# Evaluation of XL370A-Derived Maize Germplasm for Resistance to Leaf Feeding by Fall Armyworm[1]

Craig A. Abel[2], Brad S. Coates[2], Mark Millard[3], W. Paul Williams[4], and M. Paul Scott[2]

**Abstract.** The fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), is an economically important insect with larvae damaging maize (*Zea mays* L.) leaves and ear tissue. The pest has become resistant to several classes of insecticide and Bt-maize grown in some geographical areas. Once discovered and characterized, native sources of maize resistance to this pest could be effectively integrated with existing control tactics. The objective for this study was to test experimental lines derived from maize germplasm XL370A for resistance to leaf feeding by fall armyworm. Plants were grown in the field in 2018 and 2019, artificially infested with fall armyworm, and leaf damage scores recorded. Average 14-day scores for experimental maize lines GEMN-0095 (5.8), GEMN-0096 (5.7), and GEMN-0133 (5.6) were moderately resistant and 7- and 14-day scores for these entries were not significantly different across both years. Cuba 94 was not significantly different from the three entries with the exception of having greater 7-day damage scores in 2019. GEMN-0048 was not resistant but variability was observed in 14-day scores between 4 (resistant) and 8 (susceptible) in individual plants. The experimental lines are adapted for growth in temperate regions and might provide maize breeding programs with useful levels of resistance to fall armyworm.

## Introduction

The fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), reduces maize (*Zea mays* L.) yield potential primarily by damaging leaf and ear tissue (Marenco et al. 1992, Capinera 1999). Timing insecticide applications is difficult and must be done before larvae move to and feed in protected areas of the maize whorl or ear. The pest is resistant to several classes of insecticide (Yu et al. 2003). Additionally, although transgenic maize expressing delta-endotoxins from *Bacillus thuringiensis* Berliner (Bt) provides some level of control, the fall armyworm developed resistance to Bt-Cry1Ab-maize in Brazil (Omoto et al. 2016), and Bt-Cry1F-maize in Brazil (Farias et al. 2014), Puerto Rico (Storer et al. 2010), and the southeastern United States (Huang et al. 2014).

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[1]Lepidoptera: Noctuidae

[2]USDA, Agricultural Research Service, Corn Insects and Crop Genetics Research Unit, Iowa State University, Ames, IA 50011
[3]USDA, Agricultural Research Service, North Central Regional Plant Introduction Station, Iowa State University, Ames, IA 50011
[4]USDA, Agricultural Research Service, Corn Host Plant Resistance Research Unit, Mississippi State, MS 39762.

Native sources of resistance to the pest could be used by maize breeders to enhance current control efforts. A series of 'Mp__' inbred lines were developed in Mississippi that use maize germplasm from Antigua (CIMMYT, El Batan, Mexico) as the resistant donor (Williams and Davis 1997, Mohan et al. 2006, Womack et al. 2018). Two inbred lines, 'FAW7061' and 'FAW7111' (Ni et al. 2000), derived from population GT-FAWCC(C5) (Wiseman et al. 1996), were developed for resistance to leaf feeding by fall armyworm, with 'FAW7061' as resistant as check 'Mp708' (Williams et al. 1990). The fall armyworm readily adapts to new control tactics so additional sources of maize resistant to the pest are needed.

The USDA-ARS Germplasm Enhancement of Maize Project (GEM) is a cooperative effort to facilitate the introduction of exotic maize germplasm into U.S. breeding programs. A project funded by the USDA-NIFA Organic Agriculture Research and Extension Initiative used GEM germplasm to develop breeding lines with yield potential for organic maize producers. While growing the breeding lines at an organic-certified maize nursery at Lajas, Puerto Rico during 2015 and 2016, several lines were observed to show less feeding damage under heavy natural infestation by fall armyworm. One of the experimental lines was derived from XL370A. XL370A was a hybrid developed in Brazil in 1991 and donated (Eaton D., Dekalb-Pfizer Genetics) to the U.S. National Plant Germplasm System (NPGS) in 1996. The donated seed was assigned an accession number (Ames 23671) and used by the GEM project and others for maize improvement, including advancements in yield potential (Balint-Kurti et al. 2006). The objective for this study was to test XL370A derived-maize germplasm for resistance to leaf feeding by fall armyworm.

