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Screening of Maize Genotypes against Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith) under Artificial Infestation

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ABSTRACT: The fall armyworm (FAW), *Spodoptera frugiperda*, has a detrimental effect on the sustainable production of maize, particularly in India's small- and marginal-scale farming systems. FAW has indeed spread throughout India, and currently the primary means of control is pesticide spraying. Given the harmful effects of insecticide spray on natural enemies as well as resurgence and resistance problems, there is a need to develop an effective, eco-friendly, and feasible techniques. A screening experiment was carried out during 2021–22 in an insect screening net house under artificial infestation at Winter Nursery Centre, ICAR-Indian Institute of Maize Research, Rajendranagar, Hyderabad, to identify resistant/tolerant maize genotypes to fall armyworm. Twenty-two maize genotypes were evaluated based on the fall armyworm leaf damage score on a scale of 1 to 9, as specified by Davis and Williams (1992), which was later modified by CIMMYT. The pooled mean data of leaf damage score (LDS) per plant varied from 3.93 to 6.84 in CML 71 and CM 501, respectively, and differed significantly from each other. Among the maize genotypes screened, CML 71, CML 67 and DMRE63 recorded significantly lower leaf damage scores of 3.93, 4.00 and 4.17, to fall armyworm. The mean leaf damage score per plant of CML 71, CML 67, DMRE63, CML 561, AEBY-1, CML 335, CML 345, and CML 337 were 3.93, 4.00, 4.17, 4.36, 4.42, 4.57, 4.72, and 4.80, respectively and were categorized as moderately resistant genotypes. These genotypes can be utilized in breeding programmes to develop fall armyworm-resistant/tolerant cultivars.

Keywords: Maize genotypes, fall armyworm, screening, artificial infestation, leaf damage, resistant.

INTRODUCTION

Maize (*Zea mays* L.) commonly known as the Queen of cereals, is the third most important food crop after wheat and rice. It can be grown throughout the world under varied agroclimatic conditions and has a good yield potential among the cereals (Singh and Jaglan, 2018). Globally, maize covers an area of nearly 193.7 million hectares and is cultivated in over 170 countries with a production of 1147.7 million MT and mean productivity of 5.75 tonnes per hectare (FAOSTAT, 2020). Among the maize-growing countries, India ranked 4th in area and 7th in production, representing around 4.6% of the world maize area and 2.4 % of total production (FAOSTAT, 2020). Maize is recognized as a potential crop for doubling farmers' income.

Maize is confronted by several biotic and abiotic factors to attain maximum yield. As many as 141 insect pests are known to cause varying levels of damage to maize starting from sowing till the harvest (Reddy and Trivedi, 2008). But the recent invasion of Fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is of prime importance due to its outrageous polyphagous behaviour. Fall armyworm (FAW) is native to Western Hemisphere (North & South America) (Nagoshi, 2009). FAW has spread to over 109 nations in Africa, the Near East, and Asia (FAO, 2020). In India, it was first reported in Karnataka in May 2018 (Ganiger *et al*., 2018; Sharanabasappa *et al*., 2018). Later on, it spreads rapidly throughout the country and infested the maize crop in all growing areas (Rakshit *et al*., 2019). It is a devastating polyphagous pest which feeds on more than 350 plant species (Montezano *et al*., 2018), causing significant yield losses in economically important crops such as maize, cotton, soybean, and beans (Nagoshi *et al*., 2007; Bueno *et al*., 2010). Yield loss due to FAW in maize is reported to be as high as 33% (Aruna Balla *et al*., 2019).

In Telangana, the incidence of FAW was recorded on maize from 2018-19 (*Kharif*, 3-60% and *Rabi*, 30.8%) (Lavakumar Reddy *et al*., 2019). Within a year FAW has spread to 15 districts of Telangana. The hot and humid temperature (between 20° to 32°C), as well as extensive maize cultivation in the state, leads to rapid multiplication of fall armyworm in a short period. Hence Telangana is categorized as one of the high risked zones in terms of fall armyworm infestation. Farmers are growing a wide range of cultivars all over the state, however, the cultivars with superior crop vigour and natural innate resistance are most preferred to counter FAW.

