Emergence Pattern of Sorghum Midge and its Major Parasitoids on Midge-resistant and Susceptible Genotypes

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Studies were conducted on the species composition of parasitoids of sorghum midge, Stenodiplosis sorghicola *Coquillett (Diptera: Cecidomyiidae), emergence pattern and level of parasitism. They took place at the International Crops Research Institute for the Semi-Arid Tropics Asia Centre using three midge-resistant (ICSV 745, ICSV 89058 and IS 10712) and three susceptible (Swarna, CSH 9 and ICSV 112) genotypes during the 1992–93 post-rainy and 1993 rainy seasons. The species of parasitoids collected were* Aprostocetus gala *Walker,* A. coimbatorensis *Rohwer (Hymenoptera: Eulophidae) and* Eupelmus *spp. (Hymenoptera: Eupelmidae). The species composition varied with the season, but was unaffected by varietal resistance and susceptibility to the midge. Although both species of* Aprostocetus *were present in rainy and post-rainy seasons,* A. gala *was predominant during the rainy season whereas* A. coimbatorensis *was predominant in the post-rainy season. There was no significant difference in the pattern of parasitoid emergence or the level of midge parasitization between resistant and susceptible genotypes. These results indicate that resistance to midge in the genotypes studied was not antagonistic to parasitoid activity, and that there is potential to interface biological control with host-plant resistance in the management of this insect.*

Keywords: Stenodiplosis sorghicola, *sorghum midge, resistant genotypes, parasitoids,* Aprostocetus gala, Aprostocetus coimbatorensis

INTRODUCTION

Sorghum midge, *Stenodiplosis* (= Contarinia) *sorghicola* Coquillett (Diptera: Cecidomyiidae), is a cosmopolitan pest of economic importance in Asia, Africa, Australia, Europe and the Americas (Harris, 1976; Sharma, 1985a,b). Damage is caused by larvae that suck the sap from developing grain inside the glumes. The incidence of midge is influenced by pest multi-voltinism, natural enemies, larval diapause, climatic conditions and the availability of flowering sorghum panicles during the cropping season. When properly understood, these factors can play an important role in the management of sorghum midge. Proper management of this pest is particularly important

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in Africa and Asia, where sorghum is a major source of food for over 400 million of the world's poorest population. In these areas, insecticides are not desirable, and other control options must therefore form the basis for an integrated approach in the management of sorghum midge. In Australia and the US, host-plant resistance and a range of crop management practices form the core around which this pest is kept under control. Except in a few cases, improved high-yielding commercial sorghums are susceptible to sorghum midge in Africa and India (Sharma *et al*., 1993). While efforts are continuing in the development of midge-resistant sorghum, other pest population limiting factors should be explored.

Several natural enemies are associated with midge; the commonest species which have been reported are in the genera *Aprostocetus* (initially identified as *Tetrastichus*), *Eupelmus* and *Orius* (Chundurwar, 1977; Gowda & Thontadarya, 1977; Wiseman *et al*., 1978; Baxendale *et al*., 1983; Brooks & Gilstrap, 1985, 1986; Gilstrap & Brooks, 1991). Studies in Texas (Baxendale *et al*., 1983) and Senegal (Gahukar, 1984) have revealed a positive relationship between sorghum midge and parasitoid densities. In the latter case, parasitoids were effective in checking the pest only at the end of the cropping season, when a population ratio of 1 midge:22 parasitoids was observed. However, in India, during the post-rainy season, *Tetrastichus* spp. were the prime factors in the decline in midge populations in January and February (Garg & Taley, 1978). Although overall parasitism by *E. popa* Girault, *A. diplosidis* Crawford, *T. venustus* Gahan and *T. blastophagi* Ashmead was only 8.2% in Texas (Baxendale *et al*., 1983), elsewhere the figures are encouraging. *A. diplosidis* was responsible for 90% of total parasitization (33%) of midge larvae (Busoli *et al*., 1984) in São Paulo, Brazil, and in Argentina. Diaz (1988) reported 28% parasitism of *C. sorghicola* by *A. diplosidis*, *E. popa* and *Tetrastichus* spp.