## Materials and Methods

The terms "maize" and "XL370" were used on 9 January 2018 to search the USDA-ARS GRIN-Global database, and 13 germplasm accessions (Table 1, entry rows 2-14) had available seed. At the time of this study, XL370A (Ames 23671), was not available for distribution and was not evaluated. Inbred line B97 was selected as a susceptible check (Abel et al. 2000), and 'Mp708' was selected as a resistant check (Williams et al. 1990). Cuba 94 was selected for testing based on field observations while grown in a winter nursery in Puerto Rico. All the test entries are cultivars that are partially inbred with the exception of the very inbred cultivar GEMN-0186 and the Cuba 94 landrace population. On 10 May 2018 and 16 May 2019, maize entries were planted in single-row plots (4.6 x 1 m, 24 seeds per row) in Nicollet clay loam soil at the Agricultural Engineering/Agronomy and Central Iowa Research Farms (Boone, IA), receiving fertilizer pre-plant based on soil tests and a maize yield goal of 12.5 tons per hectare of grain. The experimental design was a randomized complete block with genotypes as treatments and four replications blocked to control field variation.

Fall armyworm eggs were acquired from the Corn Host Plant Resistance Research Unit, USDA-ARS, Mississippi State, MS. The colony was maintained on wheat germ-casein based diet, and wild adults were added to the colony annually to maintain genetic diversity and colony vigor. The fall armyworm eggs were kept at 25 ± 0.4ºC, 75 ± 10% relative humidity, and a photoperiod of 14:10 light:dark hours until eclosion in a laboratory. After eclosion, the neonates were added to sterilized corn-cob grits and calibrated so one inoculator "shot" of corn-cob grits contained 15 ± 5 neonates. For the 2018 study, one calibrated shot was added to each V6-V7 stage maize whorl (Benson and Reetz 1985) on 26 July, and two shots were added to each maize whorl the following day for a total of approximately 45 neonates per plant. For the 2019 study, one calibrated shot was added to each V6-V7 stage maize whorl on 26 June and another shot on 27 June for a total of 30 neonates. The infestation technique is fully described by Davis et al. (1996). At 7 and 14 days, a scale of 0 (no damage) to 9 (extensive damage) was used to visually rate the plants for leaf-feeding damage by fall armyworm (Davis et al. 1992). At 7 days, each row was given an overall score. At 14 days in 2018, each row as given an overall score. At 14 days in 2019, the first 10 plants in each row were scored individually and the scores were averaged per row and used in the analysis. Data were analyzed by PROC GLIMMIX, and means were separated using LSD at $P \leq 0.05$ (SAS Institute 2011).

Table 1. Fall Armyworm Leaf-Feeding Damage Scores at 7 and 14 Days Post Infestation of 16 Maize Genotypes at Ames, IA, 2018 and 2019

| | 2018 | | 2019 | |
|---|---|---|---|---|
| Genotype | FAW 7 days | FAW 14 days | FAW 7 days | FAW 14 days |
| Cuba 94 | 5.5 ± 0.4de | 6.0 ± 0.4d | 5.0 ± 0.3ef | 5.6 ± 0.3h |
| GEMN-0048 | 6.0 ± 0.4cde | 6.8 ± 0.4c | 5.1 ± 0.3def | 6.3 ± 0.3efg |
| GEMN-0077 | 6.3 ± 0.4bcd | 7.3 ± 0.4bc | 5.8 ± 0.3ab | 7.2 ± 0.3abc |
| GEMN-0094 | 6.8 ± 0.4abc | 7.5 ± 0.4ab | 5.1 ± 0.3def | 7.0 ± 0.3bcd |
| GEMN-0095 | 5.3 ± 0.4e | 5.8 ± 0.4d | 4.0 ± 0.3g | 5.7 ± 0.3gh |
| GEMN-0096 | 5.3 ± 0.4e | 5.8 ± 0.4d | 4.5 ± 0.3fg | 5.6 ± 0.4h |
| GEMN-0128 | 7.3 ± 0.4a | 7.8 ± 0.4ab | 5.9 ± 0.3a | 7.8 ± 0.3a |
| GEMN-0129 | 7.5 ± 0.4a | 8.0 ± 0.4a | 5.7 ± 0.3abcd | 7.7 ± 0.3a |
| GEMN-0130 | 7.0 ± 0.4ab | 7.8 ± 0.4ab | 5.2 ± 0.3bcde | 6.8 ± 0.3cde |
| GEMN-0131 | 7.3 ± 0.4a | 8.0 ± 0.4a | 6.1 ± 0.3a | 7.8 ± 0.3a |
| GEMN-0132 | 7.3 ± 0.4a | 7.8 ± 0.4ab | 5.5 ± 0.3abcde | 7.2 ± 0.3abc |
| GEMN-0133 | 5.8 ± 0.4de | 5.5 ± 0.4d | 4.2 ± 0.3g | 5.8 ± 0.3fgh |
| GEMN-0186 | 6.0 ± 0.4cde | 7.5 ± 0.4ab | 5.0 ± 0.3ef | 6.5 ± 0.3de |
| GEMS-0237 | 6.8 ± 0.4abc | 7.3 ± 0.4bc | 5.7 ± 0.3abc | 7.7 ± 0.3ab |
| B97 | 5.8 ± 0.4de | 6.8 ± 0.4c | 5.2 ± 0.3bcde | 6.4 ± 0.3def |
| Mp708 | 3.3 ± 0.4f | 3.8 ± 0.4e | 2.7 ± 0.3h | 4.3 ± 0.3i |

