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Screening of maize cultivars/genotypes for resistance against fall armyworm, *Spodoptera frugiperda* (J.E. Smith)

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Abstract
The field experiment was conducted at Main Maize Research Station, Anand Agricultural University, Godhra during *kharif* 2019 & 2020 and Entomology farm, Department of Entomology, BACA, AAU, Anand during *kharif* 2020 to screen the maize hybrids, inbred lines, composite varieties, sweet corn and pop corn hybrids for resistance against fall armyworm, *Spodoptera frugiperda* (J. E. Smith). During the period of investigation, 09 hybrid maize cultivars (GAYMH 1, GAYMH 3, GYH 1603, GYH 1703, GWH 1257, GWH 1005, GWH 1604, GWH 1704 and GAWMH 2), 09 inbred lines (yellow maize-HO7R-4-3, LM-13-2, I-07-63-18-5, I-07-63-36-2 and white maize-CML 176, IL-15-52, 40527, CML 260, IL-15-50), 02 composite varieties (white maize- GM 6, NARMADA MOTI), 03 sweet corn hybrids (yellow maize- GSCH 0918, GSCH 1601, GSCH 0915) and 01 pop corn hybrid (yellow maize- IGPHC 1603) were evaluated based on the leaf damage rating scale (1-9). Among all the maize cultivars evaluated, significantly the lowest leaf damage rating scale was observed in hybrid maize cultivars *viz*., GAYMH 3, GAYMH 1 and GAWMH 2 as well as composite varieties *viz*., NARMADA MOTI and GM 6 and proved as resistant cultivars, whereas the highest leaf damage rating scale was observed in sweet corn hybrid GSCH 0918 and found susceptible under natural condition.

Keywords: Fall armyworm, *Spodoptera frugiperda*, maize cultivars, screening, resistance

Introduction
Maize (*Zea mays* L.) is the most adaptable crop having wider acceptability under varied agro-climatic conditions. Universally, maize is known as "Queen of cereals" because of its high genetic yield potential among the cereals and third important cereal crops next to wheat and rice in the world (Kumar *et al*, 2020) [8]. It is a high yielding crop of considerable commercial and industrial value, as many goods are made from its grains. However, maize production is generally hampered by abiotic and biotic stresses such as insect pests, diseases, soil nutrients and unstable temperatures (Tefera *et al*, 2011) [17]. Regarding the insect- pests, over 40 species were recorded as pests which attacked maize crop in different growth stages and four species of moth group including cutworms, stem borers, earworms and army worms were considered as the major pests which caused serious damage to maize worldwide (Capinera 2000) [3].

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: *Noctuidae*) is a polyphagous pest, native to tropical and sub tropical regions of the United States causing a huge infestation throughout the Southeast and along the Atlantic coast during 1970. In recent years, *S. frugiperda* has been reported its first detection in Southern India during 2016 (Anonymous, 2018) [2]. In Gujarat, It was also reported from Anklav village of Anand district of Gujarat (Sisodiya *et al*., 2018) [15]. FAW larvae cause damage to the plant by consuming foliage. Young larvae mainly feed on epidermal leaf tissue and also make holes in leaves, which is the typical damage symptom of FAW. In older plants, the larger larvae can feed on maize cob or kernels, reducing yield and quality (Abrahams *et al*., 2017) [1]. Damage due to this pest attack can reduce corn grain yield up to 34 per cent reported from Brazil (Lima *et al*., 2009) [9], 20 to 50 per cent as reported from Africa (Early *et al*., 2018) [6] and has also caused huge yield losses in India during recent years. According to Hruska and Gould (1997) [7], infestation during the mid to late corn stage resulted in yield losses of 15-73%, when 55-100% of the plants were infested with *S. frugiperda*. For the development of an adequate management strategy with minimum pesticide use, requires basic knowledge on resistant of insect-pests.

To manage this pest, farmers are using a range of management tactics, including host plant resistance, insecticide applications and biological control (Cisneros *et al*., 2002) [4].