Although these studies clearly indicate the prospects for biological control in the management of sorghum midge, the extent to which parasitoid activity may be influenced by sorghum genotype is not well known. Such interactions are known to exist in corn (Isenhour & Wiseman, 1989) and tomato (Campbell & Duffey, 1979). Franzmann *et al*. (1989), in a preliminary study, reported that the parasitization of sorghum midge larvae by *A. diplosidis* was higher in resistant genotypes than in susceptible ones. In order to optimize the benefits from integrating the breeding for resistance to midge and biological control, it is desirable that these management options are either complementary or synergistic and not antagonistic. The effects of resistance in sorghum on midge development should be exhibited in the next trophic level of association, i.e. on midge parasitoids. The extent to which increased sorghum resistance to insect pests could affect the complex of natural enemies and their activity is not known. This is an area of research with limited available information, and was the basis for recent studies at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Field experiments were designed at ICRISAT Asia Centre research farm to study the biological interaction of midges and midge parasitoids as influenced by sorghum genotypes and environmental conditions.

MATERIALS AND METHODS

Field studies were conducted during two cropping seasons: the 1992–93 post-rainy season (October–March) and the 1993 rainy season (June–October). Experiments were laid out in a randomized block design of eight rows, each 9 m in length, at a plant spacing of 75×10 cm, with three replications. Three sorghum-midge-resistant (ICSV 745, ICSV 89058 and IS 10712) and three susceptible (Swarna, CSH 9 and ICSV 112) genotypes and three planting dates (in each season) were used to facilitate the population monitoring of sorghum midge and its parasitoids throughout the season. Plantings I, II and III during the 1992–93 post-rainy season were on 29 October, 13 November and 1 December 1992 respectively, and plantings I, II and III during the 1993 rainy season were on 2 and 19 July and 6 August 1993 respectively. A basal dose of ammonium phosphate at the concentration of 150 kg ha^{-1} and a top-dressing of urea at the concentration 100 kg ha^{-1} were applied at sowing time. Thinning was carried out 10 days after seedling emergence (DAE), and each crop was protected from shoot fly infestation during early seedling growth (10–20 DAE) by applying cypermethrin (22.5 g a.i. ha^{-1}) at weekly intervals.

Emergence of Sorghum Midge and Parasitoids

During each season, three sorghum panicles of each genotype at 50% anthesis were randomly selected and caged in each replication and planting date. Forty female midges collected between 0830 and 1100 h from surrounding flowering sorghum fields were released into the cages (Kausalya *et al*., 1997) for 2 successive days. Forty midge flies were used to obtain maximum midge damage in the cage (Sharma *et al*., 1988). Five days after sorghum midge infestation, the panicles were exposed to natural parasitization for 10 days, and thereafter recaged for development and emergence of the midge flies and parasitoids.

Using the head cage technique, daily observations on emerging natural parasitoids and midge flies were recorded on a total of 54 panicles (three panicles/replication of six genotypes) per planting for several weeks to ensure that all emerging insects were collected. Emergence records were kept for each planting date, and data were averaged for standard calendar weeks of the year. The parasitoids collected were initially identified to the genus level at the ICRISAT Insect Collection Museum before being sent to the British Museum for identification to the species level.

Level of Parasitism

The total emergence of midges and *Aprostocetus* spp. from panicles exposed for natural parasitization was estimated from all three planting dates in each season. The level of parasitization was calculated as follows:

$$\text{Parasitism (\%)} = \frac{p}{m+p} \times 100$$

where p is the total number of emerging parasitoids and m the total number of midge flies from the exposed panicles.

Influence of Climatic Factors on Sorghum Midge and Parasitoids

Data on temperature, relative humidity (RH) and rainfall were obtained from the meteorological station at the ICRISAT farm and correlated with sorghum midge and parasitoid activity. Data given are for the period after 50% anthesis during post-rainy and rainy season trials.

Statistical Analysis

The data collected were subjected to analysis of variance (SAS Institute, 1985). The significant means between the genotypes within a planting date were separated using the Student Neuman Keuls test.

RESULTS

Species Composition

Two species of *Aprostocetus*, *A. gala* (Walker) and *A. coimbatorensis* (Rohwer), dominated (90%) the complex of parasitoids of sorghum midge in the 1992 and 1993 cropping seasons at the ICRISAT Centre (Figure 1). Other parasitoid species included *Eupelmus* spp. Although the species composition did not vary between genotypes, more individuals were recovered from susceptible than from resistant genotypes in both seasons. However, *A. gala* was predominant in the rainy season whereas *A. coimbatorensis* was predominant during the post-rainy season.

