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Biology and Seasonal Abundance of Hymenopterous Parasitoids of Sorghum Midge (Diptera: Cecidomyiidae)[1]

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ABSTRACT Four hymenopterous parasitoids of the sorghum midge, *Contarinia sorghicola* (Coquillett), were found in Burleson County, Texas: *Eupelmus popa* Girault, *Tetrastichus* near *venustus* Gahan, *Tetrastichus* near *blastophagi* (Ashmead), and *Aprostocetus diplosidis* Crawford. *E. popa* and *A. diplosidis* were ectoparasitic on the midge host in sorghum spikelets, while *T.* near *venustus* fed both externally and internally. Members of the parasitoid complex oviposited and developed to adults in spikelets containing 1- to 18-day-old immature midges, which corresponded to larval and pupal stages of midges. Most parasitoids developed from midges parasitized as mid-stage larvae. Developmental time from egg to adult emergence ranged from 7 to 32 days for the parasitoid complex. Emergence of most adults of the individual parasitoid species ranged from 15 to 19 days. This developmental time corresponded to that of the midge host, which emerged as adults in 15 to 18 days after oviposition. *E. popa* was most abundant during spring and early summer in both johnsongrass and sorghum. *A. diplosidis* reached its highest density in late summer and fall. *T. venustus* was primarily a mid-season parasitoid and *T. blastophagi* densities were relatively high during the spring and summer months. *T. blastophagi* showed a preference for sorghum midges infesting johnsongrass while *T. venustus* and *A. diplosidis* preferred midges infesting sorghum. Over the course of the season, 20.0 and 8.2% of sorghum midges were parasitized in johnsongrass and sorghum, respectively.

The sorghum midge, *Contarinia sorghicola* (Coquillett), is a key insect pest of sorghum worldwide (Callan 1941). Larvae develop cryptically from eggs deposited in flowering spikelets, and their feeding prevents grain production. Wild hosts such as johnsongrass, *Sorghum halepense* L, maintain sorghum midge generations before flowering sorghum is available. Control of sorghum midge is primarily achieved by early uniform regional planting of sorghum to avoid high midge densities later in the season, and by insecticide applications when the economic threshold of one adult midge per panicle is reached (Bottrell 1971, Young and Teetes 1977). Use of midge-resistant sorghum hybrids provides an additional management tactic (Teetes 1975).

Natural enemies of sorghum midge include most general predators found in a sorghum field (Dean 1910, Walter 1941, Harding 1965). In addition, several parasitoids of sorghum midge have been recorded. These include the eupelmids *Eupelmus popa* Girault, *E. australiensis* Girault, *E. varicolor* Girault, and *E. urozonus* Dalman, and the eulophids *Aprostocetus diplosidis* Crawford, *Ceratoneura petiolata* Ashmead, *Pediobius pyrogo* Walker, *Tetrastichus venstus* Gahan, and several unidentified *Tetrastichus* species (Crawford 1907, Callan 1941, Passlow 1958, Priore and Viggianai 1965, Wiseman et al. 1978). A ceratopogonid fly (*Dasyhelea* sp.) and braconid wasp (*Apanteles* sp.) are also reported to parasitize sorghum midges (Seshu Reddy and Davis 1979).

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Biological data for sorghum midge parasitoids are scarce for most species, although *Eupelmus popa* was well studied by Woodruff (1929). Parasitoid oviposition occurred 6 days after female midges had laid their eggs. *E. popa* larvae fed on one to three midge larvae to reach the adult stage. This species feeds ectoparasitically, primarily on nondiapausing midge larvae, with older parasitoid larvae readily attacking pupae. *E. popa* also feeds on the developing sorghum ovary after consuming at least one host, irrespective of additional hosts in the spikelet. Developmental time from oviposition to adult emergence ranged from 14 to 18 days, with an average of 16 days. This parasitoid species overwinters, like the midge host, as larvae within the sorghum spikelet, and emerges in the spring shortly after the first midge adults appear.

