Mortality of the Corn Earworm (Lepidoptera: Noctuidae) on Sorghum Panicles in Georgia[1]

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Abstract The mortality of the corn earworm, *Helicoverpa zea* (Boddie), on sorghum panicles in Georgia was determined in a 2-yr study. Percent total real mortality (r_x) of *H. zea* exceeded 99% for each year and planting date. Percent total real mortality was highest for eggs followed by 1st instars. Parasitization and predation were the primary mortality factors for eggs on sorghum panicles. Larval mortality was due in part to predation, parasitization, and infection by pathogens. *Trichogramma pretiosum* Riley was the only egg parasitoid observed on sorghum panicles. *Orius insidiosus* (Say) was the predominant predator of *H. zea*. Other predators observed feeding on *H. zea* included the big-eyed bug, *Geocoris punctipes* (Say), the spined soldier bug, *Podisus maculiventris* (Say), green lynx spiders, *Peucetia viridans* (Hentz), and lady beetles (mainly *Hippodamia convergens* Guérin-Méneville). A variety of parasitoids attacked larvae on sorghum. The braconid *Cotesia marginiventris* (Cresson) parasitized small to medium-sized larvae. The tachinids *Eucelatoria rubentis* Coquillett and *Archytas marmoratus* (Townsend) parasitized large larvae. Two pathogens, HzNPV, a naturally-occurring nuclear polyhedrosis virus of *H. zea*, and the fungus, *Entomophthora aulicae* (Reichardt) G. Winter, caused mortality of larvae. In conclusion, biological control by natural enemies of *H. zea* on sorghum panicles resulted in significant mortality for this pest.

Key Words *Helicoverpa zea*, corn earworm, life table, sorghum

The corn earworm, *Helicoverpa zea* (Boddie), is an economically important pest of various crops including sorghum, corn, and cotton in Georgia. Sorghum, *Sorghum bicolor* (L.) Moench, has been shown to be much more attractive to *H. zea* than cotton, and this preference for sorghum is in part responsible for the success of a sorghum trap crop for this pest in cotton (Tillman and Mullinix 2004). In a trap crop, mortality of a pest needs to be sufficiently high to effectively control the insect, or the pest has to be eliminated through crop destruction or application of insecticides. The goal of this paper was to evaluate mortality of *H. zea* on sorghum in Georgia over a 2-yr study by constructing partial life tables for this pest on the panicles of sorghum.

Materials and Methods

Crop management and design. Sorghum (DeKalb E57) was planted at a rate of 25,500 seeds/ha using a 2-row John Deere (Deere & Co., Moline, IL) planter. For

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each planting date, sorghum was planted in four rows. Sorghum was planted in Mystic, GA, on three planting dates (3 planting dates × 4 rows = 12 rows) in three fields in 2001 (30 April, 14 May, and 7 June) and 2002 (13 May, 23 May, and 3 June) and for only the first planting date (1 planting date × 4 rows = 4 rows) for two fields in 2002. For both years of the test, three plots, 45 m long × 4 or 12 rows deep, of sorghum were planted in a strip between a large commercial corn and cotton field.

Insect sampling. Corn earworm eggs and larvae along with predators of this pest were monitored every 3-4 d throughout the development of the sorghum panicles. For sampling purposes, each sorghum plot was subdivided into three 15-m sections (length of row). In 2001, all sorghum panicles in 0.15 m of row were collected. Three of these random collections were obtained per 15-m section of row per planting date. Therefore, 36 samples (3 sections × 3 samples × 4 rows) were collected per planting date per plot. In 2002, panicles from three plants were randomly obtained per 15-m section of row so that 36 panicles (3 sections × 3 samples × 4 rows) were collected per planting date per plot. In the field, sorghum panicles were cut, placed in paper bags that were stapled closed, transported to the laboratory, and stored at 15°C.

