EVALUATION OF FOUR INTEGRATED PEST MANAGEMENT PACKAGES FOR CONTROLLING MAIN PESTS OF COTTON IN RAINFED FIELDS

Evaluasi Empat Paket Pengendalian Hama Terpadu pada Kapas di Lahan Tadah Tujan

Nurindah and Dwi Adi Sunarto

Indonesian Sweetener and Fibre Crops Research Institute
Jalan Raya Karangploso, PO Box 199 Malang 65152, East Java, Indonesia
Phone +62 341 491447, Fax. +62 341 485121, email: balittas@litbang.deptan.go.id
Corresponding author: nurindah@litbang.deptan.go.id

Submitted 6 May 2013; Revised 16 November 2013; Accepted 25 November 2013

ABSTRACT

Cotton production nationally is low due to various constraints, including pests. Two main pests commonly found in cotton plantation in rain fed fields are cotton leafhopper (*Amrasca biguttula*) and cotton bollworm (*Helicoverpa armigera*). The study aimed to evaluate four packages of integrated pest management (IPM) techniques to control cotton leafhopper and cotton bollworm in rain fed fields. The experiment was conducted in farmers' fields at Asembagus, East Java, between January and July 2012. Four packages of IPM evaluated were cotton varieties, i.e. Kanesia 10 or Kanesia 13, and seed treatment with synthetic insecticide (imidacloprid) before sowing or spraying molasses (10 ml L^{-1} water) as food for natural enemies. The cotton plants were intercropped with groundnut and sprayed with neem seed extract (NSE) at the action threshold level for pest control. These packages were compared among themselves and also with the methods usually used by farmers, i.e. planting cotton variety Kanesia 8 intercropped with groundnut and pest control using synthetic chemical insecticides. Twenty five plants were sampled randomly per plot and measured for their growth, leafhopper and bollworm populations, as well as cotton seed yield per plot. Observations were made weekly, starting at 30 days after planting (DAP) until 120 DAP. The results showed that the use of Kanesia 10 or Kanesia 13 intercropped with groundnut and spraying molasses to conserve natural enemies was the best pest management practice and superior to farmers' practices. Conserving natural enemies is not only profitable (saving production cost of IDR1,150,000 to IDR1,500,000 ha^{-1} $season^{-1}$), but also safe for the environment (no need to spray chemical insecticides).

[***Keywords*:** Cotton, pest management, rain fed field]

ABSTRAK

*Produksi serat kapas nasional masih rendah karena beberapa kendala, termasuk gangguan hama. Hama utama pada pertanaman kapas di lahan tadah hujan ialah wereng kapas (*Amrasca biguttula*) dan penggerek buah (*Helicoverpa armigera*). Penelitian ini bertujuan untuk mengevaluasi empat paket teknik pengendalian hama terpadu (PHT) kapas di lahan tadah hujan. Penelitian dilaksanakan di lahan petani di Asembagus, Situbondo, Jawa Timur, pada Januari-Juli 2012. Paket PHT yang diuji yaitu varietas unggul kapas Kanesia 10 atau Kanesia 13 serta perlakuan benih atau penyemprotan tetes tebu (10 ml L^{-1}) sebagai makanan musuh alami. Kapas ditanam secara tumpang sari dengan kacang tanah dan disemprot dengan ekstrak biji mimba (EBM) berdasarkan hasil pemantauan dan ambang kendali. Paket-paket PHT tersebut dibandingkan satu sama lain dan juga dengan cara budi daya yang biasa diterapkan petani, yaitu menggunakan varietas Kanesia 8, tumpang sari kapas dan kacang tanah, dan penyemprotan insektisida kimia. Pengamatan dilakukan terhadap 25 tanaman per petak perlakuan dengan mengamati parameter pertumbuhan, populasi wereng dan penggerek buah kapas, serta hasil kapas berbiji. Pengamatan dilakukan setiap minggu mulai 30 hari setelah tanam (HST) hingga 120 HST. Hasil penelitian menunjukkan bahwa penggunaan varietas Kanesia 10 atau Kanesia 13 yang ditumpangsarikan dengan kacang tanah dan penyemprotan tetes tebu untuk konservasi musuh alami merupakan teknik pengelolaan hama terbaik dibandingkan dengan praktik budi daya petani. Konservasi musuh alami tidak hanya menguntungkan (menghemat biaya produksi Rp1,150,000-Rp1,500,000/ha/musim), tetapi juga aman bagi lingkungan (tanpa penyemprotan insektisida kimia).*

[***Kata kunci*:** Kapas, pengelolaan hama, lahan tadah hujan]

INTRODUCTION

Cotton development program in Indonesia was initiated 30 years ago to decrease dependency on imported cotton fiber and to increase domestic cotton production. The Directorate General of Estate Crops recently applied two approaches for increasing cotton production, i.e. widening cotton growing areas and increasing cotton fiber productivity (Hasanudin 2007). However, the national production of cotton fiber contributes less than 1% of national demand for textile and textile-product industries (Permatasari

2011). This is partly because areas for cotton growing have only reached 30-45% of the area targeted, i.e. 55,000-70,000 ha (Hasanuddin 2007).

A technical factor obstructing cotton cultivation is the high cost of production. In particular, the cost for pest control reaches 65% of the total costs for cotton cultivation (Basuki *et al*. 2001), mainly because of the cotton bollworm (*Helicoverpa armigera)* that causes losses up to 40% (Nurindah 2003). Although the pest control is relatively high using chemical insecticide, the seed cotton yield has only been 400-500 kg ha^{-1} or 30-40% of the yield potential of improved variety (Balittas 2009). Cotton farming is, therefore, unprofitable and less competitive economically than other cash crops (Basuki *et al*. 2001; Hasnam *et al*. 2005).

Pest management by conserving natural enemies has been shown to make a significant contribution to the improvement of cotton farming efficiency by increasing vegetation diversity, lowering cost of production due to the use of botanical insecticides as substitutes for synthetic chemical insecticides, and parasitoid augmentations (Nurindah 2011). Increasing the role of natural enemies has been achieved through habitat management, such as planting moderately resistant cotton varieties to leafhopper (*A. biguttula*) and intercropping cotton with secondary food crops, such as maize or soybean. These resistant cotton varieties removed the need for aerial sprays of insecticides in the early season thus conserving the natural enemy populations (Nurindah and Sudarmo 1993; Nurindah *et al*. 2004).

