Integrated control of two tortricid (Lepidoptera) pests in apple orchards with sex pheromones and insecticides

Control integrado de dos tortricidos (Lepidoptera) plaga en huertos de manzanos con feromonas sexuales e insecticidas

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Abstract: The apple is attacked by a significant number of insect pests in Brazilian commercial orchards, including Bonagota salubricula and Grapholita molesta (Lepidoptera: Tortricidae). Sexual disruption of B. salubricula and G. molesta was evaluated in an apple orchard using the flowable pheromone formulations, SPLAT Grafo+Bona (SG+B), SPLAT Attract and Kill Grafo+Bona (SAKG+B), and compared with the standard insecticides used for management in the Integrated Apple Production (IAP) system. Both formulations were applied at a rate of 1 kg/ha on October 10, 2005 and December 13, 2005 using 300 and 1000 point sources/ha of SG+B and SAKG+B, respectively in experimental units of 7 ha. Adult male captures of B. salubricula and G. molesta were evaluated weekly in Delta traps with specific synthetic sex pheromone from October 10, 2005 to February 14, 2006. Damage to fruits was evaluated on November 21 and December 21, 2005, and January 25 and February 14, 2006. In the SPLAT treated experimental units a significant reduction was observed in the number of B. salubricula and G. molesta males caught in Delta traps compared to the experimental unit IAP. Damage by B. salubricula at harvest ranged from 1.63 to 4.75% with no differences between treatments, while damage by G. molesta was near zero in all experimental units. Mating disruption using SG+B and SAKG+B was sufficient to control B. salubricula and G. molesta with results equivalent to IAP guidelines. This technology is promising for management of both pests in Brazilian apple orchards with immediate reduction of 43% in the number of insecticide applications.

Key words: Attract and kill. Integrated Apple Production. Lepidoptera. Mating disruption. SPLAT.

Resumen: Las plantaciones comerciales brasileñas de manzana son atacadas por un gran número de insectos plaga, entre ellas Bonagota salubricia y Grapholita molesta (Lepidoptera: Tortricidae). La interrupción del apareamiento de B. salubricula y G. molesta fue evaluada en huerto de manzanas usando las formulaciones de feromonas pastosa, SPLAT Grafo + Bona (SG+B) y SPLAT Attract and Kill Grafo + Bona (SAKG+B), y comparado con los insecticidas estándares que se usan para el manejo en la Producción Integrada de Manzanas (PIM). Ambas formulaciones se aplicaron a una tasa de 1 kg/ha el 10 de octubre de 2005 y el 13 de diciembre 2005 usando 300 y 1.000 fuentes puntuales /ha de SG+B y SAKG+B, respectivamente, en unidades experimentales de 7 ha. La captura de adultos machos de B. salubricula y G. molesta fue evaluada semanalmente en trampas Delta con feromona sexual sintética específica del 10 de octubre de 2005 al 14 de febrero de 2006. Los daños en las frutas se evaluaron el 21 de noviembre y 21 de diciembre de 2005, y el 25 de enero y 14 de febrero de 2006. En las unidades experimentales tratadas con SPLAT se observó una reducción significativa en el número de machos de B. salubricula y G. molesta capturados en trampas Delta en comparación con la unidad experimental PIM. El daño causado por B. salubricula en la cosecha varió desde 1.63 hasta 4.75%, sin diferencias entre los tratamientos, mientras que los daños causados por G. molesta estaban cerca de cero en todas las unidades experimentales. La interrupción del apareamiento con SG+B y SAKG+B fue suficiente para controlar B. salubricula y G. molesta con resultados equivalentes a las directrices de la PIM. Esta tecnología es promisoria para el manejo de ambas plagas en huertos de manzanas brasileños con reducción inmediata del 43% en el número de aplicaciones de insecticidas.

Palabras clave: Atraer y matar. Producción integrada de manzanas. Lepidoptera. Interrupción del apareamiento. SPLAT.

