

application of 100 ml of pesticide proved stressful to trees already growing under poor conditions (sometimes water-logged and lacking fertilizer) or a biological agent was affected. Predators are thought to have little influence on coconut mite levels, but their effect is difficult to quantify. Possibly predators were reduced by eating coconut mites that had taken up some vamidothion; however, there is no evidence to support either of these suggestions. The greater number of young nuts from the vamidothion-treated trees (Table 3) did not reflect control of mites as damage levels were worse with the treatment, though the pesticide may have killed other incidental sucking pests such as scales. The results at Choc Estate did suggest an effect of the vamidothion, even when applied 1 month after drilling the trees.

The results from Fond Estate were somewhat contradictory, although again they provided no positive support for pesticide use. Although the treated trees appeared to have produced more nuts (Table 7), the damage results do not suggest that this was due to mite control; again, incidental pests may have been controlled.

The delay in applying pesticide after drilling at Choc Estate may have impeded uptake but circumstantial evidence suggests that the pesticide was taken up. For example, the level of pesticide in the holes dropped over a matter of a few hours and within a week a very dilute concentration was present. Additionally, the results from Choc Estate suggest an effect of the pesticide. It is possible that embolism occurring at drilling could be overcome by the high root pressures that occur in palms (Davis, 1961), especially with the interconnecting nature of the vascular tissues. At Fond Estate the pesticide was added soon after drilling and still did not produce evidence of control.

Coconuts are a very valuable crop in St Lucia and other Windward Islands and the mite is causing serious financial loss. As such, well-publicized methods of control receive a great deal of support, even without careful examination of the experimental proof. Griffith (1982, 1983, 1984) worked on young short trees, which may explain differences from the present work. However, his claims for the pesticide were not justified by the data that he presented, nor by the manner in which the experiments were conducted. For example one of Griffith's main experiments (Griffith, 1982) had no control trees with which to make valid comparisons and no yield data have been produced from the experiments. Other data do not stand up to critical analysis and some claims are obviously false.

Although there is evidence that chemicals can control the coconut mite (Hernandez, 1977; Julia and Mariau, 1979) they normally have to be applied at uneconomic intervals while the treatments are con-

sidered too damaging for older trees. In these two trials the single applications of vamidothion to medium-aged and old trees in St Lucia were unsuccessful. As most trees in the island are 30-50 years old, as is the case with some other Windward Islands, it is unlikely that the use of vamidothion would have beneficial results. Proposals for the use of vamidothion should be closely examined for new evidence showing its value and should not be based on previous claims.

Acknowledgements

The Government of St Lucia provided the facilities for the project which was funded by the Food and Agricultural Organization of the United Nations. Thanks are due to Paul Adlien, Paul Alexander, Lester Biscette and Titus Philip for cheerful and able assistance in the field work.

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Received 8 September 1986

Revised 13 February 1987

Accepted 9 March 1987

Chemical control of sorghum head bugs (Hemiptera: Miridae)

JA 662

H. C. SHARMA AND K. LEUSCHNER

*International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Patancheru
PO, 502 324 AP, India*

ABSTRACT. Eight contact and three systemic insecticides, and an enriched neem extract were tested for the control of sorghum head bug, *Calocoris angustatus* Leth. at the ICRISAT Center. The insecticides were applied at the complete-anthesis and milk stages (at 500 l/ha) with a knapsack sprayer. On the basis of effectiveness of head bug control, grain yield and 1000-grain mass, carbaryl (at 500 g a.i./ha) was the most effective insecticide followed by fenvalerate (at 50 g a.i./ha), and chlorpyrifos (at 250 g a.i./ha). Among the systemic insecticides, demeton-S-methyl (at 250 g a.i./ha) was the most effective. Demeton-S-methyl and dimethoate were also effective for the control of other head bug species—*Eurystylus bellevoeyi* Put. and Reut. and *Campylomma* sp. Plots sprayed with demeton-S-methyl gave higher grain yields than those treated with carbaryl, which was the best contact insecticide. Two sprays of carbaryl (at 500 g a.i./ha) applied at the complete-anthesis and milk stages have been found to be effective for head bug control. Dichlorvos, fenitrothion and monocrotophos were highly phytotoxic and resulted in burning and drying of entire leaves. Dimethoate resulted in a slight drying of leaf tips and margins.

