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Integrated management of leaf miners *Liriomyza* spp. (Diptera: Agromyzidae) on shallot crops by trap cropping system and arbuscular mycorrhizae

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ABSTRACT

Integrated pest management (IPM) has been recognized as the best solution to minimize the adverse effects of insecticides applied to farmland. This study aims to evaluate the effectiveness of the trapping crop system (TCS) and arbuscular mycorrhizae (AM) against leaf miner, an important horticultural pest throughout the world including on shallot crops in Indonesia. In a factorial research design, cucumbers use in TCS was planted in three different pattern: one rows in the center; TC1, two rows in the middle; TC2, and one-row surroundings the shallot; TC3, while AM consists of two levels that are with (M1) and without AM (M2) application. The variables measured were: population and infestation of leaf miners as well as parasitism at the main and trap crops. The results showed that the leaf miners population was significantly reduced by TCS application but had no relation with AM. The leaf miners population decreased by about 40.1% at the TCS compared with the controls. However, the combination of TCS and AM reduced the leaf miner infestation by about 47.5% where TC3M1 showed the best treatment against leaf miners. Increasing of the parasitoids population and parasitism at the shallot and cucumbers as trap crops as well as the shallot resistance against leaf miner may explain the compatibility of TCS and MA to manage the pest. The study denoted the importance of IPM against shallot leaf miners to support sustainable farming system.

Keywords: Sustainable management, leaf miners, shallot, natural enemies

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INTRODUCTION

Efforts to reduce yield losses due to pests and plant diseases are increasingly triggering the use of chemical pesticides in agricultural land. It was predicted that on a global scale the production of pesticides will be 2.7 times higher in 2050 than in 2000 (Sexton *et al*., 2007). This also occurs in Indonesia where the registered brands of pesticides have been double increased from 1500 in 2006 to 3207 by 2016 (DG of PSP 2006, 2016). As a result, a high residue of pesticides on soil and crops has been recorded in Indonesia including chlorpyrifos residue in the shallot tubers at one of the shallot cultivation centers in Central Sulawesi Indonesia (Jamaluddin *et al*., 2015). Unfortunately, insecticides application has been increasing of the leaf miner resistance to insecticides (Ferguson, 2004; Silva *et al*., 2015) and decreasing of the natural enemies population and their role as biocontrol agents (Hidrayani *et al*., 2005; Hernandez *et al*., 2011). It is not surprising that an excessive use of pesticides significantly increases the economic and environmental costs (Pimentel and Burgess, 2014; FAO, 2017).

Therefore, more sustainable alternative controls are needed to mitigate the adverse effects of insecticides by combining several compatible control techniques in accordance with the concept of integrated pest management (IPM) (Barzman *et al*., 2015).

Application of trap-cropping system (TCS) has been successfully reported for controlling various types of pests (Shelton and Badenes-Perez, 2006; Cook *et al*., 2007; Cotes *et al*. 2018).

Our previous study denotes a high potential of several crops including cucumber (*Cucumis sativus* L.) as the trap crops to manage the leaf miner in shallot plantation (Shahabuddin *et al*., 2015). However, it needs to be studied further whether the design of TCS influencing their efficacy because the effectiveness of TCS is depended on several factors such as attractiveness and spatial pattern of trap crops as well as the pest characteristics (Shelton and Badenes-Perez, 2006). Therefore, the performance of TCS could be increased by manipulating both factors. Moreover, a supplemental management strategy may escalate the success of the TCS (Fenoglia *et al*.,2017).

The beneficial fungi such us arbuscular mycorrhiza (AM) has a high potential to be combined with TCS to combat the pest due to their capability of AM to induced the defense mechanism of the plant to herbivory (Vannete and Hunter, 2009; Sharma *et al*., 2017). Therefore, this study aiming at 1) analyzing the effects of TCS design and AM, individually or simultaneously against leaf miner on shallot crops, 2) comparing parasitoid diversity and parasitism in shallot and trap crop (cucumber) to evaluate the efficacy of TCS in supporting the diversity of useful insects.