Introduction

The apple, Malus domestica Borkhausen, 1760 (Rosaceae), has a number of phytosanitary problems, with emphasis on the occurrence of insect pests that significantly reduce yield. The Brazilian apple leafroller, Bonagota salubricula (Meyer, 1937) (Lepidoptera: Tortricidae) and the Oriental fruit moth, Grapholita molesta (Busck, 1916) (Lepidoptera: Tortricidae), stand out as the main apple pests (Arioli et al. 2007; Botton et al. 2009) causing significant losses if control measures are not adopted (Botton et al. 2000a). B. salubricula larvae feed on apple leaves and fruits, causing severe damage and economic losses (Botton et al. 2000a, 2009). Damage from G. molesta moths can be seen on shoots and fruits, causing significant losses when the attack occurs in nurseries, orchards, and cultivars with greater fruit production in terminal buds, such as ‘Fuji’ (Arioli et al. 2007). Bonagota salubrica and G. molesta have been primarily managed with insecticides (Arioli et al. 2004; Botton et al. 2000a, 2009), which can leave harmful residues on fruits (Thomson et al. 2001). New control alternatives need to be studied, especially when the crop is managed by Integrated Apple Production (IAP) system, this is a new approach production which targets consumer concerns over the impact

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of crop production practices on the environment. The pest management philosophy embodied in Integrated Fruit Production (IFP) requires greater emphasis on the use of biological control, pest thresholds, minimal use of broad-spectrum pesticides and replacement with selective products (Protas and Sanhueza 2002). One alternative for the management of insect pests is the use of sex pheromones: chemicals that are used for mating communication between both sexes of the same species (Karlson and Luscher 1959) that can be produced by males or females (Cardé and Minks 1995). These substances can be synthesized and used for insect monitoring or control by mating disruption or attract and kill strategies (Cardé and Minks 1995; Bosa et al. 2008; Pastori et al. 2008).

The availability of new pheromone formulations to control G. molesta allows for a wide use of the technology in M. domestica (Monteiro et al. 2008; Pastori et al. 2008). However, where this technology is employed, there is a need for insecticide applications against other pests, particularly the South American fruit fly, Anastrepha fraterculus (Wiedemann, 1830) (Diptera: Tephritidae) (Monteiro et al. 2008). The sex pheromone of B. salubricola has been isolated, identified (Unelius et al. 1996; Coracini et al. 2001), and is commercially used for monitoring purposes (Kovaleski et al. 2003; Botton et al. 2009). Specialized Pheromone & Lure Application Technology, or SPLAT®, allows for the combination of multiple pheromones into a single formulation, as for B. salubricola and G. molesta, expanding the possibility for simultaneous control of these Lepidopteran pests.

The global market offers a variety of pheromone products for control of mainly Lepidopteran pests. The various products available differ in their formulations and in their costs and times of application (Degen et al. 2005; Stelinski et al. 2005; Epstein et al. 2006; Miller et al. 2006a, b). Most products are applied by hand, requiring an intensive labor force (Jenkins 2002; Stelinski et al. 2005, 2006). Microencapsulation of pheromone formulations is one alternative to minimize labor, using sprinklers or irrigation systems for application. However, several reapplications are required over the crop cycle because of the short residual effect (Knight et al. 2004; Botton et al. 2005) and resistance problems (Suckling et al. 1999). Because SPLAT is an inert wax matrix, it allows the user the flexibility to control the pheromone release in the field by varying the number and size of point sources (Miller et al. 2006a, b; Mafra-Neto et al. 2008). In addition, the formulation is not washed away by rain and can be adapted to many different forms of application, from small-scale hand application (calibrated dosing guns, caulking tubes, pastry bags, etc.) to mechanical application for large areas (tractor equipment), which maximizes efficiency by decreasing the application cost (Stelinski et al. 2005, 2006; Mafra-Neto et al. 2008).

Sex pheromones are species-specific (Degen et al. 2005); the presence of other species that are not controlled with pheromones can still result in severe damage, hampering the use of this technology. One alternative is the application of sex pheromones to control key pests along with a reduced number of chemical insecticide applications for other species (Meissner et al. 2001; Trimble et al. 2001; Kovanci et al. 2005). The objectives of this study were to evaluate the integrated control of B. salubricola and G. molesta based on 1) the timing, quantity, and spacing of SPLAT treatments and 2) the mechanism of semiochemical control (i.e. mating disruption versus attract and kill).

