

RESEARCH PAPER

Abundance of arthropod in the various intensity of pesticides applied on shallots crop Local Palu

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ABSTRACT

Abundance of arthropod in the various intensity of pesticide applied on shallots crop local Palu. Excessive use of pesticides confers several ecological and environmental consequences. In this research, we evaluated arthropod occurrence on shallot crops in Palu Valley, Central Sulawesi as an impact of pesticide application in different frequencies. Almost all farmers used synthetic pesticides for controlling pests and diseases where 46.7%, 43.3%, 10.0% of them applied in high, moderate, and low frequency, respectively. By comparing to the last application, the first reduced arthropod diversity index, evenness index, and abundance by 13.8%, 6.7%, and 70.6%, while the second by 7.3%, 2.3%, and 33.5%, respectively. Analysis of the dynamic abundance of pests and natural enemies in seven weeks observation indicated that the pests abundance at low and moderate levels was no different. Whereas predator abundance at low frequency was significantly different with moderate and high rate and between the last two not distinct and the presence of parasitoids was not observed at all, it means the natural enemies were susceptible to pesticides. These data showed the negative impact of pesticides application to arthropods including pests resistance and natural enemies lost; therefore it is necessary to minimize the use of pesticides and integrated pests.

Key words: natural enemy, pest, resistance, susceptible, synthetic pesticide

INTRODUCTION

Shallot is one of the important commercial vegetable crops grown in Palu Valley, Central Sulawesi, Indonesia. Due to its specificity compared to other varieties, the shallot derived from this region is called as Palu local variety and grouped in *Allium cepa* var *aggregatum* and used in general as raw material for the fried shallot. Its average crop yield that is still low and accompanied by high demand has compelled the farmers for planting this commodity continuously in the field (Maskar et al., 1999; Shahabuddin et al., 2012). This situation offer consequences on the high infestation of pests such as mole cricket (*Gryllotalpa* spp.), armyworm (*Spodoptera litura*), leafminer (*Liriomyza chinensis*), trips (*Thrips tabaci*) and disease like basal bulb rot (*Fusarium oxysporum*), purple blotch (*Alter-*

naria porri), downey mildew (*Peronospora destructor*), anthracnose (*Colletotrichum gloeosporioides*) and leaf spot (*Cercospora duddiae*) (Semangun, 1989; Rivai, 1995; Shahabuddin et al., 2012).

Economic implications of the shallot damage and shallot loss due to pests and diseases encourage the farmers to resort to frequent pesticide applications. The pesticide is considered responsible for the improvement of crop yield and the total concentration used can reach 150 higher than the recommended rates with some time mixing two or three pesticides (Basuki, 2011; Waryanto et al., 2014). Study on pesticide residues found in the soil of shallot crops in Brebes, Central Java show that organophosphate residues consisting of methidathion, malathion, and chlorpyrifos reach around 0.014 mg/kg crops, 0.1370–0.3630 mg/kg, 0.0110–0.0630 mg/kg, respectively, meanwhile in Alahan Panjang, West Sumatra, organophosphates residues in the range of 0.067–2.006 mg/kg (Reflinaldon, 2009; Joko et al., 2017). This superfluous pesticide usage has potential for soil quality and a negative impact on arthropods such as pest predators and parasitoids.

Arthropods represent as much as 85% of the soil fauna in richness comprising a large proportion of the mesofauna (80 µm–2 mm in size, e.g., Collembola, Acari) and macrofauna (50 mm in size, e.g., earth-

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worms, termites). Their presence can improve soil porosity providing adequate aeration and water-holding capacity below ground, facilitating root penetration, and preventing surface crusting and erosion of topsoil. As well, their movement from lower horizons to the surface aid in mixing the organic and mineral fractions of the soil and with their feces permit the formation of soil aggregates and humus, which physically stabilize the soil and increase its capacity to store nutrients (Culliney, 2013; Bagyaraj et al., 2016). Also, arthropods function as litter transformers or ecosystem engineers. As litter transformers, a large part or fragments of plant debris comminute, ingested, and humidified by arthropods become a suitable substrate for microbial decomposition and fostering the growth and dispersal of microbial populations. While as ecosystem engineers, they modify the habitat physically, directly or indirectly regulating the availability of resources to other species (Jones et al., 1994; Lavelle et al., 1995). Therefore, the disturbance to their presence, diversity, and abundance would affect the ecosystems including soil fertility, microorganisms population, and pest and pathogen population.

