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Sowing techniques for sorghum on soil infested with black field earwigs and sugarcane wireworms

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Abstract

Sowing techniques for controlling soil-dwelling insects affecting grain sorghum establishment were evaluated on a heavy black cracking clay on the Darling Downs. Estimated populations of 6 500 black field earwigs *Nala lividipes* (Dufour) and 6 500 sugarcane wireworms *Agrypnus variabilis* (Candèze) per hectare were present. We tested three insecticides applied in water injection and in-furrow sprays (heptachlor, chlorpyrifos, carbofuran), two insecticides applied as seed dressings (heptachlor, chlorpyrifos) and five press wheel forces (0, 2, 4, 8 and 16 N/mm width of wheel).

The press wheel at 4 N/mm increased establishment from 16 to 68% and there was little further increase with insecticides in combination with this press wheel force. We therefore recommended the use of press wheels for sowing sorghum on heavy cracking clays infested with earwigs and wireworms. Heptachlor was the most effective insecticide, with carbofuran less effective than chlorpyrifos. Application of insecticides by water injection or in-furrow sprays allowed better emergence than did application by seed dressings.

Consideration of pest populations and seedling losses in this trial and the currently accepted population thresholds for economic damage by wireworms suggests that these thresholds should be reduced.

INTRODUCTION

Soil-dwelling insect pests can cause major sorghum establishment problems in southern Queensland and northern New South Wales (Passlow *et al.* 1985). Pests involved include the black field earwig (*Nala lividipes* (Dufour)) and the sugarcane wireworm (*Agrypnus variabilis* (Candèze)) as well as a number of false wireworms and the seedharvesting ants *Pheidole* spp.

Heptachlor, applied as a seed dressing, an in-furrow spray or in water injection, improves establishment on pest infested soils (Radford and Allsopp 1987). However, some populations of *A. variabilis* are resistant to heptachlor (Gunning and Forrester 1984) and, on the basis of the Australian Agricultural Council's decision on organochlorine use, heptachlor will not be registered for use in Queensland. Chlorpyrifos is currently registered as a seed dressing but it is not always effective. Terbufos, ethroprophos, phoxim and bendiocarb were tested as insecticide–fertiliser mixtures against *A. variabilis* by Forrester *et al.* (1984). Alternative chemicals, such as carbofuran, and alternative methods of application that are acceptable and efficacious are being sought. Press wheels may also improve establishment on infested soils (Radford and Allsopp 1987).

This study evaluates and compares the performance of four press wheel pressures with the insecticides heptachlor and chlorpyrifos applied as seed dressings, in-furrow sprays and water injection and the insecticide carbofuran applied as an in-furrow spray and water injection. The population of soil insects was also determined and related to levels of damage in the experiment and in commercial sowings.

MATERIALS AND METHODS

We tested combinations of press wheel pressure, insecticide and application methods in a trial sown at Formartin, Queensland (27°22′S, 151°28′E) on a heavy black cracking clay on 29 October 1985, 6 days after 28 mm of rain. The seeder was a single-row cone planter with a rigidly-mounted tine opener 15 mm wide. Grain sorghum (*Sorghum bicolor* (L.) Moench) cv. Pride (87% laboratory germination) was sown in single-row plots 10 m long and 2 m apart with 100 seeds per plot. The seed was treated with thiram (2.2 g a.i./kg seed) to control seedling diseases caused by fungi. Sowing speed was about 4 km/hr. The following treatments were laid out in a randomised block design with three replications:

Five press wheel pressures. We used a press wheel 400 mm in diameter and 93 mm wide with a split rim covered by a zero pressure rubber tyre. This design reduces soil compaction directly over the seed, aiding seedling emergence. Since press wheel pressure varies within the area of soil–wheel contact and since the area of contact itself may vary with soil conditions and the press wheel loading, we quantified press wheel loadings in units of force per unit width of wheel. We tested four forces (2, 4, 8 and 16 N/mm width of wheel) and an unpressed treatment (0 N/mm), which included a chain harrow (a loop of chain behind the sowing tine) to cover the seed furrow with loose surface soil.

Two seed dressings. Chlorpyrifos wettable powder (w.p.) at 0.4 g a.i./kg seed and heptachlor emulsifiable concentrate (e.c.) at 0.8 g a.i./kg seed.