KEYWORDS: Sorghum; head bugs; chemical control; insecticides

Introduction

Sorghum is the third most important cereal crop in India after rice and wheat. Insect pests are one of the most important factors limiting sorghum production on the farmers' fields in the semi-arid tropics. The mirid head bugs, *Calocoris angustatus* Leth., *Eurystylus bellevoeyi* Put. and Reut., *Creontiades pallidus* Ramb. and *Campylomma* sp. are important pests of developing sorghum grain in India and result in severe loss in grain yield and quality. Sorghum midge, *Contarinia sorghicola* Coq. and the bollworm, *Heliothis armigera* Hb. are other important pests which feed on sorghum panicle from flowering to the hard-dough stage.

Calocoris angustatus is the predominant head bug species in India. Both the adults and nymphs feed on the sorghum panicle from the time of emergence to the hard-dough stage. Eggs are laid in the florets from panicle emergence to shortly after anthesis. Damage during the early stages of grain development may result in a complete loss of grain, while the grains damaged during the milk stage shrivel, and remain small. Under low levels of infestation the grain may develop normally but shows distinct brown feeding punctures, which affect the food quality both in terms of consumer acceptance and nutritional value (Sharma,

1985).

Because of the limited possibility of success with host-plant resistance as a method of reducing head bug damage (Sharma, 1985), chemical control may become necessary in situations of moderate to high levels of head bug damage. Very little information is available on the chemical control of head bugs. Cherian, Kylasam and Krishna (1941) recommended sulphur dusting while Puttarudraiah (1947) suggested dusting of powdered tobacco (mixed with soap in the ratio of 1:1). David, Sivagami and Janagarajan (1969) found that carbaryl gave effective control of head bug. Paul, Subba Rao and Narayana (1983) reported that dusts of phenthoate, carbaryl, malathion and quinalphos, and sprays of chlorpyrifos, leptophos and carbaryl were highly effective against head bug; in those studies, the exact crop stage and number of sprays required were not mentioned. Studies at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Center were carried out to compare the relative effectiveness of eleven insecticides and an enriched extract of neem (*Azadirachta indica* A. Juss) kernels, and to determine the optimum insecticide dosage, optimum stage of panicle development for spraying, and the number of sprays required for effective head bug control.

Materials and methods

The experiments were conducted on a commercial sorghum hybrid (CSH 1). Four infester rows of mixed maturity head bug susceptible sorghum hybrids (CSH 1: CSH 5,1:1) were planted 20 days before the experimental plots. The infester rows were sown after every 16 rows. The crop was planted on ridges 75 cm apart, and plants were thinned to 10 cm spacing within the rows 15 days after emergence. Carbofuran 3G (at 40 kg/ha) was applied at the time of sowing to protect the seedlings from sorghum shoot fly (*Atherigona soccata* Rond.) and spotted stem borer (*Chilo partellus* Swin.) damage. The experiments were laid out in a randomized block design.

Head bugs collected from other fields were uniformly spread in the infester rows at the time of panicle emergence. The head bugs multiplied for one generation on the infester rows and then moved to the test plots. This provided a uniform infestation and increased the head bug abundance in the experimental plots.

The insecticides were sprayed at 500 l/ha with a knapsack sprayer having a hollow cone nozzle, and a pump pressure of 2.5–3.0 kg/cm². A 2 × 2 m polyethylene screen was held down wind to minimize the insecticide drift to the adjacent plots. The infester rows also helped to prevent the spray drift.

Head bugs were counted in 10 randomly selected panicles in each plot before and/or 24 h after each spraying at different stages of panicle development. Data were also recorded on other head bug species, sorghum midge, and the bollworm, whenever their incidence became high. At maturity, sorghum panicles in the central four rows were harvested to record grain yield and 1000-grain mass in each plot. Data on 1000-grain mass were not recorded in experiments conducted during the 1985 rainy season. Data were analysed statistically to determine the least significant differences between treatments. Data on head bug numbers were transformed into \sqrt{n} or $\sqrt{n+1}$ before statistical analysis.