In the laboratory, all insects were removed from a sorghum panicle within 24 h of field collection by rubbing fingers through the panicle along its length whereas gently twirling it (Tillman and Mullinix 2004). Predators were counted and recorded as they dropped from the panicles. All other material removed from the sorghum panicles was collected and examined under a dissecting microscope. Heliothine eggs and larvae were identified to species using a compound microscope and Neunzig's (1969) description of immature stages of corn earworms. All heliothine eggs were held for emergence of parasitoids or corn earworm first instars, which were reared to adults on a laboratory bean diet (Perkins et al. 1973) to insure that the previous identifications of egg species were correct. All heliothine larvae also were held in diet cups to determine if they were parasitized, or if not parasitized, to await emergence of adult moths to verify that they were identified correctly. Nuclear polyhedrosis virus infection of *H. zea* larvae (HzNPV) was identified by John J. Hamm (USDA-ARS). *Trichogramma pretiosum* Riley were identified by John D. Pinto (University of California). Tachinid parasitoids were identified by Norman E. Woodley (USDA-ARS). Predators and *Cotesia marginiventris* (Cresson) were identified by the author. Voucher specimens of all insects are held in the USDA-ARS, Crop Protection & Management Research Laboratory in Tifton, GA.

Life table and statistical analysis. Numbers of eggs and larvae collected from sorghum panicles and plant population densities in field plots were used to calculate abundances of each life stage converted to per hectare basis. Partial life tables for *H. zea* occurring on the panicles of sorghum for each of the three planting dates, when appropriate, for both years of the study were constructed using the graphical method (Southwood 1978). Real (r_x) and apparent (q_x) mortality were calculated for each life stage (x) based on numbers of individuals entering each life stage (l_x). Egg and larval mortality were classified as failure to hatch (eggs only), diseased (larvae only), preyed-on, parasitized, and unknown fate. Eggs which have been fed upon by sucking insects were shriveled, tepee-shaped, and had very little egg material remaining inside them (Fletcher and Thomas 1943). Eggs with this characteristic appearance were categorized as preyed-on eggs. Corn earworm larvae that appeared to be chewed on also were placed in the preyed-on category. An estimated development time of 3 d was used for healthy eggs (Quaintance and Brues 1905) and 10 d for eggs parasitized by *T. pretiosum* (Strand and Vinson 1985). An estimated development time of 2.2, 1.8, 1.3, 1.9, 5.3, and 5 d at 30°C was used for healthy 1st, 2nd, 3rd, 4th, 5th, and 6th instars, respectively (Fye and McAda 1972). Development times of parasitized *H. zea* larvae were obtained from the literature and are as follows: 7 d for *C. marginiventris* (Boling and Pitre 1970), 12 d for *Eucelatoria rubentis* Coquillett (Reitz 1996), and 8 d for *Archytas marmoratus* (Townsend) (Hughes 1975).

Percent total real mortality and percent total apparent mortality data were analyzed using PROC MIXED (SAS Institute 1999). The fixed effects were life stage, planting date, year, and year by planting date. The random effects were field and residual error. Least squares means were separated by least significant difference (LSD) (SAS Institute 1999) where appropriate. Data on percent parasitism of *H. zea* by *T. pretiosum* and data on mean number of *O. insidiosus* per sorghum panicle were analyzed using PROC MIXED (SAS Institute 1999). The fixed effects were year, planting date, and year by planting date. The random effects were field and residual error. Least squares means were separated by least significant difference (LSD) (SAS Institute 1999) where appropriate. Comparisons of frequency of occurrence of *O. insidiosus*, spiders, and *G. punctipes* on sorghum panicles were performed using PROC FREQ (SAS Institute 1999). Means for frequency of occurrence over all planting dates were compared between *O. insidiosus* and spiders using *t*-tests.