MATERIALS AND METHODS

The experiment was carried out in the shallot planting area in the village of Guntarano, one of the shallow cultivation centers in Central Sulawesi, Indonesia. The research was conducted from March to August 2018 in a factorial design with two treatments. The first treatment was the design of trap crop (TC) at shallot plantation consisted of four levels, namely; without TC (T0), one row in the center (T1), two rows in the center (T2), and one-row surroundings the shallot/perimeter system (T3). The second factor was the application of mycorrhizae (M) consists of two levels, namely: without mycorrhizae application (M0) and mycorrhizae application (M1). The mycorrhizae (MycoVir; product by PT. Myco Agro Lestari) established in a zeolite with ca. 50 spores per five gram were applied in each shallot seed before planted. Each treatment combination was set up in triplicate.

The shallot was planted using standard cultivation methods at a 3 x 2 m^2 plot. The plots and treatments distances were 30 and 100 cm, respectively. The cucumbers were grown as trap crop two weeks before planting the shallot with a spacing 50 cm from the shallot. Variable observed were; 1) population and infestation level of leaf miners on shallot, 2) leaf miners population and parasitoid diversity the trap crop, and 3) parasitism at the shallot and trap crop.

Pest observations on shallot and trap crops were observed every week from two weeks after planting (WAP) until one week before harvest. Yellow sticky traps were used to monitor the leaf miner population as described by Shahabuddin *et al*. (2015). Every week one trap was installed in the center of the plot for one day. Imago of leaf miner was collecting manually using a plastic bag for identification purpose. Ten shallot and three cucumber crops were selected as the samples to calculate the number of mines to determine leaf miner infestation then ten of infested leaves was collected to rear the parasitoids and calculate the parasitism (Shahabuddin *et al*., 2015). All leaf miners and parasitoids collected were identified by using the available keys (Shiao, 2004; Reina and La Salle, 2003; Fisher *et al*., 2006).

An analysis of variance (ANOVA) followed by mean comparison based on Honestly Significant Difference (HSD) was calculated for testing the effect of the treatment on population and infestation level of leaf miners by using the statistical program Statistix 8.

RESULTS AND DISCUSSION

The results showed that the population of leaf miners (*Liriomyza* spp.), as indicated by the imago caught in the yellow trap, was significantly affected by the trap cropping system (TCS) and not by mycorrhizae application and it is combination with TCS. This effect was mainly recorded in the peak population of leaf miners that is at 3 WAP ($F3;21 = 4.32$; $P < 0.05$) and 4 WAP ($F3;21 = 5.06$; $P < 0.01$). A small number of this pest has been detected in yellow sticky traps since 2 WAP but it was peak population occurred in the 4 and 5 WAP. In general, it denoted the leaf miner population in the control treatment (without trap plants) was tended to be higher than in the TCS (T1, T2, and T3) but there was no significant effect of the TCS design on leaf miner population. The leaf miner population on shallot without trap crops was higher about 40.1 % than that of trap crop groups in both weeks of observation (Table 1).

Table 1. Effect of trap crop and mycorrhizae on the leafminer population on shallot crop

Time of Observation	Population of leaf miners (mean ± SE)*				
	Treatment	T0	T1	T2	T3
3 WAP	M0	20.67 ± 9.51	12.99 ± 4.72	9.23 ± 5.12	6.00 ± 2.48
	M1	26.72 ± 4.17	6.80± 1.08	8.68± 2.63	6.64 ± 2.53
	Mean	23.70 ± 6.84^{b}	9.90 ± 2.90^{ab}	8.96 ± 3.87^{ab}	6.32 ± 2.51^{a}
4 WAP	M0	117.76 ± 27.44	38.10 ± 9.92	88.19 ± 15.82	29.37 ± 9.44
	M1	103.12 ± 19.38	38.54 ± 4.25	55.67 ± 11.63	46.85 ± 10.43
	Mean	110.44± 23.41^{b}	38.32± 7.09^{a}	71.93± 13.73^{ab}	38.11± 9.94^{a}

WAP: weeks after planting. M: Mycorrhiza. T: Trap Crop
*Mean numbers with the same characters not significantly different (HSD test,α=0.05).

In contrast with the leaf miner population, the infestation level of *Liriomyza* spp. on shallots is significantly influenced by the application of trap crop ($F3;21 = 18.52$; $P < 0.01$), or mycorrhizae ($F1; 21 = 5.82$; P <0,05) independently and by the interaction between the both treatments, simultaneously ($F3; 21 = 4.40$; $p < 0.05$). The females of leaf miners attack the crop by ovipositing their eggs inside the leaf mesophyll of crops, in which the larvae hatch, feed and consuming the photosynthetic area of the leaf. This activity creates the punctures and tunnels on plant leaves (Fig. 1).