Host plant resistance has the potential to serve as an important tool for successful FAW management (Day *et al*, 2017). To reduce damage from insect pests, the adoption of resistant cultivars as a part of Integrated Pest Management (IPM) is an economical, safe and reliable approach (Rasool *et al*., 2017).

Though, the available information on FAW management is inadequate and scanty. Indeed, it is essential to screen various maize genotypes for resistance against FAW which forms a basis for integrated pest management (IPM). Hence, the development of resistant cultivars offers an effective, economical, and eco-friendly management option to control the FAW.

MATERIALS AND METHODS

Experimental site. The present study has been conducted at WNC, ICAR-IIMR, Rajendranagar during the *kharif* and *rabi* seasons of 2021-22, respectively. The experimental area comes under Telangana's Southern Zone (Zone-3). It is located between 17.184°N latitude and 78.240°E longitude, at an elevation of 494 metres above Mean Sea Level (MSL).

Sowing and Artificial infestation. This experiment includes 22 maize genotypes (Table 1) and each genotype was sown in a 2.4m² area and replicated twice under Randomized Block Design (RBD) in an insect screening net house facility. The sowing was done on August 9, 2021. Except for crop protection practices, all 22 genotypes were cultivated according to the recommended agronomic practices, with a spacing of 60 cm × 20 cm between rows and plants. Each plant of the chosen genotype was released with 20 fall armyworm neonate larvae using a camel hair brush on 02-09-21 at the V_4-V_5 leaf stage.

Table 1: List of genotypes selected for screening against fall armyworm.

Sr. No.	Genotype name	Maturity	Kernel colour and Texture
1.	DMRE 63	E	Orange, Flint
2.	CML 71	L	Yellow, Flint
3.	CML 337	M	Yellow, Dent
4.	CML 338	M	Yellow, Semi Flint
5.	CML 345	M	White, Flint
6.	CM 111 / *Zea diploperennis*	L	Yellow, Flint
7.	BML 6	M	Yellow, Semi Dent
8.	BML 7	M	Orange, Flint
9.	CM 501	E	Yellow, Semi Flint
10.	CM 400	M	White, Flint
11.	CM 500	E	Orange, Flint
12.	ENT 2-3	M	Orange, Flint
13.	CML 144	L	White, Flint
14.	CML 139	M	Yellow, Semi Flint
15.	CML 336	M	Yellow, Dent
16.	CML 335	M	Yellow, Semi Flint
17.	CML 334	E	White, Semi Dent
18.	CML 330	E	White, Semi Dent
19.	CML 561	M	White, Flint
20.	CML 67	L	Yellow, Semi Dent
21.	AEB Y-1	E	Orange, Flint
22.	AEB(Y) 5-34-1	E	Orange, Flint

E – Early Maturing, M – Medium Maturing, L – Late Maturing.

Methodology of observation. After the establishment of the crop in the net-house, observations on fall armyworm leaf damage were recorded by using a modified Davis and Williams scale (1-9 rating) at 7, 14, 21, 28 and 45 days after larval release.

Foliar damage ratings. The data on leaf-feeding damage caused by the fall armyworm larvae was recorded using the modified Davis and Williams scale (1992). Where the response of maize genotypes was characterized as highly resistant, resistant, moderately resistant, susceptible and highly susceptible (Table 2).

Statistical analysis. During the current investigation, the mean leaf damage score of all plants within the genotype was calculated. The data collected from all genotypes were subjected to a one-way ANOVA (RBD). Duncan's Multiple Range Test (DMRT) was used to compare the variations in the observations by using SPSS statistical software.

Table 2: Classification of maize germplasm based on the degree of damage by the fall armyworm. (Modified Davis and Williams scale, 1992).