The polyculture system increases the diversity of beneficial insects (Olson and Wäckers 2007; Thompson and Hoffmann 2009). Intercropping cotton with secondary food crops contributes significantly to cotton pest control thus delivers economic benefits (increasing farmers' income of IDR574,500 ha^{-1} season^{-1}) as well as ecological benefits (the environment is free from toxic synthetic insecticide) (Nurindah *et al*. 1993). Combination of these two methods (using moderately resistant verieties to cotton leafhoppers and intercropping cotton with maize) decreased crop losses due to cotton bollworm by 40% (Nurindah 2003). Furthermore, conserving natural enemies by providing food for parasitoids and predators of cotton pests increased cotton productivity to more than 3,000 kg ha^{-1}, increased farmers' income up to 40%, and saved pest control costs by IDR500,000 ha season^{-1} (Nurindah and Sunarto 2006). In addition, several new superior cotton varieties such as Kanesia 10 and Kanesia 13 have been recommended to replace the older one (Kanesia 8) because they have higher potential productivity (1,700-3,026 kg seed cotton and 1,920-3,174 kg seed cotton ha^{-1}, respectively, as compared to 1.850-2.730 kg seed cotton ha^{-1} for Kanesia 8) (Sulistyowati and Sumartini 2009). However, Kanesia 10 is relatively susceptible to cotton planthopper so it has to be supported by appropriate control actions in pest management.

In developing good agricultural practices on cotton, integrated pest management (IPM) packages are the main actions to be applied. The use of cotton varieties resistant to leafhopper is the main component of the IPM. However, as the cotton varieties used in the cotton development program are mostly moderately resistant to the planthopper, seed treatment with systemic insecticide before sowing is recommended. Intercropping cotton with secondary food crops is a component of recommended IPM practices. Application of action threshold level developed by Nurindah and Sunarto (2008) is another component that enhances the possibility for cotton cultivation without any chemical insecticide sprays. As a consequence, applying this concept would conserve natural enemies and also increase cost efficiency for pest control. Furthermore, in a preliminary study, spraying molasses at 5 mL L^{-1} of water as supplement food for natural enemies, especially predatory insects, increased predator populations and suppressed leafhopper populations on cotton intercropped with mungbean, so that this food spray could replace the seed treatment. However, molasses spray has not been included as a part of cotton pest control or natural enemy conservation in cotton agro-ecosystems in Indonesia. Therefore, the IPM package on cotton includes the use of varieties with moderate resistance to leafhoppers, seed treatment with systemic insecticide before sowing or molasses foliar sprays, intercroping system, applying action threshold levels that consider the predators' presence, and use of botanical insecticides when the pest population reaches the action threshold level.

The advantages of the innovations were obtained from research activities conducted in a research station in separate trials for each pest management component as detailed above. These components have not been integrated into a package of cultivation techniques. Therefore, the research reported here was designed to evaluate these cultivation techniques in different combinations or packages. The packages are expected to provide an efficient and environmentally friendly cultivation technique to increase cotton competitiveness in rain fed fields. The increase in economic returns is expected to enhance the farmers' enthusiasm to grow cotton, and this should, in turn, increase national cotton production.

MATERIALS AND METHODS

The trial was conducted on rain fed fields in Asembagus, Situbondo, East Java between January and May 2012. In this trial, four packages of pest management were tested for comparison with farmers' practices. The experiment was designed in randomized blocks with five replicates. The total experimental plot size was 2.5 ha. The blocks were separated from one to another by five rows of maize plants.

The four integrated pest management packages tested were cotton varieties Kanesia 10 or Kanesia 13, seed treatment with synthetic insecticide (imidacloprid) before sowing or spraying with molasses (10 mL L^{-1} water) as food for natural enemies (Table 1). The cotton plants were intercropped with groundnut and sprayed with neem seed extract (NSE) at the action threshold level for pest control. These packages were compared with farmers' practices, i.e. using cotton variety Kanesia 8, intercropping with groundnut, and synthetic insecticide spraying.

The action threshold level for NSE spraying was based on the recommendations developed by Nurindah and Sunarto (2008) as follows:

- Cotton leafhopper (*A. biguttula*): 50% of the 25 sampled plants are infested by the pest and show damage. The observations were made on the top third leaves that were fully opened.
- Cotton bollworm *(H. armigera)*: four plants of 25 observed plants are infested by the pest. The number of infested plants observed is lessened by one point when eight natural enemies (e.g., spiders, lady beetles, mirid bugs or ants) were found on the same plant.

Twenty five plants were sampled randomly per plot and observed for their growth (plant height and number of generative branches), total number of mature bolls, and also for cotton leafhopper and cotton bollworm populations. Cotton seed production per plot was recorded after boll picking. Observations were made weekly, starting at 30 days after planting (DAP) until 120 DAP. Daily rainfall was noted during the cotton growing season. Data were analyzed by two-way ANOVA's and the differences were assessed using Fisher's Least Significant Difference test. Costs of production of both cotton and groundnut were analyzed by usng a simple technical efficiency analysis.

RESULTS AND DISCUSSION

Pest Population

Monitoring of cotton leafhopper and cotton bollworm populations showed that densities of these two important pests were relatively low and below the action threshold levels (Table 2). This resulted in no need to spray botanical insecticides. This also indicated that increasing vegetation diversity by intercropping cotton with groundnut, as well as using imidacloprid for seed treatment before sowing or spraying molasses for natural enemies food, successfully conserved the natural enemies populations, so they play an important role in controlling the pests effectively. However, in plots of farmers' practices, the farmers needed to spray two times using 1.6 L metomyl ha^{-1} $spray^{-1}$ on 65 and 80 DAP. These sprays were done based on the farmer's interpretation of the situation and risk assessment. As a result, the bollworm population increased (Fig. 1).

Table 1. Components of cotton integrated pest management (IPM) packages tested compared with farmer's practice.

Package components	IPM package				Farmer's practice
	1	2	3	4	
Variety	Kanesia 10	Kanesia 10	Kanesia 13	Kanesia 13	Kanesia 8
Seed quality	Certified	Certified	Certified	Certified	Certified
Seed treatment	Imidacloprid	None	Imidacloprid	None	None
Foliar plant spray	None	Molasses	None	Molasses	None
Intercropping with groundnut	Yes	Yes	Yes	Yes	Yes
Pest control	NSE spray when pest population reaches the action threshold	NSE spray when pest population reaches the action threshold	NSE spray when pest population reaches the action threshold	NSE spray when pest population reaches the action threshold	Chemical synthetic insecticide spray based on the judgment of the farmers

Table 2. Number of times that action thresholds for cotton leafhopper and cotton bollworm were reached in each treatment based on 7-day interval scouting on 30-100 days after planting (DAP), Asembagus, Situbondo, East Java, April-July 2012.

