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Research Article

Melanaphis Sorghi, Colonization And Population Growth In Grain Sorghum And Johnson Grass In Oklahoma

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Abstract

Grain sorghum, *Sorghum bicolor* (L.), is an important rainfed crop in Oklahoma because it produces adequate and relatively consistent yields in the typically hot and dry Oklahoma summers. The sorghum aphid, *Melanaphis sorghi* (Theobald [13]), was first found in Oklahoma late in the 2013 sorghum growing season and by 2015 was a severe pest of sorghum throughout Oklahoma. In addition to sorghum, *M. sorghi* survives and reproduces on johnsongrass, *Sorghum halepense* (L.), an invasive grass species that grows throughout the state in field edges, along roadways, and in other disturbed habitats. This study had two objectives. First to determine if *M. sorghi* was present on johnsongrass in Oklahoma at an earlier calendar date than on sorghum. And second to determine if the population growth rate of M. sorghi differed on johnsongrass compared to sorghum. To accomplish these objectives, we sampled fields of sorghum and nearby stands of johnsongrass at locations in Oklahoma weekly to bi-weekly during the growing seasons of 2019, 2020, and 2021. *M. sorghi* was first detected on johnsongrass an average of 2.8, 8.7, and 3.4 days later than on sorghum in 2019, 2020, and 2021, respectively. *Melanaphis sorghi* population growth rate averaged over all sampling dates for each location and across locations for a particular year was greater for sorghum than for johnsongrass in each of the three years, varying from a low of four times greater in 2021 to a high of approximately 500 times greater in 2019. Population growth rate differed significantly among the two plant species ($\chi2 = 5.48$; df = 1; $P = 0.02$). Results are discussed in terms of local and landscape perspectives regarding the role of johnsongrass in the population dynamics of *M. sorghi* in grain sorghum fields in Oklahoma.

Introduction

Grain sorghum, *Sorghum bicolor* (L.), is an important grain crop in the US state of Oklahoma. Of the 21-grain sorghum producing states in the US Oklahoma usually ranks third in hectares planted. In 2022, 174,150 ha of grain sorghum were planted in Oklahoma of which 145,800 ha were harvested yielding an average of approximately 28 q/ha (USDA/NASS Quickstats, Accessed November 15, [1]). Sorghum is a critical rainfed crop in Oklahoma because it produces relatively consistent yields in the typically hot, dry, and unpredictable weather that characterizes the state during summer. The sorghum aphid, *Melanaphis sorghi* (Theobald 1904), was discovered in grain sorghum, *Sorghum bicolor* L., in the states of Louisiana and Texas in 2013. *Melanaphis sorghi* was initially thought to be the closely related sugarcane aphid *Melanaphis sacchari* (Zehntner) but was recently determined by genetic and morphometric analysis to be *M. sorghi* (Nibouche et al. [2]). *Melanaphis sorghi* was found in Oklahoma late in the 2013 sorghum growing season (Villanueva et al. [3]) and by 2015 had become a severe pest of grain sorghum throughout sorghum growing areas of the state (Bowling et al. [4]).

Johnsongrass, *Sorghum halepense* (L.), is a widely distributed invasive weed in the US (Klein and Smith [11]). Johnsongrass is a perennial grass that can overwinter vegetatively or as seeds. Hybridization occurs between johnsongrass and sorghum (Arriola and Ellstrand [5]), and between johnsongrass and other Sorghum species such as Columbus grass, *S. almum* Parodi (Klein and Smith [11]). Partly the consequence of hybridization johnsongrass displays a high degree of environmental adaptability (Burt [3], Klein and Smith [6]). *Melanaphis sorghi* can survive and reproduce on johnsongrass (Bowling et al. [4], Haris-Shultz et al. 2018). In south Texas, johnsongrass is an important alternate host for *M. sorghi* to bridge the autumn and winter months when cultivated sorghum is absent from the agroecosystem (Esquivel et al. [7]). Population growth of *M. sorghi* on johnsongrass in south Texas during the sorghum growing season was slower than on an *M. sorghi* susceptible grain sorghum variety. Survival during the period between sorghum harvest and planting the next year does occur and is thought to be critical to the ability of *M. sorghi* to persist in the agroecosystem as a serious pest of grain sorghum in south Texas (Esquivel et al. [7]). The population growth of *M. sorghi* on johnsongrass has not been studied in Oklahoma.