Results and Discussion

Percent total real mortality (r_x) of *H. zea* on sorghum panicles was very high, exceeding 99% for each year and planting date (Tables 1-2). The number of *H. zea* eggs on sorghum was within the same range previously reported for sorghum by Teetes et al. (1992), and the variability in occurrence of *H. zea* between years was expected for this pest (Quaintance and Brues 1905, Wilson 1976). Percent total real mortality was similar among years ($F = 0$; df = 1, 94; $P = 0.9655$) and planting dates ($F = 0$; df = 2, 94; $P = 0.9999$), and there was no significant year × planting date interaction ($F = 0$; df = 2, 94; $P = 1.0$). Therefore, mortality data were combined over years and planting dates. Percent real mortality was highest for the egg stage and second highest for 1st instars ($F = 142.15$; df = 5, 98; $P = 0.0001$) (Table 3). These results concur with those of Teetes et al. (1992) for real mortality for both this open-panicle sorghum variety and a compact-panicle sorghum variety in Texas.

Percent total apparent mortality (q_x) of *H. zea* on sorghum panicles was similar among years ($F = 0.02$; df = 1, 94; $P = 0.8768$) and planting dates ($F = 0.55$; df = 2, 94; $P = 0.576$), and there was no significant year × planting date interaction ($F = 0.62$; df = 2, 94; $P = 0.5409$). Therefore, mortality data were combined over years and planting dates. Percent apparent mortality was lowest for the 1st and 2nd instars compared with the other life stages ($F = 5.94$; df = 5, 98; $P = 0.0001$) (Table 3). In contrast to these findings, Teetes et al. (1992) determined that percent apparent mortality was generally very high for small *H. zea* larvae. Apparent mortality may possibly be underestimated for young larvae in the Georgia tests.

The characteristic shriveling of eggs preyed on by sucking predators was easy to detect in the laboratory, but many of these eggs were probably lost in the field. Both of the sucking predators *Orius insidiosus* (Say) and *Geocoris punctipes* (Say) occasionally were observed pulling individual *H. zea* eggs off of a sorghum panicle sometime during the feeding process. Also, shriveled eggs on sorghum panicles in the field become desiccated and can possibly drop off the plant. It was impossible to account for the number of lost shriveled eggs or for the number of eggs consumed by chewing

Table 1. Partial life table for *H. zea* on sorghum panicles for each planting date (PD) in 2001

				Apparent mortality (q_x)					
PD	Life stage (x)	No./ha entering stage (l_x)	Real mortality (r_x)	Total	Hatch failure	Disease	Preyed on	Parasitized	Unknown fate
1	Egg	222,944.7	90.7	90.7	3.2		2.2	9.1	76.2
	1st	20,685.8	4.8	51.8		14.1	4.2	0	33.5
	2nd	9,973.8	1.2	27.6		6.6	1.1	0	19.9
	3rd	7,218.7	2.7	83.6		11.1	0	0	72.5
	4th	1,181.8	0.4	83.0		0	0	0	83.0
	5th/6th	200.6	0.1	—		0	0	0	—
	Total	—	99.9	—					
2	Egg	207,990.0	78.4	78.4	2.1		2.6	13.0	60.7
	1st	44,925.4	8.0	37.1		9.1	3.0	0	25.0
	2nd	28,273.7	6.5	47.5		1.9	1.2	0	44.4
	3rd	14,841.6	5.0	70.7		4.4	1.1	0	65.2
	4th	4,343.4	1.8	89.4		0	0	0	70.7
	5th/6th	460.6	0.1	—		0	0	10.0	—
	Total	—	99.8	—					
3	Egg	60,073.2	72.0	72.0	1.8		0.8	35.0	34.4
	1st	16,800.9	13.2	47.1		4.7	1.5	0	40.9
	2nd	8,890.4	8.6	58.6		0	0	0	58.6
	3rd	3,679.3	5.4	88.2		0	0	0	88.2
	4th	433.6	0.5	76.9		0	0	0	76.9
	5th/6th	100.3	0.1	—		0	0	0	—
	Total	—	99.8	—					

Table 2. Partial life table for *H. zea* on sorghum panicles for each planting date (PD) in 2002

