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SOIL SAVING PRACTICE REDUCES DISRUPTIVE INSECTICIDES

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Abstract

We investigated sowing cotton into standing cereal stubble to reduce insect pest populations. Reducing *Helicoverpa armigera* and *Aphis gossypii* numbers through the use of standing stubble is a viable option, as it can limit the need for disruptive insecticides in early season cotton.

The abundance of *A. gossypii* throughout the trial enabled us to examine the effect of stubble on aphid population dynamics and the impact of natural enemies on the population. However, low *H. armigera* activity throughout the trial resulted in no significant difference between treatments for this pest.

Cotton sown into standing sorghum stubble had significantly fewer aphids than cotton sown into wheat stubble and cotton sown conventionally. Furthermore there was significantly more parasitism of *A. gossypii* by *Lysephlebus testaceipes* in cotton sown into sorghum stubble (53%) compared to cotton sown conventionally (15%) and cotton sown into wheat stubble (13%). It is apparent from this investigation that stubble, in particular sorghum stubble, has the potential to prevent aphids from colonising cotton plants. Plants sown into stubble had more squares.

The move towards an integrated pest management approach using a variety of tools and techniques to control pests such as *H. armigera* and *A. gossypii* will ensure that the cotton industry continues to be economically and environmentally sustainable.

Introduction

Stubble retention is a key part of conservation/zero tillage cropping. It leads to improved soil structure, reduced erosion, and improved nutrient retention (Angus and Kirkergaard 1998, Kavalaris and Gemtos 1998, Thurston 1998, Waters and Sequeira 2000). Crop residues left on the surface also improve rainfall infiltration (Bauer and Busscher 1996), increase organic matter in the soil and reduce soil pH (Kavalaris and Gemtos 1998), thereby improving soil health. Standing stubble creates a more favourable microclimate for crops by reducing wind, solar radiation and evaporative demand for water (Aase and Siddoway 1976, McConkey*, et al.* 1998). The main focus of the current research is to identify the potential benefits in insect pest management.

Waters*, et al.* (1999) and Waters and Sequeira (2000) found cotton sown into wheat stubble was sprayed fewer times for insect pests than cotton sown conventionally (no stubble). We have developed a number of theories why this may occur, and these are currently being investigated. The two main ideas are that firstly, cereal stubble acts as a visual deterrent and physical obstruction to egg-laying *Helicoverpa armigera* (Hübner) moths and *Aphis gossypii* Glover and secondly that the stubble acts as a refuge for natural enemies which prey on or parasitise the *H. armigera* eggs and young larvae and *A. gossypii.* The study seeks to determine if different types of cereal stubble have an impact on pests and natural enemy numbers.

Materials and Methods

To investigate these ideas, a trial was conducted at the Department of Primary Industries Kingsthorpe Research Station (27°33'S, 151°58'E) on the Darling Downs, Queensland, Australia. Wheat stubble was already present in the field. Sorghum (variety DK35 Pacific Seeds) was sown on December 14 2001 and sprayed with Roundup® on February 4 2002 at the pre flowering stage to create stubble.

Conventional cotton (variety Delta TOPAZ) was sown on February 18 2002 in a single skip configuration into standing wheat stubble (CWS), standing sorghum stubble (CSS) and conventionally tilled soil (C). The trial design was a 3 x 3 Latin Square, and plots were 60 m long and 16 m wide each containing 6 pair rows.

For the purpose of the trial the main period of interest was when the cotton plants were shorter than the standing stubble. This was considered to be the period when stubble effects would be most pronounced. The average height of the wheat and sorghum stubble was 29 cm and 81 cm respectively. Sorghum stubble provided a longer 'protection' period, compared to wheat stubble, as it took 90 days after sowing (DAS) for the cotton to reach the top of the sorghum stubble, compared to wheat stubble that took 40 days.

Pest and natural enemy numbers were regularly monitored to determine if there was a difference between treatments. Different sample methods were used to determine insect numbers on the ground (pitfall traps) and on the plants (visual counts, beat sheet method and suction samples).