Relative effectiveness of insecticides

Eight insecticides—carbaryl (1-naphthyl methylcarbamate), endosulfan ((1,4,5,6,7,7-hexachloro-8,9,10-trinorborn-5-en-2,3-ylenebismethylene) sulphite), malathion (diethyl(dimethoxyphosphinothioylthio)succinate), quinalphos (*O,O*-diethyl *O*-quinoxalin-2-yl phosphorothioate), dichlorvos (2,2-dichlorovinyl dimethyl phosphate), chlorpyrifos (*O,O*-diethyl *O*-(3,5,6-trichloro-2-pyridyl phosphorothioate), fenitrothion (*O,O*-dimethyl *O*-4-nitro-*m*-tolyl phosphorothioate), fenvalerate ((*RS*)- α -cyano-3-phenoxybenzyl (*RS*)-2-(4-chlorophenyl)-3-methylbutyrate)—and an enriched neem extract from seeds (Sharma *et al.*, 1984) were tested, together with an untreated control during the 1982 rainy season (June–October). There were three replications and each plot measured 54 m². The insecticides were sprayed at the

complete-anthesis and milky stages. Five insecticides were retested during the 1983 rainy season, on the basis of their effectiveness for head bug control.

During the 1984 and 1985 rainy seasons, three systemic insecticides—demeton-S-methyl (*S*-2-ethylthioethyl *O,O*-dimethyl phosphorothioate), dimethoate (*O,O*-dimethyl *S*-methylcarbamoylmethyl phosphorodithioate), and monocrotophos (dimethyl (*E*)-1-methyl-2-(methylcarbamoyl)vinyl phosphate)—were evaluated for head bug control together with carbaryl and an untreated control. Each plot measured 54 m² and there were three replications. Head bugs were counted in five randomly selected panicles at the complete-anthesis and the milk stages.

Insecticide dosage required

On the basis of the relative effectiveness of insecticides for head bug control, carbaryl was selected for detailed studies on the rate of application, optimum stage of panicle for spraying and the number of sprays required for head bug control. Four dosages of carbaryl (250, 500, 1000 and 2000 g a.i./ha) together with an untreated control were tested on CSH 1 under field conditions during the 1983 and 1985 rainy season. There were four replications. Each plot measured 90 m² during the 1983 and 54 m² during the 1985 rainy season. The crop was sprayed twice at the complete-anthesis and milk stages. Head bugs were counted 24 h after each spraying.

Optimum stage of panicle development for spraying

To determine the optimum stage of panicle for protection against head bugs, carbaryl at 500 g a.i./ha was sprayed once at the top-anthesis, complete-anthesis or milk stage during the 1983 and the 1985 rainy seasons. Untreated plots were kept as controls. There were four replications. Each plot measured 90 m² during the 1983 and 54 m² during the 1985 rainy season. Head bug numbers were counted 24 h after each spraying at the top-anthesis, complete-anthesis and milky stages.

Number of insecticide sprays

The effectiveness of three spray schedules of carbaryl (at 500 g a.i./ha) was evaluated for head bug control on CSH 1. The crop was sprayed at the half-anthesis, half-anthesis and complete-anthesis, or at the half-anthesis, complete-anthesis and milky stages. There were four replications and each plot measured 90 m² during the 1983 and 54 m² during the 1985 rainy season. Grain yield was recorded in the central six rows.

Results

Relative effectiveness of insecticides

Results on the relative effectiveness of different insecticides for head bug control are given in Tables 1

to 4. During the 1982 rainy season, there were 24–31 head bugs per panicle before spraying; the infestation levels therefore were quite uniform and high. All insecticides reduced the head bug numbers significantly over the untreated plots. However, the decrease in head bug numbers was not observed in neem-treated plots after the second spraying. The head bug numbers increased substantially 10 days after the first spraying. However, the increase in head bug density was lower (<22 head bugs per panicle) in carbaryl- and chlorpyrifos-treated plots compared with untreated plots (73 head bugs per panicle). The incidence of *C. pallidus*, *E. bellevoeyi*, *Campylomma* sp. and *H. armigera* was less than one insect per panicle. Midge-damaged chaffy florets ranged from 13% to 20%, and the differences were not significant between the treatments. The maximum grain yield was recorded in fenvalerate-treated plots (1780 kg/ha), followed by those treated with carbaryl (1690 kg/ha) and malathion (1490 kg/ha). The 1000-grain mass was maximum in carbaryl-treated plots (Table 1).