Score	Damage symptoms /description	Response
1	No visible leaf feeding damage	Highly Resistant
2	Few pinholes on 1-2 older leaves	Resistant
3	Several shot-hole injuries on a few leaves (<5 leaves) and small circular hole damage to leaves	Resistant
4	Several shot-hole injuries on several leaves (6–8 leaves) or small lesions/pinholes, small circular lesions, and a few small elongated (rectangular-shaped) lesions of up to 1.3 cm in length present on whorl and furl leaves	Moderately Resistant
5	Elongated lesions (>2.5 cm long) on 8-10 leaves, plus a few small- to medium-sized uniform to irregular-shaped holes (basement membrane consumed) eaten from the whorl and/or furl leaves	Moderately Resistant
6	Several large elongated lesions present on several whorl and furl leaves and/or several large, uniform to irregular-shaped holes eaten from furl and whorl leaves	Susceptible
7	Many elongated lesions of all sizes present on several whorl and furl leaves plus several large uniform to irregular-shaped holes eaten from the whorl and furl leaves	Susceptible
8	Many elongated lesions of all sizes present on most whorl and furl leaves plus many mid to large-sized uniform to irregular-shaped holes eaten from the whorl and furl leaves	Highly Susceptible
9	Whorl and furl leaves, almost totally destroyed and plant dying as a result of extensive foliar damage	Highly Susceptible

RESULTS

The mean leaf damage score of the maize genotypes based on the 1-9 Davis scale ranged from 3.17 to 4.93 at seven days after infestation (Table 3). The mean leaf damage score per plant was lowest in DMRE 63 (3.17) and was followed by CML 335 (3.25), CML 71 (3.39), AEBY-1 (3.40), CML 67 (3.43), CML 345 (3.56), CML 337 (3.59), and CML 561 (3.44) and these were on par with one another. In the remaining genotypes, *viz*., CML 111 (3.81), CML 334 (4.00), ENT 2-3 (4.10), BML 7 (4.17), CML 144 (4.19), CML 139 (4.23), CML 338 (4.24), AEBY 5-34-1 (4.29), CML 330 (4.31), CML 336 (4.46), BML 6 (4.54), CM 501 (4.72), CM 400 (4.88), and CM 500 (4.93), the mean leaf damage score ranged between 3.81 to 4.93 at 7 days after larval release.

Whereas, at 14 days after larval infestation, the leaf damage score ranged from 4.15 to 6.38 (Table 3). The lowest leaf damage per plant was recorded in the genotype, CML 71 (4.15), followed by CML 67 (4.19) and DMRE 63 (4.31), which were statistically on par with each other. The next best genotypes were AEBY-1 (4.75), CML 345 (4.80), CML 335 (4.94), and CML 337 (5.00), respectively. The highest leaf damage score was recorded in CM 400 (6.38), AEBY 5-34-1 (6.17) and CM 501 (5.99), which were on par. In the remaining genotypes, the leaf damage score ranged between 5.12 to 5.78, CML 561 (5.12), CML 111 (5.13), CML 336 (5.19), CML 338(5.20), BML 7 (5.36), CML 330 (5.45), ENT 2-3 (5.50), BML 6 (5.53), CML 139 (5.59), CML 144 (5.60), CML 334 (5.65), CM 500 (5.78) at 14 days after infestation.

Later, at 21 days after fall armyworm infestation, the mean leaf damage score per plant in maize genotypes increased progressively, and it varied from 4.38 (CML 71) to 8.03 (CM 501) (Table 3). The lowest leaf damage score was observed in CML 71 (4.38), was followed by CML 67 (4.44), DMRE 63 (4.55), AEBY-1 (4.94), CML 337 (5.19), and CML 335 (5.19) and were on par with each other. The remaining genotypes' mean leaf damage score ranged from 5.23 in CML 345 to 8.03 in CM 501.

