Compatibility of trap cropping system and insecticides in managing leafminers *Liriomyza* spp. (Diptera: Agromyzidae) on shallot crop

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Abstract. Trap cropping system has been widely used as a management strategy against various types of pests. However, the efficacy of this strategy varies and need to be increased by combining it with another additional control strategy. This study aimed to evaluate the efficacy of trap cropping system and insecticides against leafminers, an important pest of crops in the world including in shallot crop in Indonesia. The study was arranged in a randomized complete block design with 6 treatments, which were 1) without any treatments (control), 2) trap crops, 3) botanical insecticide (Agonal), 4) synthetic insecticide (Abamectin) 5) trap crops and Agonal, 6) trap crops and abamectin. The results showed that the trap cropping system has a stronger effect on reducing infestation than the population of leafminers. Trap crops reduced leafminer infestation by around 50% when combined with insecticides but only reduced by 32% without insecticides. Agonal and abamectin insecticides had similar efficacy against leafminers. Trap crop application combined with insecticides had the highest parasitoid population compared with insecticides and control. This study revealed that trap crops were compatible with insecticides in controlling shallot leafminers and supports the integrated pest management of leafminers.

1. Introduction
Shallot (*Allium ascalonicum* L) is an important horticulture commodity in Indonesia and throughout the world. Indonesia, particularly Central Sulawesi has a local variety of shallot called "Palu Shallot" which contributes significantly to increase farmers incomes in this area [1]. However, the sustainability of this local variety is threatened by leafminer, a new exotic pest of shallot and other horticulture crops in Central Sulawesi [2, 3].

At present, the shallot farmers are highly dependent on synthetic insecticides to control leafminers and another pest. This is indicated by a high residue of chlorpyrifos on the tuber of Palu Shallot at one of the shallots cultivation area [4]. However, this approach was less effective in managing leafminers due to the increase of resistance of this pest to some group of chemical insecticides and it is a hazardous effect on natural enemies [5-7]. Therefore, some sustainable control method has been developed to combat the pest such us trap crop, botanical and biological insecticides.

Trap-cropping system has generally used 1 or more pest-attractive trap-crop species and 1 less-pest-attractive target crop species to be protected [8]. This pest management strategy has been successfully reported for controlling various types of pests and diseases of plants [8-10]. This control
method could promotes pest suppression directly by trap the pest and push away from the main crop or indirectly by enhancing natural enemies of the pest [8,11]. For example, intercropping of pepper and sugarcane has been reported could suppress infestation of leafminer (Liriomyza huidobrensis) in pepper [12] because it can enhance the role of parasitoids of these pests. A similar advantages effect of trap crop on shallot plantation was also reported in our previous study [3]. Another eco-friendly control technique is by using biorational insecticide including botanical pesticides that have a minimum impact on natural enemies and supporting the implementation of integrated pest management [13, 14].

In this study, we integrate trap crop and insecticides to evaluate its efficacy in controlling leafminer on shallot population. Previous study showed that cucumber (Cucumis sativus) and string bean (Vigna chinensis) has high potential as trap crops for leafminers [3] while AGONAL as acronym of botanical insecticide extracted from 3 plant species (Andropogon nardus, Alpinia galanga, and Tithonia diversifolia) performed effectiveness on reducing leafminer population [15, 16].

2. Methods
The research was conducted in 2017 at the farmer's shallot field in Petobo village, South Palu Sub District, Central Sulawesi. The field experiment was arranged according to a randomized block design with 6 treatments, which were; 1) without any treatments (control), 2) trap crops (tc), 3) botanical insecticide (Agonal), 4) chemical insecticide (Abamectin) 5) trap crops and Agonal, 6) trap crops and abamectin. Two trap crops (cucumber and string bean) were grown at 2 wk before planting shallots.

The plot size for each treatment was 3 x 1.5 m$^2$ with 3 replications. Shallot seeds were planted with a spacing of 15 x 20 cm$^2$ and 30 cm spacing between plots. The trap crops were grown as a border surrounding the shallot crops following perimeter and sequential trap cropping method [8]. Variable observed were population and infestation level of leafminers, diversity of leafminers, as well as parasitoids diversity and their parasitism level.