PD	Life stage (x)	No./ha entering stage (l_x)	Real mortality (r_x)	Apparent mortality (q_x)					
				Total	Hatch failure	Disease	Preyed on	Parasitized	Unknown fate
1	Egg	1,139,043.0	74.59	74.59	1.6		2.8	14.7	55.49
	1^{st}	289,420.7	14.99	59.01		0.6	0	0.1	58.31
	2^{nd}	118,624.6	4.4	452.21		0	0	0	42.2
	3^{rd}	68,556.4	4.76	79.16		0.8	0	0	78.36
	4^{th}	14,283.9	0.76	60.89		3.4	0	0	57.49
	5^{th}	5,587.1	0.38	77.67		0	0	0	77.67
	6^{th}	1247.7	0.11	—		0	0	20.0	—
	Total	—	99.99	—					
2	Egg	439,871.4	66.66	66.66	1.1		1.6	33.7	30.26
	1^{st}	145,638.6	19.23	57.68		0.1	0	0	57.58
	2^{nd}	62,064.5	3.33	23.57		0.9	0	0	22.67
	3^{rd}	47,437.6	9.20	85.42		0	0	0	85.42
	4^{th}	6,916.2	0.78	49.87		5.3	0	10.5	34.07
	5^{th}	3,467.3	0.46	58.23		18.2	0	0	40.03
	6^{th}	1448.2	0.33	—		9.1	0	0	—
	Total	—	99.9	—					

Table 2. Continued.

PD	Life stage (x)	No./ha entering stage (l_x)	Real mortality (r_x)	Apparent mortality (q_x)					
				Total	Hatch failure	Disease	Preyed on	Parasitized	Unknown fate
3	Egg	331,051.8	83.9	83.9	0.1		0.5	64.0	19.3
	1st	53,288.8	9.1	56.53		0	0	0	56.53
	2nd	23,166.4	4.54	64.93		0	0	0	64.93
	3rd	8,125.2	1.29	52.64		0	0	0	52.64
	4th	3848.4	1.06	91.53		0	0	28.6	62.93
	5th	326.1	0.08	82.49		0	0	0	82.49
	6th	57.1	0.02	—		0	0	0	—
	Total	—	99.9	—					

Table 3. Least squares means for percent total real mortality for each life stage of *H. zea* on sorghum panicles

Life stage	% Total real mortality (r_x)	% Total apparent mortality (q_x)
Egg	70.16 a	70.16 a
1st	16.38 b	48.55 b
2nd	5.36 c	43.52 b
3rd	6.42 c	68.14 a
4th	1.30 c	72.6 a
5th	0.46 c	82.92 a

Least squares means within a column followed by the same lowercase letter are not significantly different between life stages for percent total real mortality (PROC MIXED, LSD, $P > 0.05$, n = 111, SE = 3.13, df = 98) and percent total apparent mortality (PROC MIXED, LSD, $P > 0.05$, n = 111, SE = 8.11, df = 98).

predators. Therefore, it was assumed that percent apparent mortality in the "unknown fate" category for the *H. zea* eggs was due in part to predation. Teetes et al. (1992) classified egg mortality of *H. zea* as failure to hatch, parasitized, and disappeared. Because the major mortality factor for eggs was disappearance, they also speculated that predation accounted for some level of this mortality factor.

Trichogramma pretiosum was the only egg parasitoid of *H. zea* in sorghum plots in Georgia, and a range of 1-4 parasitoids emerged from individual parasitized *H. zea* eggs. Steward et al. (1990) previously reported that the wasps *T. pretiosum*, *Trichogramma exiguum* (Pinto and Planter), and *Telenomus heliothidis* Ashmead were important natural enemies of *H. zea* eggs on sorghum in Arkansas, OK, and Texas. Teetes et al. (1992) reported that a few *Telenomus* spp. along with *Trichogramma* spp. parasitized *H. zea* eggs on sorghum in Texas.