Plant age (DAP)	Cotton leaf hopper					Cotton bollworm				
	K-10 + ST	K-10 + M	K-13 + ST	K-13 + M	Farmer's practice	K-10 + ST	K-10 + M	K-13 + ST	K-13 + M	Farmer's practice
30	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0	0	1
79	0	0	0	0	0	0	0	0	0	0
86	0	0	0	0	0	0	0	0	0	1
93	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0

K-10 + ST = Kanesia-10 + seed treatment; K-10 + M = Kanesia-10 + molasses; K-13 + ST = Kanesia-13 + seed treatment; K-13 + M = Kanesia-13 + molasses. Farmer's practice plots were sprayed with insecticides on 65 and 80 DAP based on the farmer's interpretation of the situation and risk assessment.

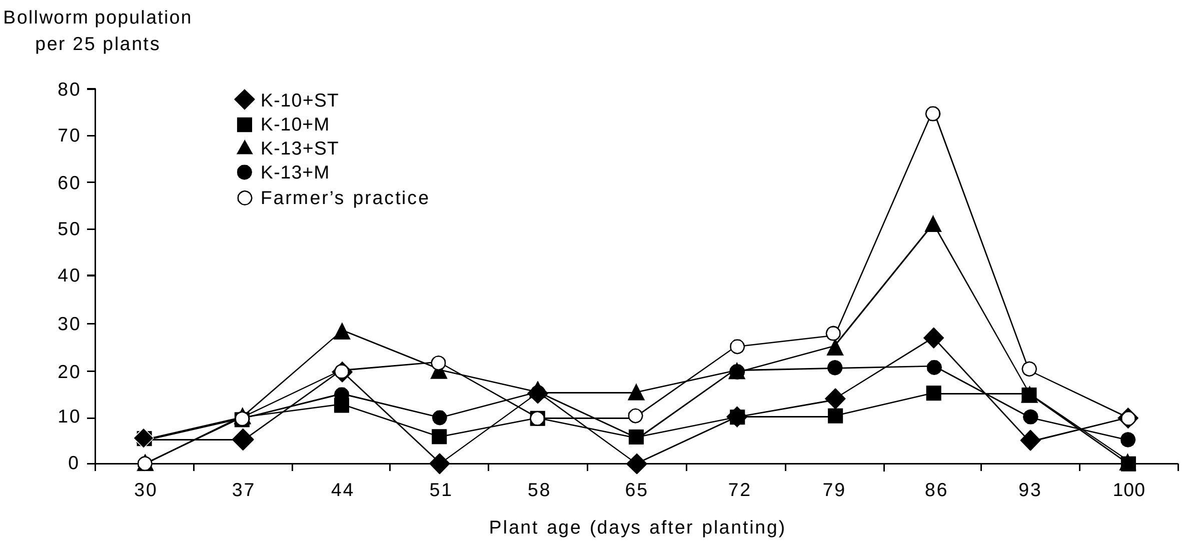

Fig. 1. Bollworm populations on cotton treated with four integrated pest management packages and farmer's practice, Asembagus, Situbondo, East Java, January-April 2012. K-10 + ST = Kanesia-10 + seed treatment; K-10 + M = Kanesia-10 + molasses; K-13 + ST = Kanesia-13 + seed treatment; K-13 + M = Kanesia-13 + molasses.

Cotton leafhopper density was relatively low (10-40 nymphs per 25 plants) during 30-80 DAP and increased slightly afterward (Fig. 2). However, this density level did not cause the infested leaves to show damage symptoms. As a result, no action threshold was ever reached in any treatments (Table 2).

The cotton bollworm density during the season in this study was always under the action threshold levels, including that in farmer's practice plots. When the action threshold that considers the predators' presence was applied, the cotton bollworm population was low. However, when chemical insecticides were sprayed, as in farmer's practice, the bollworm population increased and reached the action threshold levels. This phenomenon indicated that the predators were conserved, but they are very sensitive to the chemical insecticide sprays, so they cannot play an important role in keeping the pest population at low levels. The conservation of predator was also supported by the planting system, i.e. intercropping cotton and groundnut.

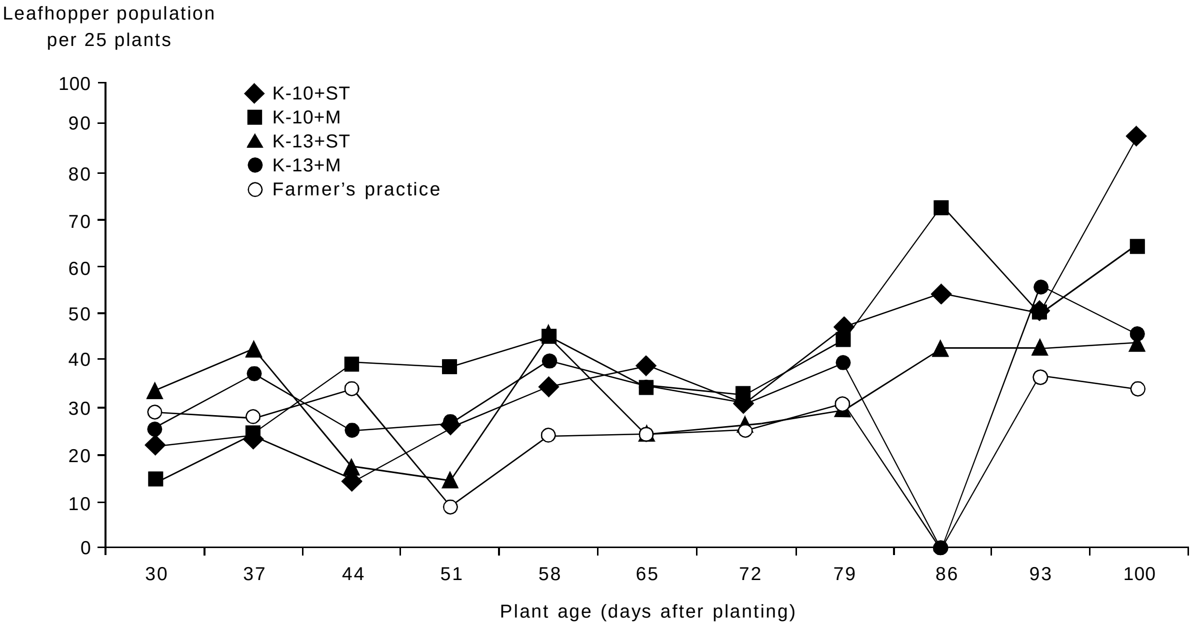

Fig. 2. Leafhopper populations on cotton treated with four integrated pest management packages and farmer's practice, Asembagus, Situbondo, East Java, January-April 2012. K-10 + ST = Kanesia-10 + seed treatment; K-10 + M = Kanesia-10 + molasses; K-13 + ST = Kanesia-13 + seed treatment; K-13 + M = Kanesia-13 + molasses.

