Rice Stubble and Straw Mulch Suppression of Preflowering Insect Pests of Cowpeas Sown After Puddled Rice

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ABSTRACT After rice, Oryza sativa L., harvest, sowing cowpeas, Vigna unguiculata (L.) Walp, by minimum-tillage methods among standing stubble reduced colonization of bean fly, Ophiomyia phaseoli (Tryon), thrips, Thrips palmi Karny, and leafhopper, Amrasca biguttula biguttula (Ishida) during the first 2 weeks of crop growth. Thrips and leafhopper, but not bean fly, were also negatively affected by rice straw mulch covering high-tillage plots with the rice stubble plowed under. We hypothesize that the rice stubble and straw mulch, by covering bare soil, interfered with visual cues used by the migratory thrips and leafhopper to locate a favorable habitat. To explain the negative effect of standing rice stubble on bean fly colonization, we hypothesize that the adults first select the topmost crop canopy—the site of newly formed leaves—and plant host suitability is determined after landing. When the stubble is taller than cowpeas, most bean flies repeatedly alight on the nonhost, leaving the field without coming in contact with the host. This effect reverses after the cowpeas grow to the height of the stubble. Cowpeas established in plow furrows opened between rows of rice stubble 20 to 25 cm tall offered the best combination of insect control and high yield.

In rain-fed areas of the Philippines, cowpeas, Vigna unguiculata (L.) Walp., and mungbeans, Vigna radiata (L.) Wilczek, are commonly grown in the dry season after puddled rice, Oryza sativa L., (Suzuki and Konno 1982). The rice–grain legume cropping pattern is particularly adapted to wetland rice areas in which the monsoonal rains end abruptly to create a distinct dry season favorable to legume growth.

Small-scale farmers traditionally broadcast legume seeds without tillage directly into rice crop fields before harvest or into the rice stubble after harvest. The legume crop grows on residual soil moisture among rice stubble 15 to 60 cm tall (traditional variety) or 2 to 15 cm tall (short-statured variety). Rice stubble remains erect for ca. 3 weeks after harvest, and lack of rainfall prevents ratooning.

Yields of zero-tillage cowpeas and mungbeans in rain-fed rice environments normally are below 0.2 t/ha because of uneven stands and poor root growth in previously puddled soils (Syarifuddin and Zandstra 1981). In favorable moisture conditions, yield potential is increased by plowing puddled rice soils to change their physical and chemical properties, thus allowing deeper root penetration in the soil horizon. But plowing and harrowing the entire field dries the soil, and legumes established with high tillage can suffer moisture stress during the postflowering period.

To overcome the problems associated with zero and high tillage, a minimum-tillage technique of sowing legume seeds into plow furrows between alternate rows of rice stubble has been developed (Syarifuddin and Zandstra 1981). Also, mulching with rice straw immediately after high tillage can curtail moisture loss.

In the Philippines, mungbeans and cowpeas share a common insect pest complex. The key pests during the preflowering period are: bean fly, Ophiomyia phaseoli (Tryon) (Diptera: Agromyzidae); thrips, Thrips palmi Karny (Thysanoptera: Thripidae); leafhopper, Amrasca biguttula biguttula (Ishida) (Homoptera: Cicadellidae); aphid, Aphis craccivora Koch (Homoptera: Aphididae); and flea beetle, Medelythia sutoralis (Motschulsky) (Coleoptera: Chrysomelidae). The key postflowering pests are pod borers, Maruca testulalis (Geer) (Lepidoptera: Pyralidae) and Heliothis armigera (Hübner) (Lepidoptera: Noctuidae). Research trials conducted from 1975 to 1980 on cowpeas and mungbeans under high tillage after puddled rice in two Philippine sites showed 61 to 100% yield losses due to those insects, of which 20 to 35% occurred in the preflowering growth stage (International Rice Research Institute 1980).

Filipino farmers spray insecticide on mungbeans or cowpeas infrequently and concentrate on the postflowering period with little apparent effect (Litsinger et al. 1977). We attributed the farmers' reluctance to apply insecticide during preflowering to their inability to recognize many of the pest species (Litsinger et al. 1980). But rice stubble-free, high-tillage plots, designed to increase plant

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stand and crop vigor, have shown higher preflowering insect populations than farmers’ zero-tillage plots with stubble (IRRI 1978).

