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Evaluation of Maize Germplasm from Saint Croix for Resistance to Leaf Feeding by Fall Armyworm

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Abstract

Maize (*Zea mays* L.) is a preferred host of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera:Noctuidae), with larvae primarily feeding on developing leaves and ear tissue. The fall armyworm is resistant to several classes of insecticide and Bt-maize grown in certain areas. Native sources of plant resistance to the pest are available for public use, but new sources of resistance need to be discovered and developed. The objective for this study was to test maize germplasm collected from Saint Croix, U.S. Virgin Islands, for resistance to leaf feeding by fall armyworm. Plants were grown in the field and artificially infested at a high level. Scores of damage by fall armyworm feeding on leaves at 7 and 14 days differed significantly for the 13 maize genotypes tested. Scores at 14 days for Saint Croix Group 1 (5.8), Saint Croix Group 3 (5.6), Saint Croix 2 (5.6), and Saint Croix 7 (6.0) were moderately resistant and not significantly different from one another. Individual plants in the populations were variable for resistance to leaf feeding, and scored between 4 and 7. It should be possible to select within the populations for greater resistance to damage by fall armyworms feeding on leaves.

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Evaluation of Maize Germplasm from Saint Croix for Resistance to Leaf Feeding by Fall Armyworm[1]

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Abstract. Maize (*Zea mays* L.) is a preferred host of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera:Noctuidae), with larvae primarily feeding on developing leaves and ear tissue. The fall armyworm is resistant to several classes of insecticide and Bt-maize grown in certain areas. Native sources of plant resistance to the pest are available for public use, but new sources of resistance need to be discovered and developed. The objective for this study was to test maize germplasm collected from Saint Croix, U.S. Virgin Islands, for resistance to leaf feeding by fall armyworm. Plants were grown in the field and artificially infested at a high level. Scores of damage by fall armyworm feeding on leaves at 7 and 14 days differed significantly for the 13 maize genotypes tested. Scores at 14 days for Saint Croix Group 1 (5.8), Saint Croix Group 3 (5.6), Saint Croix 2 (5.6), and Saint Croix 7 (6.0) were moderately resistant and not significantly different from one another. Individual plants in the populations were variable for resistance to leaf feeding, and scored between 4 and 7. It should be possible to select within the populations for greater resistance to damage by fall armyworms feeding on leaves.

Introduction

Maize (*Zea mays* L.) is a preferred host of the polyphagous fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera:Noctuidae), with larvae primarily feeding on developing leaves and ear tissue, reducing yield potential (Marenco et al. 1992, Capinera 1999). Economical control of the pest is challenging, and years of insecticide use have selected for resistance by fall armyworm to several classes of insecticide (Yu et al. 2003). Commercial use in the United States and Brazil of transgenic maize containing genes encoding delta-endotoxins from *Bacillus thuringiensis* Berliner (Bt) has helped with control. However, field-evolved resistance by fall armyworm to Bt-maize occurred for Cry1Ab in Brazil (Omoto et al. 2016) and Cry1F in Brazil (Farias et al. 2014), Puerto Rico (Storer et al. 2010), and the southeastern U.S. (Huang et al. 2014).

Native sources of plant resistance to the pest have been identified and made available for public use. Inbred lines were developed in Mississippi that primarily used maize germplasm Antigua Gpo. 2 (CIMMYT, El Batan, Mexico) as the resistant donor (Williams and Davis 1997). Biochemical and genetic mechanisms of resistance have been well characterized (Mohan et al. 2006, Womack et al. 2018). In addition, two inbred lines, 'FAW7061' and 'FAW7111' (Ni et al. 2000), derived from population GT-

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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). Fall armyworm adapted to new control tactics, so new sources of resistance to the pest need to be discovered and developed.

The USDA-ARS Germplasm Enhancement of Maize Project uses traits from tropical maize to improve germplasm adapted to the U.S. Corn Belt. A project funded by the USDA-NIFA Organic Agriculture Research and Extension Initiative used Germplasm Enhancement of Maize germplasm to develop breeding lines with yield potential for organic maize producers. While growing the breeding lines in an organic-certified maize nursery at Ponce, Puerto Rico, several lines were less damaged from feeding by fall armyworm under heavy natural infestations during 2015 and 2016. Two experimental lines had germplasm originally collected from Saint Croix (U.S. Virgin Islands) in their parentage. The objective for the study was to test maize germplasm from Saint Croix for resistance to leaf feeding by fall armyworm.

Materials and Methods

The terms "maize" and "Saint Croix" were used on 9 January 2018 to search the USDA-ARS GRIN-Global database, and 11 germplasm accessions (Table 1, entries 1-11) had available seed. Inbred line B97 was selected as a susceptible check from results by Abel et al. (2000), and 'Mp708' was selected as a resistant check (Williams et al. 1990). In 2018, maize entries were planted in single-row plots (4.6 x 1 m) on 10 May at the Agricultural Engineering/Agronomy and Central Iowa Research Farms (1308 U Ave., Boone, IA) on Nicollet clay loam soil, receiving fertilizer pre-plant based on soil tests and a maize yield goal of 12.5 tons per hectare of grain. Twenty-four seeds were planted per genotype per row. The experiment was a randomized complete block with genotypes as treatments and four replications blocked to control for variations in soil type and drainage in the field. A border of conventional, commercial maize hybrid surrounded the edge of the experiment.

