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Policy Priorities for Disseminating Biopesticide in Chili Farmers

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ABSTRACT

Controlling pests and diseases of chili plants still relies on synthetic chemical pesticides, which have negative effects on agroecosystems. Biopesticides can be used as alternatives to synthetic pesticides. The use of biopesticides in Indonesia is still low, and popularization efforts are required. The government plays a role in determining policies that encourage the popularization of biopesticides. This study aimed to determine policy priorities for the popularization of biopesticides for chili farmers. Policy priorities are determined using the analytical hierarchy process (AHP) method, which allows the identification of priority criteria and priority sub-criteria. The current policy on crop protection is insufficient to encourage the popularization of biopesticides. Low commercialization and government programs that are not yet massive are indications of the low use of biopesticides. The AHP results showed that the criteria for knowledge about biopesticides are policies that must be prioritized, where the sub-criteria of the level of intensity and quality of extension are the top priorities. The effectiveness and efficiency policy criteria need to prioritize the effectiveness of sub-criteria in controlling pests and diseases over the efficiency of use, preservation of natural enemies, and product quality, while the ease of obtaining products is the main factor in prioritizing the availability and affordability criteria.

Keywords: analytical hierarchy process, AHP, biopesticide, farmers, IPM, policy

INTRODUCTION

Chili is an important commodity for households and industries, both food and non-food. Chili farming households have income sourced from chili farming businesses, accounting for 50% of the total income received by families. This shows that chili farming is the family's foundation for meeting their daily needs. Chili commodities also provide foreign exchange contributions to the country through exports. The export value of chili commodities increased from 2019 to 2020 by 69.86%, worth US$25.18 million (BPS 2020). This proportion of exports is one of the largest contributors to Indonesia's total agricultural production exports. The role and potential of chili commodities in Indonesia have not been fully optimized. In general, chili production tends to increase from 2016 to 2020 (BPS 2022). A different trend happened to the cayenne pepper commodity, which experienced a decrease in production in 2020 from 1.5 million tons to 1.39 million tons in 2021 (BPS 2022). The decline in chili production remains a challenge on the production side, considering that the demand for domestic chili is still very high.

Plant pest and disease attacks are the main challenge in field chili cultivation. Plant pest and disease attacks can directly decrease crop production by damaging crops. Control and management efforts must be made to reduce plant pest and disease attacks. Some of the plant pest and diseases from the pest group that cause damage to chili plants include thrips (*Thrips parvispinus*), fruit flies (*Bactrocera* sp.), mites (*Tetranychus* sp.), and whiteflies (*Bemisia tabaci*) (Renfiyeni 2023). Common diseases that attack chili plants in the field include yellow virus (*Gemini virus*), Fusarium wilt (*Fusarium oxysporum* f. sp.), and Anthracnose fruit rot (*Collectrotichum gloeospoiroides*) (Hasbi 2021; Azzahra 2023). Control of plant pest and diseases is currently carried out using synthetic chemical pesticides. In addition to having a negative impact on agroecosystems, the cost of controlling synthetic chemical pesticides is high. According to the Structure of Cayenne Pepper Plant Business Costs per Hectare per Planting Season in Indonesia (SOUH 2018), the percentage of costs for the purchase of chemical pesticides is 8.3% for cayenne pepper and 15% for large chili. Pesticide purchases are also the third-largest expenditure after labor costs and fertilizer purchases.

Biopesticides with microbe-active ingredients can be more environmentally friendly and sustainable alternatives to plant pest and disease control. The microbes *Trichoderma*, PGPR*, yeast Rodotorula minuta*, and *Lecanicillium* in intensive microbial technology packages have been tested to replace 100% synthetic chemical pesticides in chili plants (BIC 2021). Various studies and developments of biopesticide products have been carried out by research institutions from the government, campuses, and the private sector. However, the use of

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biopesticides for plant pest and disease control in Indonesia remains limited. Farmers still rely more on synthetic chemical pesticides. Utami *et al.* (2020) stated that the use of chemical pesticides on agricultural land in the upper reaches of the Citarum River is quite large, namely 24.6 kg/hectare/year. Ratnaningrum (2019) found that there are several factors that make the use of biopesticides not yet widespread, including products that are still limited in the market; biopesticides are considered to require a special application time, complicated licensing constraints, investment in the biopesticide sector is still low, quality control at the farmer level is still lacking, and the infrastructure is inadequate.