The seasonal distribution of the sorghum midge parasitoid *E. australiensis* was studied by Passlow (1965) in Australia. He collected this parasitoid on most occasions when sorghum midges were present in the field. Wiseman et al. (1978) found similarities in the abundance and seasonal distributions between *A. diplosidis, T. venustus* and *E. popa* and that of the sorghum midge host. Over 95% of all sorghum midge parasitoids collected in the 3-year study were *A. diplosidis*. Seasonal percentages of parasitism ranged from 11 to 26%.

Hymenopterous parasitoids may be an important regulator of sorghum midge density, yet understanding of parasitoid-host interaction is limited. Additional information concerning the biology, behavior, and seasonal abundance of these parasitoids is essential to a better understanding of sorghum midge population dynamics. Therefore, the objectives of this study were twofold: first, to examine several biological aspects of the prevalent parasitoid species of the sorghum midge, and second, to monitor the seasonal abundance of these

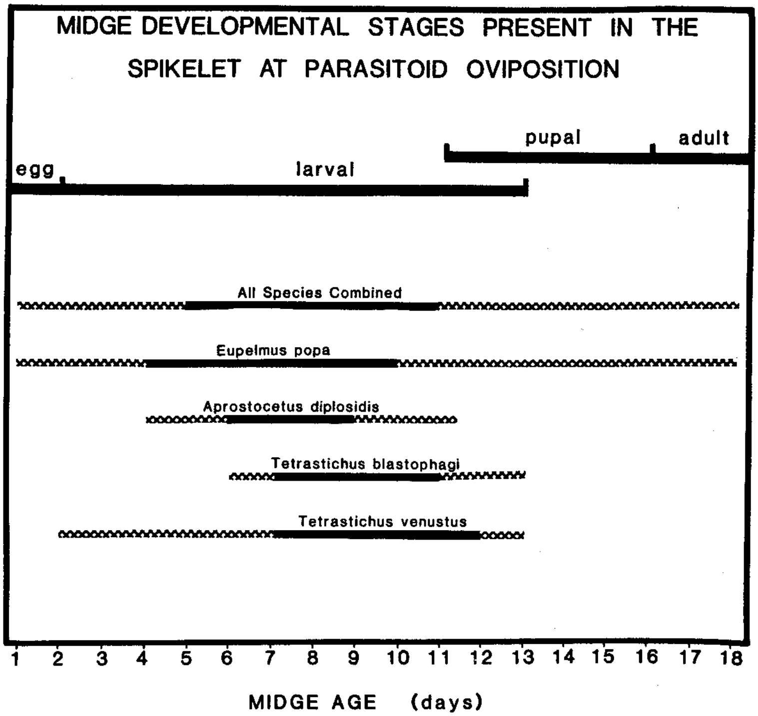

FIG. 1. Range in midge age (in days) and midge developmental stages in which parasitoids oviposited and developed to adults, with 68% adult emergence shown as a solid line, for each parasitoid species and all species combined, with 1980–1981 data combined.

parasitoids and evaluate their impact as mortality factors in the population dynamics of the midge.

Materials and Methods

Studies were conducted in sorghum and johnsongrass plots on the Texas A&M University plantation in Burleson County. Successive biweekly plantings of sorghum were made beginning in early April so that flowering sorghum was available from June through October. A pure stand of johnsongrass was established in an adjacent field.

Biology and Nature of Parasitism

To determine parasitoid mode of feeding on the midge host, 10 randomly selected sorghum panicles were caged in the boot stage to protect them from midge or parasitoid infestation. When panicles reached 50% flower (yellow anthers exposed), cages were removed for 24 h to allow for oviposition by naturally occurring midges. When these midges reached middle larval stages (ca. 6 days), a known species of parasitoid collected from nearby sorghum panicles was introduced into each caged panicle. Caged panicles were returned to the laboratory 5 to 7 days after parasitoid infestation, where spikelets were dissected and the midge-parasitoid interaction was determined.