Similarly, at 28 days after infestation, the mean leaf damage score per plant decreased gradually as compared to 21 days after infestation, and it varied between 3.50 (CML 71) to 7.30 (CM 501) (Table 3). Leaf damage scores per plant were significantly lower in the genotypes, CML 71 (3.50), CML 67 (3.62), CML 561 (3.66), CML 335 (3.69), DMRE 63 (3.91) and AEBY-1 (3.94), and also these genotypes were on par with each other. A significantly highest leaf damage score per plant was observed in CM 501 (7.30). While the genotypes AEBY 5-34-1 (6.07), CML 144 (6.16), CML 330 (6.20), BML 6 (6.30), CML 338 (6.33), and CM 400 (6.60), were recorded the highest mean leaf damage score i.e., above 6.00 and they were statistically on par with each other.

Following that, at 45 days after fall armyworm infestation, the mean leaf damage score increased significantly and registered a score that varied between 4.09 (CML 561) and 8.15 (CM 501). The genotypes CML 561 (4.09), CML 71 (4.20), CML 67 (4.33), and DMRE 63 (4.90) suffered significantly lower leaf damage and were statistically on par with each other (Table 3). The genotype, CM 501 scored the highest leaf damage score of 8.15. Whereas CML 336 (7.15), AEBY 5-34-1 (7.36), CML 338 (7.37), BML 7 (7.39), CML 330 (7.65), BML 6 (7.73), CML 139 (7.79), CM 400 (7.90), CM 500 (7.98), and CML 144 (8.01), recorded significantly higher leaf damage scores ranged between 7.15 to 8.01.

The pooled mean data of leaf damage score per plant varied from 3.93 to 6.84 in CML 71 and CM 501, respectively, and differed markedly from each other (Table 3). The lowest leaf damage score was recorded in CML 71 (3.93) and was followed by CML 67 (4.00) and DMRE 63 (4.17) and were at par with each other. The mean leaf damage score of the following genotypes CML 71 (3.93), CML 67 (4.00), DMRE 63 (4.17), CML 561 (4.36), AEBY-1 (4.42), CML 335 (4.57), CML 345 (4.72), and CML 337 (4.8), were more than 3.00 and less than 5.00 and were categorized as moderately resistant. The maximum damage score was recorded in the genotypes, ENT 2-3 (5.25), CML 111 (5.32), CML 334 (5.50), CML 336 (5.61), BML 7 (5.78), CML 139 (5.85), CML 338 (5.98), CM 500 (6.05), CML 144 (6.12), BML 6 (6.12), AEBY 5-34-1 (6.22), CML 330 (6.25), CM 400 (6.52), and CM 501 (6.84) and were categorized as susceptible genotypes, where the leaf damage score lies between 5.00-7.00.

Table 3: Response of various maize genotypes to *Spodoptera frugiperda* under artificial infestation.