Host plant resistance is an important component of integrated pest management (Mihm, 1997) [10], thus finding any maize cultivars that are FAW resistant could be a key aspect for developing sustainable strategies to control this voracious insect and minimize yield losses in a context of low input agriculture in developing countries (Mihm *et al*., 1988) [11]. Screening for FAW resistant maize germplasm has been carried out comprehensively by Wiseman *et al*., 1966; Widstrom *et al*., 1972 and Smith 1982 [16]. FAW larval feeding and plant damage vary depending on maize cultivars [19].

Nature of damage and behaviour of this pest makes it very difficult to control by conventional insecticides and biological control agents. Thus, there is a need to develop alternative management strategies. Keeping in view the above facts, the study was conducted on 24 cultivars of maize with an objective to find out resistant cultivar against fall armyworm.

Materials and Methods

The field experiment has been carried out at two locations *viz*., Main Maize Research Station, Anand Agricultural University, Godhra during *Kharif* 2019 & 2020 and Entomology farm, Department of Entomology, BACA, AAU, Anand during *kharif* 2020. Out of twenty four maize inbred lines/cultivars, 09 hybrid maize cultivars (GAYMH 1, GAYMH 3, GYH 1603, GYH 1703, GWH 1257, GWH 1005, GWH 1604, GWH 1704 and GAWMH 2), 09 inbred lines (yellow maize-HO7R-4-3, LM-13-2, I-07-63-18-5, I-07-63-36-2 and white maize-CML 176, IL-15-52, 40527, CML 260, IL-15-50), 02 composite varieties (white maize- GM 6, NARMADA MOTI), 03 sweet corn hybrids (yellow maize-GSCH 0918, GSCH 1601, GSCH 0915) and 01 pop corn hybrid (yellow maize- IGPHC 1603) were evaluated for resistance against fall armyworm, *S. frugiperda* in Randomized Block Design with two replications. Each of maize inbred lines/ cultivars has been sown in two rows of 5 m length with spacing of 60 X 20 cm by following all standard agronomical practices except plant protection. Observations on fall armyworm were recorded at 15, 30 and 45 days after sowing from ten randomly selected plants. The fall armyworm infestation in different maize cultivars was recorded based on leaf damage. A numerical scale (1-9), also known as the Davis scale was used to evaluate leaf damage (Davis and williams, 1992) [5] [Table 1].

Table 1: Scale for assessment of foliar damage due to FAW in maize

Score	Character	Rating
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 mid-sized uniform to moderately resistant 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 Highly susceptible damage	Highly susceptible

Results and Discussion

The results on leaf damage (scale:1-9) by *S. frugiperda* during *kharif*, 2019, 2020 and pooled over years at Godhra are presented in Table 2. Among twenty four maize inbred lines /cultivars, H07R-4-3 (2.89), GAYMH 3 (2.96), GAYMH 1 (3.03), 40527 (3.34) and GWH 1704 (3.42) found resistant against fall armyworm. The descending order of mean leaf damage rating scale in the category of moderately resistant were IL-52-52 (5.40) > GWH 1005 (5.16) > NARMADA MOTI (5.12) > GM 6 (4.93) > GWH 1257 (4.88) > GYH 1703 (4.79) > IGPHC 1603 (4.74) > I-07-63-36-2 (4.43) > IL-15-50 (4.34) > GSCH 1601 (3.99) > GSCH 0915 (3.78) > CML 176 (3.74) > GAWMH 2 (3.66) > CML 260 (3.62) > GWH 1604 (3.54). The descending order of mean leaf damage rating scale in the category of susceptible were GSCH 0918 (6.47) > I-07-63-18-5 (6.00) > LM 13-2 (5.90) > GYH 1603 (5.55).

During *kharif* 2020, maize inbred lines/ cultivars GAYMH 3 (1.90), GAYMH 1 (2.22), NARMADA MOTI (2.42), GAWMH 2 (2.53) and GM 6 (2.74) found resistant against fall armyworm among twenty four maize inbred lines/cultivars evaluated (Table 2). The maize cultivars in which mean leaf damage rating scale ranged between 3.62 - 5.16, categorized as moderately resistant. H07R-4-3 (5.75) categorized as susceptible cultivar.