Intercropping system is a cultivation practice that increases biodiversity in agro-ecosystems (Jackson *et al*. 2010). This cultivation system is a common practice for Indonesian farmers. In all cotton growing areas, cotton is always intercropped with secondary food crops such as maize, soybean and mungbean or groundnut (Machfud 2002). From a pest control perspective, this system has the incidental benefit of a relatively high diversity and population of natural enemies. The number of predators of *H. armigera* in cotton intercropped with soybean has been reported to be higher than that in cotton monocultures (Nurindah *et al.* 1993). Conversely, on cotton intercropped with mungbean, populations of common predators such as *Paederus* sp. (Coleoptera: Staphylinidae) increased and kept the cotton leafhopper and bollworm populations below the action threshold levels (Nurindah and Sujak 2006). Nurindah *et al.* (2008) also reported that species diversity of *H. armigera* egg parasitoids in such ecosystems was also higher than that in monoculture habitat. The higher species diversity of egg parasitoids increased *H. armigera* mortality. The mortality of *H. armigera* on cotton intercropped with mungbean reached 36% (egg stage), 20% (larval stage) and 36% (pupal stage) (Nurindah *et al*. 2006).

On the other hand, foliar sprays of insecticides have a negative effect on the development of natural enemy populations, and their application further resulted in the build up of the herbivore population. Mansfield *et al.* (2006) reported that in unsprayed cotton fields, beneficial insects were more abundant compared to those in which broad-spectrum-insecticide sprays were used. Populations of predators on cotton were negatively affected by insecticide sprays (Nurindah and Sudarmo 1993), whereas natural enemies of cotton bollworm play an important role in keeping the bollworm population under the action threshold levels (Nurindah and Sunarto 2008). Insecticide sprays, as in the farmers' practice plot, seem to have led to the build up of bollworm populations. Therefore, conserving natural enemies by supporting their population build up is an important action in cotton pest management.

Food sprays for natural enemies have been reported to be a potentially pest management practice on cotton (Mensah and Singleton 2003). Molasses is derived from cane sugar and contains sucrose as well as reducing sugars that could be a food source for parasitoids as well as predators. This could increase their populations in the vicinity or act as arrestants for the beneficial insects. Consequently they would kill more herbaceous pests. As a sugar mill waste, molasses could be used as a cheap mean for conservation of natural enemies in pest management.

Effect of IPM Packages on Plant Growth

Cotton growth is indicated by plant height and number of generative branches. Kanesia 8 (farmer practice), Kanesia 13 (with seed treatment or molasses sprays), and Kanesia 10 with seed treatment showed a normal growth up to 90 DAP and stopped growing after that. Kanesia 10 with molasses sprays continued to grow up to 120 DAP because it was slower than that in the other treatments up to day 90 (Fig. 3 and 4).

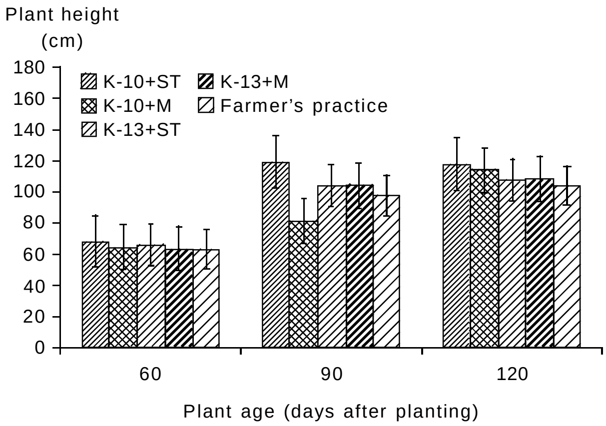

Fig. 3. Height (mean ± SD) of cotton plants subjected to four pest management packages and farmer's practice, Asembagus, Situbondo, East Java, January-April 2012. K-10 + ST = Kanesia-10 + seed treatment; K-10 + M = Kanesia-10 + molasses; K-13 + ST = Kanesia-13 + seed treatment; K-13 + M = Kanesia-13 + molasses.

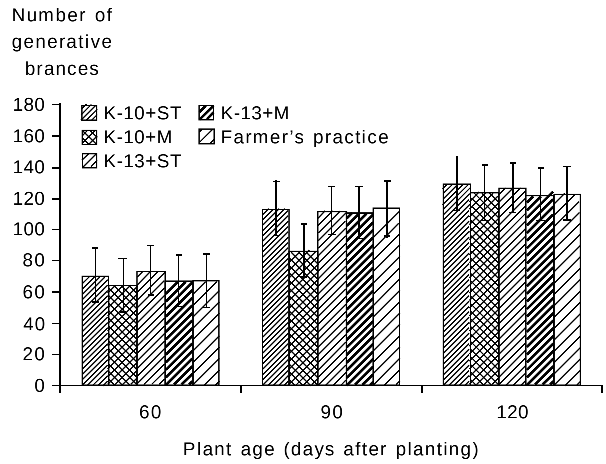

Fig. 4. Number of generative branches (x ± SE) of cotton plants subjected to four integrated pest management packages and farmers' practice, Asembagus, Situbondo, East Java, January-April 2012. K-10 + ST = Kanesia-10 + seed treatment; K-10 + M = Kanesia-10 + molasses; K-13 + ST = Kanesia-13 + seed treatment; K-13 + M = Kanesia-13 + molasses.