Pitfall Traps
Conduit sleeves (41 mm diameter x 150 mm) were placed in the soil next to cotton plants using a soil auger, ensuring that the top of the sleeve was level with the surrounding soil. Pitfall tubes (120 mm x 40 mm diameter) were $^{1}/_{3}$ filled with 70% ethanol and placed into the conduit sleeves weekly and collected after 48 hours. Each pitfall tube was examined in the laboratory using a stereomicroscope and the contents were identified and recorded.

Visual
Visual inspections of five consecutive plants at four randomly selected sites per plot were examined for pests and natural enemies, twice a week. All eggs, larvae/nymphs and adults were recorded.

Suction Samples
A Stihl BG72 suction machine was used to sample cotton plants for pests and natural enemies 18, 25, 33 and 39 DAS. Two random 10 m lengths or row in each plot were sampled. The contents of each sample were placed into a plastic sealable container containing 70% ethanol and material collected was recorded in the laboratory using a stereomicroscope.

Beat Sheet
After 50 DAS, the method used to sample cotton plants for pests and natural enemies was changed. Instead, three 1 m rows of cotton plants were randomly selected in each plot and visually inspected. The beat sheet method is more effective in determining insect populations than the suction sample when cotton plants are taller (Scholz*, et al.* 2001). The beat sheet method cannot be used until the plants are strong enough to withstand the beating process.

A 1 m long piece of plastic conduit was used to knock the insects from the plants onto the yellow sheet. The cotton plants were struck with the stick 10 times gradually moving from the base of the plants to the top, in accordance with the method described by Scholz *et al.* (2001). The insects landing on the sheet were then recorded and added to the visual count data. This was completed twice a week.

Statistical Analyses
All insect counts were analysed using a generalized linear model with Poisson errors and over dispersion parameter estimated. Treatment means were compared using pair wise t-tests on the model parameters when there was a significant overall treatment effect. Counts from each measurement time were pooled over the whole trial period.

Plant Measurements
Plant measurements were taken at the end of the trial period (89 DAS). In the laboratory, the root length, shoot length and number of leaves were recorded for each plant. Data were analysed by analysis of variance (ANOVA), and means were compared using Fisher's LSD technique.

Results
Large infestations of *A. gossypii* allowed us to compare their development under different stubble regimes. Low *H. armigera* population throughout the trial resulted in low egg and larval numbers, which showed no significant difference between treatments (P>0.05).

Pitfall traps showed no significant difference (P>0.05) between treatments in the numbers comprising major groups of natural enemies (Table 1). Ants were the most abundant natural enemy group with the CSS containing the highest densities. When total natural enemies were combined for each treatment, there were significantly more (P<0.05) natural enemies in the CSS treatment.

Visual inspections of the cotton up to 50 DAS established that cotton sown conventionally and CSW had significantly more (P<0.05) predatory bugs than CSS (Table 2). Cotton sown conventionally had significantly more (P<0.05) natural enemies than CSS. While ants were the predominant group of natural enemy, differences between treatments were not significant (P>0.05). Hunting spiders formed the majority of the spider complex (67%), particularly Anyphaenidae (33%), closely followed by Theridiidae (web building) (Figure 1). Cotton into wheat stubble had more natural enemies than other treatments although the difference was not significant (P>0.05).

When sampled using the suction sample method (39 DAS), CSS had significantly more (P<0.05) spiders than C or CWS (Table 3). Spiders were the most abundant natural enemy in all treatments. Total numbers of natural enemies were highest in the CSS, however there was no significant difference (P>0.05) between treatments. Numbers of *H. armigera* larvae were too few to analyse.

Based on beat sheet samples, C and CWS had significantly more (P<0.05) aphids than CSS (Table 4). Subsequently there were significantly more (P<0.05) mummified aphids in these treatments, with 15%, 13% and 53% aphid's parasitised by *Lysephlebus testaceipes* (Cresson) on C, CWS and CSS respectively. Cotton sown into wheat stubble had significantly (P<0.05) more loopers than in CSS.