Parasitoid oviposition and developmental times were determined by simultaneously exposing the flowering portion of selected sorghum panicles to midge oviposition for 24 h before caging. Beginning on the day of midge oviposition, four of these caged panicles were randomly chosen for exposure to parasitoid oviposition. These four panicles were uncaged for 24 h to allow for oviposition by naturally occurring parasitoids. This exposure of four panicles per day to detect parasitoid oviposition continued for 13 to 18 days from the day of midge oviposition. Daily collection of emerged parasitoid adults from caged panicles revealed the days (midge age) when parasitoids were able to oviposit and develop to adults, and the range in developmental time from oviposition to adult emergence.

Seasonal Abundance of Sorghum Midges and Parasitoids

The seasonal abundance of sorghum midges and their parasitoids was monitored in field samples of naturally infested johnsongrass and sorghum spikelets. Three times each week, johnsongrass and sorghum panicles in 50% anthesis were randomly selected. From the selected panicles, rachis branches were removed until only 200 spikelets in anthesis remained susceptible to midge (and subsequently parasitoid) infestation. Panicles bearing the 200 spikelets were left undisturbed until day 10, when they were caged within cotton bags (10 by 15 cm). Cages were equipped with drawstrings to allow the opening to be tightly sealed around the peduncle of the panicle.

On day 14 after anthesis, spikelets were excised and returned to the laboratory where emerged parasitoids and midges were identified and counted. The spikelets were then placed in covered, 473-ml containers to permit continued emergence of parasitoids and midges. After an additional 45 days, emerged parasitoids and midges were removed from containers, identified, and counted. These