Botanical insecticide (Agonal) is a crude extract of A. nardus, A. galanga, and T. diversifolia with 3:3:4 in part as described in Roziyanto et al. [16] that prepared at the laboratory of plant pests and diseases, Faculty of Agriculture, University of Tadulako. The agonal extract with 0.5 % concentration was used. We also use a synthetic insecticide, Demolish 18EC (abamectin) and applied at recommended concentrations (0.5 ml/L) for comparing the effectiveness of both insecticides. Applications of insecticides were done 5 times during the experiment with a 1-week interval between applications by using a knapsack sprayer.

A yellow sticky trap was used to count the leafminer population as described in Shahabuddin et al. [3]. One trap was placed every week for 1 day in the center of the plot with a height of about 10 cm above the shallot crops from 2 wk after shallot planting (WAP) to 6 WAP. Imago of leafminer was also collecting manually using a plastic bag for identification purpose. Pest infestation level was determined based on the number of mines at shallot leaves as described in Shahabuddin et al. [2].

The presence of parasitoids was determined by collecting 10 infested leaves from each plant sample. The infested leaves from the field were brought to the laboratory and placed in plastic containers for rearing the leafminers and its parasitoids [3]. All caught parasitoids and flies were counted and preserve into vials with 70% ethyl alcohol for further identification. The identification was conducted in Plant Pest and Diseases Laboratory, University of Tadulako by using available keys [17]. Data analyzed was performed by using a statistical program, i.e. Statsoft 7 for analysis of variance (ANOVA).

3. Results and discussion
Application of trap crop or insecticides has no differences with control plot on flies population but the combination of trap crops with agonal or abamectin reducing leafminers population significantly (Fig. 1).
The efficacy of trap crops and insecticides on leafminer infestation and its parasitism level were clearly recorded (Fig. 2). Overall, flies infestation on control plot was higher compared to all other treatment but significant differences only detected at trap crops combined with insecticides. Leafminer infestation was reduced by more than 50% when the trap crop combined with insecticides but only reduced 32% without insecticides. On the other way parasitism level on control plot was the lowest among all treatment while double treatment with trap crops and insecticides was significantly increasing the parasitism activity compared all other treatment. Interestingly, agonal tended to be more effective in decreasing of leafminer infestation and increasing parasitism than the abamectin.

During the study period, we recorded 3 species of leafminers (Liriomyza chinensis, L. sativae, and L. huidobrensis) and 4 species of parasitoids that is Hemiptarsenus varicornis, Gronotoma micromorpha, Chrysocharis pentheus and Opius sp. The most dominant leafminers were L. chinensis and L. sativae while parasitoids dominated by H. varicornis, G. micromorpha, and Opius sp.
Hemiptarsenus varicornis was collected from the shallot and both trap crops, while the rest only recorded from 1 or 2 trap crops. Interestingly, application of trap crop or its combination with insecticides had the highest parasitoid population compared with insecticides or control (Table 1).

| Treatments       | Species and number of parasitoids | Total |
|------------------|-----------------------------------|-------|
|                  | C. penteus (Eulophidae) | G. micromorpha (Figitidae) | H. varicornis (Eulophidae) | Opius sp. (Braconidae) |       |
| Control          | 3                                | 3       | 7                        | 0                   | 13    |
| Abm              | 0                                | 2       | 5                        | 0                   | 7     |
| Agn              | 1                                | 4       | 7                        | 0                   | 12    |
| T. crop          | 12                               | 14      | 24                       | 9                   | 59    |
| T. crop + Abm    | 0                                | 13      | 11                       | 0                   | 24    |
| T. crop + Agn    | 5                                | 15      | 19                       | 0                   | 39    |
| Total            | 21                               | 51      | 73                       | 9                   | 154   |

The study revealed that integrating trap crop with insecticides (Agonal or abamectin) was better in managing the leafminers than the single treatment (trap crop, agonal, abamectin) and it could be considered as a part of integrated pest management (IPM) of this shallot pest. This study and our previous study [3] showed that planting cucumber and string bean as trap crop has a capability in reducing leafminer infestation on shallot crop. It is likely that this cropping system attracting more leafminers and their parasitoids on shallot crops (Table 1). The fact that 3 leafminers and 4 parasitoids species that found during study periods indicate that the trap crop used in this study could attract and become a reservoir of leafminer's parasitoids. Increasing of parasitoid population and communities due to the existence of trap crop resulting in a higher parasitism level at the trap crop treatment or its combined with insecticides than without trap crop (Fig. 2). H. varicornis was the dominant parasitoids collected indicating their high potential as natural enemies of leafminer, that also found in our previous study [3]. In Lesser Sunda Islands of Indonesia, H. varicornis was the second most abundance of leafminer's parasitoids after Neochrysocharis formosa [18].