In the post-rainy season, *A. coimbatorensis* numbers varied considerably with planting dates (Figure 1). During this season, the highest numbers of *A. coimbatorensis* were recorded in planting III (1 December 1992–93), whereas for *A. gala* this occurred in planting I (29 October 1992–93). There was a considerable drop in parasitoid numbers in planting II (13 November 1992–93). Furthermore, *A. coimbatorensis* was twice as abundant as *A. gala* in planting I and II, whereas in planting III there was a seven-fold difference in numbers.

During the rainy season, *A. coimbatorensis* activity was lower than during the post-rainy

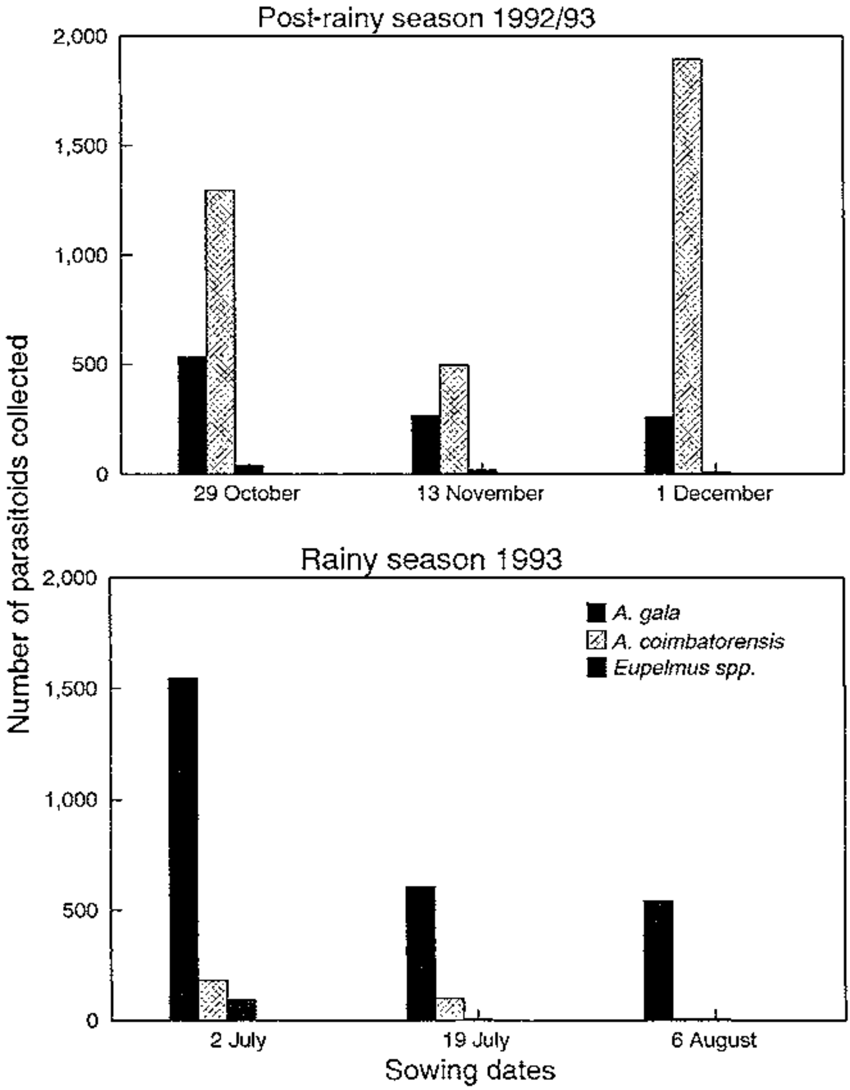

FIGURE 1. Parasitoids of sorghum midge collected during the 1992–93 post-rainy and 1993 rainy season at ICRISAT Asia Centre.

season (Figure 1). Species predominance was the reverse, with *A. gala* predominating over *A. coimbatorensis*. In contrast to the post-rainy season, the highest numbers were collected in planting I (2 July 1993) and practically no *A. coimbatorensis* activity was observed in planting III (6 August 1993).

Other parasitoid and predatory species occurred at considerably lower numbers. *Eupelmus* spp. were active during early plantings but declined as the season progressed.

Emergence of Sorghum Midge and Parasitoids During the 1992–93 Post-rainy Season

Sorghum midge. Adult midge flies emerged 2–3 weeks prior to parasitoid emergence during the 1992–93 post-rainy season. The first distinct peak in midge emergence occurred in the second week of February (Figure 2) in susceptible ICSV 112, CSH 9, Swarna and resistant ICSV 89058.