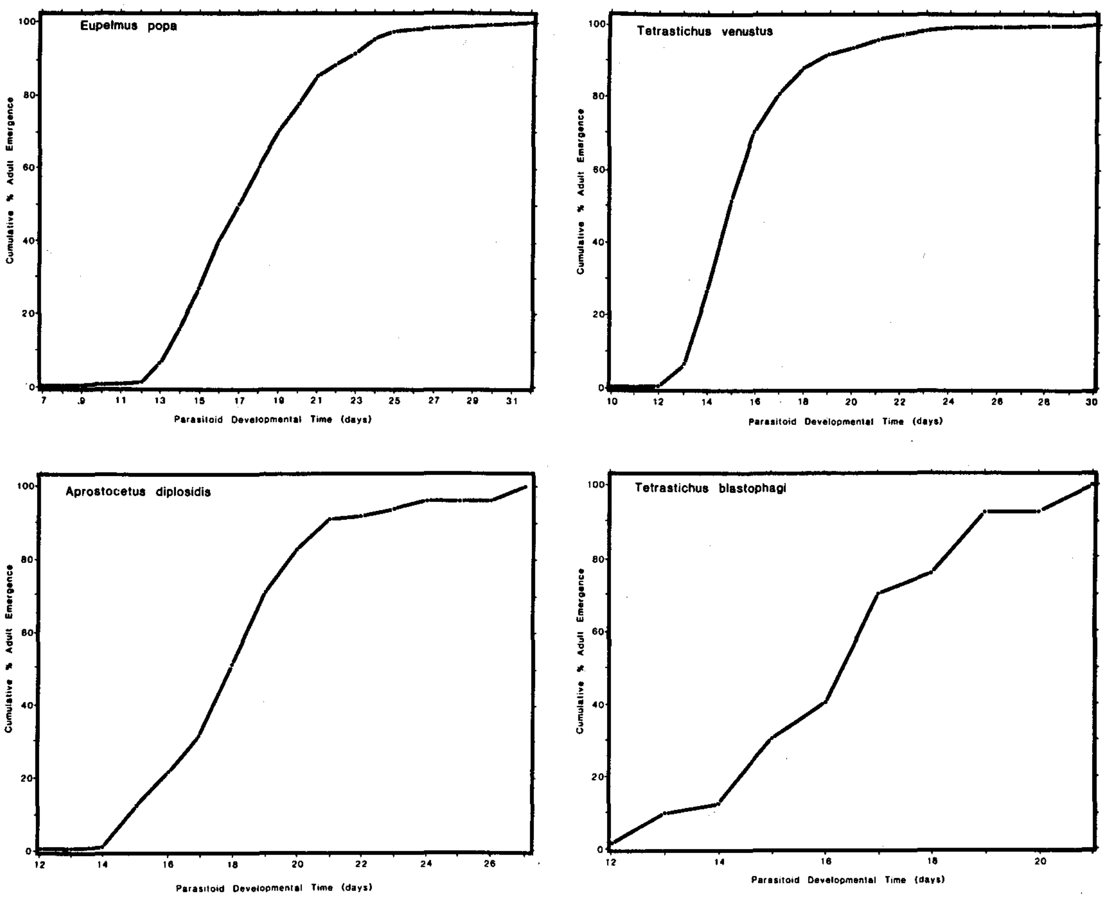

FIG. 2. Cumulative percent of total parasitoid adults which emerged after a specific developmental time (in days) for each parasitoid species, with 1980–1981 data combined.

totals were added to those previously recorded for the cotton cages. Weekly means were calculated for parasitoid densities.

Results and Discussion

Sorghum midge parasitoids collected in Burleson County, Tex., were identified by E. E. Grissell as *Eupelmus popa, Aprostocetus diplosidis, Tetrastichus* near *venustus,* and *Tetrastichus* near *blastophagi.* Voucher specimens of the two *Tetrastichus* species were retained at the U.S. National Museum for later verification.

Biology and Nature of Parasitism

E. popa and *A. diplosidis* fed ectoparasitically on the midge host. *T. venustus* was primarily an external feeder, although a few endoparasitic individuals were observed. This mixed feeding habit has also been reported for another member of this genus, *Tetrastichus bruchophagi,* a parasitoid of the clover seed chalcid (Urbahns 1917). Mode of feeding by *T. blastophagi* was not determined. Late-stage larvae of the three observed parasitoid species were hymenopteriform with dark-colored, partially sclerotized mandibles and lacked the prominent anterior spiracles of midge larvae.

As a group, sorghum midge parasitoids were capable of oviposition and successful development to adults in immature midges 1 to 18 days of age (Fig 1). Therefore, oviposition and subsequent parasitism occurred in midge stages from first-stage larvae through pupae. Sixty-eight percent of the parasitoid adults (i.e., 1 SD) emerged from sorghum panicles which contained middle-stage midge larvae at the time of parasitoid oviposition.

E. popa had the broadest range in time of oviposition, with more parasitism occurring in middle-stage midge larvae. This species has been reported to feed on the sorghum ovary after some initial host feeding, irrespective of other midge hosts within the sorghum spikelet (Woodruff 1929). This facultative phytophagy would account for the ability of this parasitoid to oviposit and develop in sorghum spikelets containing midge in a wide range of developmental stages.

A. diplosidis primarily attacked middle-stage midge larvae, whereas *T. blastophagi* and *T. venustus* parasitized mostly middle to late larval stages of midges.