Five insecticides (carbaryl, fenvalerate, malathion, quinalphos and chlorpyrifos) which were effective for head bug control during the 1982 rainy season were retested during the 1983 rainy season. All the insecticides reduced head bug numbers significantly compared with the untreated control plots (Table 2). Head bug numbers in samples collected from the untreated

control plots were also lower after first spraying, possibly because of the nature of the population distribution (the insects are generally distributed in patches) or some mortality of head bugs due to insecticide drift. Midge damage ranged from 5% to 10% and the differences were not significant between the treatments. The incidence of other head bug species and of *H. armigera* was negligible. Carbaryl-treated plots gave the maximum grain yield (2400 kg/ha) followed by those treated with fenvalerate (2360 kg/ha) and chlorpyrifos (2350 kg/ha). The 1000-grain weight was highest in carbaryl-treated plots followed by those treated with quinalphos. Carbaryl, fenvalerate and chlorpyrifos were the most effective insecticides for head bug control.

Results relating to the relative effectiveness of systemic insecticides are presented in Tables 3 and 4. There were 1–2 *C. angustatus* adults per panicle at the complete-anthesis stage before spraying. All insecticides reduced the head bug numbers significantly over the untreated control, of which demeton-S-methyl was the most effective (less than one head bug per panicle) followed by monocrotophos, dimethoate and carbaryl (Table 3). At the milk stage, the head bug numbers increased substantially in dimethoate- and carbaryl-treated plots (15–28 head bugs/panicle) compared with plots treated with demeton-S-methyl and monocrotophos (four head bugs per panicle). The numbers

TABLE 1. Relative effectiveness of two sprays of some insecticides for head bug control in sorghum hybrid CSH 1 (1982 rainy season)

Insecticide	Dosage (g a.i./ha)	No. of head bugs per panicle				Grain yield (kg/ha)	1000-grain r (g)
		Complete-					
		Before spray	24 h after spray	Before spray	24 h after spray		
Carbaryl	500	26 (5.1)* a	1 (1.1)* a	21 (4.6)* a	1 (0.5)* a	1690 b	29.4 c
Fenvalerate	50	29 (5.4) a	1 (1.2) a	57 (7.4) ab	1 (0.7) ab	1780 b	25.0 bc
Chlorpyrifos	250	30 (5.5) a	1 (1.3) a	22 (4.7) a	2 (1.3) abc	1160 ab	26.7 bc
Malathion	250	31 (5.5) a	2 (1.8) a	61 (7.3) ab	6 (2.3) d	1490 ab	24.4 bc
Fenitrothion	250	25 (5.0) a	1 (1.4) a	39 (6.2) ab	1 (0.7) ab	1130 ab	23.2 b
Quinalphos	250	24 (4.9) a	4 (2.1) a	41 (6.3) ab	3 (1.7) c	1120 ab	28.8 c
Endosulfan	250	23 (4.7) a	1 (1.2) a	46 (6.7) ab	3 (1.7) c	1250 ab	26.1 bc
Neem extract	500	27 (5.2) a	8 (2.7) b	44 (6.6) ab	51 (7.1) c	900 ab	25.1 bc
Dichlorvos	250	24 (4.8) a	4 (2.1) a	89 (9.2) b	4 (2.0) cd	600 ab	22.1 b
Untreated check	—	25 (5.0) a	22 (4.8) b	73 (8.5) b	77 (8.8) f	350 a	16.4 a
SE		± (0.28)	± (0.42)	± (1.12)	± (0.30)	± 448.4	± 2.01

* Figures in parentheses are the $\sqrt{n+1}$ transformed values. Figures followed by the same letter are not significantly different at $P=0.05$