Parasitization by *T. pretiosum* and predation were the two main specific mortality factors detected for *H. zea* eggs on sorghum panicles (Tables 2-4). A good estimate for percent parasitization by *T. pretiosum* was obtained because a large number of eggs was collected from the field, and these eggs were protected in diet cups in the

Table 4. Least squares means for percent parasitism of *H. zea* eggs by *T. pretiosum* in sorghum for each planting date in 2001 and 2002

Planting date	% Parasitism 2001	% Parasitism 2002
1	9.11 b	14.73 c
2	13.02 b	33.72 b
3	35.01 a	63.95 a

Least squares means within a column followed by the same lowercase letter are not significantly different between planting dates (PROC MIXED, LSD, $P > 0.05$, n = 20, SE = 7.77, df = 8).

laboratory to await emergence of the parasitoid. Factorial analysis revealed that percent parasitism of *H. zea* by *T. pretiosum* was significantly higher in 2002 (37.47% ± 4.79) than in 2001 (19.05 ± 5.49) (F = 6.4; df = 1, 8; P = 0.0353). There was no significant year × planting date interaction (F = 2.5; df = 2, 8; P = 0.1437). Percent parasitism of *H. zea* by *T. pretiosum* was significantly different among planting dates (F = 25.75; df = 2, 8; P = 0.0003) for both years. In 2001, parasitization of corn earworm eggs by this wasp was significantly higher for the third planting date compared with the other two planting dates (Table 4). In 2002, percent parasitism of eggs of this pest by *T. pretiosum* increased over each planting date (Table 4). Except for the high (64.0%) level of egg parasitization found in 2002 for the third planting date of sorghum, rates of egg parasitism were within the range of those reported by Teetes et al. (1992).

A variety of predators were observed to prey on *H. zea* eggs and 1st instars on sorghum panicles plots in Georgia. *Orius insidiosus* and *G. punctipes* were the only sucking-predators observed in the field to prey on these development stages of this pest. *Orius insidiosus* has been previously reported to be an important natural enemy of *H. zea* in various cropping systems including corn, cotton and sorghum (Barber 1936a, Fletcher and Thomas 1943). *Geocoris punctipes* has been reported to be one of the most predominant and effective predators of heliothines in cotton (Bell and Whitcomb 1963, Lingren et al. 1968, Lopez et al. 1976). Even though *Hippodamia convergens* Guérin-Méneville is an important predator of the cotton aphid, *Aphis gossypii* Glover, in cotton (Flint and Dreistadt 1998), in this study it was observed to chew on *H. zea* eggs on sorghum panicles. The green lynx spider, *Peucetia viridans* (Hentz), also was observed chewing on eggs of this pest on sorghum panicles. Observations of natural enemies feeding on *H. zea* eggs focused on day-active predators. Pfannenstiel and Yeargan (2002) demonstrated that nocturnally active predators were important in the biological control of *H. zea* eggs. Thus, even though nocturnal predation presumably was a significant component of mortality of *H. zea*, the relative importance of nocturnal predators in sorghum is unknown and will be considered in the future.

Orius insidiosus, G. punctipes, and spiders were the most numerous predators of *H. zea* on sorghum panicles. Frequency of occurrence was significantly higher for *O. insidiosus* compared with spiders and *G. punctipes* for each planting date in 2001 (Table 5) and 2002 (Table 6). Also, the mean total frequency of occurrence over all planting dates for *O. insidiosus* was significantly higher than that for spiders in 2001 (Table 5) and 2002 (Table 6). These results indicate that *O. insidiosus* was the predominant day-active predator of *H. zea* on sorghum panicles.

Factorial analysis revealed that mean number of *O. insidiosus* per sorghum panicle was significantly higher in 2002 (2.31 ± 0.28) than in 2001 (0.59 ± 0.27) (F = 20.11; df = 1, 14,000; P = 0.0001). There was a significant year × planting date interaction (F = 376.41; df = 2, 14,000; P = 0.0001) for mean number of *O. insidiosus* per sorghum panicle. Therefore, these data were analyzed separately for years. Mean number of *O. insidiosus* per sorghum panicle significantly decreased over each planting date in 2001 (F = 32.43; df = 2, 8672; P = 0.0001) and 2002 (F = 362.32; df = 2, 5822; P = 0.0001) (Table 7).

Number of *O. insidiosus* per sorghum panicle and subsequent predation on *H. zea* eggs decreased over planting dates whereas parasitism of eggs of this pest increased over planting dates for both years of this study. *Orius insidiosus* were observed preying on eggs of this pest on corn silks in corn fields adjacent to the sorghum plots.