Johnsongrass occurs in every county in Oklahoma but is most common in eastern and central Oklahoma (Hoagland [8]) and overwinters as both seeds and rhizomes (Hickman et al. [9]). In a survey accomplished each year from 2017-2020 in mid-March ca. 15 johnsongrass stands located on south facing slopes along south to north highways in Oklahoma from near the Texas border in the south to near the Kansas border in the north were visually surveyed for evidence of emergence from the soil of johnsongrass shoots (NCE unpublished). No emerged johnsongrass shoots were observed in any of the years except 2018. In 2018 recently emerged shoots ranging from ca. 2 to 8 cm in length were observed in two of the 15 stands inspected, but no *M. sorghi* were found on the shoots (NCE unpublished data). These observations indicate that overwintering by *M. sorghi*, in Oklahoma, if it occurs, is very limited and the availability of johnsongrass as a host for *M. sorghi* migrating northward from southern latitudes would be minimal prior to late March or early April. Beyond the above mentioned observations, little is known about the role of johnsongrass as a host for *M. sorghi* in Oklahoma from which it can disperse to infest grain sorghum fields.

Sorghum typically is planted from late-April through May in Oklahoma (Hawkins et al. [10]) and there may be potential for johnsongrass to be colonized by *M. sorghi* migrating from southern latitudes on southerly winds earlier than sorghum usually is planted. In that case johnsongrass could serve as a local source of *M. sorghi* to colonize sorghum soon after plants emerge from the soil. *Melanaphis sorghi* population growth rate on johnsongrass and sorghum has not been studied in the field in Oklahoma. However, a plant growth chamber study of *M. sorghi* population growth demonstrated a positive growth rate on johnsongrass but at a 40% slower rate than *M. sorghi* growing on a susceptible grain sorghum variety (de Sousa and Davis [11]). If *M. sorghi* on johnsongrass in the field grow at a rapid rate, then johnsongrass could serve as a source of locally dispersing aphids to contribute to the severity of *M. sorghi* infestations on sorghum.

This study had two related objectives. The first objective was to determine if *M. sorghi* was present on johnsongrass in Oklahoma at an earlier calendar date than on sorghum. This would indicate that *M. sorghi* migrating from the south had potential to colonize johnsongrass prior to sorghum being available as a host, in which case johnsongrass could serve as a local source of *M. sorghi* to colonize sorghum fields. The second objective was to determine if the population growth rate of *M. sorghi* differed between johnsongrass and sorghum. A high population growth rate of M. sorghi on johnsongrass would indicate potential for *M. sorghi* dispersing from johnsongrass to contribute significant numbers of immigrants to sorghum fields and intensify infestations. Accomplishing the two objectives would contribute substantially to understanding the role of johnsongrass in *M. sorghi* population dynamics in Oklahoma agricultural landscapes and its importance as a reservoir for *M. sorghi* from which to infest sorghum fields.

Materials and Methods

Field Locations and Sampling

Grain sorghum fields in Oklahoma were sampled for *M. sorghi* during the summers of 2019, 2020, and 2021. Sorghum fields were sampled in the main sorghum growing areas in Oklahoma, from Altus in southwestern Oklahoma, north-central Oklahoma from Stillwater west to Enid, and north to Ponca City, and in northwestern Oklahoma including the Oklahoma Panhandle (Figure 1). In total, there were 36 locations where a sorghum field and a nearby johnsongrass stand were sampled, 10 in 2019, 10 in 2020, and 16 in 2021. The number of fields studied was dictated by the number of sorghum fields found in an initial survey of fields that had a substantial johnsongrass stand either directly adjacent to it, or within approximately 100 m from the field. Fields were more difficult to find in northwestern Oklahoma including the panhandle because johnsongrass is less common there.