While predatory beetles were the most abundant natural enemy group (Table 4), the differences between treatments were not significant (P>0.05). The natural enemy beetle population consisted of 45% variable ladybirds (*Coelophora inaequalis* Fabricius), 33% white collared ladybirds (*Hippodamia variegata* (Goeze)), 10% minute two spotted ladybirds (*Diomus notescens* Blackburn), 5.9% striped ladybirds (*Micraspis frenata* Erichson), and 5% red and blue beetles (*Dicranolaius bellulus* Guérin-Méneville).

There were more spiders in CSS compared to C or CWS, however the differences were not significant (P>0.05) (Table 4).

The *A. gossypii* infestation first appeared in the C 18 DAS. Aphid numbers increased rapidly in the C and the CWS 47 DAS and decreased rapidly 71 DAS (Figure 2). *Aphis gossypii* numbers remained low in the CSS throughout the trial. Natural enemy numbers peaked 71 DAS (Figure 2)

Cotton plants were significantly (P<0.05) taller in CSS compared to other treatments (Table 5). Average leaf area and number of leaves were greater in CSS than C or CWS, however the differences were not significant (P>0.05). There were significantly more (P<0.05) squares (fruiting bodies) on CWS and CSS plants compared to C.

Discussion

This trial was inconclusive in determining if cotton sown into wheat and sorghum stubble affects oviposition behaviour of female *H. armigera* moths. However, stubble was seen to provide positive crop outcomes in relation to management of aphids. Sorghum stubble positively influenced natural enemy abundance and limited aphid infestation. Both wheat and sorghum stubble produced cotton plants with more squares, and sorghum stubble suppressed weed populations through competition for space. Such outcomes contribute to the concept that planting cotton into standing stubble is beneficial.

Aphis gossypii was the predominant pest throughout the trial, with the peak population reaching 3094 per metre in CWS. Cotton sown conventionally and CWS had significantly more aphids than CSS. The abundance of *A. gossypii* throughout the trial enabled the examination of the effect of different stubble types on aphid population dynamics and the impact of natural enemies on the population. *Aphis gossypii* first appeared in the cotton sown into wheat stubble and quickly infested the conventionally sown cotton, eventually peaking at 52 and 59 DAS respectively. The reason for this may be a result of the large weed population, in particular bell vine (*Ipomoea plebeia* R.Br) and milk thistle (*Sonchus olerаces* L.) in these plots as it provided a greater abundance of green foliage, therefore attracting *A. gossypii*. Conversely sorghum stubble may have provided visual camouflage to the cotton plants or acted as a physical barrier (Altieri 1994) to *A. gossypii*. Way (1976) suggests that plant diversity might decrease pest attacks by providing camouflage, making the at-risk crop less visible to the pest, act as a barrier or hazard to the pest.

The use of tall plants as barriers around and within the crop not only aids in the reduction of insects, but also reduces the spread of viruses. For example aphids spread veinbanding mosaic virus in capsicums (*Capsicum frutescens* L.). Simons (1957) found that the incidence of virus was reduced when sunflowers (*Helianthus annuus* L.) were grown as a windbreak. The principal manner in which the sunflowers caused the reduction in the virus was apparently by acting as a mechanical barrier to aphids. Shade, provided by stubble, may effect feeding of certain insects and/or increase relative humidity, which could enhance natural enemy complexes (Altieri 1994). Root (1973) suggested that differences in the physical conditions prevailing in the crop could have some influence on the herbivore fauna. This may be a reason why there were fewer *H. armigera*, *Creontiades dilutus* (Stål) (green mirid), *A. gossypii*, *Amrasca terraereginae* (Paoli) (jassids), *Anomis flava* (F.) (cotton looper), and *Nezara viridula* (L.) (green vegetable bug) in the CSS compared to the other treatments as the plants were less visibly exposed.

Disruption of olfactory and visual responses, physical barriers and diversion to other hosts are important mechanisms regulating herbivores in multiple cropping systems (Altieri 1994). Once the pests become established in the field, their populations may be regulated by limitation of dispersal, feeding disruption, reproduction inhibition, and mortality imposed by biotic factors. Successful manipulation of an agricultural environment makes the environment less acceptable to pests and more hospitable to natural enemies (Perrin 1980). The continual monitoring of pests and natural enemies throughout the trial showed that although there was a major infestation of aphids, natural enemies controlled the population without insecticides and plants suffered minor negative effects.