Based on the risk of pesticides application on shallot crops in Palu Valley, we evaluated pesticide usage by farmers through survey and then determined arthropods diversity, richness, and abundance as the impact of pesticide. This evaluation and determination comprised frequency rate of pesticide application, types of pesticides, insect pests, predators and parasitoids, and the probability of pest-resistant occurrence. Data obtained from this research would be useful for designing integrated pest management (IPM) on shallot.

MATERIALS AND METHODS

Research Site. Observation and interviews in Olubuju Village, Sigi Biromaru Sub-district, Sigi Regency known as Palu Valley were done to obtain quantitative and qualitative data concerning practices of shallot cultivation. According to data of local agricultural service, there were around 300 farmer families in this village, and 10% or 30 farmers were taken as samples for the interview concerning acreage of shallot field owned by farmers, the frequency rate of pesticides application per season at around 60 days, and types of pesticides. From the interview it was known that three farmers just applied herbicide and natural pesticide, 13 farmers used pesticides less than 10 times, and 14 farmers applied more than 10 times per season. These pesticides application on shallot crops was for the low

application pesticide only one pesticide for time per season. Moderate of application pesticide less than or equal ten of time per season and high of application pesticide more than or equal ten of time per season.

Assessment of Arthropods Diversity, Abundance, and Richness. In each category of pesticide application (low, moderate, and high), one sample plot of 5 × 5 m was established for arthropods observation both in soil and in around of shallot crop. Five pitfall traps per plot were arranged diagonally to observe soil arthropods, one in the middle and four in 50 cm from each corner. These pitfalls consisted of plastic cup measuring 8.5 cm in diameter and 13 cm in height and containing water mixed with a little detergent (5 g/200 mL⁻¹) were immersed into the soil until their aperture flattened to the ground surface and installed at around 08:00 am. After 24 hours, arthropods trapped in water were filtered and then transferred into a vial (5.5 cm in diameter and 9 cm in height) containing alcohol 70% for further identification in the laboratory. The observation was carried out seven days after planting and repeated every week until one week before harvesting. The arthropods around the shallot crop were caught using five double swing sweep net. The area used sweep net sampling were 5 × 5 m and the diameter of the sweep net was 32.5 cm. Sampling was carried out at the same time with the trap of soil arthropods.

Collected arthropods were identified using the appropriate guidebook of Johnson & Triplehorn (2005) and differentiated their character as a pest, parasitoid, and predator. Diversity index, evenness index, Order richness, and Family richness meanwhile, were also determined from the total of arthropods collected in one season. The dynamic abundance of pests and natural enemies was calculated every week in one season of shallot crop. The diversity index of arthropods was analyzed by using the Shannon-Wiener index, the evenness of arthropod morphospecies by Simpson's evenness index, and richness by the total number of taxonomic units collected in the sample (Krebs, 2000). The formula for calculation of diversity and evenness is described below:

a. Diversity index (H') Shannon-Wiener

$$H' = -\sum_{k=1}^n p_i (\ln p_i)$$

$$p_i = \frac{n}{N}$$

H' = Diversity index;

- p_i = Species proportion in the i^{th} species;
- n = Individual abundance of morphospecies;
- N = Total number of individuals.

b. Evenness index of morfospecies

Evenness index of morfospecies according to Piellou (Ludwig and Reynold, 1988) with formula:

$$e' = \frac{H'}{\ln S}$$

- e' = Evenness index;
- H' = Diversity index;
- S = Whole species;
- \ln = Natural logarithm.

Data Analysis. The data of diversity, evenness, and richness were analyzed after transformation to \sqrt{x} . The same was done to data of pest and predator abundance per week. Evaluation significant differences between the treatment mean used t-test.

