1-3 = resistance, 4-5=moderately resistance, 6-9=susceptible

natural maize leaves in plastic jars, while older larvae were individually placed in plastic vials (5 cm × 5 cm) with fresh artificial diet (Sagar et al., 2022), replaced every other day until pupation. Pupae were transferred to plastic jars (14 cm × 12 cm) containing moist sand and covered with muslin cloth to allow adult emergen-

ce. Three-day-old male and female moths were paired and placed in oviposition cages (30 cm × 24 cm), with a 10% honey solution provided on a cotton swab suspended through the muslin cloth for adult feeding. Freshly laid eggs from this culture were used for subsequent experiments.

Table 2 - Foliar damage at peak infestation (21 DAI) and ear damage in maize hybrids under artificial infestation of fall armyworm (*Spodoptera frugiperda*)

S. No.	Hybrids	Pedigree	Foliar damage (21 DAI)	Ear damage rating
1	JH 23128	CML 46 × CML 72	4.57 ± 0.03	3.14 ± 0.09
2	JH 23129	CML 46 × VL 181545	4.87 ± 0.07	3.20 ± 0.09
3	JH 23130	CML 71 × CML 72	4.53 ± 0.01	3.44 ± 0.08
4	JH 23131	CML 72 × CML 71	4.47 ± 0.04	3.77 ± 0.08
5	JH 23132	CML 574 × CML 71	5.43 ± 0.11	4.07 ± 0.01
6	JH 23133	CML 574 × CML 72	5.47 ± 0.04	4.17 ± 0.07
7	JH 23134	CML 574 × CML 139	5.33 ± 0.11	3.77 ± 0.03
8	JH 23135	VL 181545 × CML 71	5.97 ± 0.05	4.14 ± 0.09
9	JH 23136	VL 181545 × CML 72	5.17 ± 0.10	3.77 ± 0.06
10	JH 23137	VL 21948 × CML 72	5.63 ± 0.03	3.84 ± 0.06
	Mean	-	5.06 ± 0.02	3.73 ± 0.02
	C.D. (p<0.05)	-	0.22	0.186
	SE(m)	-	0.073	0.062

Data presented as Mean ± SE of three replicates. p<0.05 Damage scale 1=highly resistance, 2-3=resistance, 4-5=moderately resistance, 6-7=susceptible, 8-9=highly susceptible

Artificial infestation and evaluation of maize inbreds and introgression lines

For field screening of maize inbreds, seeds of each line were manually sown in a randomized block design (RBD) with three replications in *Kharif* 2023. Each entry was planted in a single row of 2 m length, maintaining a row-to-row spacing of 60 cm and plant-to-plant spacing of 20 cm. Fifteen days after germination, maize inbred lines were artificially infested with 10 neonate larvae of *S. frugiperda* per plant, introduced into the whorl during evening hours (post 4:00 PM). The larvae, reared on maize whorl leaves, were used for infestation. Leaf injury ratings were recorded at 7, 14, 21, 28, and 35 DAI, while ear damage was assessed at harvest. Foliar and ear damage were evaluated using a 1 – 9 numerical scale, commonly referred to as the Davis scale (Davis and Williams., 1992).

Generation and Evaluation of F₁ Hybrids

F₁ hybrids were developed in spring 2024 by crossing selected maize inbred lines exhibiting moderate resistance to *Spodoptera frugiperda*, based on flowering synchronization. Parental lines were planted in two rows (2 m each) with 10 plants per row, spaced at 60 cm × 20 cm. Controlled pollination was ensured by detasseling female plants, and ears were harvested separately and sun-dried to ~12% moisture. Pedigree details of the hybrids are provided in Annex 2. The F₁ seeds were sown during *Kharif* 2024, in a RBD with two replications and a plot size of 4.8 m². Hybrids were evaluated for agronomic traits - plant height, ear height, cob length, cob girth, and grain yield and screened for FAW tolerance using the same artificial infestation method as for inbreds.

Statistical analysis

For all parameters, data were expressed as mean ± standard error (SE) based on three replicates. Statistical analysis was performed using analysis of variance (ANOVA) appropriate for a randomized block design, conducted with SAS software version 8.3. Mean comparisons were carried out using Duncan's Multiple Range Test (DMRT) at a 5% level of significance.