Plant height and node length were affected when cotton was grown into stubble. This may be a result of limited sunlight reaching the plants when they are young, therefore inducing the plants to grow taller and faster. This resulted in the distance between nodes being greater in CSS and CWS compared to C. Sorghum stubble provided an added advantage to the system over wheat stubble, as it was taller, therefore increasing the period of "protection" for the cotton plants. It took 90 DAS for the cotton to reach the top of the sorghum stubble; compared to 40 DAS in wheat stubble. This period of protection was evident in the insect data as there were significantly more squares in cotton sown into stubble compared to cotton sown conventionally.

It is apparent from this investigation that stubble, in particular sorghum stubble, has the potential to prevent aphids from colonising cotton plants. This study also showed that natural enemies were able to control the aphid population without the use of disruptive insecticides.

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References

Aase JK, Siddoway FH. 1976. Influence of tall wheat grass wind barriers on soil drying. *Agronomy Journal* **68**: 627-631.

Altieri MA. 1994. *Biodiversity and pest management in agroecosystems.* New York: Food Products Press. 185 pp.

Angus J, Kirkergaard J. 1998. Short-term benefits and costs of stubble. In *Australian Grain*, pp. 10-12

Bauer PJ, Busscher WJ. 1996. Winter over and tillage influences on costal plain cotton production. *Journal of Production Agriculture* **9 (1)**: 50-54.

Carruthers K, Cloutier D, Fe Q, Smith DL. 1998. Intercropping corn with soybean, lupin and forages: weed control by intecrops combined with interrow cultivation. *European Journal of Agronomy* **8**: 225-238.

Charles G. 2002. Weed management. In *Australian dryland cotton production guide*, pp. 53-62. Narrabri: Cotton Research and Development Corporation.

Kavalaris C, Gemtos TA. 1998. Soil tillage effect in cotton crop. *Proceedings of the World Cotton Research Conference: 2*, Athens, Greece.

McConkey B, Cutforth H, Ulrich D, Miller P. 1998. Wind speed, stubble heights, and moisture conservation. In *1998 Direct Seeding Conference: Fine Tuning the System*. Regina Exhibition Park, Canada: Saskatchewan Soil Conservation Association.

Mensah R, Wilson LT. 1999. *Integrated pest management guidelines for Australian Cotton*. Narrabri: Australian Cotton Cooperative Research Centre. 1-18 pp.

Perrin RM. 1980. The role of environmental diversity in crop protection. *Protection Ecology* **2**: 77-114.

Root RB. 1973. Organisation of a plant-arthropod association in simple and diverse habitats: The fauna of collards (*Brassica oleracea*). *Ecological Monograph* **43(1)**: 95-124.

Scholz BCG, Cleary AJ, Lloyd R. 2001. Sheet unbeatable for sampling predators in cotton. In *The Australian Cotton Grower*, pp. 14-17

Shirley. C, Bowman. G, Cramer. C. 1998. Managing cover crops profitably.: Sustainable Agricultural Network.

Simons JN. 1957. Effects of insecticides and physical barriers on field spread of pepper veinbanding mosaic virus. *Phytopathology* **47**: 139-145.

Thurston DH. 1998. Cover crops for sustainable agriculture. International Development Research Centre, Canada.

Waters D, Drysdale R, Kimber S. 1999. Benefits of planting into wheat stubble. In *The Australian Cotton Grower*, pp. 8-13

Waters D, Sequeira R. 2000. Cereal stubble and trap crops in heliothis management. In *Central Queensland Cotton Trial Yearbook 1999-2000*, ed. D Kelly, pp. 70-71. Emerald: Queensland Department of Primary Industries.

Way MJ. 1976. Pest and disease status in mixed stands verses monocultures: the relevance of ecosystem stability. *The 18th Symposium of The British Ecological Society*, Bangor.