RESULTS AND DISCUSSION

Pesticide Usage by Farmers. Oloboju is one of the great villages cultivating shallot in Sigi Regency known as Palu Valley. Around 286 ha of the field was managed by 300 farmers. Shallot was grown continu-

ously, an average of four planting seasons in a year. In controlling of pests and diseases indicated that 46.7% of farmers used synthetic pesticides with more than ten applications per one planting season, 43.3% of farmers used less than ten applications, and just 10.0% did not use any synthetic pesticide, it was categorized as high, moderate, and low utilization, respectively. The last farmers applied natural pesticides of neem origin for controlling pests and disease and herbicides for controlling weeds. Pesticides usage including fungicides and insecticides can be seen in Table 1. Fungicides used were in general classified as unlikely to present acute hazard in regular use, while insecticides used were in general classified as moderately hazardous (II), but one as highly hazardous (Ib). These all pesticides were used to control main shallot pests and diseases.

Impact of Pesticides on Arthropod. Pesticides usage by farmers offered an impact on the soil arthropods abundance. Total arthropods collected on seven weeks of observation in one season with a low, moderate, and high application of pesticides were 194, 129, and 57 arthropods per five pitfall traps and ten consecutive swings of sweep net in 5 × 5 m area, respectively (Table 2). Comparing by pesticide application in low frequency, a decrease of arthropod abundance by high and moderate pesticide application was 70.6% and 33.5%,

Table 1. Pesticides used by farmers on shallot crops in Oluboju Village, Sigi Regency and their classification according to WHO

Type of Pesticide	Active Ingredients	Group	Class
Fungicide	Ziram	Dithiocarbamate	III
Fungicide	Mancozeb	Dithiocarbamate	U
Fungicide	Propineb	Dithiocarbamate	U
Fungicide	Carbendazim	Benzimidazole	U
Fungicide	Phosphorous acid	Phosponate	U
Fungicide	Thiophanate-methyl	Benzimidazole	U
Fungicide	Procloraz	Imidazole	III
Fungicide	Iprodione	Dicarboximide	U
Insecticide	Chlorpyrifos	Organophosphate	II
Insecticide	Alpha-cypermethrin	Botanical	II
Insecticide	BMPC	Carbamate	II
Insecticide	Methomyl	Carbamate	Ib
Insecticide	Chlorantraniliprole	Anthranilic diamide	U
Insecticide	Emamectin Benzoate	Avemectin	U
Insecticide	Chlorfenapyr	Pyrrole	II
Insecticide	Carbosulfan	Carbamate	II

Ia= Extremely hazardous; Ib= Highly hazardous; II=Moderately hazardous; III= slightly hazardous; U= Unlikely to present acute hazard in normal use (WHO, 2005).

respectively. Based on result research in Figure 1 diversity index of low, moderate, and high application pesticide each of 2.47, 2.29, and 2.13. Evenness index of low, moderate, and high application pesticide each of 0.41, 0.38, and 0.35. Order richness of low, moderate, and high application pesticide each of 7, 7, and 6. The family richness of low, moderate, and high application pesticide each of 13, 11, and 10. A reduction was also observed by 7.3% and 13.8% for diversity index, 7.3% and 14.6% for evenness index, 0.0% and 16.7% for order richness, and 15.4% and 23.1% for family richness, respectively (Figure 2).

Order richness was reduced by the loss of Dermaptera and Family richness by the loss of Forficuloidae, Gryllotalpidae, and Gryllidae. The Forficuloidae family belongs to the Dermaptera Order and is the predator.

The arthropods consist of pests, predators, and parasitoids. Pests included *Sarcoptes scabiei* (Sarcoptiformes: Sarcoptidae), *Liriomyza chinensis* (Diptera: Agromyzidae), *Spodoptera exigua*, *S. litura* (Lepidoptera: Noctuidae), *Valanga nigricornis* (Orthoptera: Acrididae), *Gryllotalpa orientalis* (Orthoptera: Gryllotalpidae), *Gryllus bimaculatus* (Orthoptera: Gryllidae), *Sexava nubila* (Orthoptera: Totigonidae), *Musca*

domestica (Diptera: Muscidae) and *Sarcoptes scabiei* (Araneae: Sarcoptidae). Predators included *Oxyopes sertatus* (Araneae: Oxyopidae), *Chelisoche morio* (Dermaptera: Forficuloidea), *Coccinella* sp. (Coleoptera: Coccinellidae), *Scarabaeidae* sp. (Coleoptera: Scarabaeidae), *Oecophylla smaragdina*, *Solenopsis invicta* (Hymenoptera: Formicidae) and *Vespula vulgaris* (Hymenoptera: Apidae). While parasitoids were not observed; they did not present both in soil and around of shallot crop.