Sampling in fields was initiated when sorghum was in its early growth stages, usually during the 5-7 leaf stage of development, but for three fields sampling was not initiated until ca. two weeks prior to boot stage. Sampling continued at weekly to biweekly intervals until the crop either matured or was treated with insecticide to suppress an *M. sorghi* infestation. In sorghum fields 36 plants were sampled along an inverted V-shaped transect with the first sampling point located about 25 m from the field edge. For sampling each field, six sampling points were located along the inverted V, each about 25 m apart, with the third point located at the apex of the

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V and the last point located about 25 m from the field edge. Six plants in two groups of three were sampled at each point. The two groups were located about 3 m apart, and the three plants sampled in each group were located within reaching distance of the person sampling while stationary. Two leaves were inspected from each plant, one from the lower part of the sorghum plant that was over 90% green, and one from the upper part of the plant, excluding the flag leaf, that was completely unfurled. In total, two leaves were sampled from each of 36 plants for a total of 72 leaves.

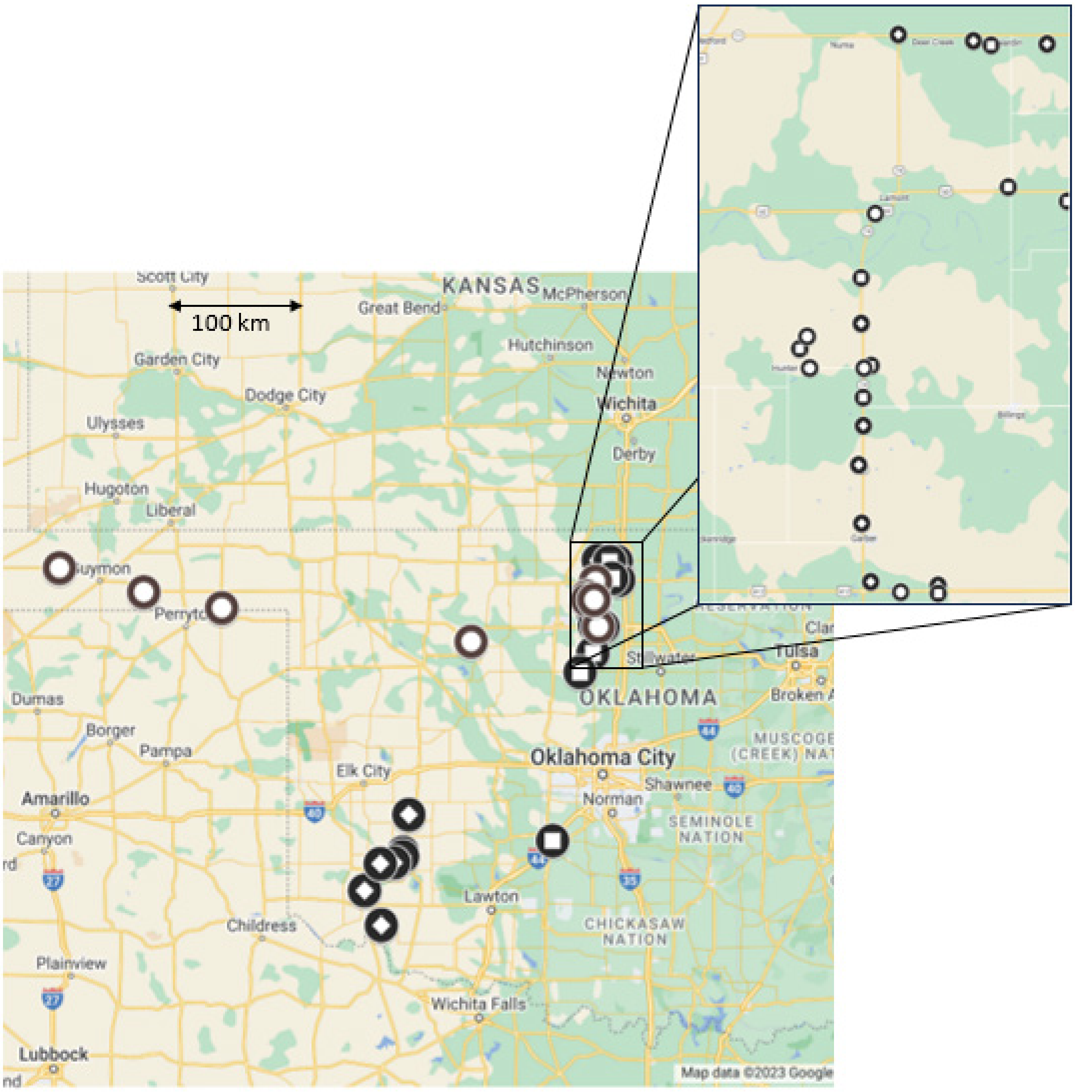

Figure 1: Locations of grain sorghum fields and johnsongrass stands sampled in 2019, 2020, and 2021. Sites sampled in 2019 are represented by circles, sites in 2020 are represented by squares, and sites in 2021 are represented by diamonds. Locations of five sites are hidden.

For each leaf, the number of *M. sorghi* were counted in two categories, the number of apterous *M. sorghi* on the leaf and the number of alate *M. sorghi* on the leaf. In addition, during 2019 and 2020 the proportion of *M. sorghi* nymphs on each leaf that would become alate adults was recorded. The proportion of alatoid nymphs was visually estimated by determining the proportion of such nymphs out of the total wingless *M. sorghi* on the leaf. This estimation was accomplished by comparing the number of dark colored nymphs (mostly destined to become alates) to the number of paler aphids (either nymphs destined to be apterous or apterous adults). Johnsongrass stands sampled were typically aligned along an edge of the sampled sorghum field. Sampling in johnsongrass was accomplished similarly to that in sorghum but we did not sample along an inverted V because the shape johnsongrass stands, which were typically linear stands 10-20 m wide aligned along a field edge, did not permit use of V-shaped transects. Instead, we sampled johnsongrass along transects aligned with the long axis of the stand. In some stands we had to adapt the transect shape to account for the unusual shape of the stand. In each stand 36 johnsongrass plants were sampled by inspecting two leaves on each. Population growth rate for each sampling interval was estimated as:

$$R_{t,t_o} = (N_t - N_{t_o}) / (t - t_o)$$

where R_{t,t_o} is population growth rate for the interval from calendar date t_o to calendar date t, N is population intensity. The average of R_{t,t_o} across all sampling dates during a growing season at a site $(\bar{R})$ was calculated for sorghum and johnsongrass.

Data Analysis

Descriptive statistics (mean, minimum, and maximum) were calculated for the number of *M. sorghi* counted per leaf using PROC MEANS (SAS Institute [14]). Preliminary visual inspection of $\bar{R}$ indicated severe righthand skewing to the extent that the distribution of $\bar{R}$ was markedly asymmetric. Therefore, non-parametric methods were used for statistical comparison of $\bar{R}$ for sorghum fields and nearby johnsongrass stands. The Wilcoxon matched pairs signed-ranks test was used to compare mean population growth rates for *M. sorghi* averaged across all sampling occasions for each sorghum field paired to mean growth rate for the adjacent johnsongrass stand. PROC NPAR1WAY was used to calculate Wilcoxon tests (SAS Institute [1]).

The date of first detection of M. sorghi in a sorghum field or johnsongrass stand was the calendar day when the first non-zero count of *M. sorghi* was recorded for a field or stand. That day was considered an estimate of the day the sorghum field or johnsongrass stand was colonized by *M. sorghi*. Date of first detection for each location was recoded to one if *M. sorghi* was detected on sorghum on a date prior to when it was first detected on johnsongrass, to zero if the date of first detection was the same for M. sorghi on sorghum and johnsongrass, and to negative one if *M. sorghi* was detected on johnsongrass at an earlier date than on sorghum. A two-tailed Wilcoxon test was used to test whether there was a difference in date of first detection of *M. sorghi* on sorghum and johnsongrass.

Results and Discussion

The average number of *M. sorghi* per leaf during the three-year study was roughly 10 times greater on sorghum than on johnsongrass (Table 1). Counting *M. sorghi* on leaves provides estimates of population intensity and not of absolute population, and while the number of *M. sorghi* per leaf was not comparable among the plant species the order of magnitude difference suggests that *M. sorghi* population density is considerably greater in sorghum fields than in johnsongrass stands.