Figure 1. The punctures and tunnels create by leafminer activities on the leaves of shallot (a) and trap crop (b)

The significant effect of the treatment is mainly detected at 5 WAP and 6 WAP in which the peak of the leaf miners infestation occurs. Infestation level in the control treatment (P0M0) at both weeks was higher compared to the TCS and mycorrhizae. Combination treatment between TCA and MA was successful in reducing the leaf miner infestation about 47.5 % compared with the control group in both weeks of observation (Table 1).

The study demonstrates the successful application of TCS to suppress the leaf miners population and infestation. The results obtained was in accordance with the previous study notifies the efficacy of trap-cropping system against pests infestation (Cook *et al*., 2007; Cotes *et al*. 2018). The TCS could decreased insect herbivory directly by trap the pest and push away from the main crop or indirectly by attracting the natural enemies of the pest (Shelton and Badenes-Perez, 2006; Cook *et al*., 2007).

A sequential system implemented in which the trap crops planted two weeks before the shallot was also synchronized with phenology of both crops and leaf miners. It is known that the effectiveness of TCS was varied and strongly dependent on the characteristic of trap crops and targeted insect pest (Shelton and Badenes-Perez, 2006). Proportion, spatial arrangement, and attractiveness of trap crops are influencing the successful implementation of TCS (Shelton and Badenes- Perez; 2006). For example, Perez *et al*. (2005) noted that planting 10% of a field with the yellow rocket was sufficient to reduce *Plutella xylostella* population in cabbage but Hussain and Bilal (2007) found that increasing proportion of marigold as trap crop was more effective in reducing tomato fruit borer. This study did not detect a significant effect of the spatial arrangement of trap crops on leaf miner infestation indicating the high attractiveness of cucumber as trap crops, regardless of their spatial design.

Population and infestation of leaf miners on trap crops. Infestation of leaf miners at the trap crop was high. *Liriomyza* spp. began attacking the cucumbers since three weeks after planting (3 WAP) and it reached the peak population at the 4 and 5 WAP (Fig. 2).

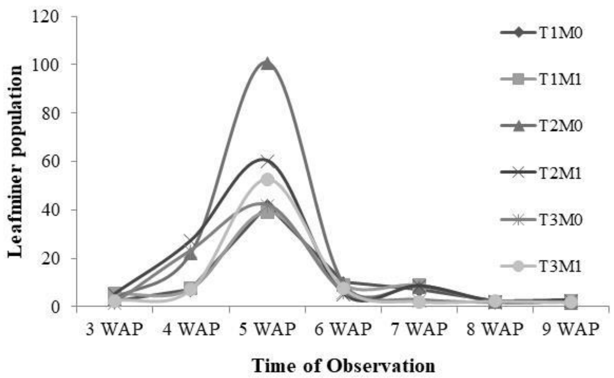

Figure 2. Population fluctuation of leaf miners at the trap crop; WAP-weeks after planting.

This occurred both in the treatment of trap crops combined with mycorrhizae and those not combined with mycorrhizae, indicating the high attractiveness of the cucumber as trap crops for leaf miners.

There are two possible mechanisms explaining the positive effects of the trap crop. First, trap crops act as the host of the leaf miners and therefore resulting in a bottom-up resource concentration. Second, trap crops also attract the parasitoids comes to the shallot crops and they induced the top-down regulation of crop pests by preserving biological control agents, accordingly. In this scheme, trap crop may support the natural enemy populations as an alternate host of pest (Ratnadss *et al*., 2012).

Two species of leaf miners namely *L. chinensis* and *L. sativae* were collected in this study. *L. sativae* occurred at the shallot and trap crops and was the most abundance species but *L. chinensis* is only found at shallot crops. On the contrary, of five parasitoids species recorded, four of them emerge from leaf miners that attack red shallot and cucumber (Table 3).