The results on pooled over periods of Godhra during *kharif* 2019 and *kharif* 2020 presented in Table 2 revealed that among all inbred lines/cultivars screened for its resistance against FAW based on leaf damage rating scale; maize inbred lines/cultivars GAYMH 3 (2.39), GAYMH 1 (2.60) and GAWMH 2 (3.07) found resistant (Table 2). The maize inbred lines/ cultivars in which mean leaf damage rating scale ranged between 3.62 - 5.36, categorized as moderately resistant. GSCH 0918 (5.80) categorized as susceptible cultivar.

The results on leaf damage by *S. frugiperda* during *kharif*, 2020 at Anand are presented Table 3. Among twenty four maize inbred lines/cultivars, GAYMH 3 (1.90), GAYMH 1 (2.42), GAWMH 2 (2.63), NARMADA MOTI (2.78), GM 6 (2.81), GWH 1005 (3.22) and CML 260 (3.50) found resistant against fall armyworm. The maize inbred lines/ cultivars in which mean leaf damage rating scale ranged between 3.54 -

5.31, categorized as moderately resistant. GSCH 0918 (5.60) categorized as susceptible cultivar.

The results on leaf damage by *S. frugiperda* pooled over locations over years are presented in table 3. Maize cultivars GAYMH 3 (2.23), GAYMH 1 (2.55), GAWMH 2 (2.92), NARMADA MOTI (3.35) and GM 6 (3.43) found resistant against fall armyworm among twenty four maize inbred lines/cultivars evaluated. The descending order of mean leaf damage rating scale in the category of moderately resistant was I-07-63-18-5 (5.28) > GYH 1603 (4.98) > LM 13-2 (4.82) > GYH 1703 (4.82) > IL-52-52 (4.71) > GSCH 1601 (1601) > I-07-63-36-2 (4.59) > GSCH 0915 (4.50) > IGPHC 1603 (4.47) > 40527 (4.28) > CML 176 (4.25) > IL-15-50 (4.18) > H07R-4-3 (4.14) > GWH 1704 (4.07) > GWH 1257 (3.99) > GWH 1005 (3.97) > GWH 1604 (3.76) > CML 260 (3.59). Among all the evaluated maize inbred lines/cultivars, the maximum leaf damage rating scale was observed in GSCH 0918 (5.73) which is categorized as susceptible.

Table 2: Damage caused by fall army worm, *S. frugiperda* on different maize inbred lines /cultivars during *kharif*, 2019, 2020 and pooled over years (Godhra)

Tr. No.	Cultivars	Leaf damage scale (1-9)					
		Godhra-2019	Reaction	Godhra-2020	Reaction	Pooled	Reaction
1	GAYMH-1	1.88 (3.03)	R	1.65 (2.22)	R	1.76 (2.60)	R
2	GAYMH-3	1.86 (2.96)	R	1.55 (1.90)	R	1.70 (2.39)	R
3	HO7R-4-3	1.84 (2.89)	R	2.50 (5.75)	S	2.17 (4.21)	MR
4	LM-13-2	2.53 (5.90)	S	2.20 (4.34)	MR	2.36 (5.07)	MR
5	I-07-63-18-5	2.55 (6.00)	S	2.30 (4.79)	MR	2.42 (5.36)	MR
6	I-07-63-36-2	2.22 (4.43)	MR	2.25 (4.56)	MR	2.24 (4.52)	MR
7	GYH-1603	2.46 (5.55)	S	2.19 (4.30)	MR	2.32 (4.88)	MR
8	GYH-1703	2.30 (4.79)	MR	2.21 (4.38)	MR	2.25 (4.56)	MR
9	GSCH-0918	2.64l (6.47)	S	2.38 (5.16)	MR	2.51 (5.80)	S
10	IGPHC-1603	2.29 (4.74)	MR	2.22 (4.43)	MR	2.25 (4.56)	MR
11	GSCH-1601	2.12 (3.99)	MR	2.32 (4.88)	MR	2.22 (4.43)	MR
12	GSCH-0915	2.07 (3.78)	MR	2.34 (4.98)	MR	2.20 (4.34)	MR
13	CML-176	2.06 (3.74)	MR	2.26 (4.61)	MR	2.16 (4.17)	MR
14	IL-15-52	2.43 (5.40)	MR	2.22 (4.43)	MR	2.32 (4.88)	MR
15	40527	1.96 (3.34)	R	2.32 (4.88)	MR	2.14 (4.08)	MR
16	CML-260	2.03 (3.62)	MR	2.04 (3.66)	MR	2.03 (3.62)	MR
17	GWH-1257	2.32 (4.88)	MR	2.03 (3.62)	MR	2.17 (4.21)	MR
18	GWH-1005	2.38 (5.16)	MR	2.03 (3.62)	MR	2.21 (4.38)	MR
19	GWH-1604	2.01 (3.54)	MR	2.12 (3.99)	MR	2.06 (3.74)	MR
20	GWH-1704	1.98 (3.42)	R	2.19 (4.30)	MR	2.09 (3.87)	MR
21	GAWMH-2	2.04 (3.66)	MR	1.74 (2.53)	R	1.89 (3.07)	R
22	IL-15-50	2.20 (4.34)	MR	2.16 (4.17)	MR	2.18(4.25)	MR
23	GM-6	2.33 (4.93)	MR	1.80 (2.74)	R	2.06 (3.74)	MR
24	NARMADA MOTI	2.37 (5.12)	MR	1.71 (2.42)	R	2.04 (3.66)	MR
S.Em.±	Treatment (T)	0.07	-	0.09	-	0.15	-
	Year (Y)	-	-	-	-	0.018	-
	Period (P)	0.02	-	0.03	-	0.038	-
	Y x P	-	-	-	-	0.030	-
	Y x T	-	-	-	-	0.086	-
	T x P	0.13	-	0.16	-	0.105	-
	Y x P x T	--	-	-	-	0.149	-
C. D. at 5%		0.21	-	0.26	-	NS	-
C.V. %		8.55	-	10.84	-	9.72	-