Table 5. Frequency of occurrence of *O. insidiosus,* spiders, and *G. punctipes* on sorghum panicles for three planting dates (PD) in 2001

	O. insidiosus		Spiders		*G. punctipes*		Total by PD	
PD	n	Freq. (%)	n	Freq. (%)	n	Freq. (%)	n	Freq. (%)
1	2413	85.63	257	9.12	148	5.25	2818	46.94
2	1582	87.16	182	10.03	51	2.81	1815	30.23
3	1195	87.23	133	9.71	42	3.07	1370	22.82
Total by predator	5190	86.46	572	9.53	241	4.01	6003	100.0
						$\chi^2 = 21.81$, df = 4, $P = 0.0002$		

Mean ± SE for total frequency of occurrence		*O. insidiosus* vs. spiders			
O. insidiosus	86.46 ± 0.48	difference	SE	$\|t\|$	*P*
Spiders	9.53 ± 1.23	76.83	0.59	91.0	0.0001

Table 6. Frequency of occurrence of *O. insidiosus,* spiders, and *G. punctipes* on sorghum panicles for three planting dates (PD) in 2002

	O. insidiosus		Spiders		*G. punctipes*		Total by PD	
PD	n	Freq. (%)	n	Freq. (%)	n	Freq. (%)	n	Freq. (%)
1	6941	97.04	186	2.60	26	0.36	7153	61.0
2	3706	97.65	67	1.77	22	0.58	3795	32.36
3	767	98.46	9	1.16	3	0.39	779	6.64
Total by predator	11414	97.33	262	2.23	51	0.43	11727	100.0
						$\chi^2 = 15.0$, df = 4, $P = 0.0047$		

Mean ± SE for total frequency of occurrence		*O. insidiosus* vs. spiders			
O. insidiosus	97.33 ± 0.15	difference	SE	$\|t\|$	*P*
Spiders	2.23 ± 0.01	95.1	0.203	469.7	0.0001

Results from rubidium-marking tests demonstrated that *O. insidiosus* adults on sorghum had previously fed on *H. zea* eggs in corn indicating that these predators dispersed from maturing corn into young sorghum panicles (P. G. T., unpubl. data). Dispersal from corn to sorghum probably resulted in a high population of *O. insidiosus* on the first planting of sorghum because these predators were dispersing from a large (corn field) to a small (sorghum plot) area. Later decreases in the *O. insidiosus* population in sorghum could be due to dispersal into newly available vegetation. For

Table 7. Least squares means for number of *O. insidiosus* per sorghum panicle for each planting date in 2001 and 2002

Planting date	2001	2002
1	0.72 a	3.39 a
2	0.56 b	2.65 b
3	0.49 c	0.88 c

Least squares means within a column followed by the same lowercase letter are not significantly different between planting dates in 2001 (PROC MIXED, LSD, $P > 0.05$, n = 8677, SE = 0.03, df = 8672 and 2002 (PROC MIXED, LSD, $P > 0.05$, n = 5827, SE = 0.09, df = 5822).

example, Parajulee and Slosser (1999) demonstrated that a spring planting of a sorghum strip crop on both sides of a cotton plot enhanced predator abundance in the cotton. Populations of the egg parasitoid *T. pretiosum*, however, probably can only increase as hosts become available in sorghum.

Mortality of *H. zea* larvae was due in part to predation, parasitization, and infection by pathogens (Tables 2-4). Teetes et al. (1992) classified larval mortality as diseased, parasitized and disappeared. In their study, the major mortality factor for the larval stages of *H. zea* was disappearance, the cause unknown. As mentioned above, *O. insidiosus* and *G. punctipes* preyed on young *H. zea* larvae on sorghum panicles in our study. The spined soldier bug, *Podisus maculiventris* (Say), a generalist predator feeding on a variety of insect prey in a diversity of crop and noncrop ecosystems (McPherson 1980), ingested *H. zea* larvae of all stages on sorghum depending on the developmental stage of the predator. The green lynx spider fed on large *H. zea* larvae and many other insects, including some of the beneficial insects. Nyffeler et al. (1987) reported that in cotton *H. zea* and the cotton leafworm, *Alabama argillacea* (Hübner), together consisted of 8% of the prey of green lynx spiders. Occurrence of these predators on sorghum was not incidental, for each of the predator species was able to complete at least one generation on sorghum.