Challenges in disseminating biopesticide facilities require policy intervention to be systematically overcome. Disseminating biopesticides involves complex variables that intervene with policies. Some of the variables that can affect the dissemination of biopesticides are product availability and affordability, effectiveness of plant pest and disease control and efficiency of use, and knowledge of biopesticides. Considering the complexity of these variables, it is necessary to arrange priorities so that policy interventions can be targeted. The complex factors involved in disseminating biopesticides require appropriate policy interventions and involve a wide range of parties. Priorities are prepared using the analytic hierarchy process (AHP) method based on several criteria for the dissemination of biopesticides. The AHP makes it possible to find priority variables that need to be considered when making decisions. The working principle of AHP is to simplify complex problems that are unstructured, strategic, or dynamic. They are then arranged in a hierarchical structure (Marimin 2008). Complex criteria can be ranked as policy priorities that need intervention first (Saputra 2021). This study aimed to determine policy priorities for the dissemination of biopesticides among chili farmers in Java.

METHODS

The priority of disseminating biopesticide policy in AHP consists of three aspects: (1) availability and affordability, (2) effectiveness and efficiency, and (3) knowledge. Availability and affordability are important criteria for the dissemination of biopesticides. This is related to the ease of accessing biopesticide products, finished products and isolates, and biopesticide propagation materials. The affordability of biopesticides is related to the price and availability of propagation infrastructure. The first criterion is the effectiveness and efficiency related to whether biopesticide products are effective in controlling plant pest and disease and maintaining the existence of natural enemies. The second criterion is product efficiency, which includes product quality, time efficiency, labor, and cultivation costs. The last criterion is knowledge, which includes easy access to biopesticide information, counseling and mentoring, and understanding of biopesticide products. The process of prioritizing various criteria in the dissemination of biopesticide policies was carried out in the following AHP stages.

Preparation of a Multicriteria Hierarchy of Disseminating Biopesticide Policy

The creation of the hierarchy began by setting goals and was placed at the top level. At the intermediate level, criteria that affect biopesticide dissemination were prepared, in this case availability, affordability, effectiveness, efficiency, and knowledge. The last hierarchy consists of sub-criteria related to criteria at the top level. The hierarchy that has been arranged is shown on Figure 1.

Prioritizing Criteria

The priorities of the criteria were determined at each level. The priority was determined by conducting multiple comparisons (pairwise comparisons). Pairing comparisons were performed from the first to the last level. The result of the comparison was a vector of priority or the relative importance of one element to another element at one level. Benitez *et al.* (2015) also stated that multiple comparisons can determine alternative priorities in each criterion. The multiple comparison assessment was quantified into a value weight on a nominal scale of 1–9. The interpretation of each value is listed in Table 1.

The priority of the criteria was determined by considering expert judgment of the representative of stakeholders. Decision-making in the AHP involved many subjective considerations that required input from the parties who were made as respondents and was based on the representation of the parties who play a role in the dissemination of biopesticide processes through their respective roles (Zanakis *et al.* 2015).

Data was collected through interviews with respondents to obtain statements on multiple comparisons that had been prepared. The respondents were representatives of the central government (Directorate of Horticultural Protection), local governments (Kediri Regency Agriculture and Plantation Service), Tegal Regency Food Security and Agriculture Office, Garut Regency Agriculture Office), and company (CV WiSH Indonesia), research institutions (IPB University), field officers, and farmers during three regencies: Kediri, Tegal, and Garut. The results of multiple comparisons were used to determine the priority of the criteria and sub-criteria.