Note: 1. Figures in parenthesis are retransformed values; those outside are Vx+0.5 transformed values.
2. Significant parameters and its interactions: Y, P, Y X P, Y X T
3. DAS: Days after Sowing

Table 3: Damage caused by fall army worm, spodoptera frugiperda on different maize inbred lines/ cultivars during kharif, 2020 at Anand and pooled over locations over years

Tr. No.	Cultivars	Leaf damage scale (1-9)				Reaction
		Godhra, 2019	Godhra, 2020	Anand, 2020	Pooled	
1	GAYMH-1	1.88 (3.03)	1.65 (2.22)	1.71 (2.42)	1.75 (2.55)	R
2	GAYMH-3	1.86(2.96)	1.55 (1.90)	1.55 (1.90)	1.65 (2.23)	R
3	HO7R-4-3	1.84 (2.89)	2.50 (5.75)	2.12 (3.99)	2.15 (4.14)	MR
4	LM-13-2	2.53 (5.90)	2.20 (4.34)	2.19 (4.30)	2.31 (4.82)	MR
5	I-07-63-18-5	2.55 (6.00)	2.30 (4.79)	2.36 (5.07)	2.40 (5.28)	MR
6	I-07-63-36-2	2.22 (4.43)	2.25 (4.56)	2.30 (4.79)	2.26 (4.59)	MR
7	GYH-1603	2.46 (5.55)	2.19 (4.30)	2.37 (5.12)	2.34 (4.98)	MR
8	GYH-1703	2.30 (4.79)	2.21 (4.38)	2.41 (5.31)	2.31 (4.82)	MR
9	GSCH-0918	2.64 (6.47)	2.38 (5.16)	2.47 (5.60)	2.50 (5.73)	S