TABLE 2. Relative effectiveness of two sprays of five insecticides for head bug control in sorghum hybrid CSH 1 (1983 rainy season)

Insecticide	Dosage (g a.i./ha)	No. of head bugs per panicle				Grain yield (kg/ha)	1000-grain mass (g)
		Complete-anthesis		Milk stage			
		Before spray	24 h after spray	Before spray	24 h after spray		
Carbaryl	500	13 (3.3)* a	1 (1.4)* a	18 (4.2)* b	2 (1.2)* a	2400 a	27.8 b
Fenvalerate	50	8 (2.6) a	1 (1.4) a	26 (5.0) b	5 (2.3) a	2360 a	27.0 b
Chlorpyrifos	250	13 (3.3) a	5 (2.3) b	16 (2.9) a	19 (3.9) b	2350 a	24.7 ab
Quinalphos	250	9 (2.8) a	2 (1.5) ab	19 (4.1) ab	5 (1.8) a	2040 a	27.1 b
Malathion	250	11 (2.6) a	2 (1.6) ab	19 (4.2) b	7 (2.4) a	2030 a	24.3 ab
Untreated check	—	9 (2.4) a	1 (1.4) a	26 (4.9) b	54 (7.3) c	1800 a	23.3 a
SE		± (0.74)	± (0.30)	± (0.44)	± (0.52)	± 312.4	± 1.33

* As Table 1

TABLE 3. Relative effectiveness of two sprays of four insecticides for head bug control in sorghum hybrid CSH 1 (1984 rainy season)

Treatment	Dosage (g a.i./ha)	No. of head bugs/panicle								Gram yield (kg/ha)	1000 grain mass (g)
		<i>Callosobruchus angustatus</i>			<i>Campylomma</i> sp.			<i>Eurystylus bellevoeyi</i>			
		Complete-anthesis			Complete-anthesis			Hard-dough			
		Before spray	After spray	Milk stage	Before spray	After spray	Milk stage	Before spray	After spray		
Demeton-S-methyl	250	1 (1.0) [†] a	1 (1.1) [*] a	4 (1.9) [†] a	1 (0.9) [†] a	1 (1.0) [†] a	1 (1.3) [†] a	3 (1.4) [†] a	2 (1.1) [†] ab	3740 c	30.4 b
Monocrotophos	250	1 (1.1) a	1 (1.1) a	4 (1.9) a	1 (0.9) a	1 (1.1) a	1 (1.2) a	5 (2.1) a	3 (1.5) a	3480 bc	28.3 a
Carbaryl	500	1 (1.1) a	1 (1.3) a	15 (3.6) ab	1 (0.9) a	1 (1.3) a	1 (1.3) a	4 (1.8) a	3 (1.8) bc	3350 abc	29.5 ab
Dimethoate	250	2 (1.1) a	1 (1.2) a	28 (5.1) bc	1 (1.1) a	1 (1.2) a	1 (0.9) a	2 (1.4) a	1 (0.9) a	3100 ab	29.5 ab
Untreated check	-	1 (0.9) a	4 (2.1) b	47 (6.8) c	2 (1.2) a	2 (1.5) a	1 (0.9) a	4 (1.7) a	3 (2.3) c	2890 a	28.6 a
SE		± (0.20)	± (0.18)	± (0.61)	± (0.18)	± (0.11)	± (0.08)	± (0.34)	± (0.27)	± 206.7	± 0.45

* As Table 1

† Figures in parentheses are \sqrt{n} transformed values

TABLE 4. Relative effectiveness of two sprays of four insecticides for head bug control in sorghum hybrid CSH 1 (1985 rainy season)