Shallot presence in the field for around eight weeks and dynamic pattern of pests had an optimum at four weeks post-planting with the abundance of applied by pesticides with moderate frequency. While on that with high frequency, had an optimum at three weeks post-planting with the abundance of five pests/plot and its abundance at one week until seven weeks was different significantly with on low and moderate frequency (Figure 1). The dynamic pattern of the predator with low frequency had an optimum of 28 predators/plot at four weeks post-planting and with moderate and high frequency 15 predators/plot and 11 predators/plot, respectively, at five weeks post-planting (Figure 2). This predator abundance at each week mentioned above on low frequency was significantly different with on mod-

Table 2. Total population of pests and predators sampled from five pitfall traps and ten consecutive swings of sweep net in 5 × 5 m area of one season shallot crop treated by pesticides in low, moderate, and high frequency

Species	Function	Pesticides application frequency		
		Low	Moderate	High
<i>Oxyopes sertatus</i>	Predator	20	1	3
<i>Sarcoptes scabiei</i>	Pest	4	4	0
<i>Scarabaeidae</i> sp.	Predator	8	1	3
<i>Coccinella</i> sp.	Predator	2	1	2
<i>Chelisoche morio</i>	Predator	5	2	0
<i>Liriomyza chinensis</i>	Pest	3	20	1
<i>Musca domestica</i>	Pest	4	0	3
<i>Oecophylla smaragdina</i>	Predator	22	12	8
<i>Solenopsis invicta</i>	Predator	30	25	18
<i>Polyrhachis pruinosa</i>	Predator	32	17	10
<i>Vespula vulgaris</i>	Predator	4	2	1
<i>Spodoptera litura</i>	Pest	18	17	2
<i>Spodoptera exigua</i>	Pest	12	10	3
<i>Valanga nigricornis</i>	Pest	21	11	2
<i>Gryllotalpa orientalis</i>	Pest	4	4	0
<i>Gryllus bimaculatus</i>	Pest	4	2	0
<i>Sexava nubila</i>	Pest	1	0	1