Table 3. Leafminers and its parasitoids recorded from infested leaves reared in the laboratory

Leafminers and Parasitoids	Number of insects (mean ± SE) on	
	Shallot (main crop)	Cucumber (trap crop)
Leafminers		
Liriomyza chinensis	15.00 ± 1.50	0 ± 0
Liriomyza sativae	35.67 ± 5.13	53.00 ± 14.90
Parasitoids		
Hemiptarsenus varicornis	6.00 ± 0.87	1.00 ± 0.30
Chrysocharis pentheus	2.00 ± 0.33	4.17 ± 1.24
Gronotoma micromorpha	3.00 ± 0.50	4.00 ± 0.70
Opius charomatomyiae	8.33 ± 2.08	1.00 ± 0.40
Dacnus ariolaris	0.67 ± 0.29	0 ± 0

These show that the presence of trap plants can attract the parasitoids to the shallot crop. All parasitoids observed was able to parasitize the leaf miners on shallot and trap craps except *D. ariolaris* that only infested the shallot (Fig.3).

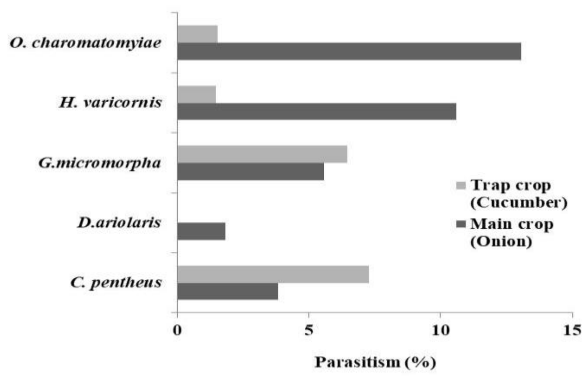

Figure 3. Parasitism of five parasitoids species observed from the infested foliage of shallot and cucumber

The results indicated that parasitoids might fly from the cucumber to search and parasitize the leaf miners at the shallot crops supporting the idea that cucumber as the trap crops has a high capacity to support parasitoid diversity and to encourage their role as biological control agents of the shallot pests.

Mycorrhizae arbuscular applied in this study has synergism effect with the TCS in suppressing leaf miner infestation (Table 2). It could be due to the ability of mycorrhizae to induce red shallot resistance against leaf miner attacks, directly or indirectly. In their research on the resistance of tomato plants against *Spodoptera exigua*, Shrivastava *et al*., (2015) found that tomato plants inoculated with MA produce more terpenoids that induce the defense mechanism compared to non-inoculated MA tomato plants. Feeding on inoculated MA tomato reduces the weight of *S. exigua* larvae.

Changes in the composition and concentration of terpenoids in plants colonized by MA can also invite the presence of natural enemies of pests that attack plants. Several studies report that association of mycorrhizae and plants could induce the plant defenses through the release of volatiles such as Jasmonic Acid. This chemical might increases the attractiveness of plants to parasitoids and predators which then parasitize or prey on pests (Leitner *et al*., 2010; Jung *et al*., 2012). Although some of the mechanisms that have been proposed can explain the role of MA in increasing plant resistance to herbivore insects, laboratory and field tests testing is still needed to find out which mechanism is most dominant in explaining the role of mycorrhizae in inducing red shallot resistance to leaf miner or other pests.

Mycorrhizae used in this study consists of three different genera that are Gigaspora, Glomus and Aucalospora and was applied in a similar dosage, thus it may explain the less efficacy of the mycorrhizae to induce the shallot resistance against leaf miner (see Table 2). It was known that different species of mycorrhizal showed the dissimilar effect on herbivorous insect (Bennett and Bever, 2007) and the Mycorrhizae efficacy depended on it is application dose (Al-Hmoud and Al-Momany, 2017; Muktiyanta *et al*., 2018) and plant traits or life history strategies of the targeted pest (Minton *et al*., 2016). Therefore, it is interesting to study whether differences in mycorrhizal species and application dosages will affect differently the shallot resistance to pests.