Table 1. Collective pitfall counts of natural enemies for the trial period (10 tubes per replicate per week).

Treatment	Total Natural Enemies	Predatory Beetles	Ants	Spiders	Wasps
C	477.9a	40.52	249.40	170.00	22.54
CWS	447.1a	18.41	298.20	97.70	24.61
CSS	1008.4 b	2.13	778.00	139.30	14.49
P value	0.012	0.101	0.113	0.739	0.343

Means in a column followed by the same letters are not significantly different (*P*>0.05). No letters indicate no significant difference (*P*>0.05). Key to treatments: C = cotton sown conventionally; CWS = cotton sown into standing wheat stubble; CSS = cotton sown into standing sorghum stubble.

Table 2. Collective visual counts of pests (*) and natural enemies per 108 row metres from 1-50 DAS.

Treatment	***Helicoverpa armigera**** Eggs	Whitefly*	Aphis gossypii*	Jassids*
C	10.2	2.4	567.0 a	3.8
CWS	18	1.5	1162.2 a	2.1
CSS	4.7	8.6	54.2 b	2.5
P value	0.473	0.222	0.048	0.166

Treatment	Predatory Bugs	Ants	Spiders	Total Natural Enemies
C	4.9 a	1.2	7.2	14.2
CWS	4.8 b	9.0	2.6	20.0
CSS	0.0 c	13.2	4.7	17.8
P value	<0.001	0.156	0.299	0.854

Means in a column followed by the same letters are not significantly different (*P*>0.05). No letters indicate no significant difference (*P*>0.05). Key: C= cotton sown conventionally; CWS= cotton sown into standing wheat stubble; CSS= cotton sown into standing sorghum stubble.

Table 3. Collective suction sample of pests (*) and natural enemies per 240 row metres from 1-39 DAS.

Treatment	*Aphi gossypii**	Jassids*	Predatory Beetles	Ants	Spiders	Total Natural Enemies
C	64.5	24.3	2.4	3.4	7.9 a	40.7
CWS	167.0	29.4	5.9	6.1	8.0 a	35.3
CSS	21.4	18.3	2.4	6.8	12.3 b	60.6
P value	0.140	0.808	0.933	0.910	0.017	0.360

Means in a column followed by the same letter are not significantly different (*P*>0.05). No letters indicate no significant difference (*P*>0.05). Key to treatments: C = cotton sown conventionally; CWS = cotton sown into standing wheat stubble; CSS = cotton sown into standing sorghum stubble.

Table 4. Collective beat sheet counts of pests (*) and natural enemies per 90 row metres from 51-89 DAS.

Treatment	*H. armigera* Eggs*	*H. armigera* Larvae*	A. gossypii*	Hoverfly Larvae	Parasitised Aphids
C	1.4	9.3	22584 a	11.9	2997 a
CWS	2.9	6.0	20054 a	10.0	2124 a
CSS	0.7	0.8	646 b	4.4	316 b
P value	0.749	0.152	0.002	0.274	0.025

Treatment	Predatory Beetles	Predatory Bugs	Spiders	Total Natural Enemies
C	162.5	36.6	14.9	225.8
CWS	105.0	23.3	15.3	115.5
CSS	56.5	5.0	34.6	100.0
P value	0.333	0.078	0.21	0.272

Treatment	*Amrasca terraereginae**	*Nezara viridula **	*Creontiades dilutus**	*Anomis flava**
C	3.7	1.0	2.8	22.8 ab
CWS	4.0	2.3	1.0	40.7 b
CSS	2.0	0.6	0.3	5.6 a
P value	0.12	0.538	0.569	0.037

Means in a column followed by the same letter are not significantly different (P>0.05). No letters indicate no significant difference (P>0.05). Key: C= cotton sown conventionally; CWS= cotton sown into standing wheat stubble; CSS= cotton sown into standing sorghum stubble.

Table 5. Plant measurements taken at 89 DAS.