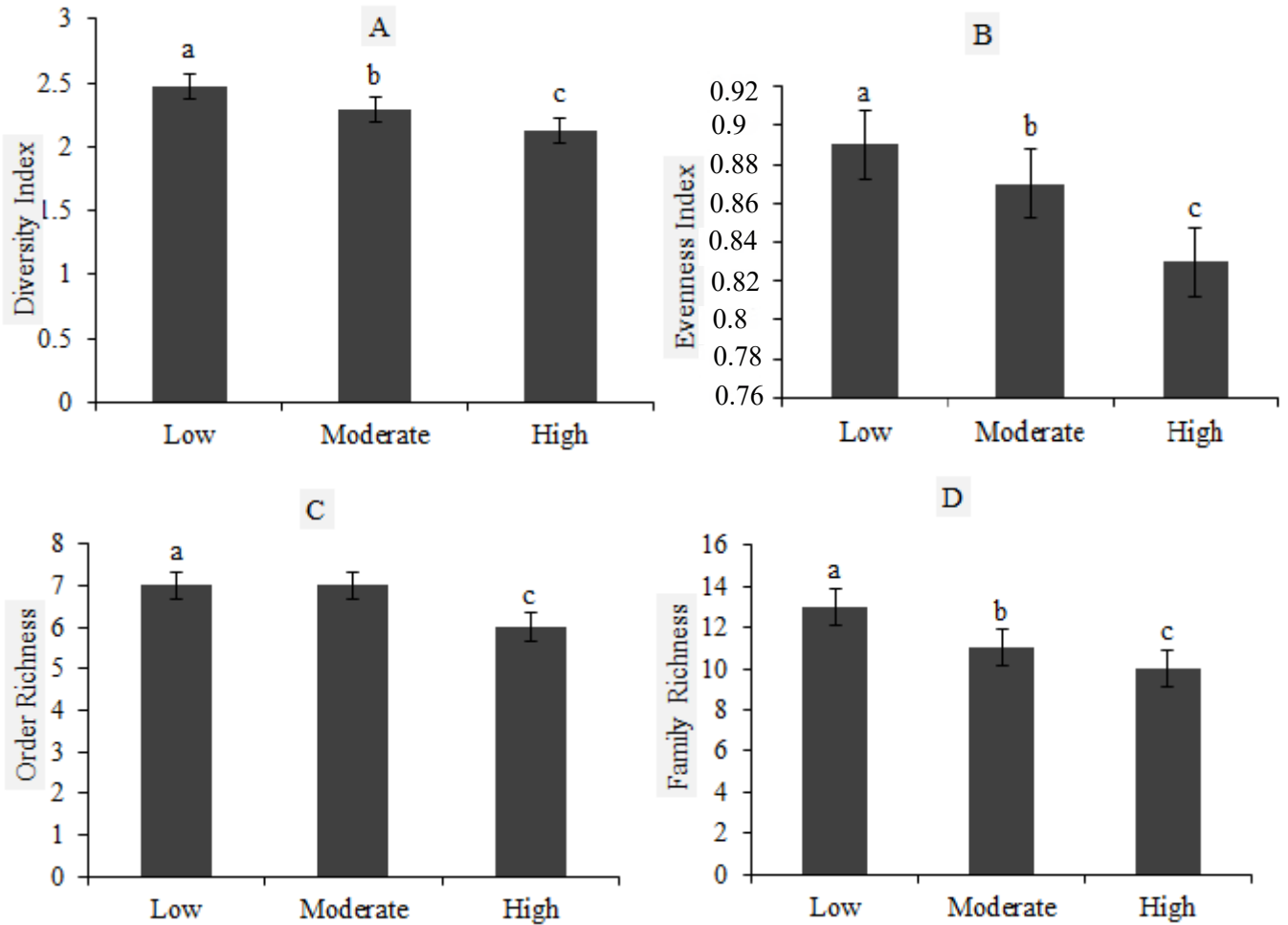


Figure 1. Arthropods on shallot crops applied by pesticides with low, moderate, and high frequencies in Palu Valley. (A) Diversity index; (B) Evenness index; (C) Order richness; (D) Family richness. Means of index and richness at the same part followed by the same letter are not significantly different according to t-test ($P < 0.05$).

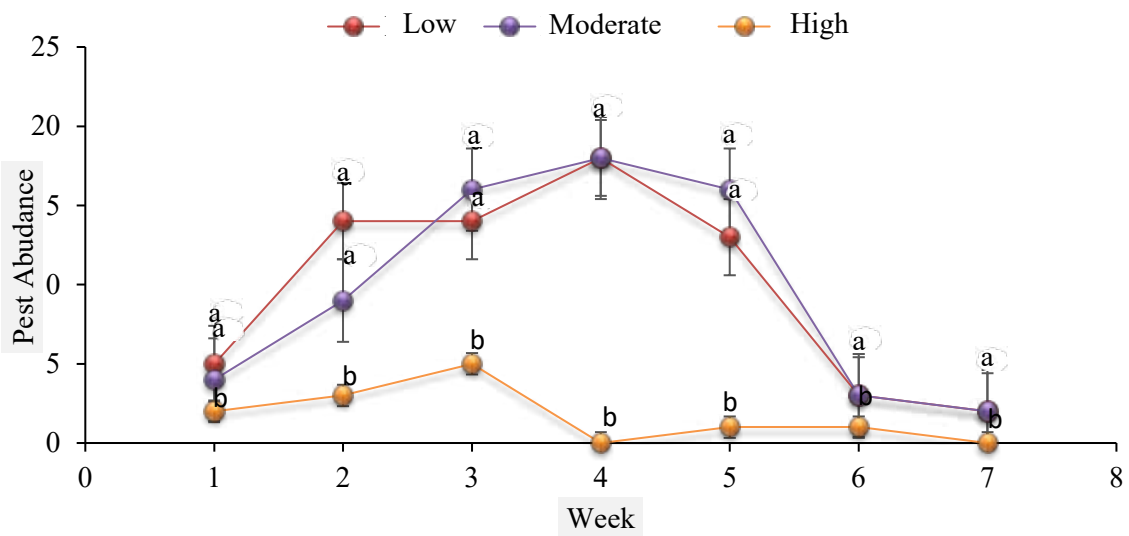


Figure 2. Dynamic abundance of pests (number per five pitfall traps and sweep net of 5 m² area) in a shallot field with pesticides application in low, moderate, and high frequency. Means of abundance at the same week followed by the same letter are not significantly different according to t-test ($P \leq 0.05$).

erate and high rate, and between the last two was not significantly different according to t-test ($P < 0.05$).