Table 2. Effect of trap crop and mycorrhizae on the leafminers infestation on shallot crop

Time of Observation*	Treatment	Number of mines (mean ± SE)*			
		T0	T1	T2	T3
5 WAP	M0	$_{q}10.34 \pm 0.83^{b}$	$_{p}8.47 \pm 0.72^{b}$	$_{p}4.37 \pm 0.43^{a}$	$_{p}4.20 \pm 0.24^{a}$
	M1	$_{p}5.87 \pm 0.89^{a}$	$_{p}7.96 \pm 1.23^{b}$	$_{p}4.22 \pm 0.14^{a}$	$_{p}4.30 \pm 0.14^{a}$
6 WAP	M0	$_{q}10.84 \pm 0.71^{c}$	$_{q}6.08 \pm 0.70^{b}$	$_{p}2.49 \pm 0.11^{a}$	$_{p}3.77 \pm 0.55^{a}$
	M1	$_{p}9.99 \pm 0.50^{b}$	$_{p}2.73 \pm 0.75^{a}$	$_{p}2.50 \pm 0.40^{a}$	$_{p}3.52 \pm 0.63^{a}$

WAP- weeks after planting; M- Mycorrhiza, T- Trap Crop
*Mean numbers with the same characters at the same line (a, b, ab) or the same column (p, q) not significantly different (HSD test,α=0.05)

The compatibility of TCS and MA in regulating leaf miners in shallot suggesting the significance of integrating method by considering the top down (host plant) and bottom-up (natural enemies) mechanism in managing the herbivores insect (see Wratten, 1992; Hassel *et al*., 1998). In general, the successful of trap crops and mycorrhiza in suppressing leaf miners attacks found in this study is in line with the principles of sustainable agriculture system that emphasizes the management of agroecosystems and optimization the ecosystem services of a useful organism to manage the pest and diseases (Sullivan, 2003; Altieri and Nichols 2004).

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REFERENCE

Al-Hmoud, G. and Al-Momany, A. 2017. Effect of four mycorrhizal products on squash plant growth and its effect on physiological plant elements. *Advances in Crop Science and Technology*,**5**: 260. doi: 10.4172/2329-8863.1000260.

Altieri, M. E. and Nicholls, C. I. 2004. Biodiversity and Pest Management in Agroecosystem. Food Products Press, Birmingham, NY, 236 P.

Barzman, M., Bàrberi, P., Birch, A.N.E. *et al*. 2015. Eight principles of integrated pest management. *Agronomy for Sustainable Development*, **35**: 1199. https://doi.org/10.1007/s13593-015-0327-9

Bennett, A. E. and Bever, J. D. 2007. Mycorrhizal species differentially alter plant growth and response to herbivory. *Ecology*, **88**:210–8.

Cotes, B., Rämerta, B. and Nilsson, U. 2018. A first approach to pest management strategies using trap crops in organic carrot fields. *Crop Protection*, **112**: 141–148.

Cook, S.M., Khan, Z.R. and Pickett, J.A. 2007. The use of push-pull strategies in integrated pest management. *Annual Review of Entomology*, **52**: 375–400.

Directorate of Fertilizers and Pesticides Directorate General of Agricultural Facilities and Infrastructure Ministry of Agriculture of the Republic of Indonesia (DG of PSP). 2006. Pesticides For Agriculture and Forestry in 2006 [In Indonesia].

Directorate of Fertilizers and Pesticides Directorate General of Agricultural Facilities and Infrastructure Ministry of Agriculture of the Republic of Indonesia (DG of PSP). 2016. Pesticides For Agriculture and Forestry in 2016.[In Indonesia].

Fenoglio, M.S., Videla, M. and Morales, J.M. 2017. Evaluating trap cropping strategies for insect pest control through simulation models. *Journal of Pest Science*, **90** (2): 601-610.

Ferguson, J. S. 2004. Development and stability of insecticide resistance in the leafminer *Liriomyza trifolii* (Diptera: Agromyzidae) to cyromazine, abamectin, and spinosad. *Journal of Economic Entomology*, **97** (1): 112–119.

Fisher, N., Ubaidillah, R., Reina, P. and La Salle J. 2006. Liriomyza Parasitoids of South East Asia. Australia.

Food and Agriculture Organization (FAO). 2017. The future of food and agriculture – trends and challenges. Rome, 128 P.

Hernandez, R., M. Harris and T-X Liu, 2011. Impact of insecticides on parasitoids of the leafminer *Liriomyza trifolii* in pepper in south Texas. *Journal of Insect Science*, **11**: 61.

Hussain, B. and Bilal, S. 2007. Marigold as a trap crop against tomato fruit borer (Lepidoptera: Noctuidae). *International Journal of Agricultural Research*, **2**(2): 185-188.