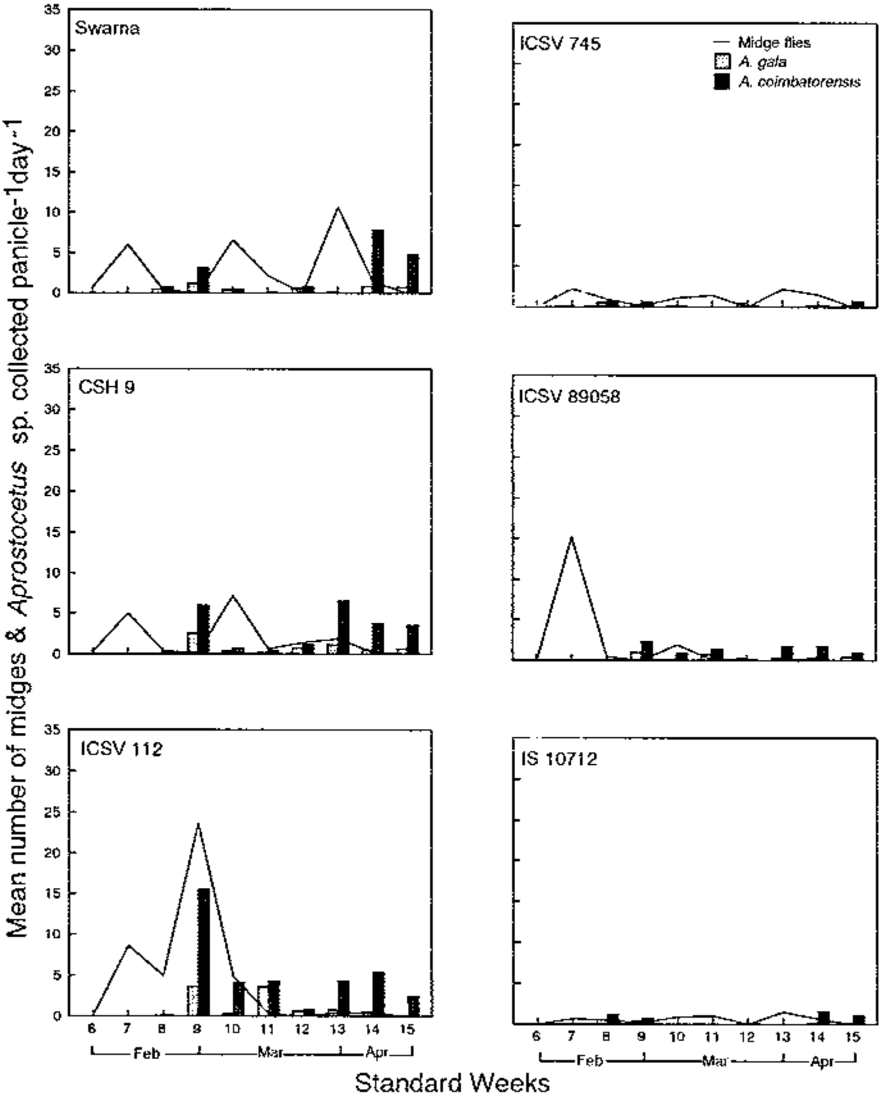

FIGURE 2. Emergence pattern of sorghum midge and *Aprostocetus* spp. during the 1992–93 post-rainy season at ICRISAT Asia Centre.

Several generations of midge flies occurred on susceptible genotypes during the season, and the highest number of midges was recorded on ICSV 112 in the fourth week of February.

Parasitoids. The first emergence of adult *Aprostocetus* was recorded in the third week of February (Figure 2), and both species of *Aprostocetus* were collected in resistant and susceptible genotypes throughout the season. However, *A. coimbatorensis* was predominant. *A. gala* activity was observed up to the third week of March, after which it declined in all genotypes. For *A. coimbatorensis*, high activity occurred in the fourth week of February and March and the first week of April. More individuals were recovered from susceptible than from resistant sorghum genotypes. Irrespective of density, parasitoid activity was always associated with midge infestation, even at low levels, in resistant genotypes.

Emergence of Sorghum Midge and Parasitoids During the 1993 Rainy Season

Sorghum midge. Midge fly emergence started 1–2 weeks prior to *Aprostocetus* spp. The first distinct peak in midge emergence occurred in the second or third week of October (Figure 3) in all genotypes. Two distinct peaks occurred in all genotypes except ICSV 112, which had only one major peak.

