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Price Exploration of Various Insecticide Groups, Their Registered Crops and Insect Pest Species for Farmers' Insecticide Choices

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Abstract: Insecticides are hazardous substance that are often used in agriculture to reduce yield loss due to insect pest. Overuse of insecticide may result in detrimental effects to the environment and human health; thus, its use should be limited. Indonesian farmers still use insecticide making studies of their use to be required, especially on how farmers choose their insecticides. This study aimed to explore the price differences of insecticide based on insecticide group and their registered insect species and crops. Insecticide brands officially registered to the Ministry of Agriculture of Republic Indonesia were used in this study together with prices collected from the internet. Analysis was done for the top 10 crops registered by formulators, including chili pepper, shallot, rice, soybean, cabbage, cacao, palm oil, tomato, potato, and corn. Results showed that there were insignificant correlations between package and application price for most crops in this study, except cabbage and tomatoes. However, insecticides belonging to pyrethroid, organophosphate, and carbamate were clustered in an area of low application and package prices. Explorations based on insect species also showed that certain groups were cheaper than others when farmers are using insecticide at recommended dosages or concentrations and also according to registered crop and pest species. Price may become a factor for farmers to help decide what product. Therefore, there a merit further understanding currently distributed products while safer and novel management strategies are being developed and disseminated to farmers.

Keywords: Active ingredient; Price; Insecticide knowledge, Agricultural insect pest

INTRODUCTION

Agriculture is an important aspect in a country due to its reasonability to provide food and therefore, efforts to maintain quality and quantity are often done, including applying insecticides to manage insect pests. Insecticide application should reside as the last option of management after economic thresholds have been reached according to Integrated Pest Management (Dara, 2019). However, insecticide application behaviour, in this case Indonesia, may not follow these protocols as information on actual threshold may be scarce or no existence of alternative solutions that farmers deem as effective. Studies have shown that farmers may use various types of insecticides during growing season that may also differ across crops (Aldini et al., 2020; Utami et al., 2020). Farmers from Cedntral and East Java often spray insecticides to manage insect pest pest control due to their practicality and quick results (Haryadi et al., 2021; Purwanti Pratiwi Purbosari et al., 2021). However, farmers began to complain about spraying chemical pesticides for not being effective to control pests now indicating that pests may have evolved resistance against pesticides. The frequent use of insecticides in general have created concerns cauisng scientist and consumer scrutinized their use.

Overapplication of insecticides have been linked to detrimental effects to the environment and human health. Application of insecticides have been reported to cause arthropod diveristy collapse that cascade to other trophic levels (Li et al., 2020; Monzo et al., 2014; Stanton et al., 2018), noticeable health symptoms (Suhartono et al., 2018; Widyawati et al., 2020), and contaminate food and produce (Chen et al., 2014). These effect may grow worse as insect become harder to manage using insecticides due to to growth of resistances that has been reported often on various active ingredients and occassions (Scott et al., 2015). This phenomenon will not only increase application frequency, but may also reduce the number of effective active ingredient through cross-resistance of groups with similar mode of actions. Unfortunately, insecticides may still remain the chosen management option in certain situations. These include condition where economic loss may be severe when insect are not managed, such as for insect vector with health concerns, crop productions where damage thresholds are low, or agroecosystem where natural enemy populations are low. Therefore, studies and research of insecticides and how to safely applicate them are still required.

Insecticides consist of different active ingredients and have been developed through various stages. Insecticides are grouped into certain class accordance to their mode of action and can be found on websites, such as Insecticide Resistance Action Committee (IRAC) (Sparks et al., 2020; Sparks & Nauen, 2015). For example, diamide has been reported to activate ryanodine receptors, effect calcium exchange, and later insect movement (Cordova et al., 2006). Meanwhile organosphosphate, another group of insecticde, would affect cholinesterase, disturb neuron transmittion, and insect movement (Main, 1979). Although insecticdes have been classified into several groups, the development of novel active ingredients requires an increase of cost and time overtime (Sparks, 2013). On of the reason of this phenomenon is the increasing concern on the harmful effects of pesticides causing more robust tesing before active ingredients may be released to the market increasing R&D cost and decreasing the number of companies involved in this discovery (Sparks & Lorsbach, 2017). As the speed of active ingredients discovery becomes slower than than how fast insecticide resistances occur within pest populations, an awaiting challenge for further insect pest management. Thus, there is merit in efforts to maintain effectivity of exisitng active ingredient while developing safer and advanced managing technology. This study is an effort to study the existing insecticide groups in Indonesia, specifically of their price and would be possible to be a affecting factor of farmers choice. This study aimed to (1) explore price differences between insecticide active ingredients; (2) determine whether there were correlations between package and application price; (3) explore differences between application price across insect pest species. Hopefully, this information may be used to for further pesticide regulations and research.

