Kansas Agricultural Experiment Station Research Reports

Volume 5
Issue 6 *Kansas Field Research*

Article 23

2019

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Recommended Citation

Serba, D. D. and Michaud, J. P. (2019) "Sugarcane Aphid Resistance in Pearl Millet," *Kansas Agricultural Experiment Station Research Reports*: Vol. 5: Iss. 6. https://doi.org/10.4148/2378-5977.7795

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Abstract

Sugarcane aphid, (*Melanaphis sacchari* (Zehntner) (Hemiptera: Aphididae)) has become an important pest of sorghum in the US. This recent invasion is assumed to be either as a result of a host shift from sugarcane in the south or introduction of a specialized strain from tropical Africa. If host shift happened through adaptive change to infest sorghum, other closely related species such as pearl millet are in danger from this voracious pest. The resistance level of pearl millet genotypes representing A-, B-, R-lines and germplasm were evaluated under climate-controlled growth chamber along with resistant and susceptible sorghum hybrids. Ten plants of the genotypes were planted in a row in a tray per replicate. Cuttings infested with a stock colony of aphids maintained on the susceptible sorghum line were evenly distributed across the soil in each tray to ascend the plants at will. The damage was scored two times (5 and 8 days after infestation) using a scale of 1 to 9 (1 = no visible damage, 9 = dead). The statistical analysis of data found that there are significant differences among genotypes for aphid feeding damage. However, none of the pearl millet genotypes were affected to the level of susceptible sorghum. Four genotypes of pearl millet had resistance levels similar to the resistant sorghum. No statistical differences were observed among the A, B, and R-lines and the germplasm—implying that the cytoplasmic male-sterility system, nuclear restorer gene, and sterility maintainer counterparts have no impact on SCA resistance and susceptibility in pearl millet.

Keywords

pearl millet, sugarcane aphid, Melanaphis sacchari, tolerance

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Summary

Sugarcane aphid, (*Melanaphis sacchari* (Zehntner) (Hemiptera: Aphididae)) has become an important pest of sorghum in the US. This recent invasion is assumed to be either as a result of a host shift from sugarcane in the south or introduction of a specialized strain from tropical Africa. If host shift happened through adaptive change to infest sorghum, other closely related species such as pearl millet are in danger from this voracious pest. The resistance level of pearl millet genotypes representing A-, B-, R-lines and germplasm were evaluated under climate-controlled growth chamber along with resistant and susceptible sorghum hybrids. Ten plants of the genotypes were planted in a row in a tray per replicate. Cuttings infested with a stock colony of aphids maintained on the susceptible sorghum line were evenly distributed across the soil in each tray to ascend the plants at will. The damage was scored two times (5 and 8 days after infestation) using a scale of 1 to 9 (1 = no visible damage, 9 = dead). The statistical analysis of data found that there are significant differences among genotypes for aphid feeding damage. However, none of the pearl millet genotypes were affected to the level of susceptible sorghum. Four genotypes of pearl millet had resistance levels similar to the resistant sorghum. No statistical differences were observed among the A, B, and R-lines and the germplasm—implying that the cytoplasmic male-sterility system, nuclear restorer gene, and sterility maintainer counterparts have no impact on SCA resistance and susceptibility in pearl millet.

Introduction

Sugarcane aphid (SCA), (*Melanaphis sacchari* (Zehntner) (Hemiptera: Aphididae)) has been an important pest of sugarcane (*Saccharum officinarum* L.) and other graminaceous crops in many tropical and subtropical regions (Singh et al., 2004). Recently, SCA has become a serious insect pest of sorghum (*Sorghum bicolor* L.) in the US. It is not yet clear whether this recent invasion resulted from a host shift from sugarcane–which SCA has infested in Louisiana and Florida for many years–or whether it represents the arrival of a novel strain, possibly from northern Africa where it is known to occur on sorghum. A sexual aphid lineages are able to undergo rapid adaptive changes without much genetic differentiation in shifting from one host plant to another (Nibouche et al., 2015).