Table 1. Scores of Leaf-Feeding Damage by Fall Armyworm at 7 and 14 Days for 13 Maize Genotypes Tested at Ames, IA, 2018

Genotype	Improvement status, uniformity	FAW 7 days	FAW 14 days
Saint Croix 1	landrace, population	4.0 ± 0.8bcd	6.2 ± 0.5bcd
Saint Croix 2	cultivated material, population	3.8 ± 0.8cd	5.6 ± 0.5e
Saint Croix 4	cultivated material, population	4.2 ± 0.8bc	6.6 ± 0.5b
Saint Croix 5	landrace, population	4.5 ± 0.8bc	6.2 ± 0.5bcd
Saint Croix 6	landrace, population	4.8 ± 0.8b	6.7 ± 0.5b
Saint Croix 7	landrace, population	3.8 ± 0.8cd	6.0 ± 0.5cde
Saint Croix 10	landrace, population	4.0 ± 0.8bcd	6.4 ± 0.5bc
Saint Croix Group 1	cultivated material, population	3.8 ± 0.8cd	5.8 ± 0.5de
Saint Croix Group 2	breeding material, population	4.8 ± 0.8b	6.2 ± 0.5bcd
Saint Croix Group 3	breeding material, population	3.2 ± 0.8d	5.6 ± 0.5e
GEMN-0059	breeding material, partial inbred	5.8 ± 0.8a	7.3 ± 0.5a
B97	FAW susceptible, very inbred	5.8 ± 0.8a	7.6 ± 0.5a
Mp708	FAW resistant, very inbred	2.3 ± 0.8e	4.1 ± 0.5f

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

Eggs of fall armyworm were acquired from the Corn Host Plant Resistance Research Unit, USDA-ARS, Mississippi State, MS. The colony is maintained on pinto bean-based diet, and wild adults were added to the colony annually to maintain 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 25 (± 5) neonates. One calibrated shot was added to each V6-V7 stage (Benson and Reetz 1985) maize whorl on 26 July, and two shots were added to each maize whorl the following day for a total of approximately 75 neonates per plant. The infestation technique was 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, the first 10 plants in each row were rated individually and the scores were averaged per row and used in the analysis. Data were analyzed by PROC GLM, and means were separated using LSD at $P \leq 0.05$ (SAS Institute 2011).

Results and Discussion

Scores of leaf-feeding damage by fall armyworm at 7 and 14 days differed significantly for the 13 maize genotypes ($F = 12.36$, df = 3,12, $P < 0.0001$; $F = 24.08$, df = 3,12, $P < 0.0001$, respectively). Resistant check Mp708 had significantly lower scores at 7 and 14 days than any other genotype (Table 1). Susceptible check B97 and GEMN-0059 had significantly greater scores than all other genotypes at 7 and 14 days. Fall armyworm ratings (± SE) at 14 days for Saint Croix Group 1 (5.8 ± 0.5de), Saint Croix Group 3 (5.6 ± 0.5e), Saint Croix 2 (5.6 ± 0.5e), and Saint Croix 7 (6.0 ± 0.5cde) were moderately resistant and not significantly different from one another. Although the genotypes were not resistant to leaf feeding by fall armyworms, plants in the populations were variable, with 14-day rating scores ranging between 4 (resistant) and 7 (susceptible). The variability might be used to select for greater resistance against leaf feeding by fall armyworms.

With the exception of GEMN-0059, all Saint Croix genotypes were tropical and not adapted to the U.S. Corn Belt region, reaching the R1 stage (Benson and Reetz 1985) at Ames, IA, in mid-late August. Several generations of backcrossing to an adapted donor parent while selecting for resistance to fall armyworm will be necessary to develop experimental lines useful for research and characterization of the trait. This will require several years of effort with the F_1 and probably the first generation of backcrossing at a winter nursery. Working with adapted maize lines with the resistance trait is necessary for continued research in the U.S. Corn Belt region.

A mission of the Germplasm Enhancement of Maize project is to increase diversity of U.S. maize germplasm by using tropical maize as source material backcrossed to U.S.-adapted recurrent parents. All available experimental lines should be reviewed for Saint Croix parentage and the lines should be evaluated for resistance to leaf feeding by fall armyworms. The lines would be adapted for growth in the U.S. and might have been selected for other useful agronomic traits (e.g., yield, resistance to disease, lodging, nutritional quality, etc.) during development. The lines might also be in different stages of advancement. If some are selfed and resistant to fall armyworm, this would aid development of mapping populations with well-characterized maize inbreds to enable identification of high-resolution candidate genes and development of tools for marker-assisted selection.

Saint Croix is in close geographic proximity (approximately 350 km) to Antigua, the source of maize germplasm Antigua Gpo. 2, that was the primary donor for resistance in the Mp__ series of inbred lines developed in Mississippi (Williams and Davis 1997). The source of resistance has been well characterized and conferred by a 33-kDa cysteine protease (Mir1-CP) that accumulates at the site of feeding and damages the peritrophic matrix of the fall armyworm midgut (Pechan et al. 2000). Resistant plants in Saint Croix Group 1, Saint Croix Group 3, Saint Croix 2, and Saint Croix 7 maize should be studied to determine if the plants are using the same mechanism of resistance or if a different or new mechanism is conferring resistance against leaf feeding by fall armyworm.

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