Treatment	Dosage (g a.i./ha)	Number of head bugs/panicle						Grain yield (kg/ha)	
		Complete anthesis			Milk stage				
		<i>C. angustatus</i>		<i>Campylomma</i> sp.	<i>C. angustatus</i>		<i>Campylomma</i> sp.		
		24 h after spray	24 h after spray	Before spray	After spray	Before spray	After spray		
Demeton-S-methyl	250	0 (1.0) [†] a	1 (1.1) [*] a	4 (2.3) [†] ab	0 (1.0) [†] a	2 (1.7) [†] bc	1 (1.1) [†] a	2430 c	
Carbaryl	500	1 (1.3) a	1 (1.3) a	10 (3.4) ab	1 (1.4) a	2 (1.8) c	1 (1.3) a	2150 c	
Dimethoate	250	1 (1.3) a	1 (1.1) a	10 (3.0) a	1 (1.4) a	1 (1.2) a	1 (1.1) a	1900 bc	
Monocrotophos	250	0 (1.0) a	0 (1.0) a	2 (1.8) a	1 (1.1) a	1 (1.3) ab	1 (1.2) a	1150 a	
Untreated check	-	12 (3.3) b	1 (1.2) a	30 (5.5) c	11 (3.2) b	3 (2.0) c	1 (1.3) a	1460 ab	
SE		± (0.41)	± (0.08)	± (0.53)	± (0.52)	± (0.13)	± (0.14)	± 225.0	

* As Table 1

† As Table 3

of *Campylomma* sp. were significantly reduced by all the insecticides, of which demeton-S-methyl was the most effective. The population of *Campylomma* sp. did not differ significantly at the milky stage among plots treated with different insecticides. During the hard-dough stage, a very high incidence of another head bug species, *Eurystylus bellevoeyi*, was recorded. Dimethoate was most effective for *E. bellevoeyi*, followed by demeton-S-methyl. The incidence of other panicle-feeding insects was low and did not differ significantly between different treatments. There were 18–40% of midge-damaged chaffy florets and 1–2 *H. armigera* larvae per panicle. Grain yield was maximum in plots treated with demeton-S-methyl followed by those treated with monocrotophos, carbaryl and dimethoate. The 1000-grain weight was maximum in plots treated with demeton-S-methyl followed by those treated with carbaryl and dimethoate.

During the 1985 rainy season, plots treated with demeton-S-methyl had the lowest density of head bugs, followed by those treated with carbaryl (Table 4). Among other head bug species, the incidence of *Campylomma* sp. was high at the milky stage (1–3 bugs/panicle), and demeton-S-methyl and dimethoate were most effective against it. Among other panicle-feeding insects, the incidence of sorghum midge ranged from 27% to 42% and that of *C. pallidus* from

two to four bugs per panicle. Grain yield was maximum in plots treated with demeton-S-methyl (2430 kg/ha) followed by those treated with carbaryl (2150 kg/ha). Thus, of the three systemic insecticides tested, demeton-S-methyl was the most effective for head bug control. Grain yield was higher in plots treated with demeton-S-methyl than in those treated with carbaryl, which was the most effective of the contact insecticides.

Dichlorvos, fenitrothion and monocrotophos were highly phytotoxic and caused burning and drying of entire leaves. Dimethoate caused slight drying of leaf margins and tips. These insecticides, therefore, should not be used for insect control in sorghum.

Insecticide dosage required

The head bug numbers at the complete-anthesis and milky stages were least in plots treated with carbaryl at 2000 g a.i./ha followed by those treated with 1000 g a.i./ha (Tables 5 and 6). The incidence of *C. pallidus*, *E. bellevoeyi*, *Campylomma* sp. and *H. armigera* was less than one insect per panicle. Midge damage was 5–12% during the 1983 rainy season and 34–51% during the 1985 rainy season, and did not differ significantly between the treatments. The grain yield was highest in plots treated with 2000 g a.i./ha.

TABLE 5. Effectiveness of different dosages of carbaryl under field conditions for head bug control in CSH 1 (1983 rainy season)

Dosage (g a.i./ha)	No. of head bugs/panicle		Grain yield (kg/ha)	1000-grain mass (g)
	Complete-anthesis	Milk stage		
250	14 (3.6)* bc	5 (2.3)* ab	1790 ab	29.9 c
500	12 (3.2) bc	7 (2.6) b	1720 ab	25.4 ab
1000	6 (2.3) ab	3 (1.6) a	1720 ab	26.3 abc
2000	2 (1.1) a	3 (1.6) a	2350 b	28.4 bc
Untreated check	17 (4.1) b	25 (5.0) c	1170 a	23.3 a
SE	± (0.65)	± (0.32)	± 245.8	± 1.54