Sr. No.	Genotypes	Leaf damage score per plant					Pooled Mean
		7 DAI	14 DAI	21 DAI	28 DAI	45 DAI	
1.	CML 335	3.25^{ab}	4.94^{bc}	5.19^{abcd}	3.69^{a}	5.79^{de}	4.57^{de}
2.	BML 6	4.54^{ghij}	5.53^{efgh}	6.47^{ghij}	6.30^{hi}	7.73^{hij}	6.12^{ij}
3.	CML 330	4.31^{fghi}	5.45^{defg}	7.61^{kl}	6.20^{ghi}	7.65^{hij}	6.25^{jk}
4.	CML 337	3.59^{abcde}	5.00^{bcd}	5.19^{abcd}	4.83^{bc}	5.41^{de}	4.80^{e}
5.	AEBY 5-34-1	4.29^{fghi}	6.17^{ij}	7.19^{jk}	6.07^{fghi}	7.36^{ghij}	6.22^{jk}
6.	CML 334	4.00^{cdefg}	5.65^{fgh}	6.05^{fghi}	5.11^{bcde}	6.69^{fg}	5.50^{fg}
7.	CML 561	3.44^{abc}	5.12^{bcde}	5.50^{cdef}	3.66^{a}	4.09^{a}	4.36^{bcd}
8.	CML 67	3.43^{abc}	4.19^{a}	4.44^{ab}	3.62^{a}	4.33^{abc}	4.00^{ab}
9.	ENT 2-3	4.10^{defgh}	5.50^{efg}	5.85^{cdef}	4.90^{bcd}	5.91^{ef}	5.25^{f}
10.	AEBY-1	3.40^{abc}	4.75^{b}	4.94^{abc}	3.94^{a}	5.05^{bcde}	4.42^{cde}
11.	CM 500	4.93^{j}	5.78^{ghi}	6.11^{fghi}	5.47^{def}	7.98^{ij}	6.05^{ij}
12.	CML 345	3.56^{abcd}	4.80^{b}	5.23^{bcde}	4.80^{b}	5.22^{cde}	4.72^{de}
13.	CML 336	4.46^{ghij}	5.19^{bcdef}	5.80^{defg}	5.45^{cdef}	7.15^{ghi}	5.61^{fgh}
14.	CML 71	3.39^{abc}	4.15^{a}	4.38^{a}	3.50^{a}	4.20^{ab}	3.93^{a}
15.	BML 7	4.17^{efgh}	5.36^{cdefg}	6.25^{fghi}	5.71^{efgh}	7.39^{ghij}	5.78^{ghi}
16.	CM 400	4.88^{ij}	6.38^{j}	6.86^{ijk}	6.60^{i}	7.90^{ij}	6.52^{kl}
17.	CML 111’	3.81^{bcdef}	5.13^{bcde}	5.52^{cdef}	5.23^{bcde}	6.90^{gh}	5.32^{f}
18.	CM 501	4.72^{hij}	5.99^{hij}	8.03l	7.30^{j}	8.15^{j}	6.84^{l}
19.	CML 338	4.24^{fgh}	5.20^{bcdef}	6.75^{hij}	6.33^{hi}	7.37^{ghij}	5.98^{hij}
20.	CML 144	4.19^{efgh}	5.60^{efgh}	6.61^{ghij}	6.16^{ghi}	8.01^{ij}	6.12^{ij}
21.	DMRE 63	3.17^{a}	4.31^{a}	4.55^{ab}	3.91^{a}	4.90^{abcd}	4.17^{abc}
22.	CML 139	4.23^{fgh}	5.59^{efgh}	6.02^{efgh}	5.65^{efg}	7.79^{hij}	5.85^{ghij}
SE.m ±		0.11	0.14	0.25	0.18	0.29	0.12
CD (p=0.05)		0.32	0.42	0.74	0.54	0.85	0.35
CV (%)		3.90	3.87	5.95	4.97	6.30	3.16

* DAI – Days after infestation

**Mean values in each column followed by a same letter do not differ significantly by DMRT (p=0.05)

DISCUSSION

Based on the above results, it was clear that the leaf damage begins to increase from 7 days after infestation (V_4 leaf stage), and the most susceptible plant stage was 21 days after infestation (V_6 leaf stage), when plants were more succulent and the larval stage progresses. Then it declined gradually at the V_8 stage. This suggested that there might be a significant relationship between the number of larvae surviving on plants and the amount of leaf damage caused. The present findings were in accordance with Wiseman *et al*. (1981), who reported that more larvae survived during the V_5 and V_{10} leaf stages. The less severe damage in moderately resistant genotypes might be attributable to either antixenosis or antibiosis mechanisms.

The leaf damage caused by fall armyworm was evaluated based on modified Davis scale of 1 to 9 and it revealed a vast range of differences among the genotypes screened in the present study. A total of fourteen genotypes were found to have recorded the leaf damage score of above 5.00, namely, ENT 2-3 (5.25), CML 111 (5.32), CML 334 (5.50), CML 336 (5.61), BML 7 (5.78), CML 139 (5.85), CML 338 (5.98), CM 500 (6.05), CML 144 (6.12), BML 6 (6.12), AEBY 5-34-1 (6.22), CML 330 (6.25), CM 400 (6.52), and CM 501 (6.84), which were classified as susceptible genotypes (Table 4). The lack of growth-inhibiting mechanisms could be the reason for the higher leaf damage in these genotypes.

Table 4: Classification of maize genotypes against fall armyworm on the basis of leaf damage score according to modified Davis and Williams scale (1-9 scale).