Plant growth is affected by water stress, pest intestation and high temperature (Buchanan 2004). The growth of Kanesia-10 with molasses spray was slow compared with other varieties, perhaps because of water stress during 30-60 DAP and leafhopper infestations (Fig. 2). Cotton plants will grow well under suitable conditions, especially when water is available (Main 2004) and water stress will delay cotton growth before the flowering stage (Oosterhuis and Kerby 2007). The amount of rainfalls up to 50 DAP, when leafhopper infestations mostly affect plant growth, was not sufficient to obtain an optimal plant growth on rain fed fields. Furthermore, leaf-hopper populations on K-10+M treatment during 45-90 DAP were relatively higher than that on the other plots (Fig. 2). Kanesia 10 was reported susceptible to cotton leafhopper and water stress (Sulistyowati and Sumartini 2009) and seed treatment before sowing (K10+ST) could support the plant to grow normally. This was because the seed treatment using systemic insecticide before sowing could prevent the leaf-hopper infestation up to 60 DAP (Sunarto *et al*. 2011). Therefore, seed treatment is useful for susceptible varieties to prevent leafhopper infestation in early season, especially for cotton grown on rain fed areas with limited water supply.

The squares of cotton on K-10+M trteatmen were formed earlier than that on other treatments, as indicated by the declining number of squares after 72 DAP. On the other treatments, square formation declined after 86 DAP (Fig. 5). Under water stress conditions and leafhopper infestations, Kanesia 10 stops forming squares and its energy is turned to boll formation and maturation. The peak of vertical growth will stop after flowering (cut out) because the energy is used for boll formation (Main 2004).

Boll formation did not follow the pattern of square formation (Fig. 6). The number of bolls was not significantly different among all treatments. This indicated that during boll formation and maturation during 60-100 DAP, the rainfall, the only water supply during the experiment, was not sufficient so squares could not be converted to the bolls. At least 132 mm of rainfall is needed for optimal boll formation and maturation (FAO 2011), but only 44.6 mm (33% of optimal plant requirement) fell during 60-100 DAP. Furthermore, water stress had a clear effect on boll formation and maturation on Kanesia 8, the variety commonly used by farmers. The number of squares of Kanesia 8 at 90 DAP was significantly higher than that of Kanesia 10 or Kanesia 13, however the number of bolls on those plots was not significantly different (Fig. 6). This indicated that during water stress (60-

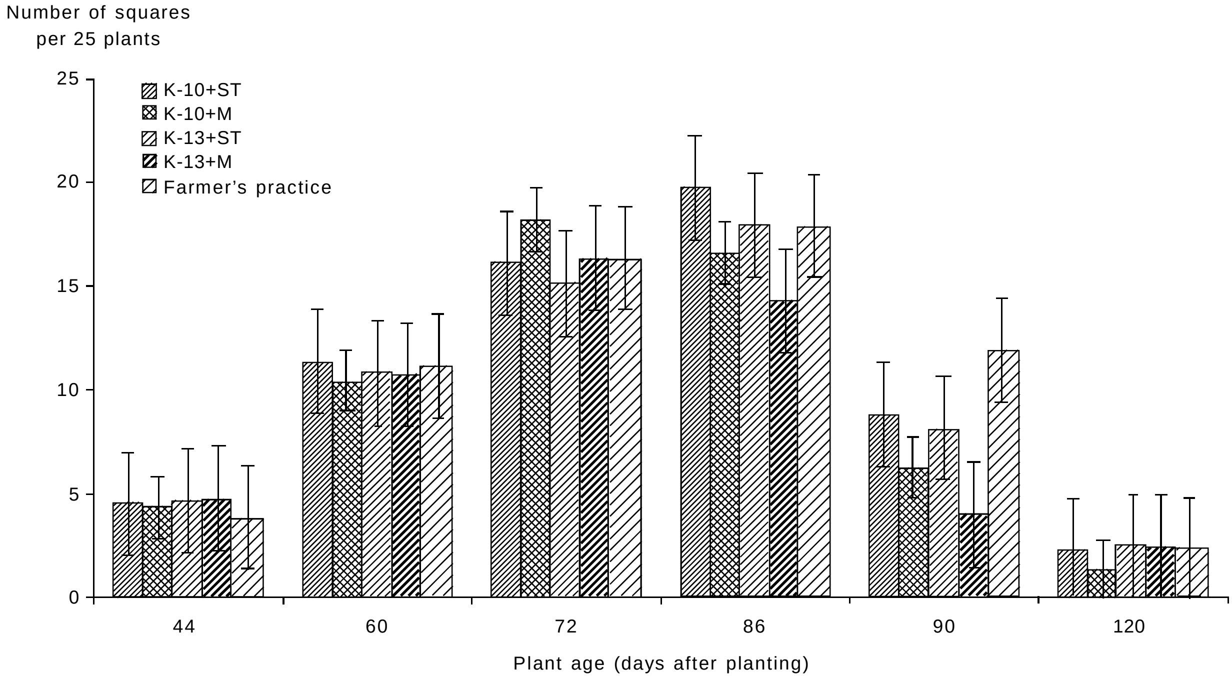

Fig. 5. Number (mean ± S.E) of squares on cotton subjected to four integrated pest management packages and farmer's practice, Asembagus, Situbondo, East Java, January-April 2012. K-10 + ST = Kanesia-10 + seed treatment; K-10 + M = Kanesia-10 + molasses; K-13 + ST = Kanesia-13 + seed treatment; K-13 + M = Kanesia-13 + molasses.