Results and Discussion

Foliar Damage Progression and Identification of Susceptible Stage

Significant variation in foliar damage due to FAW infestation was observed among the 41 maize genotypes (Table 1). Foliar injury increased from 7 to 21 DAI and then stabilized or declined, reflecting typical FAW feeding dynamics. CML 46, CML 71, and CML 139 consistently recorded the lowest foliar damage across intervals (≈2.7–3.4), indicating stable resistance. In contrast, CML 332, CML 579, LM 12, and PML 896 showed high and persistent damage (>5.0), classifying them as susceptible. ILs exhibited broad variability; IL 2 and IL 3 (LM 24 background) showed lower damage progression, whereas IL 4 and IL 8 recorded damage exceeding 5.8 at 21 DAI. The overall mean increased from 3.32 at 7 DAI to 4.28 at 35 DAI, with statistically significant genotypic differences confirmed by CD values (0.139–0.172). Similar resistance patterns in CML lines have been noted by Prasanna et al. (2021) and Nuambote-Yobila et al. (2023). The study identified 21 DAI (Table 2) as the most susceptible phase, coinciding with peak larval feeding- consistent with earlier reports (Wiseman et al., 1981; Rasool et al., 2017).

Table 3 - Agronomic performance and grain yield of maize hybrids evaluated under fall armyworm pressure

Hybrid	Plant height (cm)	Ear height (cm)	Ear girth (cm)	Ear length (cm)	1000-kernel weight (g)	Grain yield (t ha ⁻¹)
JH 23128	164 ± 1.6 ^e	85 ± 2.8 ^d	3.9 ± 0.1 ^e	15.8 ± 0.3 ^d	287 ± 2.9 ^b	5.2 ± 0.2 ^b
JH 23129	198 ± 3.3 ^{bc}	100 ± 1.6 ^b	4.5 ± 0.1 ^c	17.4 ± 0.3 ^b	297 ± 4.1 ^a	6.8 ± 0.3 ^c
JH 23130	174 ± 1.6 ^d	90 ± 1.6 ^c	4.5 ± 0.2 ^c	16.2 ± 0.3 ^c	299 ± 2.7 ^a	5.5 ± 0.3 ^f
JH 23131	168 ± 6.6 ^{de}	92 ± 1.6 ^c	4.8 ± 0.1 ^{ab}	16.4 ± 0.5 ^c	288 ± 2.6 ^b	5.4 ± 0.6 ^{fg}
JH 23132	205 ± 3.3 ^{ab}	108 ± 3.3 ^a	4.9 ± 0.1 ^a	18.6 ± 0.5 ^a	298 ± 4.1 ^a	7.0 ± 0.1 ^b
JH 23133	169 ± 4.4 ^d	86 ± 1.6 ^d	4.2 ± 0.1 ^d	16.3 ± 0.3 ^c	295 ± 1.4 ^a	5.8 ± 0.5 ^e
JH 23134	195 ± 3.3 ^c	98 ± 1.6 ^b	4.6 ± 0.1 ^{bc}	16.7 ± 0.3 ^{bc}	295 ± 5.2 ^a	6.3 ± 0.1 ^d
JH 23135	166 ± 3.3 ^e	90 ± 1.6 ^c	3.8 ± 0.1 ^e	16.1 ± 0.5 ^c	287 ± 2.4 ^b	5.3 ± 0.7 ^{gh}
JH 23136	210 ± 3.3 ^a	109 ± 1.6 ^a	4.8 ± 0.2 ^{ab}	19.2 ± 0.3 ^a	299 ± 2.6 ^a	7.3 ± 0.5 ^a
JH 23137	177 ± 1.6 ^d	88 ± 1.6 ^{cd}	4.2 ± 0.2 ^d	16.5 ± 0.8 ^c	293 ± 2.3 ^a	5.7 ± 0.3 ^e
Mean	182.5	94.6	4.4	16.9	294.8	6.03
CD (p < 0.05)	9.81	4.81	0.29	0.86	4.09	0.18

Values are mean ± SE. Means followed by different superscript letters within a column differ significantly at p < 0.05.

Ear Damage Variation and Relationship with Foliar Resistance

Ear damage ratings ranged from 2.25 to 4.63 across inbreds. CML 71 (2.25), CML 46 (2.37), and CML 72 (2.73) showed the greatest tolerance, whereas CML 332, CML 579, and LM 13 recorded higher damage (4.23–4.53), although still within moderately resistant categories. PML 898 and PML 1115 exhibited lower ear damage, while PML 1249 and PML 1275 were more affected. Among ILs, IL 7 and IL 2 showed strong ear resistance, whereas IL 5 and IL 8 were comparatively susceptible. The mean ear damage rating was 3.60, with significant differences among genotypes (CD = 0.145). Foliar and ear damage were strongly correlated ($r = 0.84$), confirming previous observations (Nuambote-Yobila et al., 2023; Matova et al., 2022). The stable performance of CML 71, CML 46, and CML 72 across plant parts demonstrates their robustness as resistance donors.