Sr. No.	Genotypes	Davis Scale	Categorization	Number of Genotypes
1.	Nil	1-2	Highly resistant	0
2.	Nil	>2-3	Resistant	0
3.	CML 71, CML 67, DMRE 63, CML 561, AEBY-1, CML 335, CML 345, CML 337	>3-5	Moderately resistant	8
4.	ENT 2-3, CML 111, CML 334, CML 336, BML 7, CML 139, CML 338, CM 500, BML 6, CML 144, AEBY 5-34-1, CML 330, CM 400, CM 501	>5-7	Susceptible	14
5.	Nil	>7-9	Highly susceptible	0

Rasool *et al*. (2017) reported similar results, registering the least leaf damage scores of 0.93 and 0.83 for the highly resistant genotypes, CM-133 and CM-123, respectively, and the maximum damage score of 8.86 for the highly susceptible genotype, Basi-local, against *Chilo partellus* in maize at 40 days after planting. The present results were also in accordance with the earlier reports of Soujanya *et al*. (2019) in which maize genotypes were screened under artificial infestation against *C. partellus.* The results revealed that the lowest leaf damage score of 2.7 was observed in the maize genotype DMRE63 and was identified as resistant genotype.

The present findings were in line with the results of Darshan (2020), who reported that resistant cultivars PMH 2244, NK 6801, and CP 818 obtained significantly higher leaf damage scores of 1.30, 1.80, and 1.95 at the V_6 leaf stage as compared to the leaf damage scores of PMH 2244 (0.20), NK 6801 (0.4), and CP 818 (0.5) at the V_8 stage. Similar results were also reported by Paul and Deole (2020) when they screened maize genotypes against fall armyworm. The genotype DKC-9190 had the lowest leaf damage score of 2.36, indicating that it was resistant, while the NK-30 had the highest leaf damage score of 8.21, indicating that it was highly susceptible. The current findings were also comparable with the results of Somashekar (2020), who found that partially resistant hybrids LG 36607, P3550, Tata Dhanya, and S 6668 had significantly higher leaf damage scores of 3.38, 3.66, 3.80, and 7.13 at V_6 leaf stage when compared to leaf damage scores of LG 36607 (2.60), P3550 (3.28), Tata Dhanya (2.93), and S 6668 (4.33) at V_8 stage.

Matova *et al*. (2022) also confirmed that the maximum fall armyworm foliar damage was observed four weeks after crop emergence (*i.e*., at V_6 whorl leaf stage). Where, the Davis score for genotype CML543/CML334 was 6.43 at four weeks after crop emergence and decreased to 5.70 after eight weeks of crop emergence.

CONCLUSION

The present study concludes that the most susceptible stage to fall armyworm infestation was found to be at V_6 whorl leaf stage. Among the 22 genotypes screened, eight genotypes, *viz*., CML 71, CML 67, DMRE 63, CML 561, AEBY-1, CML 335, CML 345, and CML 337, were found to be moderately resistant (Table 4). The remaining 14 genotypes, namely, ENT 2-3, CML 111, CML 334, CML 336, BML 7, CML 139, CML 338, CM 500, CML 144, BML 6, AEBY 5-34-1, CML 330, CM 400, and CM 501, emerged as susceptible to fall armyworm. Relying on a single season experiment, it is difficult to ascertain that CML 71, CML 67, DMRE 63, CML 561, AEBY-1, CML 335, CML 345, and CML 337 were moderately resistant. To validate resistance in these maize genotypes, three to four seasons of multi-location trials (MRTs), are required to confirm the resistance behaviour of the genotypes identified in the present study.

FUTURE SCOPE

These maize genotypes (moderately resistant) could be utilized in developing resistant/tolerant cultivars of maize to fall armyworm. The adoption of superior resistant maize cultivars reduces the number of insecticide applications, in-turn reducing the cost of cultivation. The inclusion of resistant cultivars in integrated pest management serves as a sustainable management approach by maintaining ecological and human health.

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