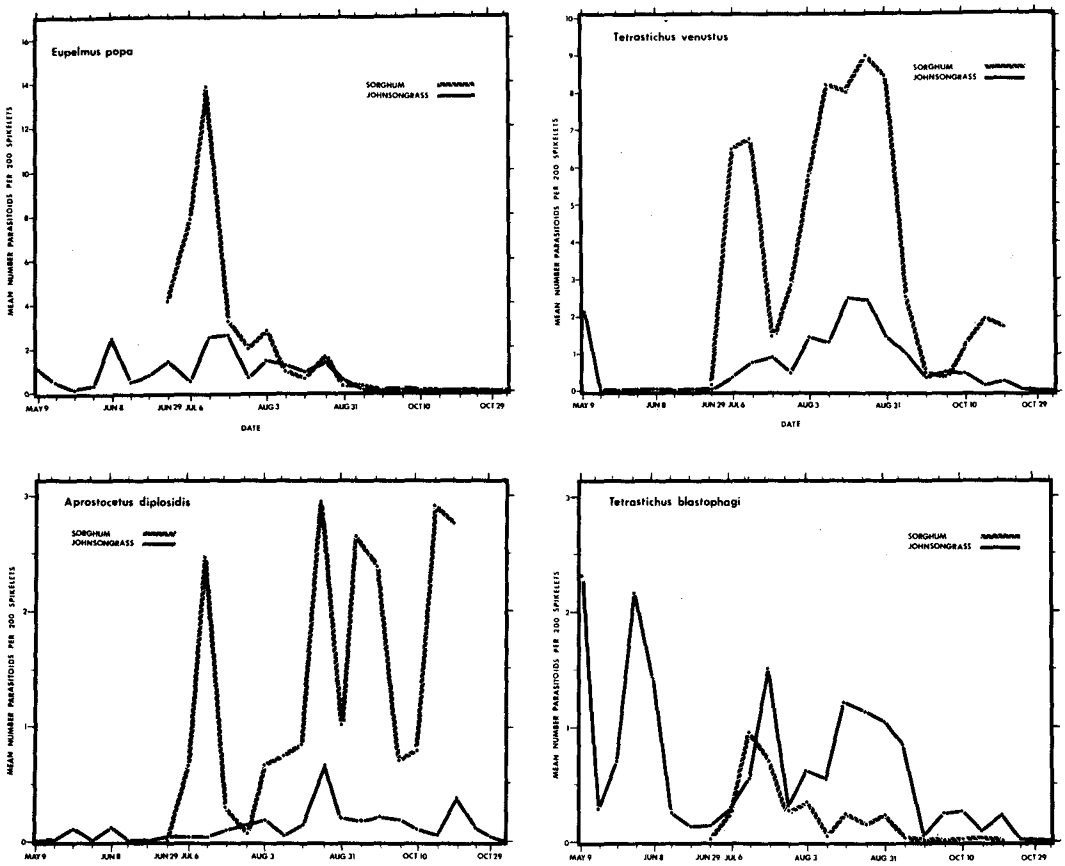

FIG. 3. Seasonal distributions of parasitoids of sorghum midges infesting johnsongrass and sorghum.

Table 1. Seasonal totals and percentages of sorghum midge parasitoids in johnsongrass and sorghum[a]

Parasitoids	Johnsongrass		Sorghum	
	No. of parasitoids	% Of total parasitoids	No. of parasitoids	% Of total parasitoids
Eupelmus popa	1,617	32.93	3,726	27.51
Tetrastichus venustus	1,500	30.54	7,080	52.23
Tetrastichus blastophagi	1,479	30.12	388	2.69
Aprostocetus diplosidis	315	6.41	2,384	17.57
Total parasitoids	4,911	100.00	13,566	100.00

[a]Samples taken from 7 May to 2 November in johnsongrass and from 27 June to 19 October in sorghum.

The developmental time from egg to adult emergence ranged from 7 to 32 days for the parasitoid complex. Peak emergence (50% cumulative) occurred on day 16 for *E. popa*, day 15 for *T. venustus*, days 18 to 19 for *A. diplosidis*, and day 17 for *T. blastophagi* (Fig. 2). *E. popa* and *T. venustus*, which occurred in large numbers, showed the broadest ranges in developmental time, whereas *A. diplosidis* and *T. blastophagi*, which were less abundant, had adult emergence over a narrower developmental period. These developmental times generally coincided with that of the midge host, which emerged as adults in an average of 15 to 18 days after oviposition.

Seasonal Abundance of Sorghum Midges and Parasitoids

Figure 3 depicts the seasonal distributions of each of the four parasitoid species of sorghum midge infesting