Materials and Methods

The experiment was carried out from October 2005 to February 2006 in an apple orchard in the municipality of Vacaria, Rio Grande do Sul State, Brazil.

Experimental site and treatments. The experiment was set in apple orchards established in 2001 with a spacing of 1.5 x 4.5 m (plants x rows) and tree height between 2.5 and 3.0 m. The orchards contained a combination of four rows of ‘Gala’ (producer) for every two rows of ‘Fuji’ (pollenizer) varieties. The orchards were divided into five experimental units of seven hectares each, spaced at least 200 m apart in order to prevent migration of mated females. Each experimental unit received one of the following treatments: A) SPLAT Grafo + Bona (SG+B) at a rate of 1 kg/ha (300 point sources, each 3.3 g) applied on 10/04/05, B) SPLAT Grafo + Bona (SG+B) at a rate of 1 kg/ha (300 point sources, each 3.3 g) applied on 12/13/05, C) SPLAT Attract and Kill Grafo + Bona (SAKG+B) at a rate of 1 kg/ha (1000 point sources, each 1 g) applied on 10/04/05, D) SPLAT Attract and Kill Grafo + Bona (SAKG+B) at a rate of 1 kg/ha (1000 point sources, each 1 g) applied on 12/13/05, and E) pest management under recommendation of the Integrated Apple Production (IAP) (Protas and Sanhueza 2002) with the following treatments: tebufenozide (Mimic SC 240, 90 mL/100L) on 10/25/05 for B. salubricola and G. molesta, phosmet (Imidan 500 PM, 120 g/100L) on 11/07/05 for A. fraterculus, fenithrothion (Sumithion 500, 150 mL/100L) on 11/18/05 and 12/05/05 for A. fraterculus and G. molesta, methidathion (Supracid 400, 100 mL/100L) on 12/20/05 and 01/08/06 for A. fraterculus, and chlorpyrifos (Lorsban 480 CE 120 mL/100L) on 01/03/06 for B. salubricola and G. molesta. Three insecticide applications were carried out in each experimental unit where SPLAT was applied, on the basis of adult monitoring for the control of A. fraterculus as follows: phosmet (Imidan 500, 120 g/100L) on 11/07/05 and methidathion (Supracid 400, 100 mL/100L) on 12/20/05 and 01/12/06. The risk of damage to production and the size of areas needed to set up the experiment did not allow for an experimental unit without insecticide application and replication the experimental units of the seven hectares each.

Synthetic sex pheromone formulation. SPLAT, developed and patented by ISCA Technologies (Riverside, California USA), is a flowable, amorphous emulsion consisting of oils and waxes that controls semiochemical release. SPLAT Grafo + Bona and SPLAT Attract and Kill Grafo + Bona are made up of a mixture of sex pheromones from B. salubricola and G. molesta including: SG+B - [(E)-8-dodecenyl acetate; (Z)-8-dodecenyl acetate; (Z)-8-dodecenol (4.4%) (44 g/kg); (E, Z)-3.5-dodecadienyl acetate (0.20%) (2 kg/g)], and SAKG+B - [(E)-8-dodecenyl acetate; (Z)-8-dodecenyl acetate; Z-8-Dodecenol (2.2%) (22 g/kg); (E, Z)-3.5-dodecadienyl acetate (0.20%) (2 kg/g); (RS)-alpha-cyano-3-phenoxibenzyl (1RS,3RS;1RS,3SR)-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate (cypermethrin) (5%) (50 g/kg)].

SPLAT application. SPLAT was applied by hand in each experimental unit using wooden spatulas adjusted to hold
3.3 g (SG+B) and 1 g (SAKG+B), applying the formulation at a dose of 1 kg/ha. Ten percent more SPLAT was applied at the inner borders of each treatment (approximately 10 m) to reduce edge effects (Albajes et al. 2002; Degen et al. 2005). SPLAT was applied on shaded portions of plants, at the base of the branches between 1.5 and 2.0 m above ground. Preliminary evaluation of pest population. Five white Delta traps baited with Iscalure Bonagota® and five others with Iscalure Grapholita® (ISCA Tecnologias Ltda., Ijui, RS, Brazil) were placed in each of the experimental units on plants 30 m apart, between 1.5 and 2.0 m above ground, on 09/20/05. These traps were evaluated seven days later to determine the homogeneity of experimental units and initial population levels of B. salubricola and G. molesta.