Contribution of *Zea mays ssp. parviglumis* and performance of introgression lines

Zea mays ssp. parviglumis, the wild progenitor of maize, exhibited inherent resistance, with foliar damage declining from 3.73 at 7 DAI to 2.68 at 21 DAI. This resistance may be attributed to morphological and biochemical traits such as narrow leaves, increased leaf toughness, trichomes, rapid growth, and the expression of defence-related genes such as wip1, mpi, and PR-1, as well as volatile emissions (Szczeplaniec et al., 2012). ILs derived from LM 24 (IL 2 and IL 3) performed better than those derived from LM 13, indicating that the recipient genetic background strongly influences the expression of introgressed resistance. In the LM 16 background, IL 6 showed clear improvement over the recurrent parent, highlighting its potential for further

breeding. Overall, IL 2, IL 3, and IL 6 emerge as promising introgression lines for FAW tolerance breeding.

Hybrid performance under FAW pressure and agronomic evaluation

Significant differences were observed among hybrids for all agronomic traits evaluated (Table 3). Plant height ranged from 164 to 210 cm and ear height from 85 to 109 cm, indicating wide variation in plant architecture. Ear length (15.8 - 19.2 cm) and ear girth (3.8 - 4.9 cm) differed significantly among hybrids, whereas 1000-kernel weight showed limited variation (287–299 g). Grain yield varied from 5.2 to 7.3 t ha⁻¹. JH 23136 recorded the highest yield, followed by JH 23132 and JH 23129, associated with superior ear traits. In contrast, JH 23128 produced lower yield despite better FAW tolerance, suggesting a possible trade-off between resistance and productivity. Hybrids such as JH 23132, combining moderate FAW tolerance with high yield, highlight the scope for concurrent improvement of yield and FAW tolerance.

Conclusions

This study establishes 21 DAI as the most critical stage of maize vulnerability to FAW and identifies CML 46, CML 71, and CML 72 as reliable sources of tolerance. The strong association between leaf and ear damage underscores the predictive value of early-stage screening for resistance.

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Annexure 1 Pedigree of inbred lines screened against FAW infestation

Sr. No.	Inbreds	Pedigree
1	CML 46	POP21-SR-W-#-B-B-B-B-B
2	CML 71	ANTGP2-5-#-1-2-1-1-3-2-2-B
3	CML 72	ANTGP2-5-#-1-2-1-1-3-3-1-B
4	CML139	MP78-518-15-1-3-2-1-3-B
5	CML 313	P501-C0-F6-3-3-2-1-f
6	CML 332	(SUWAN8422)/(P47/MP78-518)-#-183-1-7-3-1-2-B
7	CML 574	J 54 Mo 17-21-2-3-2-2-1-1-2-1-2-1-1-1-1-f
8	CML 579	WLC-Y-7-2-3-3-1-f
9	LM 5	Tux Pool C2 IC2-5-1-1-2-2-2-3-1f -1-1-f
10	LM 11	Suwan 1-26-1-1-1-1-1-1-1-1-1-f
11	LM 12	J 54 Mo 17-21-2-3-2-2-1-1-2-1-2-1-1-1- f
12	LM 13	JCY 3-7-1-1-2-1-1-1-f
13	LM 14	CA 00 310-1-3-2-3-1-f
14	LM 16	SE 539:[JS 4-30..x(Tarun x MS 1)-yellow-63-1g..]-12-4-4-2-1-selfb-1-f
15	LM 24	SE 568: (CML 32XCML25)##-2-6-1-1-1-f
16	PML 896	NK 48-#-1-1-1-2-1-1-1-f
17	PML 898	30B07-#-1-1-1-1-1-f
18	PML 912	NSX082001-#-3-1-3-4-1-1-1-f
19	PML 915	NSX082006-#-1-1-1-1-1-1-f
20	PML 923	BIO 9698-#-1-2-1-1-1-1-2-1-f
21	PML 1115	LY 558-3-1-3-4-1-2-f
22	PML 1145	Mahabeej 1114-3-3-3-4-1-f
23	PML 1230	SW 93-D-313-23 Pop 49-1-1-1-1-1-f
24	PML 1249	SW3853KU Thailand EC-468662-b-1-1-1-1-1-1 x PML 269 (HS 2816-1-1-(2)-1-1-1)-1-1-1-1-1- f
25	PML 1275	(LM 13 x Teosinte)BC ₂ F ₅ -3-1-2-1-1-1-f
26	PML 1276	(LM 13 x Teosinte) BC ₂ F ₅ -3-1-1-3-1-1-f
27	PML 1277	(LM14 x Teosinte) BC ₂ F ₅ -1-1-2-1-1-1-f
28	PML 1278	(LM14 x Teosinte) BC ₂ F ₅ -1-4-1-1-3-1-1-f
29	PML 1279	(LM13 x Teosinte) BC ₂ F ₅ -1-1-3-1-4-1-f
30	VL 21948	(CML 161 x CML 165)-B-B-#-1-1-1-2-B
31	VL 181545	(CML 176 x CML 182)-B-B-#-1-1-2-3-B



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