A variety of parasitoids attacked *H. zea* larvae on sorghum in Georgia. The highest level of parasitization, 28.6%, occurred for 4^{th} instars for the third planting date in 2002 (Table 2). The braconid *C. marginiventris* parasitized small to medium-sized *H. zea* larvae on sorghum in this study and past studies (Steward et al. 1990, Teetes et al. 1992). *Microplitis croceipes* (Cresson) was the most common larval parasitoid of *H. zea* on sorghum observed by Teetes et al. (1992), but larval parasitism by *M. croceipes* was very low for *H. zea* collected from sorghum by Steward et al. (1990). This parasitoid is rare in south Georgia, for it has been recovered from only a very few *H. zea* larvae on corn and crimson clover over the past 4 yrs (P. G. T., unpubl. data). Therefore, it was not surprising that *H. zea* larvae were not parasitized by this wasp in sorghum in this study. The tachinids *E. rubentis* and *A. marmoratus* parasitized large *H. zea* larvae on sorghum panicles. *Eucelatoria rubentis*, a gregarious endoparasitoid, has been reported as a parasitoid of *H. zea* in soybeans (Hughes and Rabb 1976), and *A. marmoratus* is a larval-pupal parasitoid of *H. zea* in corn (Quaintance and Brues 1905, Miller 1971, Gross et al. 1976) and cotton (Bibby 1942, Hughes and Rabb 1976). Teetes et al. (1992) found that *Eucelatoria bryani* Sabrosky was the only tachinid species parasitizing *H. zea* on sorghum. Steward et al. (1990)

recovered *A. marmoratus* and *E. bryani* from corn earworm larvae on sorghum panicles. Teetes et al. (1992) observed *Campoletis sonorensis* (Cameron) parasitizing medium-sized *H. zea* larvae on sorghum. This parasitoid has been recovered from *Heliothis virescens* (F.) on tobacco and cotton in Irwin Co, GA for the past 4 yrs (P. G. T., unpubl. data), but it did not parasitize *H. zea* larvae on sorghum in this study. The braconid, *Chelonus texanus* Cresson, and the eulophid, *Elasmus setosiscutellatus* Crawford, reported by Steward et al. (1990) to be two of the most abundant parasitoids of *H. zea* on sorghum, were not found on this pest in sorghum plots in Georgia.

Two pathogens, HzNPV, a naturally-occurring nuclear polyhedrosis virus of *H. zea*, and the fungus, *Entomophthora aulicae* (Reichardt) G. Winter, caused mortality of corn earworm larvae on sorghum panicles. Teetes et al. (1992) also found symptoms of HzNPV infection in *H. zea* larvae on sorghum. HzNPV is considered to be highly virulent against *H. zea* (Ignoffo 1965). Hamm (1980) reported that *E. aulicae* caused 48-100% mortality of corn earworm larvae collected from sorghum in late August and early September in 1976.

Cannibalism was not specifically observed in this study, but it probably contributed to *H. zea* population suppression and accounted for some of the percent of apparent mortality listed in the "unknown fate" category. Sigsgaard et al. (2002) reported that egg cannibalism by 1st-instar *H. armigera* not only occurred on sorghum but also was higher on this plant species than on pigeon pea. The greater cannibalism on sorghum than on pigeon pea possibly could be due to the congregation of this pest on the panicles. Cannibalism among late instars of *H. zea* also has been reported to be a major factor in the reduction in the population of this pest (Barber 1936b).

In summary, life table analyses revealed that percent of total real mortality of *H. zea* due to predation, parasitization, and infection by pathogens was very high in sorghum. Therefore, biological control by natural enemies of *H. zea* on sorghum panicles resulted in significant mortality for this pest.

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