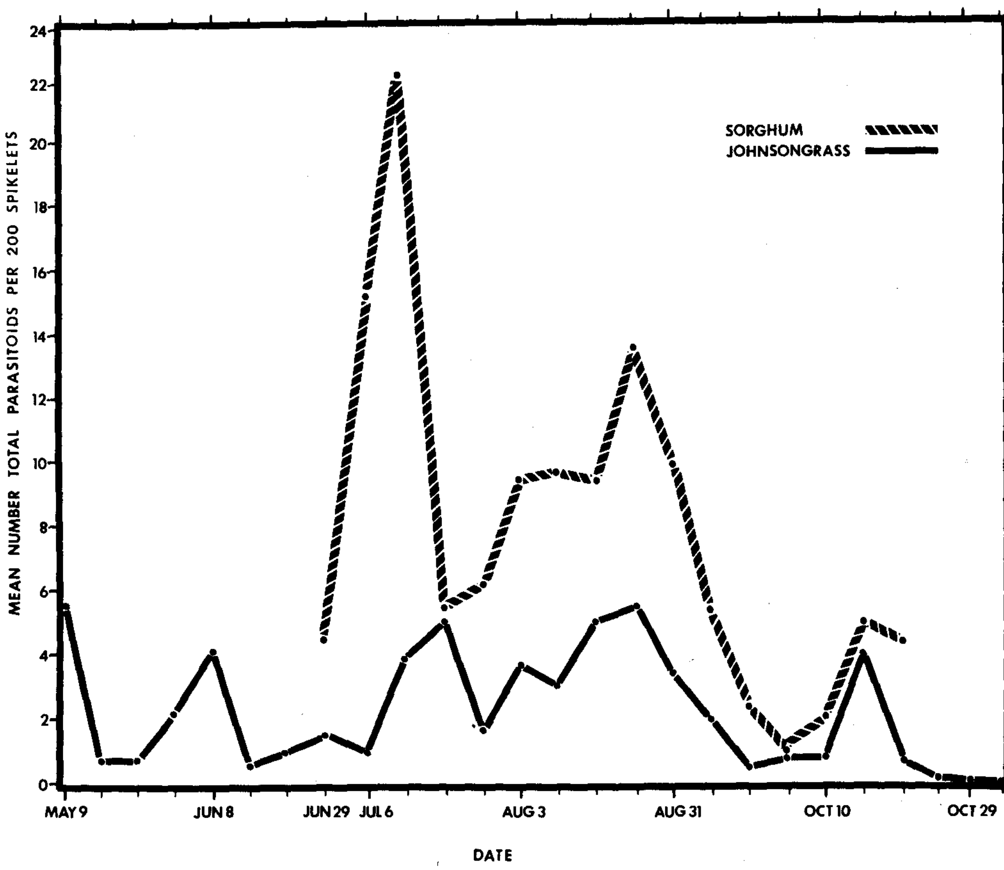

FIG. 4. Seasonal distributions of combined parasitoids of sorghum midges infesting johnsongrass and sorghum.

johnsongrass and sorghum. *E. popa* was present in the earliest johnsongrass samples and remained at relatively high densities throughout the spring and early summer. When first sorghum began to flower during the last week of June, *E. popa* densities rapidly climbed to their seasonal maximum in this crop. As the summer progressed, parasitoid densities declined rapidly and approached zero in both johnsongrass and sorghum by the second week of September.

A. diplosidis was most abundant during the latter portion of the season in both johnsongrass and sorghum. After a mid-July peak in sorghum, parasitoid densities declined and remained at reduced levels until mid-August, when numbers again increased. Throughout the remainder of the season, *A diplosidis* density stayed relatively high.

T. venustus was primarily a midseason parasitoid in both johnsongrass and sorghum, with maximum densities occurring during the last week of August. This parasitoid was present only at low densities in the spring and late summer. *T. blastophagi* was most abundant during the spring and early summer in johnsongrass, but increased to a secondary maximum during midsummer. In sorghum, maximum densities occurred during July. Fall densities were low in both johnsongrass and sorghum.

The seasonal totals and percentage of sorghum midge parasitoids in johnsongrass and sorghum are shown in Table 1. In johnsongrass, *E. popa* and the two *Tetrastichus* spp. were present in approximately equal numbers, whereas *A. diplosidis* abundance was less than that of the other three parasitoids. In sorghum, however, *T. venustus* was clearly the dominant parasitoid, accounting for greater than 50% of the monitored species. Second in abundance was *E. popa*, followed by *A. diplosidis*. These percentages are in contrast with the findings of Wiseman et al. (1978), who reported that over 95% of all parasitoids collected were *A. diplosidis*. *T. blastophagi* was least abundant and accounted for only 2.7% of the parasitoids. These data suggested that *T. blastophagi* preferred sorghum midges infesting johnsongrass, whereas *T. venustus* and *A. diplosidis* preferred midges infesting sorghum. *E. popa* showed no clear preference.