The comparative values obtained from various respondents were averaged geometrically to be included in the criteria comparison matrix. Furthermore, the compiled matrix was normalized by
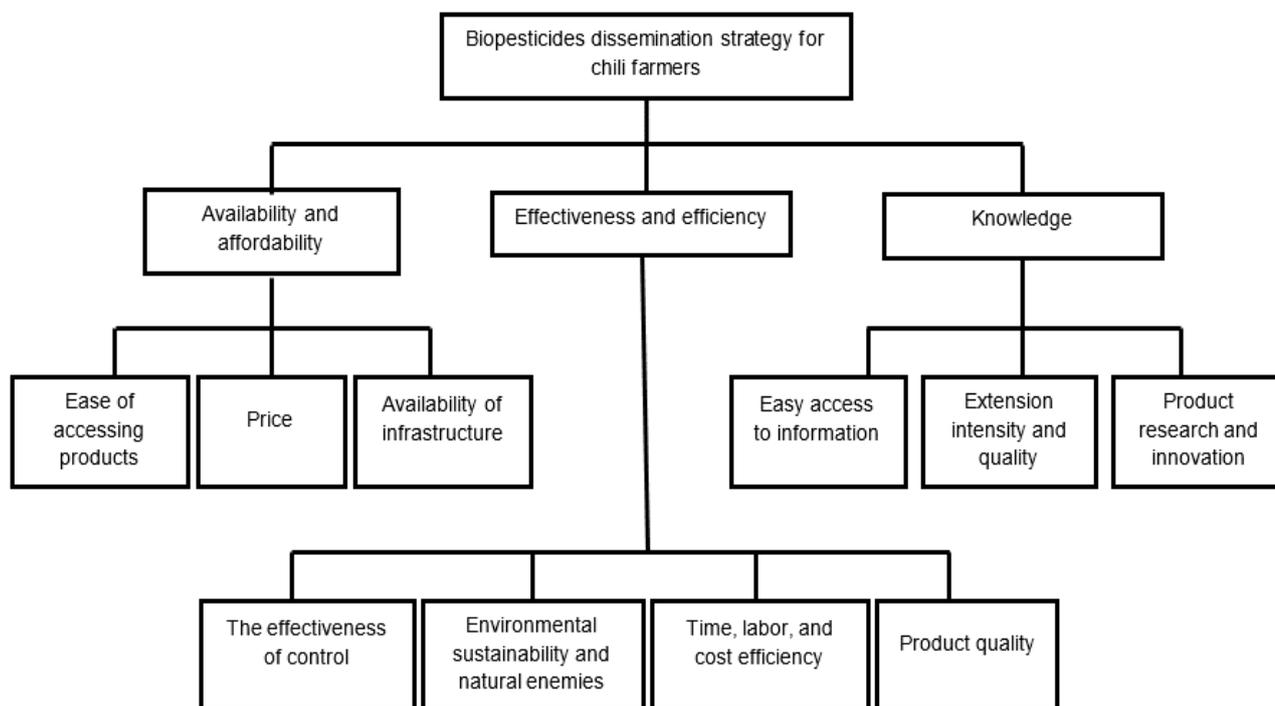
Figure 1 Hierarchy chart of biopesticide correctional strategies for chili farmers in Java.

Table 1 Rank of assessment and interpretation of paired comparison

Value	Intepretation
1	Both elements are equally important
3	One element is slightly more important than the other
5	One element is more important than the other
7	One element is very important compared to the other
9	The one element is absolutely very important compared to the other
2,4,6,8	Middle values among adjacent comparisons

determining the eigenvalue. The average eigenvalue of each comparison was ranked to determine the priority of the criteria.

Consistency Test

One of the advantages of the AHP method is that it can test the consistency of the assessment (Saaty 2008). If the consistency value is too far from the perfect consistency value, it is necessary to reassess or rearrange the hierarchy in AHP. The consistency test was performed by calculating the Consistency Ratio (CR) usin g the following formula:

CR = CI/IR

where CI is Consistency Index:

$CI = (\lambda_{maks} - n)/n$,

n = number of elements.

IR = Random Consistency Index, a constant that depends on the size of the matrix

The priority weight is said to be consistent if the consistency ratio (CR value ≤ 0.1) or ≤10%.

RESULTS AND DISCUSSION

Dissemination and Biopesticide Policy in Indonesia

Biopesticides are defined as specific materials that contain microorganisms or, more broadly, plant compounds, semichemicals, and biopesticide products (Nuruzzaman 2019). There are various types of biopesticide groupings, one of which is from the US-EPA (the United States Environmental Protection Agency). Biopesticides are divided into 3 groups: microbial pesticides; plant incoporate protectants (PIPs); and biochemical plant pesticides. The biopesticides referred to in this study are condensed into microbial pesticides, which are commonly referred to as biological agents in Indonesia.