Four in-furrow sprays at 3 mL/m row. Water (an additional control), chlorpyrifos e.c. at 0.01 g a.i./m, and carbofuran w.p. and heptachlor e.c. at 0.005 g a.i./m. An in-furrow spray is a narrow band of spray applied over the seed row immediately behind the soil opener as soil flows back into the seed furrow. Ideally the spray is distributed evenly from seed level to the soil surface in a band through which the seedlings must emerge.

Four water injection at 20 mL/m row. Water (an additional control), chlorpyrifos e.c. at 0.025 g a.i./m, and carbofuran w.p. and heptachlor e.c. at 0.01 g a.i./m. Water injection applies water into a narrow trench with the seed at sowing.

All insecticide treatments were tested without press wheel pressure (using the chain harrow) and with the press wheel at 4 N/mm, a recommended press wheel force (Radford and Allsopp 1986). A total of 25 treatments were applied (see Table 1).

We counted the emerged seedlings 15 days after sowing. During emergence there was 25 mm of rain 10 to 11 days after sowing. We used reductions in seedling emergence compared with our most efficacious insecticide treatment as our criterion of insect damage, since failure to emerge distinguishes between lethal seedling damage and damage of little commercial significance. Establishment percentages were analysed with and without an arcsin transformation but, as the transformation did not improve the F value, untransformed data are presented.

To determine the population of soil insects present at the site we collected and sieved six samples of the seedbed (to about 150 mm deep) each 0.5 m^2 in area.

RESULTS

Two black field earwigs and two sugarcane wireworms were found in the total volume of soil examined (0.45 m^3). This represents 1.3 insect pests per square metre or 6 500 of each species per hectare.

Without a press wheel only 16% of untreated seeds emerged (Table 1). The addition of water, as an in-furrow spray or water injection, did not significantly ($P>0.05$) alter this establishment, but establishment was increased significantly ($P<0.05$) by all insecticide treatments except the in-furrow sprays of chlorpyrifos and carbofuran. Heptachlor in water injection resulted in the highest establishment without the use of a press wheel (74%). However, this establishment did not differ significantly ($P>0.05$) from that provided by press wheel forces of 4 and 16 N/mm without insecticide.

Press wheel forces of 2, 4, 8 and 16 N/mm significantly ($P<0.01$) increased establishment compared with no press wheel, with no significant ($P>0.05$) difference among 4, 8 and 16 N/mm (Table 1). With the press wheel at 4 N/mm, the only additional treatment which significantly ($P<0.05$) improved establishment was heptachlor as an in-furrow spray (Table 1).

Table 1. Effect of press wheel force and insecticide treatments on percentage sorghum establishment

Insecticide treatment		Establishment (%)				
		Press wheel force (N/mm wheel width)				
		0	2	4	8	16
Nil (control)		16	55	68	58	62
Seed dressing	chlorpyrifos	35		67		
	heptachlor	45		61		
In-furrow spray	water	22		63		
	chlorpyrifos	26		74		
	carbofuran	6		70		
	heptachlor	62		82		
Water injection	water	11		65		
	chlorpyrifos	55		74		
	carbofuran	31		75		
	heptachlor	74		72		
LSD P=0.05	13					

In the unpressed in-furrow spray and water injection treatments, heptachlor gave significantly ($P<0.05$) better establishment than chlorpyrifos, which in turn was significantly ($P<0.05$) better than carbofuran (Table 1). However, different quantities of active ingredient were applied.

Without a press wheel water injection was the most effective way of applying chlorpyrifos and carbofuran ($P<0.05$) and heptachlor ($0.05<P<0.1$) (Table 1), but again different quantities of active ingredient were applied. Water injection and in-furrow sprays permit the application of more chemical than can be made to adhere to the seed.

DISCUSSION

The press wheel at 4 N/mm increased establishment from 16 to 68% (Table 1). This response exceeded the previous responses we found to the same press wheel force in the presence of soil insect pests (Radford and Allsopp 1987). The response may have been due in part to increased soil–seed contact or increased hydraulic conductivity of the compacted soil (Hyder *et al.* 1955), or reduced evaporation from the compacted soil (Johnson and Henry 1964). However, water injection gave no response, indicating that the supply of water to the unpressed seeds was adequate, whereas heptachlor in water injection increased establishment to 74%, indicating that insect activity was the most likely cause of poor establishment. It follows that the press wheel must have in some way prevented damage by the insect pests, as found in our previous experiments (Radford and Allsopp 1987). This management strategy was effective because there was little further increase in establishment when insecticides were combined with the press wheel treatment.