Means (± SE) followed by the same letter in a column are not significantly different according to LSD $P \leq 0.05$.

## Results and Discussion

Scores of leaf-feeding damage by fall armyworm at 7 and 14 days differed significantly for the 16 maize genotypes in 2018 ($F$ = 13.02; df = 3,15; $P$ < 0.0001 and $F$ = 20.81; df = 3,15; $P$ < 0.0001, respectively) and also in 2019 ($F$ = 16.66; df = 3,15; $P$ < 0.0001 and $F$ = 19.21; df = 3,12; $P$ < 0.0001, respectively). Scores for resistant check Mp708 were significantly less than for any other genotype at 7 and 14 days (Table 1). GEMN-0128, GEMN-0129, GEMN-0131, and GEMN-0132 were susceptible, and not statistically different at 7 and 14 days across both years. GEMN-0095, GEMN-0096, and GEMN-0133 were moderately resistant to fall armyworm, and not significantly different from each other. Cuba 94 was not significantly different from GEMN-0095, GEMN-0096, or GEMN-0133, with the exception of a greater 7-day damage score in 2019.

Four of the 13 GEM lines (Table 1) were tested for resistance to fall armyworm leaf feeding in a previous study. Ni et al. (2014) compared several tropically-derived maize entries including GEMN-0128, GEMN-0130, GEMN-0131, GEMN-0132, and GEMN-0133 for resistance to fall armyworm lead feeding. In the Ni et al. study, the five genotypes were not significantly different from each other, although 7- and 14-day damage scores of GEMN-0133 were numerically less.

GEMN-0048 (Table 1) was not resistant to fall armyworm leaf feeding, but variability was observed in 14-day scores between 4 (resistant) and 8 (susceptible) in individual plants. The variability may be useful for selecting greater resistance to leaf feeding fall armyworm. The GEM entries tested in the study all were adapted to the U.S. Corn Belt, reaching the R1 stage (Benson and Reetz 1985) at Ames, IA, in late July to early August. The lines do not require adaptation for growth in temperate regions and are ready for breeding and selection for agronomic traits.

All the GEMN entries (Table 1, entry rows 2-13) shared the same original parental lines with XL370A as the female parent and N11 as the male parent. The male parental line, N11, is a proprietary non-stiff stalk, temperate, inbred line donated anonymously to the U.S. NPGS. Niether parent had seed available for testing at the time of the study. Either parent could have contributed alleles that conferred moderate resistance to fall armyworm leaf feeding in GEMN-0095, GEMN-0096, and GEMN-0133. There is some indication that the female parent, XL370A, is the primary contributor to leaf feeding resistance in this study. The indication comes from evaluation of XL370A by Wiseman (1996) who found resistance to fall armyworm was not significantly different than resistant check FAWCC(C5) at 7 days after infestation. Also, XL370A was developed in Brazil where fall armyworm is abundant. During development of XL370A in Brazil, selection for resistance to fall armyworm might have occurred. Because seed is not available for the male parental line, N11, experimental lines that used N11 as a parent could be tested in the future for fall armyworm leaf feeding to determine if N11 may be a potential contributor to fall armyworm resistance.

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