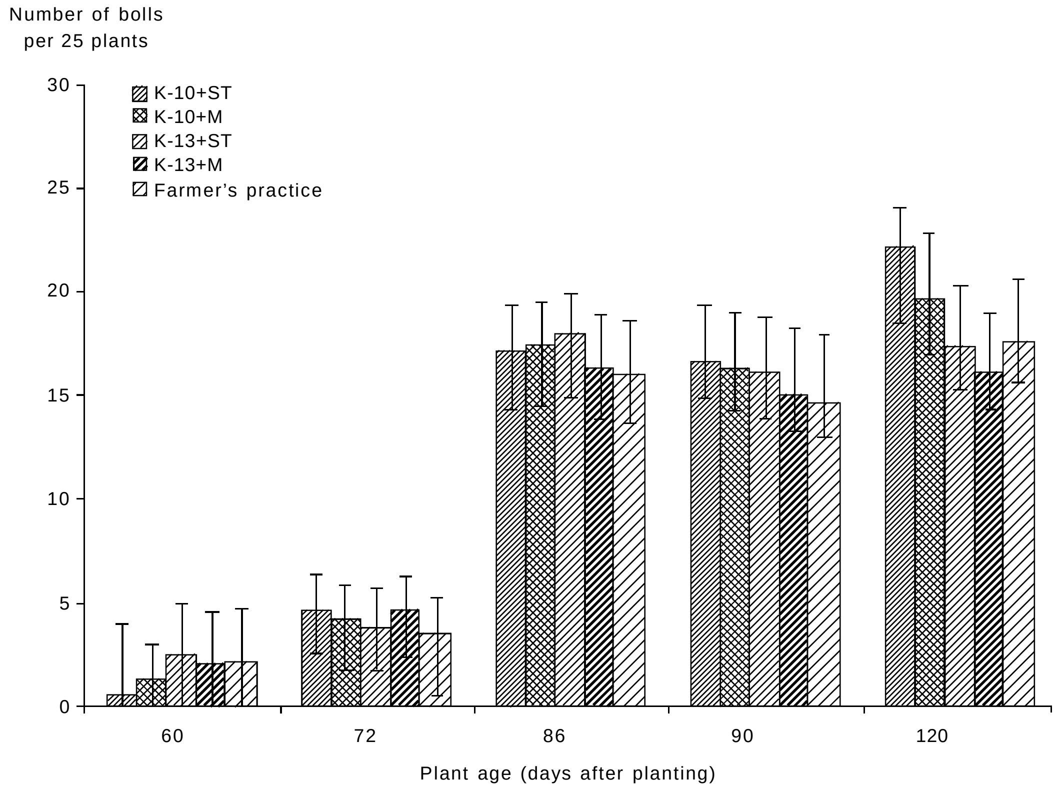

Fig. 6. Number (mean ± SE) of bolls on fcotton subjected to four integrated pest management packages and farmers' practice, Asembagus, Situbondo, East Java, January-April 2012. K-10 + ST = Kanesia-10 + seed treatment; K-10 + M = Kanesia-10 + molasses; K-13 + ST = Kanesia-13 + seed treatment; K-13 + M = Kanesia-13 + molasses.

100 DAP), Kanesia 8 could not support the boll formation for all the formed squares and shed the unsupported squares. Water deficit after flowering means that a limited amount of assimilations is possible as photosynthesis decreases, and as a consequence heavy squares and young bolls shedding occurs (Guinn 1982). Therefore, growing undetermined growth type cotton, such as Kanesia 8, in rain fed areas should be reconsidered.

Groundnut and Seed Cotton Yield

Yield of groundnut was 70-78% of the yield potential of the variety. In monoculture cropping, the average yield is 1,920 kg dried bean ha^{-1} (Balitkabi 2008) (Table 3). The density of groundnut intercropped with cotton was 19,000 plants ha^{-1} or 33% of monoculture density. In K-10+M plot, groundnut yield was the highest and significantly higher than that in other plots, perhaps because in this treatment, cotton growth was delayed up to 90 DAP compared to other plots (Fig. 4 and 5). This delay meant that the cotton plant did not shade the groundnut, so the groundnut could use the extra sunlight for maximizing yield.

The yield of seed cotton in this research was 49-66% of the yield potential of each variety. Seed cotton yield on K-13+ST treatment was not significantly different from that of farmers' practice and less than that of the other treatments (Table 3). Kanesia-10 had the highest seed cotton yield, which implies that this variety is more tolerant to intercrop conditions with groundnut compared with Kanesia-13 and Kanesia-8. Kanesia 10 has been reported to be suitable to be intercropped with mungbean and maize (Sumartini *et al*. 2008). This also indicates that Kanensia-10 is more tolerant to late season drought (water stress) than the other varieties. Kanesia 8 was reported as intolerant to drought, whereas Kanesia 13 was moderately tolerant to drought (Sumartini *et al*. 2008).

Cotton grows slowly in early developmental stage, so it is suitable for intercropping with short duration legumes. Asokaraja *et al*. (1987) reported that cotton intercropped with ground nut did not affect groundnut yield thus increasing farmer's income. Furthermore, intercropping cotton with groundnut increased seed cotton yield than cotton monocultures (Prasad *et al*. 1993) indicated a higher value of land equivalent ratio (LER) (Balkar *et al*. 1990). Although it was also reported that intercropping declined cotton yield, such a system should increase productivity (Khan and Khaliq 2004). The increase in productivity would increase farmer's income. Therefore, farmers always grow cotton intercropped with secondary food crops.

Table 3. Yield of groundnut and seed cotton of the tested integrated pest management packages and farmer's practices, Asembagus, Situbondo, East Java, January-April 2012.

Treatment[1)]	Yield (kg ha^{-1})			
	Groundnut		Seed cotton	
	Actual	Potential (%)[2)]	Actual	Potential (%)[2)]
K-10 + ST	408 a	71	1,432 b	66
K-10 + M	452 b	78	1,337 b	61
K-13 + ST	412 a	71	1,174 a	49
K-13 + M	415 a	72	1,351 b	56
Farmer's practice	406 a	70	1,160 a	53

Figures in a column followed by different letters indicate significant difference (P < 0.5) based on Fisher's Least Significant Difference.

[1)]Treatment: K-10 + ST = Kanesia-10 + seed treatment; K-10 + M = Kanesia-10 + molasses; K-13 + ST = Kanesia-13 + seed treatment; K-13 + M = Kanesia-13 + molasses.

[2)]Shows the actual yield against its yield potential. Yield potential for groundnut variety Jerapah is 1.92 t ha^{-1} (Balitkabi 2008); Kanesia 10: 1,700-3,026 kg ha^{-1}, Kanesia 13: 1,920-3,174 kg ha^{-1}, Kanesia 8: 1,850-2,730 kg ha^{-1} (Sulistyowati and Sumartini 2009).

Farming Analysis

The farming analysis was done by calculating input cost (total cost of materials and man power used for producing seed cotton), output (total income of groundnut and seed cotton selling), and revenue (output – input cost). The comparative analysis of the relative productivity of the cultivation packages and farmers' practices is presented in Table 4.