We, therefore, tested the effect of tillage method and rice plant residue management on cowpea preflowering insect pests with and without insec-
Materials and Methods

IR36, a short-statured, high-tilling rice variety, was transplanted 25 by 25 cm between hills in puddled soil. EG2 cowpeas were sown at 200,000 plants per ha 10 to 14 days after rice harvest with three tillage methods: (1) high tillage (plowed once, harrowed twice), (2) minimum tillage (plow furrows opened between alternate rows of erect rice stubble), and (3) zero tillage (seeds dibbled into holes made with a pointed stick at bases of hills of alternate rows of erect rice stubble). Mean stubble density in the minimum- and zero-tillage treatments was ca. 24 tillers per hill.

Twelve treatments tested tillage and rice plant residue management practices. High tillage involved treatments with and without rice straw mulch. Ten treatments had standing rice stubble cut to 2, 15, 30, 45, and 60 cm in both minimum- and zero-tillage practices, which spanned the range of stubble heights encountered in farmers' fields. Each treatment consisted of one half with insecticide protection during the preflowering period and another half unprotected. The 24 treatments were in plots (4 by 10 m) in a strip plot design with three replicates (Fig. 1).

Preflowering insecticide was 2% (wt/wt) carbofuran 30 ST seed treatment. All plots received sprays of monocrotophos EC at 1 kg (AI)/ha at 10-day intervals from flowering to pod filling. To prevent ratooning, paraquat EC at 0.5 kg (AI)/ha was sprayed on rice stubble 5 days before sowing cowpeas.

Bean fly adults were visually counted daily in the mornings 5 to 14 days after crop emergence (DE), and spiders were D-Vac sampled 13 DE from 30-m rows. At 10, 20, and 30 DE, thrips and leafhopper nymphs were recorded from 15 random plants per plot. At 13 and 26 DE, 15 random plants per plot were dissected to record bean fly larvae and pupae. Yield cuts were 10 m$^2$ per plot, and grain was dried to 12% moisture.

Results

Only bean fly, thrips, and leafhopper occurred in sufficient numbers to allow meaningful comparisons between treatments.

Because analysis of variance (ANOVA) showed no effect of insecticide or sampling date on bean fly adult populations, the results were combined between protected and unprotected plots over the period from 5 to 14 DE. Also, no significant differences occurred between minimum- and zero-tillage methods from 15- to 60-cm stubble heights for the three insect pests; therefore, the tillage treatments were combined.

Fitting nonlinear regression models to the bean fly, thrips, and leafhopper data without insecticide showed significant inverse relationships between insect abundance and stubble height (Fig. 2). The population-suppressing effect of rice stubble was greater for the three insects at heights between 0 and 15 cm than at 15 to 60 cm, and power equa-
Table 1. Effect of rice plant residue management and tillage method on preflowering cowpea insects, spiders, and cowpea yield

<table>
<thead>
<tr>
<th>Rice plant residue</th>
<th>Tillage methoda</th>
<th>Spiders 13 DE and pupae 26 DE (no./15 plants)</th>
<th>Thrips, nymphs and adults 30 DE (no./15 plants)</th>
<th>Yield (t/ha)b</th>
<th>Insecticide treated</th>
<th>Check</th>
<th>Significant difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>H</td>
<td>7a</td>
<td>5a</td>
<td>0.69cd</td>
<td>0.32d</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Mulch</td>
<td>H</td>
<td>12a</td>
<td>1a</td>
<td>0.57de</td>
<td>0.35cd</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>2-cm Stubble</td>
<td>M</td>
<td>13a</td>
<td>7a</td>
<td>0.48c</td>
<td>0.35ab</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>2-cm Stubble</td>
<td>Z</td>
<td>13a</td>
<td>9a</td>
<td>0.78bc</td>
<td>0.59ab</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>15-cm Stubble</td>
<td>M, Z</td>
<td>9c</td>
<td>5a</td>
<td>0.86bd</td>
<td>0.71a</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>30-cm Stubble</td>
<td>M, Z</td>
<td>17a</td>
<td>3a</td>
<td>0.70cd</td>
<td>0.44bcd</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>45-cm Stubble</td>
<td>M, Z</td>
<td>12a</td>
<td>1a</td>
<td>0.59d</td>
<td>0.27d</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>60-cm Stubble</td>
<td>M, Z</td>
<td>19a</td>
<td>3a</td>
<td>0.40e</td>
<td>0.28d</td>
<td>NS</td>
<td></td>
</tr>
</tbody>
</table>

Means within a column, followed by a common letter, are not significantly different at P = 0.05, by Duncan's multiple range test.