Parasitoids. In contrast to the post-rainy season, *A. gala* virtually overshadowed *A. coimbatorensis* during the rainy season; apart from a few individuals collected from susceptible Swarna and CSH 9, the activity of *A. coimbatorensis* was negligible (Figure 3).

A. gala activity was observed from the first week of October to the last week of November (Figure 3) but varied considerably among genotypes. Although there was continuous *A. gala* activity in susceptible genotypes, only one or two main peaks were recorded. Among resistant genotypes, only in IS 10712 was there any noticeable activity.

Level of Parasitism

Although there were significant differences in midge infestation and parasitoid numbers between resistant and susceptible genotypes (Figures 2 and 3), the percentage parasitism showed a different picture (Tables 1 and 2). Parasitism was much higher during the post-rainy season than during the rainy season, but no significant differences between genotypes in each planting was observed, except for parasitization by *A. gala* and *A. coimbatorensis* in planting III of the rainy and post-rainy seasons respectively.

1992–93 post-rainy season. The highest level of midge parasitism (69.4%) was by *A. coimbatorensis* and occurred in planting III in susceptible CSH 9 (Table 1). The lowest (3.5%), by *A. gala*, occurred in planting II in resistant ICSV 745. Parasitism was usually lower in ICSV 745 irrespective of planting dates and parasitoid species. Parasitism was low for both species in planting II. In all, parasitism by *A. gala* was highest in resistant ICSV 89058 during planting III. Similarly, low *A. coimbatorensis* activity in susceptible Swarna was comparable to that in resistant IS 10712.

1993 rainy season. Parasitism by *A. coimbatorensis* was much lower than *A. gala* during the post-rainy season (Table 2). Although the lowest level of parasitism by *A. gala* (3.1%) occurred in CSH 9 in planting II, the levels were remarkably low in susceptible ICSV 112 in planting I and II. However, in planting III, the highest level among all genotypes was also recorded from ICSV 112.

Influence of Climatic Factors on Sorghum Midge and Parasitoids

Rainfall did not occur during the 1992–93 post-rainy season until the last week of March (Figure 4). During the 1993 rainy season, rainfall (4–13 mm/week) was recorded between the second and fourth weeks of October (Figure 4). Emergence of *Aprostocetus* spp. and sorghum midge showed no positive relationship with rainfall. However, peak sorghum midge activity was recorded in October when the maximum temperature and RH ranged between 27–31 °C and 82–96% respectively and that of its parasitoids, *Aprostocetus* spp., was at 29–36 °C and 61–76%.

DISCUSSION

At the ICRISAT Asia Centre in India, sorghum midge was mainly parasitized by *A. gala*, *A. coimbatorensis* and *Eupelmus* spp. These parasitoids have been reported elsewhere and species predominance varied with location. *Aprostocetus* sp. was the predominant parasitoid in