METHOD

List of insecticide brands used in this study were obtain from pestisida.id, an official website from the *Direktorat Jenderal Prasarana dan Sarana Pertanian* under the Republic of Indonesia's Ministry of Agriculture (www.pestisida.id). List was collected in February 2021 and contained the brand names, active ingredient contained within these brands, and their specific insect species target, target crop, and recommended application dossage or concentration. Prices of these brands were collected from the internet during January 2022 and compiled for each brand together with its packing size. Several brands were not used for this analysis due to price information availability. Eventually, as much as 936 brand names were used for this analysis. Thus, price per application was estimated for an area of 2,000 m^2 when using insecticide at the maximum recommended dossage or concentration. The maximum recommended dossage or concentration was chosen take account cost when farmers using allowed dossage or concentration according to labels. This area was chosen due to the average area owned by farmer and to provide a standard comparison among different brands, active ingredients, and pest species. Due to the many crops and pest species registered by formulators, the crops and pest selected for the analysis belong to the top ten crops and >80% insect pest species. Correlations between the price of insecticde brands and application prices were tested using a linear regression for each of the most ten crops registered by insecticide formulators.

Linear regression were conducted using the `lm` function. Graphs were done using the R package `ggplot2` and all analysis were done using R 4.1.2.

RESULT AND DISCUSSION

Corelation analysis was done for the top 10 crops registered by formulators, including chili pepper, shallot, rice, soybean, cabbage, cacao, palm oil, tomato, potato, and corn. Price per aplication did not correlate with price per package across most of the crops tested, including chili pepper, shallot, rice, soybean, cabbage, palm oil, tomato, and corn (Table 1) Correlation between application price and package price were only found from insecticide brands registered for cabbage and potatoes. This implies that insecticide choice of farmers will not increase application cost (without considering labour and other resources required except insectice purchase). However, lower package and application prices demonstrated that certain insecticde groups were more prominent in these area across crop (Figure 1). These insecticide groups were pyrethroid, organophosphates, carbamate, and neonicotinoids. This implies that these insecticide groups may be easier to access by farmers based on price bariers. In addition, because they are used across many crops, their use may be used more frequently and cause harm to human health or insecticide resistances due to less options for inseciticde rotation.

Carbamates belong to the class of golden age insecticides in the 1940-1970s, an age that signified effective and reliable insecticide that are were affordable (Sparks et al., 2019). Meanwhile, neonicotinoids are new age insecticides produced after 1990. Organophosphate and pyrethroid are insecticides that are transitional between the golden age and the new age. Both insecticides, began to be produced between 1970-1990. Organoposphates use has been related to human health issues in even children (Widyawati et al., 2020), while both organophsophate and carbamates have been reported to cause harm to citizens in Kenya (Omwenga et al., 2021). Neonicotinoid has also been related to decrease of biodiversity by reducing avian diversity (Li et al., 2020) or pollinator health (Hall & Steiner, 2019), and human health issues (Thompson et al., 2020). Newer insecticide group, such as ones from spinosyns or diamides, were often distant from the group of the previous stated four. This implies that package and application prices were relatively higher and may become bariers for farmers to choose. Loosing rotation options may implicate further insect control. Spinosysn and diamides have been reported to be less persistent in the environment and have more narrow spectrum than previous groups, for example being used in poultry (George et al., 2010). Due to these reasons, further exploration of exisitng active ingredient and pest management strategies are needed to minimize these effect are required.