* Significant difference at the 5% level. NS, no significant difference.

H, High tillage; M, minimum tillage, Z, zero tillage.

Tall rice stubble in protecting cowpeas persisted for varying lengths of time for each insect—2 weeks for bean fly, 3 weeks for thrips, and 4 weeks for leafhopper (Table 1; Fig. 2). Thrips and leafhopper were more highly suppressed than bean fly in 15- to 60-cm stubble.

At 2-cm stubble, zero tillage significantly reduced bean fly adults and leafhopper nymphs, but not bean fly larvae and pupae or thrips, compared with minimum tillage (Table 2).

Rice straw mulch significantly reduced thrips and leafhopper nymphs but not bean fly populations compared with high tillage without plant residue, and was equal in its effect to tall rice stubble (Table 2). Spiders, the predominant natural enemies encountered, were most abundant in the plots with 15- to 60-cm stubble (Table 1). Spider abundance showed no consistent positive or negative relationship to bean fly, thrips, or leafhopper abundance and was positively associated only with the degree of plant residue cover.

Tall rice stubble was advantageous for insect control but not for yield. Shading during early cowpea growth in 30- to 60-cm stubble resulted in lower yield, even with insecticide protection during postflowering (Table 1). Plants within 30- to 60-cm stubble were 43 to 49 cm tall and spindly because of etiolation, but those within 2- to 30-cm stubble were of normal height. Regression analysis of yield versus stubble height showed maximum yield at 23 cm in a quadratic function (Fig. 2); low yields in short stubble arose from greater insect damage, and low yields in tall stubble arose from lower sunlight. Within treatments, preflowering insecticide showed a significant advantage in yield in high tillage with bare soil, and in zero and minimum tillage with 45-cm stubble.

Discussion

High-tillage plots with the cowpea rows set against a bare soil background resulted in maximum bean fly, thrips, and leafhopper populations during the early preflowering period. Rice stubble 15 to 60 cm tall caused significant reduction of all three pests, but only thrips and leafhopper were negatively affected by straw mulch, indicating that at least two different mechanisms were involved. The insect-suppressive effects of stubble and mulch occurred during insect colonization on a crop less than 2 weeks old, and causal explanations logically would involve differences in host-seeking behavior between them.

The diurnal colonization behavior of *T. palmi*

Table 2. Effect of rice plant residue management and tillage method on preflowering cowpea insects and cowpea yield

<table>
<thead>
<tr>
<th>Rice plant residue</th>
<th>Tillage methoda</th>
<th>Bean fly adults 5-14 DE (no./30-m row)</th>
<th>Bean fly larvae and pupae 13 DE (no./15 plants)</th>
<th>Thrips, nymphs and adults 100 DE (no./15 plants)</th>
<th>Leafhopper nymphs 10 DE (no./15 plants)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>H</td>
<td>38b</td>
<td>17a</td>
<td>87b</td>
<td>23b</td>
</tr>
<tr>
<td>Mulch</td>
<td>H</td>
<td>45b</td>
<td>15a</td>
<td>9a</td>
<td>5a</td>
</tr>
<tr>
<td>2-cm Stubble</td>
<td>M</td>
<td>32b</td>
<td>15a</td>
<td>67b</td>
<td>31b</td>
</tr>
<tr>
<td>2-cm Stubble</td>
<td>Z</td>
<td>21a</td>
<td>12a</td>
<td>60b</td>
<td>12ab</td>
</tr>
</tbody>
</table>

Means within a column, followed by a common letter, are not significantly different at P = 0.05, by Duncan's multiple range test.

H, High tillage; M, minimum tillage, Z, zero tillage.
and A. b. bigutulla is similar to that of other phytophagous, passively wind-dispersed migrants such as aphids and whiteflies (Johnson 1974). This group of specialists colonizes disturbed habitats and is highly attracted to yellow pan water traps set against a bare soil background. Bean flies are also diurnal fliers but are not attracted to yellow pan traps. Adults disperse by trivial flights, settling on the topmost portion of plants in search of young leaves on which to feed, mate, and oviposit (Cheng and Mitchell 1981).