The sugarcane aphid feeds and reproduces on grain and forage sorghum (sudangrass, sorghum/sudan hybrids, forage sorghum, and shattercane) and Johnsongrass. The widespread occurrence of the insect and the economic losses incurred over the past four years poses a threat to grain sorghum and sorghum family forage production. There is also the potential for SCA to spread to other crops such as pearl millet, a related crop with potential importance in sorghum growing regions of the central Great Plains. Besides causing direct feeding damage on susceptible cultivars, SCA can also increase the plant's susceptibility to other aphids such as greenbug, (*Schizaphis graminum* (Rondani)) (Michaud et al., 2017) and bird cherry-oat aphid, (*Rhopalosiphum padi* L). (Bayoumy et al., 2016). This probably occurs via elicitation of higher nitrogen content in the phloem, a factor which is usually limiting for aphid growth and reproduction. Though direct feeding damage is not yet a significant problem on pearl millet, facilitation of other aphid species may cause additional problems.

Plant resistance to insects can be a cost-effective pest control method because it is based on the plant's own self-defense mechanisms. Resistance is a typically heritable plant trait that results in a plant sustaining less damage because it impedes pest feeding, growth, and reproduction. Plant resistance has economic, ecological, and environmental advantages over the application of chemicals to control insect pests. It is economical because, once implemented, no further inputs are required to protect crop yields from the pest and money is saved in comparison to susceptible varieties that require protection with insecticides. Reduced use of insecticides has ecological and environmental benefits by increasing species diversity and ecosystem stability. Therefore, host plant resistance (HPR) to insects is an effective, economical, and environment-friendly method of pest control. The most attractive feature of HPR to farmers is that no extra investment in pest control is usually required. Host plant resistance will not only assist in reducing pesticide use, it will delay the evolution of resistance to insecticides in insect populations, as well as lead to increased activity of beneficial organisms and reduction in pesticide residues in food products.

Pearl millet is being considered as an alternative crop in the drought-prone areas of the central Great Plains (CGP). It has great potential as a source of grain as well as summer grazing and cut forage. However, there is limited information as to levels of susceptibility and/or resistance to SCA in millet lines. Preliminary evaluation of hybrid pearl millet (HPM) for SCA susceptibility in Texas suggested HPM was a poor host for SCA, and could be advocated as an alternative to SCA-susceptible forage sorghums (Trostle et al., 2015). However, the level of SCA resistance in different parental backgrounds and in the germplasm was not assessed. Furthermore, any possible effects of cytoplasmic male sterility (CMS) system, nuclear restorer gene, or the sterility maintainer recessive allele remain unknown.

This study was conducted to assess the level of SCA resistance in pearl millet and assess genetic variability in SCA resistance, and to investigate if the CMS system, the nuclear restorer and maintainer counterparts affect SCA resistance or susceptibility.

Procedures

A total of 20 pearl millet genotypes were examined: five male-sterile (A-lines), five maintainer lines (B-lines), five restorer lines (R-lines), and five germplasm accessions were all randomly selected from the breeding materials available in the millet breeding program at the Kansas State University Agricultural Research Center - Hays (Table 1).

For each experimental replicate, one row of ten plants of each test genotype and two rows of each sorghum check were planted in a tray filled with a mixture of soil and commercial grow mix. The experiment was arranged in randomized complete block design with four replications and conducted in a climate-controlled growth chamber set at 20°C (68°F), a temperature selected to favor the SCA. The experiment was planted on January 23, 2017, and germinated in a growth chamber at 29°C (84°F). Plants were infested when the seedlings were at the four-leaf stage on February 12, 2017 by spreading cuttings infested with apterous aphids (obtained from a stock colony maintained on the susceptible sorghum line) evenly across the soil of each tray and allowing the aphids to ascend the plants at will. Plant damage was scored five and eight days after infestation, on February 17, 2017, and February 20, 2017, using a scale of 1 to 9 (1 = no visible damage, 9 = dead). The data were subjected to statistical analysis using SAS v. 9.4 (SAS Institute Inc., Cary, NC).