Presences of shallot crops throughout the year, arthropod pests infestation in Palu Valley always exists. If pesticides are applied in high frequency, it could be seen that the abundance of arthropods dropped dramatically to level 0–1 or decreased around 94.4% until 100%. Even though pest reduction has benefits, meanwhile we observed the hazard of pesticides to natural enemies and pests resistance.

Insecticides and fungicides were used in shallot crops. Insecticides consisted of eight groups and seven groups belonging to class II and one is class Ib where the first is moderately and the second is highly hazardous (WHO, 2005). These insecticides, directly and indirectly, were harmful to natural enemies (Cloyd, 2006). The direct effect associated with mortality or survival over a given time period, 24 to 96 hours (Stapel et al., 2000), and indirect effect associated with interfering on the physiology and behavior of natural enemies by inhibiting longevity, fecundity, reproduction development time, mobility, searching and feeding, predation and/or parasitism, prey consumption, emergence rates, and/or sex ratio (Desneux et al., 2007). Whereas fungicides consisted of five groups and four groups belonging to class U and one is class III that is respectively unlikely to present acute hazard in regular use and slightly hazardous. Although this, fungicide is still critical to determine any indirection since it is extensively used in agricultural and horticultural production systems (Wright & Verker, 1995). Comparing the application with low frequency in this research, the abundance of arthropod predators was reduced significantly in crops applied by pesticides with a moderate and high rate. Also, we did not observe any parasitoids, even in the plantation with a low frequency of pesticides application. This reduction of predators and disappearance of parasitoids was due probably to the long-term impact of pesticide use. Natural enemies in agro-ecosystems are highly sensitive to the use of pesticides (Zhang et al., 2007; Lu et al., 2012).

In contrast to the natural enemies, the abundance of pests was just affected by pesticides application in high frequency (Figure 2) and it can be seen as well on the population of main pests such as *Spodoptera litura*, *S. exigua*, and *Liriomyza chinensis*, and *Sarcoptes scabiei* (Table 2), they were not influenced in low and moderate compared to in the high application. This case indicated that resistance of pests to pesticides had occurred in the research area of Palu Valley. Resistant can be defined as a heritable change in the sensitivity of a pest population reflected in the repeated failure

of a product to achieve the expected level of control when used according to the label recommendation for that pest species (Panini et al., 2016; Ratnawati & Jaya, 2020). Many pests have developed to become resistant to pesticides, the highest or 291 species are resistant to cyclodiene, 260 species to organophosphates, 85 species to carbamates, 48 species to pyrethroids, 12 species to fumigants, and 40 species to the other (Dhaliwal et al., 2006). The development of resistance depends upon a variety of genetic, biochemical, and ecological factors such as generation time, fecundity rate, dispersal ability, together with the frequency, dosage, or persistence of pesticide applications (Kliot & Ghanim, 2012; Liu, 2015). After pesticide exposure, the presence of different genotypes in a population can deliver a selective advantage to some individuals for survival (Feyereisen et al., 2015). Due to continued pesticide application, the proportion of resistant insects increases compared to susceptible ones, and the population becomes increasingly difficult to control (Nauen, 2007).

CONCLUSION

We conclude that successive pesticides application on shallot crops offer a negative impact on the occurrence of arthropods by decreasing their abundance, value diversity index of low, moderate, and high application pesticide each of 2.47, 2.29 and 2.13. Evenness index of low, moderate, and high application pesticide each of 0.89, 0.87, and 0.83. The most phenomenal of this impact is the emergence of resistant pests and sensitiveness of natural enemies including predators and parasitoids to pesticides. Therefore, these data are a warning that pesticide use should be minimized and more friendly methods and environmentally safe in controlling shallot pests should be investigated and implemented on shallot crops in Palu Valley.

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AUTHORS' CONTRIBUTIONS

KJ performed an analysis of environmental pro-

cessing related to IPM. R was in charge in collecting and identifying samples as well as compiling manuscripts. SS1, AR, and US conducted data interpretation. SS2 was in charge in collecting and conducting data analysis as well as preparing manuscript. All the authors have read and approved the manuscript.

COMPETING INTEREST

There is no relationship of competing interest regarding the contents of this published article.

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