As Table 1

Optimum stage of panicle development for spraying

Plots sprayed at the complete-anthesis stage had fewer head bugs at that stage than those treated at the top-anthesis or milky stages. More bugs were recorded at the milky stage in plots treated at the top-anthesis stage. The incidence of other head bug species and *H. armigera* was negligible. Midge damage was 13–15%

and 26–30% during the rainy season of 1983 and 1985, respectively. Grain yield and 1000-grain mass were also maximum in plots treated at complete-anthesis (Tables 7 and 8). Sprays applied at the top-anthesis stage were effective only against the adults; the head bug population built up substantially from the nymphs emerging from the eggs laid in the glumes before spraying and through the migrating adults, and this resulted in considerable damage to the grains. Although delayed application at the milk stage controlled the head bugs, a substantial amount of damage had already been inflicted on the tender grains before spraying. Sprays applied at the complete-anthesis stage provided maximum protection against head bug damage.

Number of sprays required

Head bugs were effectively controlled in plots treated with two sprays of carbaryl (Tables 9 and 10). The incidence of *C. pallidus*, *Campyloomma* sp. and *H. armigera* was less than one insect per panicle. Midge-damaged chaffy florets ranged from 5% to 7% during

TABLE 6. Effectiveness of different dosages of carbaryl for head bug control in CSH 1 (1985 rainy season)

Dosage (g a.i./ha)	No. of head bugs/panicle			Grain yield (kg/ha)
	Complete-anthesis	Milk stage		
	After spraying	Before spray	After spray	
250	1 (1.4)† b	38 (6.1)* c	2 (1.6)* a	1180 a
500	<1 (1.0) a	16 (3.9) b	1 (1.3) a	1250 a
1000	0 (1.0) a	7 (2.6) a	1 (1.2) a	1260 a
2000	<1 (1.2) ab	3 (1.6) a	<1 (1.2) a	2000 b
Untreated check	11 (4.0) c	75 (8.6) d	146 (12.2) b	917 a
SE	± (0.07)	± (0.39)	± (0.18)	± (173.0)

* As Table 3

† As Table 1

TABLE 7. Optimum stage of panicle for insecticide application (carbaryl at 500 g a.i./ha for head bug control in CSH 1 (1983 rainy season)

Stage at insecticide application	No. of head bugs/panicle			Grain yield (kg/ha)	1000-grain mass (g)
	Top-anthesis	Complete-anthesis	Milk stage		
Top-anthesis	1 (1.1)* a	11 (3.1)* b	30 (5.4)* a	1820 ab	25.1 a
Complete-anthesis	1 (1.1) a	1 (1.0) a	13 (3.4) a	2340 bc	27.2 b
Milk stage	2 (1.7) a	2 (1.4) a	17 (4.0) a	2150 bc	26.2 ab
Untreated check	2 (1.7) a	12 (3.4) b	16 (3.8) a	1630 a	24.3 a
SE	± (0.24)	± (0.48)	± (0.79)	± 150	± 0.73

* As Table 1

TABLE 8. Optimum stage of panicle for insecticide application (carbaryl at 500 g a.i./ha) for head bug control in CSH 1 (1985 rainy season)

Stage at insecticide application	No. of head bugs/panicle*				Grain yield (kg/ha)
	Top-anthesis	Complete-anthesis	Milk stage	Post-milk stage	
Top-anthesis	<1 (1.1)† a	4 (2.2)† b	22 (4.8)† b	82 (8.7)† b	800 a
Complete-anthesis	7 (2.8) b	1 (1.1) a	1 (1.2) a	2 (1.4) a	1580 b
Milk stage	5 (2.4) b	15 (3.9) c	<1 (1.1) a	1 (1.1) a	1460 b
Untreated check	14 (3.8) c	11 (3.3) c	51 (7.2) c	61 (7.6) b	510 a
SE	± (0.19)	± (0.27)	± (0.21)	± (1.03)	± 155.4

* After spray

† As Table 1

TABLE 9. Number of carbaryl (at 500 g a.i./ha) sprays required for head bug control in CSH 1 (1983 rainy season)