Planting more than 1 species of trap crops as shown in this study seems likely to increase the effectiveness of trap cropping system in the pest management program. A trap crop composed of sorghum and sunflower is highly attractive to Halyomorpha halys and native stink bug species and has a potential for reducing the pest density and injury in a pepper cash crop [18]. The effectiveness of multi-species trap-crop plantings at protecting broccoli (Brassica oleracea var. Italica) crops from the crucifer flea beetle, Phyllotreta cruciferae was also reported [19]. Of several mechanisms reviewed by Ratnadss et al. [20] explaining the reduced impact of pests and diseases by increasing plant species diversity (PSD) in agroecosystems, there are at least 2 mechanisms that are likely related to this study. Firstly, trap crop as a PSD scheme resulting in a bottom-up resource concentration/dilution effects in which that cues from the resource (crop plant) are no longer diluted by cues from other plant species (i.e. trap crop) so the pest populations are not concentrated at crop plant. Secondly, PSD induced top-down regulation of crop pests by conservation biological control. In this scheme, trap crop may support the natural enemy populations as an alternate host of pest parasitoids or predators.

Meanwhile, the efficacy of agonal extract against Liriomyza sp. has been documented [15, 16]. The agonal extract contains some bioactive compounds that are toxic to insects. Lemon grass (A. nardus)
plants contain seronelal and geraniol which has repellent and antifeedant effects. It is single or combination extract with other plant are known to have insecticidal properties against potato leafminers [15] and cabbage worms [21]. Galangal rhizome extract (A. galanga) shows toxicity effect on fruit fly [22] termite [23] while tree marigold (T. diversifolia) extract contains alkaloids, flavonoids, and saponins and shows larvacidal activity against Chrysomya bezziana [24]. The combined extracts of these 3 plants species were effective to control the important pest on potato [15]. Interestingly, this study detected a similar effect of agonal and abamectin on leafminers population and infestation. Abamectin also known as Avermectin including biorational insecticide group macrocyclic lactones isolated from soil microbes Streptomyces avermitilis. Abamectin compounds have insecticidal, acaricidal, and antihelmintics activities [13]. Therefore as expected, integrating of trap crops and insecticides will be more successful in controlling leafminers.

The importance and effectiveness of an integrated approach in pest management were already documented by some study. Integrating sex pheromone-baited water traps with alternative weekly applications using insecticides from a different mode of action groups offers [25] or by combining the microbial and botanical insecticides [26], were effective to manage the tomato leafminer T. absoluta. In addition, Javed et al. [27] reported that application of Trichogramma chilonis singly was the least effective than the incorporation of T. chilonis with other practices in managing Leucinodes orbonalis Guenee, a destructive pest of eggplant (Solanum melongena L.). Recently, Fenoglia et al. [29] demonstrating the effectiveness of trap cropping system against leafminer pest, L. huidobrensis when combining with insecticides.

Attempt to minimize the loss of yield due to pest infestation needs an integrative method as a key concept of IPM. This is including the designing of good cropping systems to improve it is resilience against the pest, combining of non-chemical methods that may be individually less effective than pesticides, and reducing pesticide use by combining it with other tactics [30]. This study showed that trap crops have a similar effect with insecticides to control leafminers but efforts to suppress leafminer infestation was more effective by combining both control technique. Anyhow, the effectiveness of the trap crops against pests may be increase by managing the spatial distribution of trap crops [31, 32]. Therefore, the further study is needed to test whether the spatial arrangement of trap crops will affect the effectiveness of trap crop in managing leafminers.

4. Conclusion

Trap cropping system combined with insecticides effectively managed shallot leafminers. Planting string bean and cucumber as a trap crops surround the shallot increasing the parasitoids population and supporting a top-down regulation of the leafminers. Agonal and abamectin insecticides have a similar synergist effect in increasing effectiveness of trap crop in pest management.