Table 1: Number of M. sorghi per leaf on sorghum and johnsongrass and mean population.

Year/Variable	N	Mean	Maximum	
2019				
M. sorghi per leaf - sorghum	10	78.75	0.1	654.98
M. sorghi per leaf - johnsongrass	10	0.64	0	2.95
M. sorghi $\bar{R}$ - sorghum	10	5.43	-0.46	47.66
M. sorghi $\bar{R}$ - johnsongrass	10	-0.02	-0.14	0.44
2020				
M. sorghi per leaf - sorghum	10	4.21	0	26.34
M. sorghi per leaf - johnsongrass	10	0.39	0	0.99
M. sorghi per leaf - johnsongrass	10	0.14	-0.11	1
M. sorghi $\bar{R}$ - johnsongrass	10	0.01	-0.01	0.05
2021				
M. sorghi per leaf - sorghum	16	0.75	0	4.8
M. sorghi per leaf - johnsongrass	16	0.26	0	1.77
M. sorghi per leaf - johnsongrass	16	0.04	-0.05	0.36
M. sorghi $\bar{R}$ - johnsongrass	16	0.01	-0.07	0.14

The difference in number of calendar days to first detection of *M. sorghi* on johnsongrass compared to sorghum was 2.8, 8.7, and 3.4 days in 2019, 2020, and 2021, respectively. The date of first detection is related to initial colonization date but also to differences in *M. sorghi* population intensity on the two plant species because detection probability would be greater for the plant species with the greater population intensity. Furthermore, estimating the number of days until colonization would be affected by the length of the interval between sampling events. For example, *M. sorghi* could initially colonize sorghum the day following sampling at a site but could not be detected until the next sampling event which was usually one week but sometimes was longer. To minimize the impact of these factors on testing for differences in the

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timing of colonization of the two plant species we converted the first occurrence data to a -1, 0, 1 score (see material and methods). The mean score was 0.17 (SE = 0.06). A Wilcoxon two-sided test was significant (z = 2.68; n = 36; P = 0.007) indicating that *M. sorghi* was significantly more likely to be detected at an earlier date in sorghum than on johnsongrass. The earlier detection date probably results from the typically greater *M. sorghi* population intensity in sorghum than on johnsongrass, which would increase the likelihood of detection during sampling. The most reasonable explanation is that both habitats are initially colonized at the same time by migrating *M. sorghi* from southerly latitudes. This explanation is supported by verified simulation model forecasts of south to north migration by *M. sorghi* (Koralewski et al. [12]), which indicate dates of colonization in early June for southern Oklahoma and late June for northern Oklahoma.

Population growth rate averaged over all sampling dates for each field and then across fields for a particular year, $\bar{R}$, was greater in sorghum than in johnsongrass in each of the three years, varying from a low of 4 times greater in 2021 to a high of approximately 500 times greater in 2019 (Table 1). $\bar{R}$ on johnsongrass was negative in 2019 and was 0.01 in both 2020 and 2021. $\bar{R}$ differed significantly for *M. sorghi* populations on sorghum compared to johnsongrass ($\chi 2 = 5.48$; df = 1; P = 0.02). $\bar{R}$ for either habitat would be affected by emigration and immigration of *M. sorghi*. For example, if proportionately more alates were produced on johnsongrass and subsequently emigrated ($\chi 2 = 5.48$; df = 1; P = 0.02). $\bar{R}$ would be reduced from actual M. sorghi natality and survival. Average production of alatae in johnsongrass was very low, with the proportion of alatoid nymphs on leaves being close to zero (Table 2). In situ recruitment of alatae on johnsongrass was low for both 2019 and 2020 indicating a low level of emigration of *M. sorghi* from johnsongrass. It is likely that most alates observed on johnsongrass were immigrants from other habitats and/or geographic locations. The much lower population growth rate for *M. sorghi* on johnsongrass compared to sorghum and lack of significant alate production indicates that johnsongrass generally did not produce significant numbers of alate *M. sorghi* to infest sorghum.