Using cotton varieties Kanesia 10 or Kanesia 13 with introduced cultivation techniques (seed treatment with systemic insecticide before sowing or molasses spray) gave a higher income than that of using Kanesia 8 with farmers' practices. The introduced cultivation techniques required more input cost, however, the income return was higher than that of the conventional technique. This was due to the implementation of pest management which significantly increased seed cotton yield and also groundnut yield in K-10+M. As a result, the revenue of the introduced cultivation techniques was higher than that of the farmers' practice. The highest B/C ratio was achieved by the use of Kanesia 10 and molasses spray to provide food for predators (K-10+M). This showed that cotton cultivation supported by means of natural enemy conservation

Table 4. Farming analysis of cotton cultivation using four integrated pest management packages and farmer's Financial practice, Asembagus, Situbondo, East Java, January-July 2012.

Items	Treatments[1)]				
	K-10 + ST	K-10 + M	K-13 + ST	K-13 + M	Farmer's practice
Cost of man power (IDR ha^{-1})					
Sowing to harvesting	2,732,468	2,732,468	2,732,468	2,732,468	2,732,468
Molasses sprays	0	30,303	0	30,303	0
Insecticide sprays	0	0	0	0	30,303
Subtotal	2,732,468	2,762,771	2,732,468	2,762,771	2,762,771
Costs of production materials (IDR ha^{-1})					
Cotton seeds	300,000	300,000	300,000	300,000	300,000
Groundnut seeds	920,000	920,000	920,000	920,000	920,000
Fertilizers	721,920	721,920	721,920	721,920	184,870
Molasses	0	45,000	0	45,000	0
Insecticide for seed treatment before sowing	50,000	0	50,000	0	0
Insecticides for aerial sprays	0	0	0	0	475,200
Subtotal	1,991,920	1,986,920	1,991,920	1,986,920	1,880,070
Total of production costs	4,724,388	4,749,691	4,724,388	4,749,691	4,642,841
Income					
Groundnut yield (kg ha^{-1})	815	903	824	830	811
Income from groundnut (IDR ha^{-1})[2)]	2,851,952	3,159,073	2,884,285	2,904,358	2,839,227
Seed cotton production (kg ha^{-1})[3)]	1,432	1,432	1,174	1,432	1,160
Income from cotton (IDR ha^{-1})	6,299,467	6,299,467	5,165,154	6,299,467	5,104,880
Total income (IDR ha^{-1})	9,151,418	9,458,539	8,049,439	9,203,824	7,944,107
Net income (IDR ha^{-1})	4,427,031	4,708,849	3,325,052	4,454,134	3,301,267
B/C ratio (IDR ha^{-1})	0.94	0.99	0.70	0.94	0.71

[1)]K-10 + ST = Kanesia-10 + seed treatment; K-10 + M = Kanesia-10 + molasses; K-13 + ST = Kanesia-13 + seed treatment; K-13 + M = Kanesia-13 + molasses.
[2)]Price of groundnut IDR4,000 kg^{-1}.
[3)]Price of seed cotton IDR4,400 kg^{-1}.

techniques is more profitable than to apply synthetic chemical insecticides.

The superior varieties Kanesia 10 and Kanesia 13 can feasibly be grown in rain fed fields by conserving natural enemies for pest management. Both application of seed treatment using imidacloprid before sowing and molasses spray gave more profit than the use of insecticides. The molasses spray at 1% concentration, aimed at natural enemy conservation, could be easily adopted by farmers because it is a waste from sugar mills, so it is cheap and readily available. It could replace the routine application of imidacloprid to seed before sowing. and have a benefit to the environment.

CONCLUSION

Pest management by conserving natural enemies in cotton production is profitable. Conservation of natural enemies can be achieved by planting cotton intercropped with groundnut and together with the use of pest management practices, viz. seed treatment with systemic insecticide before sowing or molasses spray at 1% concentration, and applied action threshold concept with the quantification of predators. The most efficient pest management practice was integrated pest management practice with Kanesia 10 and molasses spray as the main component. Molasses is important to increase predator’s populations as it would provide food for them.

ACKNOWLEDGEMENTS

The authors thank to Mr. Moch. Rifai and Mr. Syamsul Arief for their helps in conducting this experiment. The help of Mr. Sujak in field observations as well as providing useful comments for the treatment applications is truly appreciated. This research is funded by National Budget of IRISFC Year 2012.

REFERENCES

Asokaraja, N., A. Chamy, and S. Palaniappan. 1987. Studies on intercropping in groundnut. Madras Agric. J. 74(8-9): 355-359.

Balitkabi. 2008. Deskripsi varietas unggul kacang tanah 1950-2008. Balai Penelitian Tanaman Kacang-kacangan dan Umbi-umbian, Malang. 30 hlm.

Balittas. 2009. Varietas Unggul Tanaman Tembakau, Serat dan Minyak Industri. Balai Penelitian Tanaman Tembakau dan Serat, Malang. 46 hlm.

Balkar, S.Y., C.S. Vaidya, and V.R. Zade. 1990. Effect of planting pattern, fertilizer levels and intercropping on the yield and monetary returns of cotton. Ann. Plant Physiol. 4(1): 66-71.

Basuki, T., S. Bambang, and S.A. Wahyuni. 2001. Sistem usaha tani kapas di Indonesia. hlm: 55-76. *Dalam* A. Rachman, A. Sastrosupadi, Rr. S. Hartati, Subiyakto, G. Dalmadiyo, B. Santoso, dan Mukani (Eds.). Kapas, Buku I. Monograf Balittas No. 7. Balai Penelitian Tembakau dan Tanaman Serat, Malang.

Buchanan, G.A. 2004. Cotton growth and development. Bulletin 1252. The University of Georgia College of Agricultural and Environmental Sciences. 16 pp.

FAO. 2011. Irrigation Water Management: Irrigation water needs; Chapter 2: Crop Water Needs. Natural Resources Management and Environment Department. http://www.fao.org/docrep/S2022E/s2022e02.htm. (5 January 2012).

Guinn, G. 1982. Abscisic acid and abscission of young cotton bolls in relation to water availability and boll load. Crop Sci. 22: 580-583.

Hasanudin, A.R. 2007. Pengembangan Kapas Nasional. Makalah pada Pertemuan Koordinasi dan Sinkronisasi Pengembangan Kapas Nasional Tahun 2007, Makassar, 11-12 Mei 2007. 8 hlm.