Treatment evaluation. Treatment efficacy was assessed by recording the adult population and damage to fruit by B. salubricola and G. molesta. Male moth captures in Delta traps were evaluated weekly from the beginning of the experiment. B. salubricola and G. molesta lures in Delta traps were replaced every 90 and 30 days respectively, and the adhesive trap bottoms were replaced as needed.

Mating disruption was evaluated by calculating the mating interruption rate (MIR), with the formula MIR = (C-T/T)*100, where “C” is the average of males captured per trap in the experimental unit under treatment and “T” is the number of catches in the Integrated Apple Production (IAP) system (Molinari et al. 2000). MIR was calculated using the entire period of the experiment.

Damage to pests in apple fruits was evaluated on four dates (11/21/05, 12/21/05, 1/25/06 and 2/14/06) by recording the adult population and damage to fruit by B. salubricola and G. molesta after SPLAT application on 10/04/05 was significantly lower than that observed in the Integrated Apple Production (IAP) treated experimental unit (F = 14.5002; df = 20.0; P = 0.0001) (Table 1). In the experimental units treated on 10/04/05, the mating interruption rate (MIR) of B. salubricola was 84.4 and 75.5% for SG+B and SAKG+B respectively. SPLAT applied on 12/13/05 resulted in lesser MIRs; 66.1 and 65% for SG+B and SAKG+B, respectively (Table 1). These results indicate that the SPLAT application on 10/04/05 was more effective for mating disruption than the application on 12/13/05.

The number of adults of B. salubricola and G. molesta were above 90% when SG+B and SAKG+B were applied on 10/04/05 (Table 1) was significantly lower than that observed in the other treatments (F = 33.5565; df = 20.0; P = 0.0001). Applying SPLAT on 12/13/05 reduced the MIR’s to just 52.1 and 75.1% for SG+B and SAKG+B, respectively (Table 1).

The fluctuation of male populations of B. salubricola and G. molesta after SPLAT application on 10/04/05 was significantly lower than that observed in the Integrated Apple Production (IAP) system treated areas during the experiment (Fig. 1). The fluctuation of male B. salubricola and G. molesta populations in the experimental units treated on 12/13/05 showed similar behavior to the Integrated Apple Production (IAP) treated experimental unit before the SPLAT treatments were applied, and was significantly reduced after the SPLAT applications (Fig. 1). Damage to fruits caused by B. salubricola and G. molesta on 11/21/05 (first evaluation) (B. salubricola F = 1.000; df = 3.3 g (SG+B) and 1 g (SAKG+B), applying the formulation at a dose of 1 kg/ha. Ten percent more SPLAT was applied at the inner borders of each treatment (approximately 10 m) to reduce edge effects (Albajes et al. 2002; Degen et al. 2005). SPLAT was applied on shaded portions of plants, at the base of the branches between 1.5 and 2.0 m above ground. Preliminary evaluation of pest population. Five white Delta traps baited with Iscalure Bonagota® and five others with Iscalure Grapholita® (ISCA Tecnologias Ltda., Ijui, RS, Brazil) were placed in each of the experimental units on plants 30 m apart, between 1.5 and 2.0 m above ground, on 09/20/05. These traps were evaluated seven days later to determine the homogeneity of experimental units and initial population levels of B. salubricola and G. molesta.

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Damage to pests in apple fruits was evaluated on four dates (11/21/05, 12/21/05, 1/25/06 and 2/14/06) by recording the number of fruits damaged by B. salubricola and G. molesta from a sample of 1600 fruits per treatment (eight sampling locations with 200 fruits per location).

Data analysis. The population fluctuation of adult male of B. salubricola and G. molesta by plotting the average number of males/trap/week as a function of the time per each treatment. The mean number of moths for each experimental unit was compared from 10/04/05 to 02/14/06. The percentage of damaged fruit was compared by transforming data by \(\sqrt{(x+0.5)}\). Data was examined by analysis of variance and means were compared using Tukey’s test, with a significance level of 0.05.