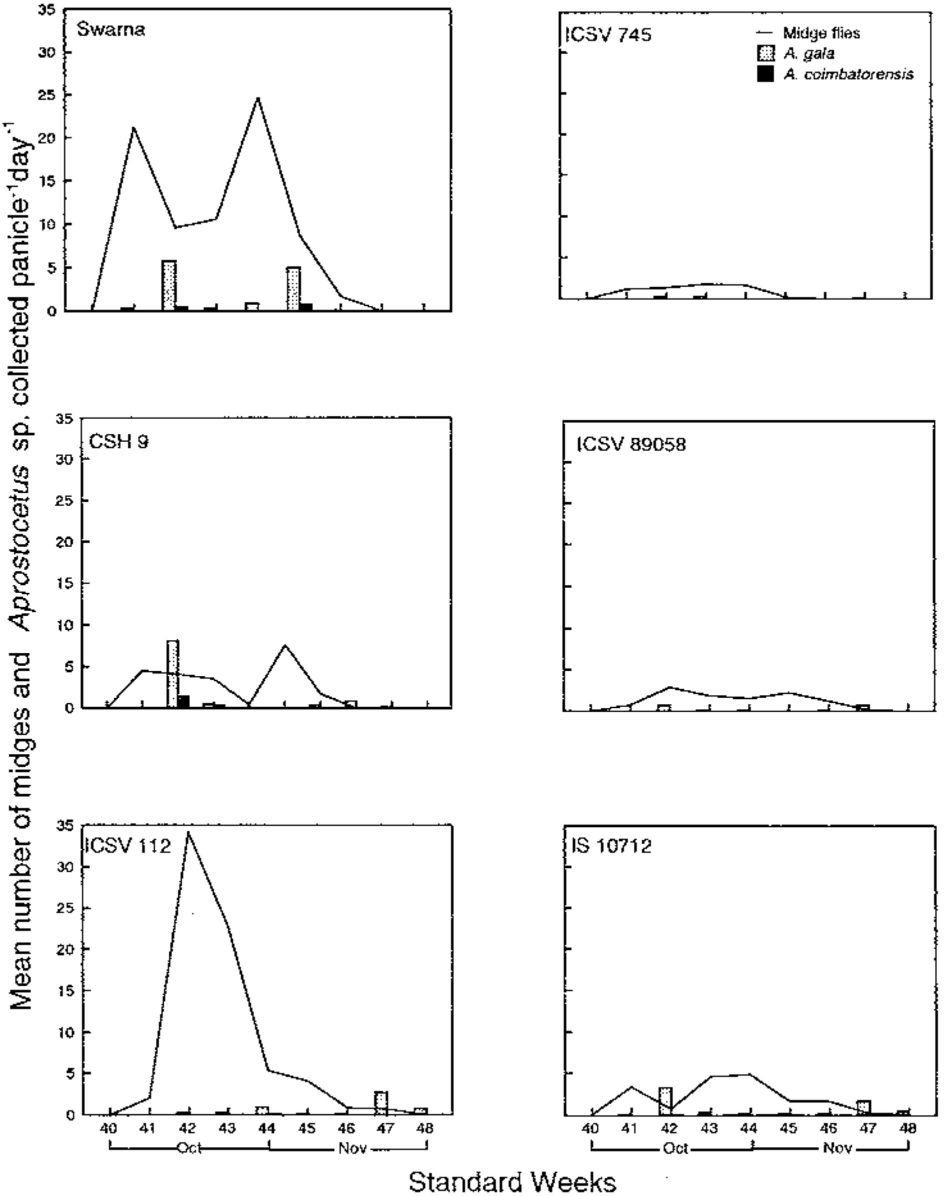

FIGURE 3. Emergence pattern of sorghum midge and *Aprostocetus* spp. during the 1993 rainy season at ICRISAT Asia Centre.

Australia (Franzmann *et al.*, 1989) while *Eupelmus* sp. was predominant in Maharashtra, India (Chundurwar, 1977) and in the Philippines (Barrion & Litsinger, 1982). *Tetrastichus* sp. was reported as being predominant in Texas, USA (Baxendale *et al.*, 1983; Brooks & Gilstrap 1986), Brazil (Busoli *et al.*, 1984), Senegal (Gahukar, 1984) and Karnataka, India (Rao *et al.*, 1986).

An increase in midge activity was followed by an increase in *Aprostocetus* activity. These results are consistent with those of Mote and Ghule (1986), who recorded a positive relationship between sorghum midge and its parasitoids. The emergence of adult *Aprostocetus* occurred

TABLE 1. Percentage parasitism of *S. sorghicola* by *Aprostocetus* spp. in relation to planting dates and sorghum genotypes during the 1992–93 post-rainy season at ICRISAT Asia Centre[a]

	Parasitism (%) from plantings[b]					
	A. gala			*A. coimbatorensis*		
Genotype	I	II	III	I	II	III
Swarna	11.1 ± 1.8a	6.7 ± 3.7a	7.4 ± 2.7a	25.1 ± 2.1a	9.3 ± 4.1a	45.9 ± 4.8b
CSH 9	12.5 ± 3.5a	7.5 ± 3.0a	8.5 ± 3.1a	26.2 ± 8.4a	17.7 ± 7.5a	69.4 ± 5.7a
ICSV 112	10.3 ± 0.6a	10.2 ± 0.9a	5.0 ± 1.9a	30.7 ± 1.6a	19.4 ± 2.2a	61.1 ± 5.8ab
ICSV 745	10.7 ± 3.8a	9.4 ± 3.0a	6.3 ± 2.1a	15.9 ± 4.8a	3.5 ± 3.5a	23.7 ± 2.3c
ICSV 89058	12.3 ± 3.4a	12.9 ± 3.4a	15.4 ± 5.6a	26.7 ± 4.5a	14.2 ± 1.9a	56.5 ± 4.9ab
IS 10712	13.6 ± 2.8a	8.2 ± 4.5a	4.1 ± 0.6a	25.5 ± 4.2a	6.8 ± 6.1a	47.3 ± 3.2b

[a] Means within a column followed by the same letter are not significantly different at $P = 0.05$; Student Neuman Keuls test.
[b] Plantings I, II and III = 29 October, 13 November and 1 December 1992–93 respectively.