Results

The various millet genotypes showed significant differences in susceptibility to damage by SCA (Table 2). Four pearl millet genotypes were as resistant as the resistant sorghum hybrid HG35W. After the susceptible sorghum hybrid 550610 was killed by the aphids, these pearl millet genotypes and the resistant sorghum hybrid remained alive and intact (Figure 1). Damage scores for pearl millet genotypes ranged from 1.7 to 6.5 on the first scoring date and 2.3 to 7.0 in the second score. Thus, there was significant variation in resistance among pearl millet genotypes, but none were as susceptible as the susceptible check, which scored an average of 8.7 and 8.9 on the first and second scorings, respectively.

Results also indicated that there were no significant differences among the A, B, R-lines, and the germplasm in levels of resistance (Figure 2). This implies that the CMS, the nuclear restorer, and the male-sterility maintainer recessive counterpart have no impact on resistance to SCA. This is an important indication that the A1 male-sterility system has no impact on the level of SCA resistance in pearl millet, at least for the time being. However, large-scale cultivation of crop hybrids based on a single CMS source can pose a hazard to sustainable crop production because of genetic uniformity. For example, maize genotypes containing the CMS system called the Texas, or T-cytoplasm (cms-T) were once widely planted until a large fraction of the entire US corn crop was lost when the cms-T system became susceptible to southern corn leaf blight (SCLB) caused by *Helminthosporium maydis* race T (Scheifele et al., 1970). Therefore, male-sterility systems require diversification to prevent epidemics of either diseases or insect pests.

The widespread economic impact of SCA on sorghum has driven significant research, extension, and industry responses (Villanueva et al., 2014; Brewer et al., 2016; Bowling et al., 2016). Study of cross-resistance from greenbug resistance reported that genotypes resistant to different strains of greenbug were mostly resistant or moderately resistant to sugarcane aphid (Armstrong et al., 2015). Though chemical control measures are not considered desirable long-term solutions from environmental and ecological points of view, insecticides with the active ingredients sulfoxaflor and flupyradifuron provide good control of SCA in sorghum. These are currently sold under the brand names 'Transform' (Dow-Dupont) and 'Sivanto' (Bayer CropScience). Older insecticide formulations containing either organophosphates or pyrethroids are not recommended for use against SCA. Their broad-spectrum activities mean they kill beneficial natural enemies that assist in controlling SCA and can actually exacerbate the problem.

The potential ability of SCA to shift host plants warrants efforts to evaluate SCA performance and damage potential on other related crops such as pearl millet. A greenhouse no-choice experiment showed that SCA could not survive on other cereals such as maize (*Zea mays* L.), teff (*Eragrostis tef* (Zucc.)), proso millet (*Panicum miliaceum* L.), barley (*Hordeum vulgare* L.), and rye (*Secale cereale* L.) but could survive on sorghum (Armstrong et al., 2015). Therefore, a continuing evaluation of related crops for their susceptibility to SCA is imperative to develop strategies for large-scale deployment of resistance.

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Table 1. Random samples and sorghum checks used for the sugarcane aphid screening

No	A-lines	B-Lines	R-Lines	Accessions	Sorghum checks
1	KPM003A	KPM009B	KPM003R	PI 164421	HG35W (Resistant)
2	KPM011A	KPM013B	KPM007R	PI 279667	550610 (Susceptible)
3	KPM015A	KPM022B	KPM012R	PI 307711	
4	KPM021A	KPM027B	KPM019R	PI 358400	
5	KPM034A	KPM032B	KPM023R	PI 521649	

Table 2. Average damage score of pearl millet parental lines and germplasm accessions to sugarcane infestation evaluated against a resistant and a susceptible sorghum hybrids