There are several mechanisms by which the press wheel could have controlled insect damage. Soil compaction with a press wheel may restrict insect movement through the soil by increasing the soil strength near the seed; it may squash and either incapacitate or kill those insects in the seed row; and it may reduce carbon dioxide diffusion from the respiring seed or seedling by reducing soil porosity — carbon dioxide has been shown to attract several species of wireworms (Doane *et al.* 1975).

Heptachlor was more effective than chlorpyrifos in both this trial and in our previous work (Radford and Allsopp 1987). Carbofuran was the least effective chemical despite its ability to be absorbed and translocated by the plant (Anon. 1973).

Water injection or in-furrow sprays were more effective ways of applying insecticides than were seed dressings. The latter restrict the quantity of insecticide applied and the distribution of the insecticide in the soil through which the seedling must emerge. Forrester *et al.* (1984) applied their insecticides mixed with fertiliser. This application method has little appeal to growers in southern and central Queensland where fertiliser is not normally applied at sowing.

Populations of soil insect pests can be much higher than those found in our experiment (Allen 1968; Forrester 1980). Although 13 000 insects/ha appear a low population, it is equivalent to one earwig or wireworm per 3.8 seeds sown in this experiment. For a typical sorghum sowing rate on the Darling Downs (130 000 seeds/ha), it would be equivalent to one pest per 10 seeds sown. Therefore, in commercial sorghum crops each pest need destroy only a few seeds or seedlings to cause serious reduction in establishment.

Because we sowed fewer seeds per hectare than commercial growers on the Darling Downs (only 50 000 seeds/ha were sown), the proportion of seedling losses caused by the measured pest population may have been higher in our experiment than could be expected from the same pest population in a commercial sowing. If we assume there was no seedling loss due to insects in our treatment with the highest establishment (82%), then the untreated controls (16% establishment) lost 33 000 viable seeds or seedlings per hectare to insects. Given the same absolute loss in a commercial sowing of 130 000 seeds per hectare, commercial establishment without press wheels or any insecticide would have been 57%. In practice, additional plant losses could be expected because of the closer proximity of seeds and pests. Soil insects typically damage confined areas, leaving gaps along rows and bare patches (Passlow *et al.* 1985). This results in a proportionately greater yield loss than a uniform reduction in plant population would cause (Wade and Douglas in press).

Ideally a study of establishment pest populations should involve a single species only, but unfortunately multiple pest problems are typical of the Darling Downs (Passlow *et al.* 1985). The currently accepted economic thresholds for wireworms are 107 500/ha in sunflowers (Forrester 1980) and 430 000/ha in cereal crops (Allen 1968); no thresholds for earwigs have been defined. Given the reductions we found in establishment due to a mere 13 000 pests per hectare, the thresholds should be reduced. It seems unlikely that the discrepancy in economic thresholds can be attributed entirely to disproportionately greater damage by the earwigs in comparison with the wireworms.

CONCLUSIONS

A press wheel at 4 to 16 N/mm significantly increased establishment of sorghum at a site infested with 13 000 earwigs and wireworms per hectare. This establishment was similar to that achieved with the most effective insecticide treatment. Insecticide in combination with the press wheel at 4 N/mm gave little further increase in establishment. Press wheel pressure is therefore recommended for sorghum sowing as a cultural method of reducing black field earwig and sugarcane wireworm damage on heavy cracking clays. Press wheels are already recommended for sorghum sowing on such soils because they improve the supply of soil water during germination and emergence (Radford and Nielsen 1985).

Carbofuran is not recommended as a replacement for chlorpyrifos and heptachlor.

Water injection and in-furrow spraying were the most effective ways of applying insecticide, as seed dressing restricts the distribution and application dose of insecticide.

A population of only 13 000 soil insects per hectare can cause economic damage to grain sorghum crops. Since large-scale soil sampling is required to estimate such a low population accurately, we recommend that press wheels or insecticides (or both) be used whenever an earwig or wireworm population is known to be present or a field has a history of such infestations. These treatments provide such a high benefit:cost ratio that we also recommend them as insurance against seedling losses in pest-prone areas.

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