### Table 1

<table>
<thead>
<tr>
<th>Treatment</th>
<th>B. salubricola</th>
<th>Grapholita molesta</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Evaluation¹</td>
<td>µ Total²</td>
</tr>
<tr>
<td>SG+B (10/04/05)</td>
<td>1.0 ± 0.28</td>
<td>28.2 ± 5.58 a</td>
</tr>
<tr>
<td>SG+B (12/13/05)</td>
<td>1.0 ± 0.28</td>
<td>61.2 ± 11.37 a</td>
</tr>
<tr>
<td>SAKG+B (10/04/05)</td>
<td>1.6 ± 0.46</td>
<td>44.2 ± 7.93 a</td>
</tr>
<tr>
<td>SAKG+B (12/13/05)</td>
<td>0.4 ± 0.22</td>
<td>63.2 ± 9.26 a</td>
</tr>
<tr>
<td>IAP</td>
<td>1.2 ± 0.46</td>
<td>180.6 ± 30.84 b</td>
</tr>
</tbody>
</table>

¹Non-significant by F test (P = 0.05).  
²Means followed by the same small letter in the column are not statistically different by the Tukey test (P = 0.05).  
³MIR = (Pheromone - IAP / IAP)*100.
Reduction in catches of male *B. salubricola* and *G. molesta* in the SPLAT treated experimental units compared to the Integrated Apple Production (IAP) system was the result of SPLAT formulations that disoriented males and prevented them from locating the Delta traps; a result reportedly observed when the same SPLAT technology was used for the control of *G. molesta* (Stelinski et al. 2005; Monteiro et al. 2008), *Paralobesia viteana* (Clemens, 1860) (Lepidoptera: Tortricidae) (Jenkins and Isaacs 2008) and *Tecia solanivora* (Povolny, 1973) (Lepidoptera: Gelechiidae) (Bosa et al. 2008).

The late application of SPLAT was not the best strategy for increasing MIRs, given that in the second application these rates were lower than in the first. Apple producers have accepted yield losses by pests of 1 to 2% at harvest, which would represent about 400 to 800 kg of apples given a production of 40 t/ha. In this case, the application of pheromone in October was more promising from the practical viewpoint for managing *B. salubricola* and *G. molesta*.

We expected to see a direct relationship between reduction in the number of males captured in Delta traps and fruit damage, but this was not the case in the experimental units treated with SPLAT or the Integrated Apple Production (IAP) system. The experimental unit receiving the Integrat-

### Table 2. Apples (% ± SE) damaged by *Bonagota salubricola* and *Grapholita molesta* in four evaluations in experimental units treated with: SPLAT Grafo + Bona (SG+B) and SPLAT Attract and Kill Grafo + Bona (SAKG+B) applied on 10/04/05 and 12/13/05, and Integrated Apple Production (IAP) system. Vacaria, Rio Grande do Sul State, Brazil, 2005/2006.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>11/21/05</th>
<th>12/21/05</th>
<th>01/25/06</th>
<th>02/14/06</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percentage of damaged apples (<em>Bonagota salubricola</em>)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SG+B (10/4/05)</td>
<td>0.00 ± 0.00</td>
<td>0.50 ± 0.38</td>
<td>0.75 ± 0.62</td>
<td>1.63 ± 0.86</td>
</tr>
<tr>
<td>SG+B (12/13/05)</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>1.38 ± 0.60</td>
<td>4.75 ± 0.75</td>
</tr>
<tr>
<td>SAKG+B (10/4/05)</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>1.00 ± 0.63</td>
<td>2.63 ± 0.96</td>
</tr>
<tr>
<td>SAKG+B (12/13/05)</td>
<td>0.00 ± 0.00</td>
<td>0.25 ± 0.25</td>
<td>0.88 ± 0.44</td>
<td>3.63 ± 1.03</td>
</tr>
<tr>
<td>IAP</td>
<td>0.00 ± 0.00</td>
<td>1.00 ± 0.63</td>
<td>1.25 ± 0.62</td>
<td>2.25 ± 0.70</td>
</tr>
</tbody>
</table>

|                     | Percentage of damaged apples (*Grapholita molesta*) |          |          |          |
| SG+B (10/4/05)      | 0.00 ± 0.00 | 0.38 ± 0.26 | 0.38 ± 0.26 | 0.13 ± 0.13 |
| SG+B (12/13/05)     | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| SAKG+B (10/4/05)    | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| SAKG+B (12/13/05)   | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| IAP                 | 0.13 ± 0.13 | 0.13 ± 0.13 | 0.13 ± 0.13 | 0.13 ± 0.13 |