Table 1. Statistical variable of linear models for correlation between application and package price

Crop	P-value	Adjusted R^2
Chili pepper	0.7234	-0.002029
Shallot	0.9546	-0.00426
Rice	0.4534	-0.001205
Soybean	0.9245	-0.004181
Cabbage	**1.14E-08**	**0.1471**
Cacao	0.6979	-0.008557
Palm Oil	0.9443	-0.01244
Potato	**6.26E-06**	**0.1912**
Tomato	0.4169	-0.004916
Corn	0.2557	0.004597

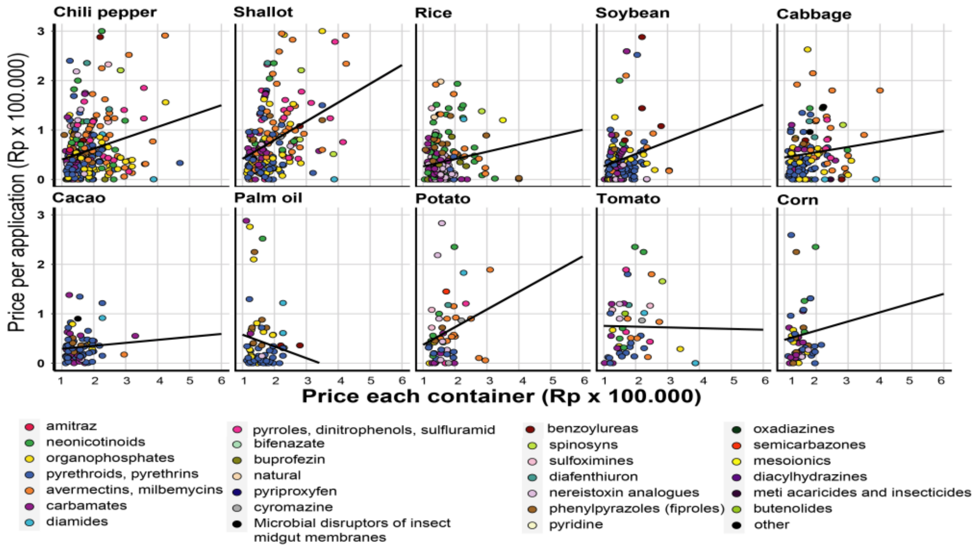

Figure 1. Realation and distribution of application and package price across the top ten crops registered for insecticide application by formulators. Each color encodes different active ingredient according to IRAC.