Hidrayani, Purnomo, A. Rauf, Ridland, P. and Hoffmann, A. 2005. Pesticide applications on Java potato fields are ineffective in controlling leafminers and have antagonistic effects on natural enemies of leafminers. *International Journal of Pest Management*, **51**:181-187.

Jamaluddin, Arief, K., Ibrahim, N. and Yuyun, Y. 2015. Analysis of pesticide residue chlorpyrifos content in "Onion Palu" (*Allium ascalonicum* L.) using gas chromatography. *International Journal of PharmTech Research*, **8**(3): 398-401.

Jung, S.C., Medina, A.M., Raez, J.A.L. and Pozo, M.J. 2012. Mycorrhiza-induced resistance and priming of plant defenses. *Journal of Chemical Ecology*, **38**:651–664.

Leitner, M., Kaiser, R., Hause, B., Boland, W. and Mithöfer, A. 2010. Does mycorrhization influence herbivore-induced volatile emission in *Medicago truncatula*? *Mycorrhiza*, **20**:89–101.

Minton, M. M., Barber, N. A. and Gordon, L. L. 2016. Effects of arbuscular mycorrhizal fungi on herbivory defense in two Solanum (Solanaceae) species. *Plant Ecology and Evolution*, **149**(2): 157–164, 2016.

Muktiyanta, M.N.A., Samanhudi, Yunus, A., Pujiasmanto, B. and Minardi, S. 2018. Effectiveness of cow manure and mycorrhiza on the growth of soybean. *IOP Conf. Series: Earth and Environmental Science*, **142** (012065).

Pimentel, D. and Burgess, M. 2014. Environmental and Economic Costs of the Application of Pesticides Primarily in the United States. *In: Integrated Pest Management*, (D. Pimentel and R. Peshin. eds.), 47-56 **PP.** DOI 10.1007/978-94-007-7796-5_2, Springer Science Business Media Dordrecht.

Ratnadass, A., Fernandes, P., Avelino, J.andHabi, R. 2012. Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: a review. *Agronomy Sustainable Development*, **32**:273–303.

Reina, P and La Salle J. 2003. Key to the word genera of eulophidae parasitoid (Hymenoptera) of leafmining Agromyzidae (Diptera). http://www.ento.csiro.au/science/eulophids.html.

Sexton, S. E., Lei, Z. and Zilberman, D. 2007. The Economics of Pesticides and Pest Control. *International Review of Environmental and Resource Economics*, **1**: 271–326.

Shahabuddin, Yunus, M., Hasriyanty and Tambing, Y. 2015. The role of trap crops for conserving of natural enemies of leaf miner on onion in Central Sulawesi, Indonesia. *Scholars Journal of Agriculture and Veterinary Sciences*, **2**(5):366-370.

Sharma, E., Anand, G. and Kapoor, R. 2017. Terpenoids in plant and arbuscular mycorrhiza-reinforced defence against herbivorous insects. *Annals of Botany*, **119**: 791–801.

Shelton, A.M., and Badenes-Perez, F.R.. 2006. Concepts and applications of trap Cropping in pest management. *Annual Review of Entomology*, **51**:285–308.

Shiao, S. F. 2004. Morphological diagnosis of six Liriomyza species (Diptera: Agromycidae) of quarantine importance in Taiwan. *Applied. Entomology and Zoology*, **39** (1): 27-39.

Shrivastava, G., Ownley, B. H., Augé, R. M., Toler, H., Dee, M., Vu, A., Köllner, T. G. and Chen. F. 2015. Colonization by arbuscular mycorrhizal and endophytic fungi enhanced terpene production in tomato plants and their defense against a herbivorous insect. *Symbiosis*, **65** (2): 65-74.

Silva, W. M., Berger, M., Bass, C., Balbino, V. Q., Amaral, M. H. P., Campos, M. R. and Sique, H. A. A. 2015. Status of pyrethroid resistance and mechanisms in Brazilian populations of *Tuta absoluta*. *Pesticide Biochemistry and Physiology*,**122**:8-14.

Sullivan, P. 2003. Applying the principles of sustainable farming. http://www.attra.ncat.org/attra-pub/PDF/Transition.pdf.

Vannette, R.L. and Hunter, M.D. 2009. Mycorrhizal fungi as mediators of defence against insect pests in agricultural systems. *Agricultural and Forest Entomology*, **11**: 351–358.

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