Migrating aphids, whiteflies, leafhoppers, and thrips have been repeatedly cited to avoid alighting on host plants surrounded by plowed soil covered with mulches made from plastic (Smith et al. 1972), aluminum foil (Kring 1972), or straw (Cardona et al. 1981), or by weeds (Dempster and Coaker 1974) or dense plantings (A'Brook 1968).

The migratory and host-seeking behavioral responses common to this group of bare-soil-seeking insects have been most elucidated with aphids. An understanding of the sequence of responses is important because it forms the basis for a hypothesis as to the cause of reduced colonization of T. palmi and A. b. bigutulla in cowpea plots with rice stubble or straw mulch.

Migation in those insects is an integral part of their life cycles, occurs before reproduction, and involves physiological changes to enable them to carry out sustained, long-distance flights (Dingle 1974). After takeoff those insects are attracted to short-wavelength radiation from the sky, causing them to rise along a steep angle of ascent. Insects become displaced horizontally by wind currents (distance flight) (Kennedy et al. 1961). With increased desiccation and depletion of energy reserves, there is a gradual increase in attraction to radiation of longer wavelengths emitted from the earth’s surface, causing the insects to descend along an angle less steep than that of ascent (alighting flight) (Kennedy et al. 1961) in preparation for selecting a suitable habitat. Once the dispersing insects reach the boundary layer of still air near the ground (Taylor 1974), they begin to level off and orient into the wind (anemotaxis), gradually descending until they perceive patterns of images streaming across their retinas emanating from a heterogenous landscape (Johnson 1974). This optomotor mechanism causes them to enter into a station-keeping attitude (Kennedy and Thomas 1974) during the terminal phase of their alighting flight, where they can make controlled, visually aimed landings.

During alighting flight, adults are strongly attracted to yellow color; actively growing leaves exhibit more yellow, which is more intensively reflective than green (Prokopy and Owens 1983). The insects’ positive phototactic response to yellow serves to distinguish vegetation from the sky and allows them to maintain a constant altitude. Upon alighting, they probe the plant tissue, and gustation determines host suitability. If they find the plant a suitable host, they settle on it or else they redisperse.

T. palmi and A. b. bigutulla were equally diverted by the presence of rice stubble and straw mulch; therefore, we reject the hypothesis that the effect is one of camouflaging them from attractive, actively growing leaves. We also reject the hypothesis that the effect interferes with an optomotor response, because the mosaic pattern offered by the 40-m² plots provided a heterogenous landscape. We, therefore, assume that the negative effect of the stubble and straw operates in reducing the insects’ attraction to long-wavelength radiation (from the bare soil) by reflecting a significant amount of short-wavelength radiation from the sky to dilute the long-wavelength signal.

Evidence to support this hypothesis comes from experiments on aphids which compared mulches of different colors—black, white, and aluminum. The highly radiation-reflective aluminum has been consistently more effective in suppressing colonization of migrating insects, particularly vectors of nonpersistent viruses (McLean et al. 1982).

Bean fly adults are highly mobile, making short, lateral flights from plant to plant. They alight and remain on the tops of leaf blades because they prefer to feed on young leaves. Bean flies readily attacked young cowpea plants and were not affected by the presence of straw mulch or rice stubble 2 cm tall. Bean fly populations were significantly reduced by the presence of rice stubble 15 to 60 cm tall. The nonhost stubble perhaps interfered with bean fly colonization in a manner similar to that described by Bach (1980) and Risch (1981) on chrysomelid beetles in host-nonhost polycultures. If the nonhosts were the tallest crops in the mixtures, then the greater the proportion of nonhosts to hosts, the shorter became the tenure time of the beetle population in the field. The beetles, like the bean flies, initially select the topmost crop canopy and do not discriminate hosts from nonhosts until after alighting on plants. If they landed on a nonhost plant they would fly off again, and a significant proportion would eventually leave the field. If the nonhost were shorter than the host, as was the case with the 2-cm-tall stubble, then the bean flies would attack the cowpeas and remain in the field.

The degree of control from plant residue obstruction of long-wavelength radiation on migratory thrips and leafhopper is more complete than that offered by host-nonhost polycultures on bean flies, because the former prevents insects from colonizing the field and the latter does not.

The highest yield would occur with cowpeas established by minimum-tillage methods between rows of 20- to 25-cm-tall rice stubble. This practice would offer the broadest spectrum of control, would be less expensive than high tillage with straw mulch, and should be encouraged as a cultural control practice to lessen dependence on insecticides which small-scale farmers cannot afford.
References Cited


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