Genotype	Score 1	Genotype	Score 2
KPM023R	1.7e	KPM023R	2.3e
KPM021A	2.0e	KPM021A	2.8de
HG35W (R)	2.9de	HG35W	3.0cde
KPM022B	3.3cde	KPM022B	4.3bcde
PI 358400	3.8bcde	PI 164421	4.5bcde
PI 164421	4.0bcde	PI 358400	4.8bcd
KPM009B	4.5bcd	KPM009B	5.0bcd
KPM007R	4.5bcd	KPM007R	5.0bcd
KPM027B	4.7bcd	KPM019R	5.3bc
KPM012R	4.8bcd	KPM027B	5.3bc
PI 521649	4.8bcd	KPM003A	5.5bc
KPM003A	4.8bcd	KPM012R	5.5bc
KPM011A	5.0bcd	KPM011A	5.5bc
KPM019R	5.3bcd	PI 521649	5.8b
KPM003R	5.3bcd	KPM003R	5.8b
PI 279667	5.5bcd	PI 279667	6.0b
KPM013B	5.8bc	PI 307711	6.5b
PI 307711	6.0bc	KPM015A	6.5b
KPM015A	6.0bc	KPM013B	6.5b
KPM034A	6.5b	KPM034A	6.8b
KPM032B	6.5b	KPM032B	7.0b
550610 (S)	8.7a	550610	8.9a

Figure 1. Partial view of the pearl millet genotypes and the resistant (sorghum-R) and susceptible sorghum (sorghum-S) checks infested with sugarcane aphid. The picture was taken on the day of final score.

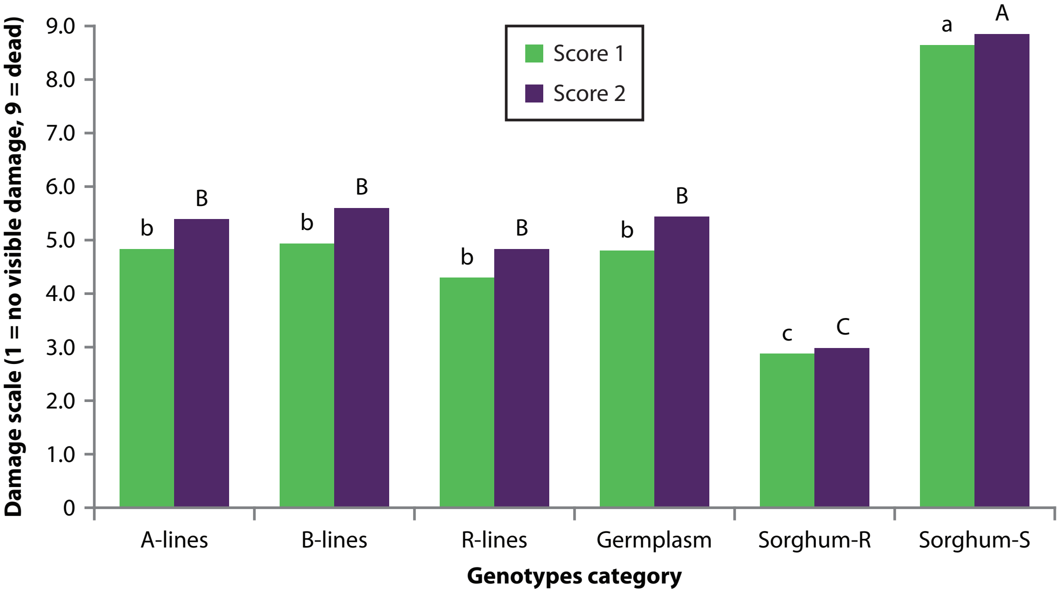

Figure 2. Average sugarcane aphid damage score on pearl millet parental lines and germplasm based on 1 to 9 damage scale. Bars labeled with the same letter (upper or lowercase) were not significantly different.