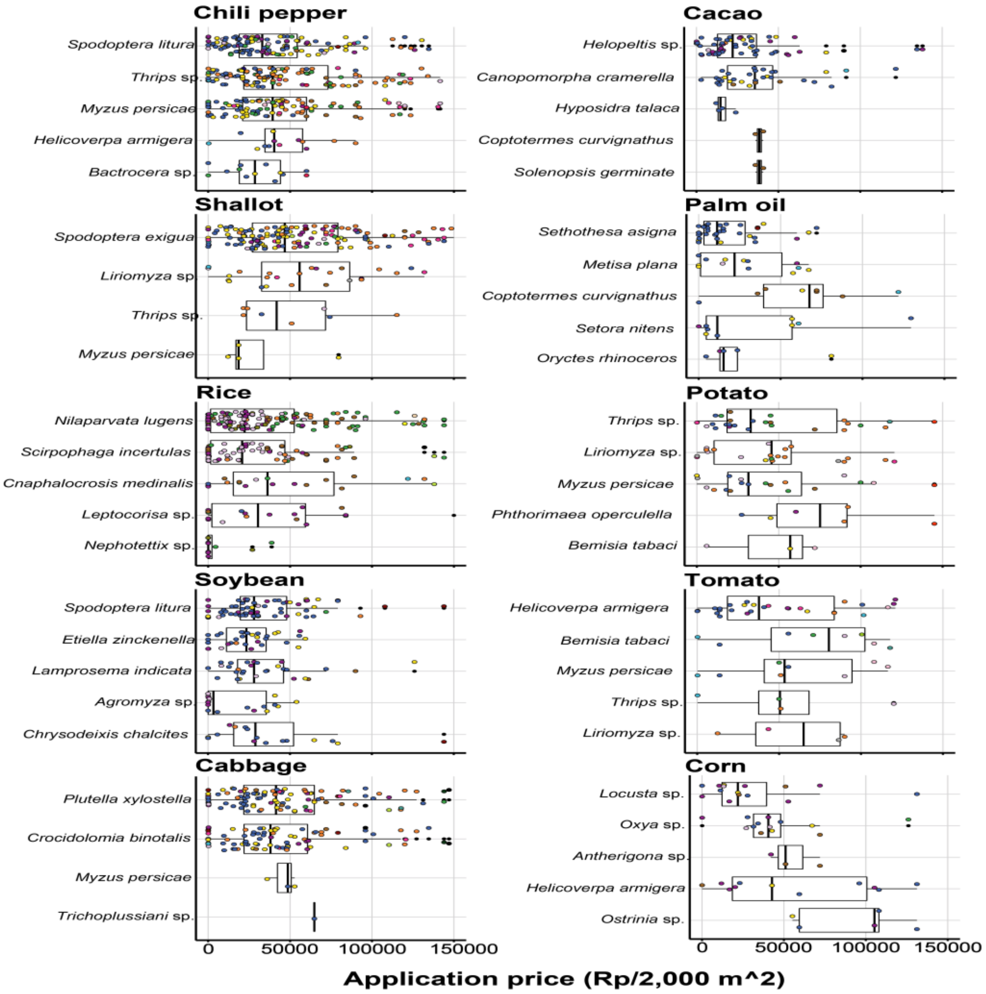

Figure 2. Distribution of application price of different insecticides across the top ten crops registered for insecticide application by formulators. Insect pests shown are ~80% of species that formulators register for within a certain crops. Each colors indicate different active ingredient group. Color codes are similar to Figure 1.

When explored across certain insect pest species, application prices demosntrated several patterns. Application prices of active ingredients from chili pepper, shallot, soybean, cabbage, and cacao showed that pyrethorid and organophosphate were grouped towards lower application prices across the several species within a crop. This again implies that these two groups may be used more frequently based on price barier considering that farmers follow application rates and crop or pest recommendation labels. It is noteworthy that some insecticide may be more focussed towards certain pests, such neonicotinoid may be more suitable for phloem feeding pests or species that are inside plant tissue. To our knowledge, this is first effort to explore application price of different pesticides.

Pesticide use, including insecticides, are globally increasing in intensifying agricultural countries (Grovermann et al., 2013; Liu et al., 2015; Zhang et al., 2015). Previous research has shown that a 1% increase in yield per hectare is associated with a 1.8% increase in pesticide use per hectare but growth in pesticide use intensity declines as countries reach higher levels of economic development (Schreinemachers & Tipraqsa, 2012). A study done in Southeastern Nigeria demonstrated that type of crop affected pesticide use (Rahman & Chima, 2018). A limitation of this study is that it does not provide the amount, dossage, or concentration often used by farmers, which may provide more confirmation whether these prices affected farmers' choices. This data would require intensive surveys as these data are not easily obtained and farmers often only estimate the amount of insecticide that they use. However, the study from (Utami et al., 2020) demonstrated that pyrethroid, carbamate, and organophosphate were frequently used by farmers around the Citarum River, while shallot farmers in Central Java and Yogyakarta used organophosphates with most farmers routinely spraying on a calendar based (Aldini et al., 2020). These trends were quite similar to ones found in Kuwait where pyrethorid and organophosphates were among the groups mostly used in this country (Jallow et al., 2017). The similar trends raise question on whether the price of these groups may be lower even across countries. Newer active ingredients may have patents entied to them causing prices being higher to earlier groups; thus, causing them to have higher market prices, less distribution area, or less pest being registered for their use.

Many previous research have shown that Indonesian farmers still rely on insecticides. As concern of environmental and human health continue to increase, strategies to reduce their use have been increasingly demanded. Current examples have shown of these strategies include creating natural based pesticides, behaviour alteration strategies, Examining insecticide prices is an initial step towards understanding why certain insecticide may be used more than others.

CONCLUSION

This study showed that package and application price did not show any correlation implying it to mostlikely not hinder farmers choice. However, based on the distribution of active ingredients, certain active ingredients tend to group on lower package and application prices on certain crops and insect pests. Further studies should implement intensive surveys to ask what are the reasons why farmers choose certain active ingredients and how much they actual apply together with the price of insecticide the puchased to confirm whether or not price can affect farmer's insecticide choices.

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