1–3 weeks after commencement of midge emergence. This delay period would naturally favour the build-up of midge populations in the cropping season, since the life cycle of the midge is completed in 17–20 days and each female produces an average of > 100 eggs (Passlow, 1973; Murthy & Subramanian, 1975). In contrast, the life cycle of *Aprostocetus* is completed in 21–25 days and the fecundity of *Aprostocetus* spp. is much lower (50 eggs/female) (Taley *et al.*, 1978; Garg, 1979; Thontadarya *et al.*, 1983). Such a disparity in developmental period and fecundity between the pest and its parasitoid will result in considerable midge damage in susceptible genotypes.

In these studies, the percentage parasitism by *Aprostocetus* was higher during the post-rainy season than during the rainy season. This was observed in all the genotypes in spite of low midge densities in resistant genotypes. Although *A. gala* was present throughout the year on midge-infested panicles, its low population levels would have little effect on sorghum midge, especially in the rainy season when this species is predominant. However, low *A. coimbatorensis* activity in midge-resistant genotypes during the post-rainy season was associated with low midge infestations in these genotypes.

The lowest parasitoid activity occurred in planting II for both species of *Aprostocetus*, irrespective of midge population, genotype and crop season. The reasons for this phenomenon are not known.

Parasitoids were always associated with sorghum midge irrespective of low midge densities in

TABLE 2. Percentage parasitism of *S. sorghicola* by *Aprostocetus* spp. in relation to planting dates and sorghum genotypes during the 1993 rainy season at ICRISAT Asia Centre[a]

	Parasitism (%) from plantings[b]					
	A. gala			*A. coimbatorensis*		
Genotype	I	II	III	I	II	III
Swarna	31.2 ± 7.7ab	21.2 ± 8.1a	3.7 ± 2.2c	2.9 ± 1.3a	3.7 ± 1.7a	0.2 ± 0.2a
CSH 9	31.6 ± 3.4ab	3.1 ± 1.4a	16.1 ± 4.6abc	5.5 ± 2.4a	0.5 ± 0.3a	0.1 ± 0.1a
ICSV 112	4.1 ± 1.2b	7.1 ± 4.9a	30.7 ± 5.8a	0.9 ± 0.6a	1.1 ± 0.9a	0.7 ± 0.1a
ICSV 745	32.8 ± 7.9ab	15.2 ± 2.8a	3.7 ± 3.7c	1.6 ± 1.6a	1.7 ± 0.9a	0.0 ± 0.0a
ICSV 89058	28.9 ± 2.3ab	15.8 ± 7.9a	9.5 ± 4.4bc	1.3 ± 1.3a	2.3 ± 1.8a	0.0 ± 0.0a
IS 10712	40.6 ± 6.2a	10.8 ± 3.7a	26.7 ± 5.4ab	5.3 ± 2.3a	3.9 ± 1.9a	0.2 ± 0.2a

[a] Means within a column followed by the same letter are not significantly different at $P = 0.05$; Student Neuman Keuls test.
[b] Plantings I, II and III = 2 July, 19 July and 6 August 1993 respectively.