References

[1] Rauf R A, Darman S and Andriana A 2015 Agrikonomika 4(2) 245-257
[2] Shahabuddin, Pasaru F, Hasriyanty 2013 JHPT Tropika 13(2) 133-140
[3] Shahabuddin, Yunus M, Hasriyanty and Tambing Y 2015 Sch. J. Agric. Vet. Sci. 2(5) 366-370
[4] Jamaluddin K A, Ibrahim N and Yuyun Y 2015 Int. J. PharmTech Res. 8(3) 398-401
[5] Hernandez R, Harris M and Liu T X 2011 J. Insect. Sci. 11(61) 1-14
[6] Wei Qing-Bo, Lei Zhong-Ren, Nauen R, Cai Du-Cheng and Gao Yu-Lin 2013 Insect Science 22(2) 243-250
[7] Silva W M, Berger M, Bass C, Balbino V Q, Amaral M H P, Campos M R and Siqueira H A A 2015 Pestic Biochem Physiol 122 8-14
[8] Shelton A M, Badenes-Perez F R 2006 Annu. Rev. Entomol. 51 285-308
[9] Hokkanen H M T 1991 Annu. Rev. Entomol. 36 119-138
[10] Parker J E, Crowder D W, Eigenbrode S D and Snyder W E Agriculture, Ecosystems and Environment 232 254-262
[11] Cook S M, Khan Z R and Pickett J A 2007 Annu. Rev. Entomol. 52 375-400
[12] Chen B, Wang J, Zhang L, Li Z and Xiao G 2011 *Crop Prot* 30 253-258
[13] Horowitz A R and Ishaaya I 2004 Biorational Insecticides – Mechanisms, Selectivity and Importance in Pest Management Programs *Insect Pest Management Field and Protected Crops* ed Horowitz A R and Ishaaya I (Berlin, Heidelberg, Newyork: Springer) pp1-28
[14] Sarwar M 2015 *International Journal of Chemical and Biomolecular Science* 1(3) 123-128
[15] Suryaningsih E 2008 *J. Hort.* 18(4) 435-445
[16] Roziyanto C, Shahabuddin and Nasir B 2013 *Agrotekbis* 1(2) 121-126
[17] Fisher N, Ubaidillah R, Reina P and Salle J La 2006 *Liriomyza Parasitoids of South East Asia* (Australia: CSIRO) https://keys.lucidcentral.org/keys/v3/Liriomyza/
[18] Wahyuni S, Supartha I W, Ubaidillah R and Wijaya I N 2017 *Biodiversitas* 18(2) 593-600
[19] Mathew C R, Blauw B, Dively G, Kotcon J, Moore J, Ogburn E, Pleiffer D G, Trope T, Walgenbach J F, Welty C, Zinati G and Nielsen A L 2017 *J. Pest. Sci.* 90(4) 1245-1255
[20] Ratnadass et al. 2012. Ratnadass A, Fernandes P, Avelino J and Habib R 2012 Agron. Sustain. Dev. 32(1) 273-303
[21] Shahabuddin and Anshary A 2010 *J. Agroland* 17(3) 178-183
[22] Sukhirun N, Pluempanupat W, Bullangpoti V and Koul O *J. Econ. Entomol.* 104(5) 1534-40
[23] Abdullah F, Subramanian P, Ibrahim H, Abdul Malek S N, Lee G S and Hong S L J. Insect Sci. 15(7) 1-7
[24] Wardhana A H and Diana N 2014 *IIAVS* 19(1) 43-51
[25] Taha A M, Afsah and Fargalla F H 2013 *Nature and Science* 11(7) 27-29
[26] El-Ghani N M A, Abdel-Razek A S, Ebadah I M A and Mahmoud Y A 2016 *Journal Of Plant Protection Research* 56(4) 372-379
[27] Anshary A, Basir-Cyio M, Hasanah U, Mahfudz, Saleh S, Edy E and Pasaru F 2017 *Asian J. Crop Sci.* 9: 125-132
[28] Javed H, Mukhtar T, Javed K and Ata-ul-Mohsin 2017 *Pak. J. Agri. Sci.* 54(1) 65-70
[29] Fenoglio M S, Videla M and Morales J M 2017*J. Pest Sci.* 90(2) 601-610
[30] Barzman M, Bärberi P, Birch A N E, Boonekamp P, Dachbrodt-Saaydeh S, Graf B, Hommel B, Jensen J E, Kiss J, Kudsk P, Lamichhane J R, Messéan A, Moonen A-C, Ratnadass A, Ricci P, Sarah J-E and Sattin M 2015 *Agronomy for Sustainable Development* 35 1199-1215
[31] Hussain B and Bilal S 2007 *International Journal of Agricultural Research* 2(2) 185-188
[32] Holden M H, Ellner S P, Lee D-H, Nyrop J P and Sanderson J P 2012 *J. Appl. Ecol.* 49 715-722