When all four parasitoids were considered collectively, it was evident that maximum parasitoid densities occurred during midseason, with smaller peaks during spring and fall (Fig. 4). To assess the impact these parasitoids had on their sorghum midge host, it was necessary to simultaneously monitor the population dynamics of midges infesting johnsongrass and sorghum (Fig. 5). In general, a positive relationship was evident between sorghum midge and parasitoid densities (Fig. 4 and 5). However, individual parasitoids species did not always

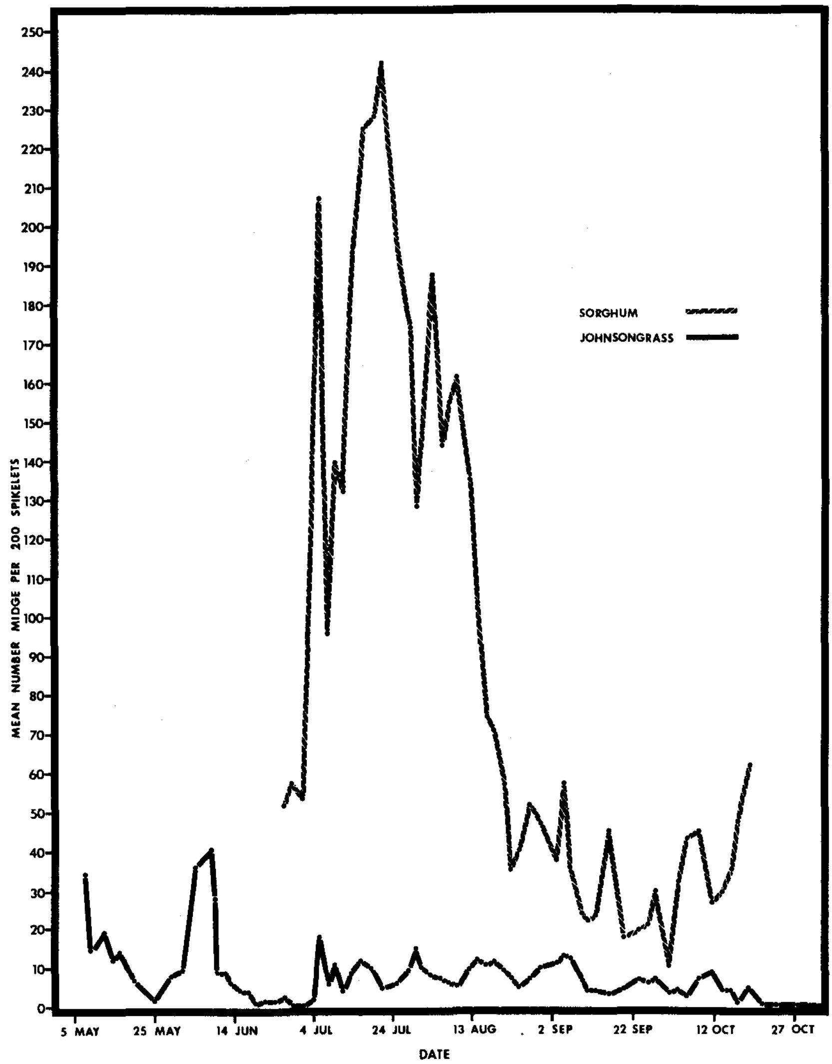

FIG. 5. Seasonal distributions of sorghum midges infesting johnsongrass and sorghum.

reflect this trend. For example, *A. diplosidis* reached its maximum densities in sorghum when midge densities were relatively low, and conversely, *T. venustus* was at its lowest densities in johnsongrass when midge densities were highest.

The pattern of seasonal percent parasitism showed little resemblance to that of midge or parasitoid seasonal abundance profiles (Fig 6). Generally, the percentages of parasitized sorghum midges increased through mid-August, reaching a maximum of 39 and 24% in johnsongrass and sorghum, respectively. Later in the season, parasitism declined considerably. Over the course of the season, 19,670 midges were collected from johnsongrass and 152,079 in sorghum. Based on these values and the parasitoid totals given in Table 1, it was determined that 20.0 and 8.2% of the sorghum midges were parasitized in johnsongrass and sorghum, respectively.