* Non-significant by F test (P = 0.05).
ed Apple Production (IAP) system treatment saw the greatest number of males caught in traps during the experiment, with damage similar to the other treatments at harvest. Traps baited with sex pheromone provided limited information about the movement patterns and density of males in the agro-ecosystem and did not consider females and sex ratio in the sampled population (Charmillot and Vickers 1991). Consequently, trap catch data may not always coincide with damage levels.

The lower efficiency of pheromone applied in December was caused by factors related to behavior and population dynamics of the target species (Cardé and Minks 1995; Moschos et al. 2004), which are still unclear for B. salubricta, an insect pest native to South America (Pastori et al. 2007). B. salubricta has no diapause and shows overlapping of generations (Botton et al. 2000b), that difficult to define the moment of pheromone treatment in the field. The delay in SPLAT applications increased the probability of random mating in the orchard. The large number of males in the treated areas facilitated accidental encounters between males and females, and increased the mating percentage which, consequently, reduced the SPLAT efficiency (Michereff Filho et al. 2002). The polyphagous habit of B. salubricta (Botton et al. 2009) allows fertilized females to migrate from nearby infested areas, while G. molesta is limited by a lower range of alternative hosts. Flight activity between apple orchards and adjacent ecosystems was important (Jeaneret and Charmillot 1995) and shows this accounts for the increase in damage caused by B. salubricta compared to G. molesta. The main factors related to the efficiency of semiochemicals for the control of G. molesta have not yet been studied in Brazilian fruit production (Molinari 2002), especially in relation to male population density and minimum area required to avoid edge effects (Albajes et al. 2002; Degen et al. 2005).

Reductions in the fluctuation of populations of male G. molesta in the areas treated with SPLAT over the course of this study and the percentage of damage to fruit, were generally similar to those reported in other countries in apple and peach crops (Vickers et al. 1985; Ricciolini and Baldi 1990; Molinari et al. 2000, 2004; Cravedi et al. 2001; Angelii et al. 2003; Il’ichev et al. 2004). Moreover, mating disruption with SPLAT has been successfully used to control G. molesta in apple (Stelinski et al. 2005, 2006, 2007) and P. vitacea in grapevines in the U.S. (Jenkins and Isaacs 2008).

Promising results with the use of sex pheromone in Brazil were reported for G. molesta in peach (Salles and Marini 1989; Botton et al. 2005) and apple (Monteiro et al. 2008; Pastori et al. 2008). In these cases, the specificity of the compounds has restricted the use of the technology, showing that the strategy of combining pheromones of more than one species in the same formulation and/or the combined use of insecticide appears to be promising for the widespread adoption of sex pheromones for mating disruption (Meissner et al. 2001; Trimble et al. 2001; Kovanci et al. 2005, Simon et al. 2007), allowing a reduction in insecticide use (Ricciolini and Baldi 1990; Atanassov et al. 2003) with less environmental degradation.

The SPLAT pheromone treatment allows growers to harvest product with no residue, allowing them to sell the product in the global market (especially being able to reach the European and Japanese markets).

Conclusions

The use of SPLAT Grafo + Bona or SPLAT Attract and Kill Grafo - Bona, together with three applications of insecticides to control A. fraterculus, proved to be an effective strategy for the management of B. salubricta and G. molesta in apple orchards, producing results similar to those of the Integrated Apple Production system, but with the use of far less insecticide.

SPLAT Grafo + Bona and SPLAT Attract and Kill Grafo + Bona are specific to B. salubricta and G. molesta, but the presence of other phytophagous species damaging the apple tree, particularly A. fraterculus, larvae of Noctuidae and Geometridae, and the wooly apple aphid, Eriosoma lanigerum (Hausmann, 1802) (Hemiptera: Aphididae), should be monitored continuously and additional control measures implemented as needed.

The integrated management of these pests associated with pheromones is essential for the implementation of integrated fruit production in Brazilian conditions.

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Integrated control of tortricid in apple


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