No. of sprays	No. of head bugs/panicle				
	Top-anthesis	Complete-anthesis	Milk stage	Grain yield (kg/ha)	1000-grain mass (g)
One	1 (1.3)* a	1 (1.0)* a	18 (4.0)* b	2600 b	24.6 a
Two	1 (1.1) a	1.1 (1.0) a	24 (4.3) b	2630 b	28.5 b
Three	1 (1.1) a	1 (1.0) a	4 (1.8) a	2540 b	26.0 ab
Untreated check	3 (1.9) b	21 (4.4) b	29 (5.4) b	1910 a	25.6 ab
SE	± (0.10)	± (0.32)	± (0.61)	± 208.3	± 1.17

* As Table 1

TABLE 10. Number of insecticide sprays (carbaryl at 500 g a.i./ha) required for head bug control (1985 rainy season)

No. of sprays	No. of head bugs/panicle			
	Top-anthesis	Complete-anthesis	Milk stage	Grain yield (kg/ha)
One	<1 (1.1)* a	4 (2.2)* b	22 (4.8)* b	1390 b
Two	<1 (1.1) a	<1 (1.1) a	2 (1.7) a	1550 b
Three	1 (1.2) a	1 (1.2) a	1 (1.2) a	1490 b
Untreated check	14 (3.8) b	11 (3.3) c	51 (7.2) c	510 a
SE	± (0.14)	± (0.21)	± (0.23)	± 102.5

As Table 1

the 1983 rainy season and 35% to 51% during the 1985 rainy season, and did not differ significantly among the treatments. Grain yield and 1000-grain mass was maximum in plots sprayed twice at the complete-anthesis and milk stages. Two sprays of carbaryl applied at the complete-anthesis and milk stages thus seem to be sufficient for effective head bug control.

Discussion

Carbaryl was found to be the most effective of the contact insecticides, followed by fenvalerate, chlorpyrifos and quinalphos. These insecticides (except fenvalerate) had earlier been reported to control head bugs (David *et al.*, 1969; Paul *et al.*, 1983). Of the systemic insecticides, demeton-S-methyl was the most effective, and was superior to carbaryl. Because of the sucking type of feeding behaviour of head bugs, the insects also imbibed translocated/absorbed residues of the systemic insecticide; this possibly led to a better control through demeton-S-methyl compared with carbaryl. These insecticides belong to three different insecticide groups: carbamates (carbaryl); organophosphates (demeton-S-methyl) and synthetic pyrethroids (fenvalerate), with different modes of action. These insecticides should, therefore, be used alternatively for effective head bug control, to avoid the development of insecticide-resistant bug populations. With regard to the other insects feeding on the sorghum panicle, the percentage of midge-damaged chaffy florets tended to be higher. The insecticide sprays were not effective against midge because midge eggs and larvae remain protected inside the glumes. Oviposition by the sorghum midge occurred before

spraying and thus the differences in midge damage were not significant. Plots treated with 2000 g a.i./ha differed significantly in grain yield from those treated with 250–1000 g a.i./ha. However, an application rate of 2000 g a.i./ha is too high whereas 500 g a.i./ha gives effective control of head bugs and compares favourably with other insecticides. Since damage by head bugs is both quantitative and qualitative, further studies should be carried out to determine an optimum dosage for application. Insecticide application at the complete-anthesis stage proved to be most effective because it coincided with the emergence of first-instar nymphs from the glumes. Two applications are necessary to control head bugs to prevent quantitative and qualitative losses in grain yield.

Conclusions

Carbaryl, fenvalerate and demeton-S-methyl are effective for head bug control in sorghum. Two applications of insecticides at the complete-anthesis and milky stages suffice for head bug control.

Notes and acknowledgements

Our thanks are due to Ms V. D. Kamath, Mr K. J. Chari and Mr D. Krishna for their assistance in carrying out this work. We also thank Dr D. Dent, Dr J. A. Wightman, Dr W. Reed, and Dr P. W. Amin for reviewing the manuscript.

Approved as Journal Article No 662 by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Patancheru PO, 502 324 AP, India.

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Received 2 February 1987

Accepted 23 March 1987