Treatment	Average Root Length (cm)	Average Shoot Length (cm)	Average Number of Squares	Average Number of Leaves	Average Leaf Area cm^2	Average Number of Nodes	Average Node Length (cm)
C	20.2	44.1 a	7.6 a	48.5	1797.9	15	2.3
CWS	26.1	60.2 b	12.0 b	59.2	2768.7	15	3.0
CSS	25.8	65.6 c	14.8 b	54.2	3023.7	16	3.3
LSD		143.5	3.43				

Means in a column followed by the same letter are not significantly different (P>0.05). No letters indicate no significant difference (P>0.05). Key: C= cotton sown conventionally; CWS= cotton sown into standing wheat stubble; CSS= cotton sown into standing sorghum stubble.

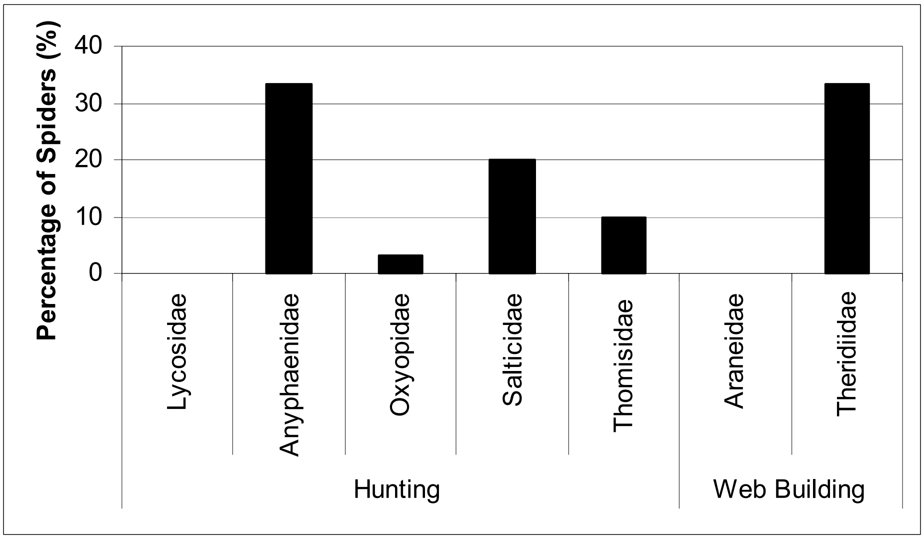

Figure 1. Percentage composition of total spiders in visual samples across all treatments.

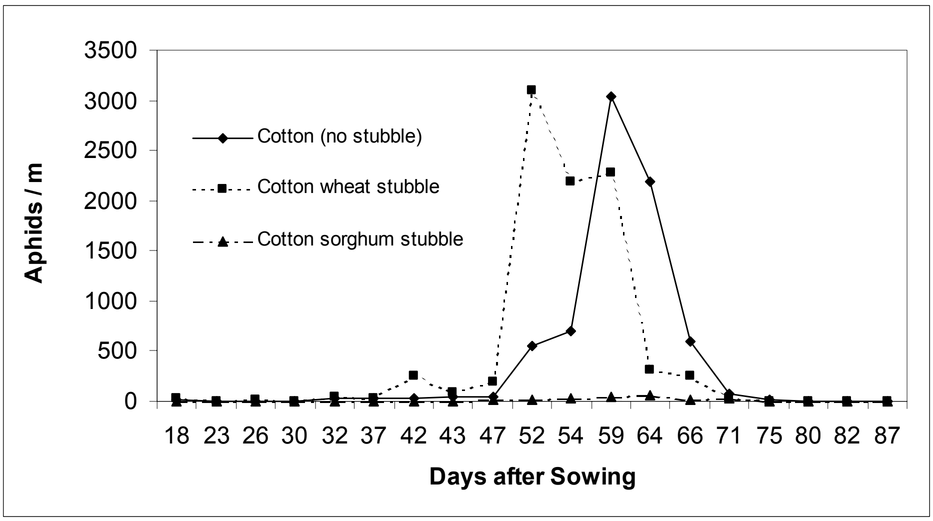

Figure 2. *Aphis gossypii* densities (numbers/m) on cotton sown into different stubble treatments.