Table 2: Average number of apterae, adult alatae, and the proportion of M. sorghi per leaf that were alatoid nymphs for johnsongrass and sorghum in 2019, 2020, and 2021. Averages were taken across all leaves sampled in each year.

Year	Johnsongrass			Sorghum		
	apterae	alatae	alatoid nymphs	apterae	alatae	alatoid nymphs
2019	0.58 (0.13)	0.12 (0.021)	0.001	24.74 (2.73)	0.50 (0.04)	0.03 (0.00)
2020	0.34 (0.04)	0.03 (0.002)	0	4.16 (0.53)	0.08 (0.01)	0.01 (0.00)
2021	0.16 (0.02)	0.03 (0.01)	-	0.53 (0.10)	0.01 (0.00)	-

There are three recent greenhouse and growth chamber studies of *M. sorghi* population growth on sorghum and johnsongrass de Souza et al. [15] and Davis [11], Esquivel et al. [7]). For two studies conducted in plant growth chambers the intrinsic rate of increase, r, was estimated to be 0.45 (de Souza et al. [15]) and 0.47 (de Souza and Davis [11]) on *M. sorghi* susceptible sorghum varieties and 0.42 (de Souza et al. [15]) and 0.29 (de Souza and Davis [11]) on johnsongrass. In both studies *M. sorghi* populations grew faster on sorghum than johnsongrass but growth rate on both plant species was positive and substantial. Esquival et al. [7] demonstrated in a growth chamber study that *M. sorghi* populations grew faster on sorghum than johnsongrass, but also noted that *M. sorghi* that were switched from one host to the other showed an intermediate growth rate that appeared to persist through multiple generations. Esquival et al.[7] sampled field populations of *M. sorghi* on sorghum and johnsongrass during spring and autumn and observed larger numbers on sorghum leaves than on johnsongrass leaves, but differences in population intensity were not as great as we observed during summer in Oklahoma.

In Oklahoma during summer johnsongrass can frequently be characterized as demographic sink habitat (see Dias [13] for *M. sorghi* where population growth rate is negative. Alate production in johnsongrass is low so *M. sorghi* emigration from johnsongrass is unlikely to explain the negative growth rates frequently observed in johnsongrass. Since all hosts for *M. sorghi* in Oklahoma are ephemeral and do not persist in vegetative form beyond one or a series of hard freezes, which typically occur in late autumn in Oklahoma, there are no long-term demographic consequences for *M. sorghi* resulting from source-sink population dynamics. However, in Oklahoma source-sink dynamics does occur during the sorghum growing season and beyond. The practical significance of these dynamics may be that johnsongrass serves as a sink for migrant *M. sorghi* in Oklahoma that colonize johnsongrass but contribute very few *M. sorghi* to migrate to sorghum fields including sorghum fields recently treated with insecticide to suppress *M. sorghi* infestations.

This study contributes to understanding the pest management implications of johnsongrass as a host for *M. sorghi* in Oklahoma agricultural landscapes in which johnsongrass is a ubiquitous host plant. First, we documented that johnsongrass does not harbor significant numbers of *M. sorghi* early in the growing season from which it could disperse into recently planted sorghum fields to establish infestations. Second, we found that *M. sorghi* population growth rate is low and sometimes negative in johnsongrass. And finally, we observed that very few alate *M. sorghi* are produced in johnsongrass. The significance of these observations is that johnsongrass stands are not usually a significant source of *M. sorghi* to contribute to *M. sorghi* infestations in proximate grain sorghum fields.

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The role of johnsongrass in contributing to *M. sorghi* infestations on sorghum at a landscape (or broader) scale is less clear. We could not find an estimate of the hectarage of johnsongrass in Oklahoma. However, it is probably safe to assume that in much of Oklahoma there are many more hectares of johnsongrass than of sorghum. Even slow growing *M. sorghi* populations with low levels of alate production could be sources of emigrants to sorghum fields, albeit in low numbers. Thus, particularly for sorghum fields planted at later than normal dates in Oklahoma johnsongrass could be significant as a source of colonists to initiate infestations in such fields.

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