10	IGPHC-1603	2.29 (4.74)	2.22 (4.43)	2.18 (4.25)	2.23 (4.47)	MR
11	GSCH-1601	2.12 (3.99)	2.32 (4.88)	2.36 (5.07)	2.27 (4.64)	MR
12	GSCH-0915	2.07 (3.78)	2.34 (4.98)	2.30 (4.79)	2.24 (4.50)	MR
13	CML-176	2.06 (3.74)	2.26 (4.61)	2.22 (4.43)	2.18 (4.25)	MR
14	IL-15-52	2.43 (5.40)	2.22 (4.43)	2.20 (4.34)	2.28 (4.71)	MR
15	40527	1.96 (3.34)	2.32 (4.88)	2.28 (4.70)	2.19 (4.28)	MR
16	CML-260	2.03 (3.62)	2.04 (3.66)	2.00 (3.50)	2.02 (3.59)	MR
17	GWH-1257	2.32 (4.88)	2.03 (3.62)	2.01 (3.54)	2.12 (3.99)	MR
18	GWH-1005	2.38 (5.16)	2.03 (3.62)	1.93 (3.22)	2.11 (3.97)	MR
19	GWH-1604	2.01 (3.54)	2.12 (3.99)	2.06 (3.74)	2.06 (3.76)	MR
20	GWH-1704	1.98 (3.42)	2.19 (4.30)	2.24 (4.52)	2.14 (4.07)	MR
21	GAWMH-2	2.04 (3.66)	1.74 (2.53)	1.77 (2.63)	1.85 (2.92)	R
22	IL-15-50	2.20 (4.34)	2.16 (4.17)	2.13 (4.04)	2.16 (4.18)	MR
23	GM-6	2.33 (4.93)	1.80 (2.74)	1.82 (2.81)	1.98 (3.43)	R
24	NARMADA MOTI	2.37 (5.12)	1.71 (2.42)	1.81 (2.78)	1.96 (3.35)	R
S.Em.±	Treatment (T)	0.07	0.09	0.10	0.09	-
	Location(L)	-	-	-	0.01	-
	Period (P)	0.02	0.03	0.03	0.03	-
	L x P	-	-	-	0.03	-
	L x T	-	-	-	0.09	-
	T x P	0.13	0.16	0.17	0.09	-
	L x P x T	-	-	-	0.15	-
C. D. at 5%		0.21	0.26	0.28	0.27	-
C.V. %		8.55	10.84	11.75	10.42	-

Note: 1. Figures in parenthesis are retransformed values; those outside are Vx+0.5 transformed values.
2. Significant parameters and its interactions: Y, P, Y X P
3. DAS: Days after Sowing

Screening for FAW resistant maize germplasm has been carried out comprehensively by Wiseman *et al*., 1967; Widstrom *et al*., 1972 and Smith (1982) [18]. Ni *et al.* (2008) [14] at Florida reported that fall armyworm resistance at the seedling stage was examined in 6 corn inbred lines, including 4 CIMMYT maize inbred lines (CML333, CML335, CML 336, and CML338) and fall armyworm-resistant Mp708 and susceptible AB24E. Xinzhi *et al.* (2010) [20] at Florida reported that based on cluster analysis of *S. frugiperda* injury rating, 'Mp708' and 'FAW7061' were the most resistant one, whereas 'Ab24E' and 'EPM6' were most susceptible to fall armyworm feeding. Ni *et al.* (2011) [12] at Florida evaluated on 2 newly-developed partial corn germplasm inbred lines, namely "FAW7061" and "FAW7111" derived from a previously released population, "GTFAWCC (C5)", were resistant to the feeding by *S. frugiperda* as to compared with the resistant Mp708 and the susceptible control "Ab24E" while FAW7061', they had lower *S. frugiperda* lesion than "FAW7111".

As per the Paul and Deole (2020) [14], out of 25 maize genotypes, DKC-9190 (2.36) genotype recorded minimum leaf damage where, genotype NK-30 (8.21) recorded maximum leaf damage. Heera-1122 (1.91) genotype recorded minimum ear damage. Whereas,NMH-707 (5.91) genotype recorded with maximum ear damage on the crop at Raipur (Chhattisgadh). Among the twenty five cultivars NMH-707 (1.59) genotype recorded minimum kernel damage while, LG-34.06 (4.31) genotype recorded with maximum kernel damage.

Conclusion

Based on the above findings, out of 24 maize inbred lines/cultivars evaluated, hybrid maize cultivars *viz*., GAYMH 3, GAYMH 1 and GAWMH 2 as well as composite varieties *viz*., NARMADA MOTI and GM 6 found resistant against fall armyworm whereas, sweet corn hybrid GSCH-0918 found susceptible under natural condition. Approaches like host plant resistance are not only easily disseminated and readily adopted by farmers due to their visible benefits but also require fewer applications of insecticides than the FAW susceptible cultivars. Hence, these cultivars can be further used in breeding programmes for its advance researches.

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All authors agree to publish the paper in Journal of The Pharma Innovation Journal

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