Hasnam, Nurheru, F.T. Kadarwati, E. Sulistyowati, P.D. Riajaya, Nurindah, dan M. Sahid. 2005. Pengelolaan tanaman terpadu pada kapas di Sulawesi Selatan dan Nusa Tenggara Barat. Laporan Hasil Kegiatan Tahun 2004. Balai Penelitian Tembakau dan Tanaman Serat, Malang. 56 hlm.

Jackson, L., M. van Noordwijk, J. Bengtsson, W. Foster, L. Lipper, M. Pulleman, M. Said, J. Snaddon and R. Vodouhe. 2010. Biodiversity and agricultural sustainability: from assessment to adaptive management. Curr. Opin. Env. Sust. 2: 80-87.

Khan, M.B. and A. Khaliq. 2004. Study of mungbean intercropping in cotton planted with different techniques. J. Res. Sci. 15(1): 23-31.

Machfud, M. 2002. Budi daya kapas di lahan sawah. hlm. 101-108. *Dalam* A. Rachman, A. Sastrosupadi, Rr. S. Hartati, Subiyakto, G. Dalmadiyo, B. Santoso, dan Mukani (Eds.). Kapas, Buku I. Monograf Balittas No. 7. Balai Penelitian Tembakau dan Tanaman Serat, Malang.

Main, C.L. 2004. Cotton Growth and Development. The University of Tennessee Institute of Agriculture, US Department of Agriculture. 5 pp.

Mansfield, S., T.M. Wither. S.F. Gous, K.J.B. Potter, D.J. Kriticos, M. Watson and M.O. Kimberley. 2006. Potential of selective insecticides for managing *Uraba lugens* (Lepidoptera: Nolidae) on eucalyptus. J. Econ. Ento. 99(3): 780-789

Mensah, R.K. and A. Singleton. 2003. Optimum timing and placement of supplementary food spray Envirofeast® for the establishment of predatory insects of *Helicoverpa* spp. on cotton system in Australia. Int. J. Pest Man. 49: 163-168.

Nurindah dan S. Sudarmo. 1993. Pengaruh penyemprotan insektisida terhadap populasi musuh alami serangga hama kapas. Bul. Tembakau dan Serat 2(9): 12-16.

Nurindah, S. Sudarmo, dan Soebandrijo. 1993. Pengaruh tumpangsari kapas dengan palawija terhadap populasi predator serangga hama kapas. Prosiding. Diskusi Panel Budidaya Kapas+Kedelai, Malang, 10 Desember 1992. Seri Pengembangan No.7: 55-60.

Nurindah. 2003. Status *Helicoverpa armigera* (Hübner) dan peran musuh alaminya pada ekosistem kapas di Indonesia. Perspektif 2(1): 11-19.

Nurindah, D.A. Sunarto, dan Sujak. 2004. Pengaruh penyemprotan insektisida terhadap prekembangan populasi laba-laba dan wereng kapas *Amrasca biguttulla* (Ishida) (Homoptera: Ciccadelidae). hlm. 62-66. *Dalam* Soebandrijo, Subiyakto, A.A.A. Gothama, dan Mukai (Eds.). Prosiding Lokakarya Pengembangan Kapas Dalam Rangka Otoda, Malang, 15 Oktober 2002. Pusat Penelitian dan Pengembangan Perkebunan, Bogor.

Nurindah dan D.A. Sunarto. 2006. Efektivitas beberapa predator terhadap *Helicoverpa armigera* (Hubner) pada kapas tumpangsari dengan kedelai. J. Penelitian Tanaman Industri 12(3): 116-120.

Nurindah dan Sujak. 2006. Keanekaragaman spesies parasitoid telur *Helicoverpa armigera* (Hübner) pada sistem tanam monokultur dan polikultur kapas. Jurnal Entomologi Indonesia 3(2): 71-83.

Nurindah, D.H. Parmono, dan Sujak. 2006. Faktor mortalitas biotik *Helicoverpa armigera* (Hubner) pada kapas tumpangsari dengan kedelai. hlm. 110-117. Prosiding Lokakarya Revitalisasi Agribisnis Kapas Diintegrasikan dengan Palawija di Lahan Sawah Tadah Hujan, Lamongan, 8 September 2005. Pusat Penelitian dan Pengembangan Perkebunan, Bogor.

Nurindah dan D.A. Sunarto. 2008. Ambang kendali penggerek buah kapas *Helicoverpa armigera* dengan mempertimbangkan keberadaan predator kapas. J. Penelitian Tanaman Industri 14(2): 72-77.

Nurindah, D. Buchori, B. Sahari, dan D.A. Sunarto. 2008. Dinamika kompleks parasitoid telur *Helicoverpa armigera* (Hubner) pada ekosistem kapas monokultur dan kapas tumpangsari jagung. J. Pengendalian Hayati 1(2): 78-82.

Nurindah. 2011. Developing cotton IPM by conserving parasitoids and predators of the main pest. J. Entomol. Indones. 8(2): 71-83.

Olson, D.M. and F.L. Wäckers. 2007. Management of field margins to maximize multiple ecological services. J. App. Ecol. 44: 13-21.

Oosterhuis, D.M. and T.A. Kerby. 2007. Measures of Cotton Growth and Development. COTMAN Manual Part 3. 6 pp.

Permatasari, R.G.I. 2011. Harga impor bahan baku tekstil meningkat 170%. Okezone, 12 Februari 2011. http://economy.okezone.com/read/2011/02/12/20/424157/20/harga-impor-bahan-baku-tekstil-meningkat. (17 June 2012).

Prasad, M., B.L. Meena and R. Prasad. 1993, Effect of intercropping in upland cotton (*Gossypium hirsuturm*) on growth and yield of component crops. Indian J. Agron. 38(2): 342-344.

Sulistyowati, E. dan S. Sumartini. 2009. Kanesia 10-Kanesia 14: Empat varietas kapas baru berproduksi tinggi. J. Tanaman Perkebunan 15(1): 24-32.

Sumartini, S., Abdurrakhman, dan E. Sulistyowati. 2008. Galur-galur harapan kapas di lahan tadah hujan. J. Penelitian Tanaman Industri 14(3): 87-94.

Sunarto, D.A., Nurindah, dan Sujak. 2011. Pengaruh perlakuan benih dengan insektisida imidakloprit terhadap pengendalian hama utama tanaman kapas varietas seri Kanesia. Agrovigor 4(2): 70-78.

Thomson, L.J. and A.A. Hoffmann. 2009. Vegetation increases the abundance of natural enemies in vineyards. Biological Control 49: 259-269.