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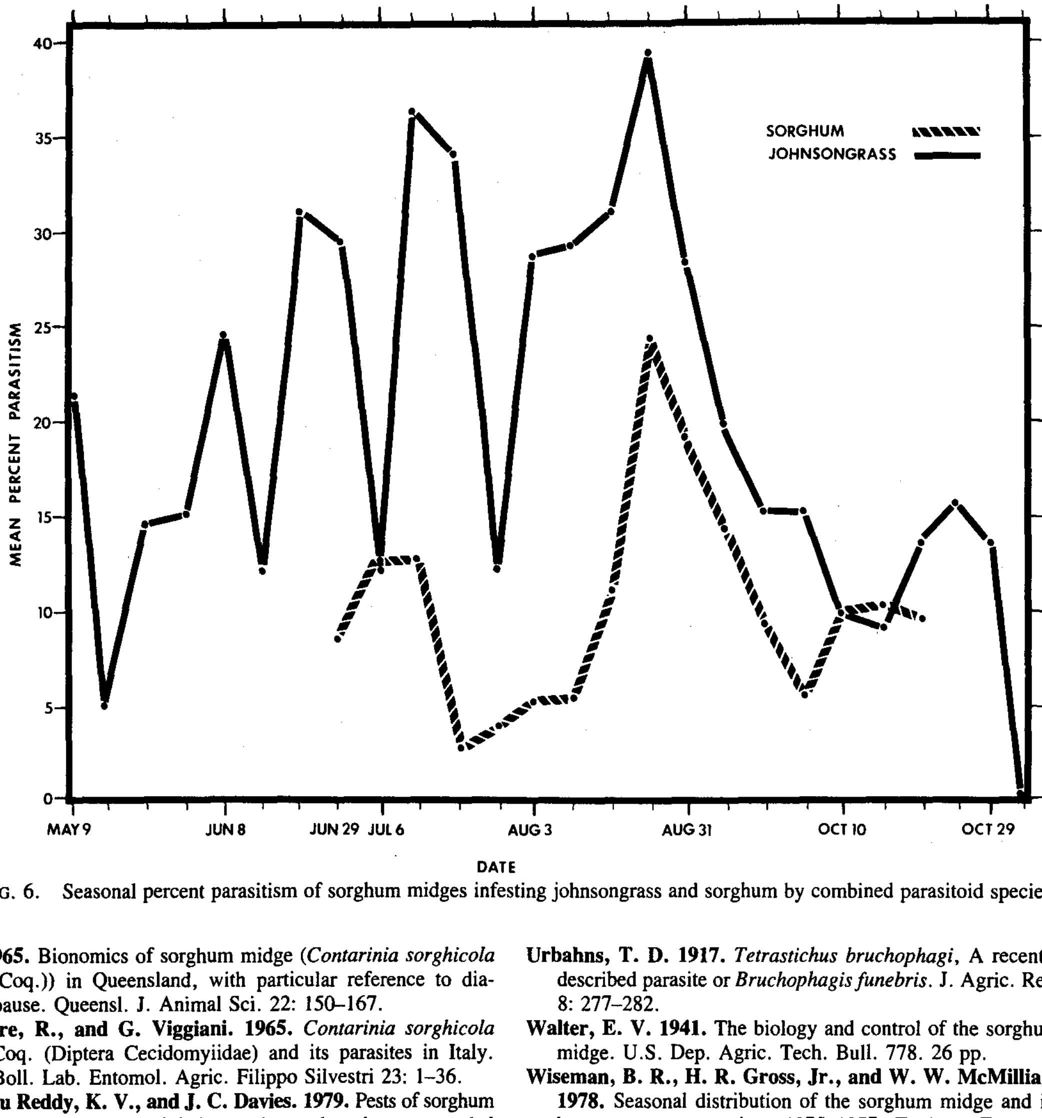

FIG. 6. Seasonal percent parasitism of sorghum midges infesting johnsongrass and sorghum by combined parasitoid species.

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