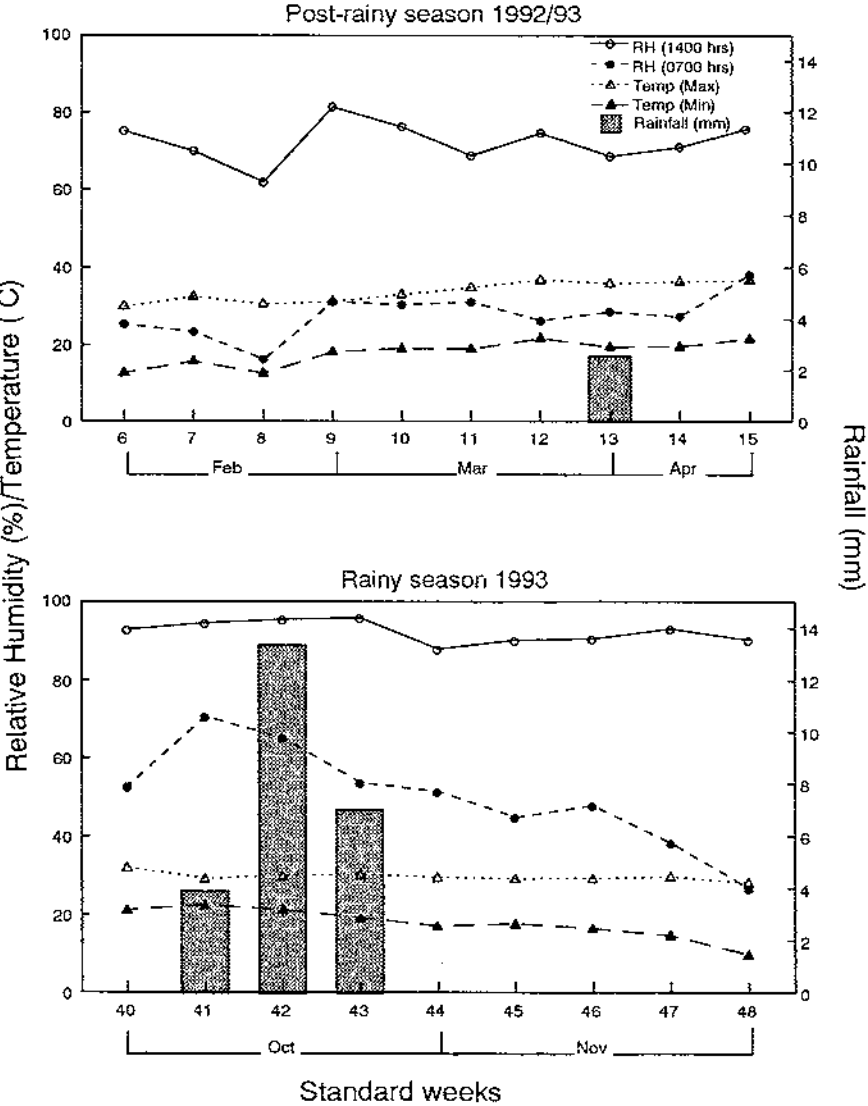

FIGURE 4. Seasonal fluctuation of climatic variables during the 1992–93 post-rainy and 1993 rainy season at ICRISAT Asia Centre.

resistant genotypes. However, low midge parasitism was always associated with midge-resistant ICSV 745, a derivative of DJ 6514. Resistance in DJ 6514 is attributed to non-preference for this genotype for oviposition (Sharma, 1985a) and faster rate of grain development (Sharma *et al.*, 1990). Since parasitoids were always associated with low midge densities in other resistant genotypes, it was concluded that other resistance factors in ICSV 745 could be responsible for the negative effect on *Aprostocetus*. This situation is also known to occur where antibiosis adversely affects the activity of natural enemies (Campbell & Duffey, 1979; Isenhour & Wiseman, 1989).

The mechanism of resistance in ICSV 89058 is not known. In contrast to ICSV 745, the levels of parasitism were high during the 1992–93 post-rainy season and were similar to, or higher than, those in the susceptible genotypes. Therefore, resistance in ICSV 89058 is not antagonistic to *Aprostocetus* but rather is favourable to successful parasitoid development.

Resistance in IS 10712 is due to antibiosis (Sharma *et al.*, 1990), and is known to affect midge fecundity, larval development and adult emergence. *A. coimbatorensis* activity in this genotype was comparable to that in susceptible ones. Similar observations were reported by Isenhour and Wiseman (1987) in corn.

In the present study, neither sorghum midge nor parasitoid activity was associated with rainfall. However, Mote and Ghule (1986) reported a positive correlation between rainfall and sorghum midge populations. Peak midge activity was recorded in October, when maximum temperature and RH ranged between 27–31°C and 82–96% respectively. Sharma (1985a) and Garg and Taley (1978) reported the same to occur in September/October when temperatures and RH ranged between 25–27°C and 75–80% respectively. However, *Aprostocetus* adults were collected at slightly higher temperatures of 29–36°C and lower RH levels of 61–76%.

CONCLUSIONS

Parasitism was higher in the post-rainy than in the rainy season, and was attributed to the presence of both species of *Aprostocetus* during the post-rainy season. Parasitoid activity was higher at the beginning and end of each cropping season but declined during the mid-season. Further studies are required to elucidate this phenomenon. The present study indicated that resistance in the genotypes studied is not antagonistic to parasitoid activity. However, it has yet to be shown whether this compatibility can be further enhanced during the rainy season when the pest is more active. The information obtained from this study provides a basis for exploring the potential of interfacing biological control with host-plant resistance as a strategy in the integrated management of sorghum midge.

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