The use of biological agents in Indonesia is still relatively low compared with the use of synthetic chemical pesticides. Some indications of this situation include the low circulation of biopesticides in the market. Considering the circulation pattern of synthetic chemical pesticides, products are widely available with

various types, active ingredients, and trademarks. The abundance of chemical pesticide products can be seen in the number of registered trademarks. In 2022, there were 5,675 registered pesticide trademarks. Of these, only 83 trademarks (1.4%) are biological pesticides (Director General of PSP 2022). The most widely circulated type of pesticide is biofungicide, the majority of which are active ingredients *of Trichoderma* sp. Global trends also show a similar tendency, where 90% of microbial biopesticides circulating in the market are *Bacillus thuringiensis* active ingredients. The low use of biopesticides by farmers is because of the dissemination process, which is also low. This is influenced by at least three factors: availability and affordability, the effectiveness and efficiency of product use, and farmers' knowledge and understanding of biopesticide products.

Research and development on biopesticides has been carried out by various parties, from government research institutions and universities to the private sector. Research has been carried out at various stages, from exploration to product formulation. For it to be widely used, biopesticides must be mass produced. In Indonesia, biopesticide production is carried out through various schemes, namely large-scale production by officially registering biopesticide products and local production by farming groups (Harman *et al.* 2010).

Mass production with a production scheme officially registered as a biopesticide is regulated by the Regulation of the Minister of Agriculture No. 43 of 2019 concerning pesticide registration. According to Wiyono (2023), the official registration system for biopesticide products took a long time, about 3–6 years. This is because pesticide licensing requires strict tests that can be distributed. The total cost incurred by the biopesticide registration scheme is quite high, at approximately IDR 3 billion per product. Judging from the synthetic chemical pesticide products used by farmers, all products in circulation originate from industrial-scale production through a pesticide registration scheme. This scheme is the largest contributor to the availability of plant pest and disease-control products. However, the commercialization of biopesticide products is still very low, which affects their availability in the field.

Local production at the farmer level is generally carried out by farmer groups or organizations in one area. The institutions that manage the propagation of biopesticides at the farmer level are the Biological Agent Service Post (PPAH) and Integrated Pest Management (IPM) Clinic. PPAH and IPM Clinic managers are expert farmers who have been trained in various government programs. The circulation of biopesticides under this scheme is regulated in Law No. 22 of 2019, which is only limited to the district level. This regulation differs from Law No. 13 of 2010 concerning horticulture, where its circulation is only at the group level. Production with this scheme also has shortcomings related to contamination and consistency of product quality; therefore, it requires adequate supervision. This production scheme is a priority for the government in the dissemination of biopesticides compared to commercialization on an industrial scale.

Agricultural pest and disease control in Indonesia refers to Law Number 22 of 2019, concerning Sustainable Agricultural Cultivation Systems. The context of plant protection can be seen in Article 48, which states that agricultural protection is carried out using an IPM system. IPM has become a mandate for the implementation of plant pest and disease protection in Indonesia. In principle, one part of the implementation of IPM is the use and management of environmentally friendly technology using an agroecosystem approach. Biopesticides should be a priority in pest and disease control in accordance with the mandate of the law.

Priorities of Disseminating Biopesticide Policy

Table 2 Paired comparison matrix of disseminating biopesticide policy criteria

Criterion	Availability and affordability	Effectiveness and efficiency	Knowledge
Availability and affordability	1.000	0.691	0.278
Effectiveness and efficiency	1.447	1.000	0.507
Knowledge	3.599	1.974	1.000

Table 3 Matrix of normalization of disseminating biopesticide policy criteria

Criterion	Availability and affordability	Effectiveness and efficiency	Knowledge
Availability and affordability	0.165	0.189	0.156
Effectiveness and efficiency	0.239	0.273	0.284
Knowledge	0.595	0.539	0.560

Table 4 Priority and weight of disseminating biopesticide policy criteria

Criterion	Priority of criteria	Percentage
Availability and affordability	0.170	17
Effectiveness and efficiency	0.265	27
Knowledge	0.565	55

Disseminating biopesticide policy priorities need to be prepared to encourage the use of biopesticides in the field. The AHP analysis was carried out by conducting a pair comparison among three important criteria in disseminating biopesticides, namely availability and affordability, the effectiveness and efficiency of product use, and farmers' knowledge and understanding of biopesticide products. The results of paired comparisons of important stakeholders in disseminating biopesticide are presented in Table 2.

The criterion matrix that was compiled was normalized by searching for eigenvalues. The eigenvalues were also arranged in a normalization matrix based on the three criteria (Table 3). The average value of the eigenvalue for each criterion was the priority value presented in Table 4. The priority values of the criteria in Table 4 represent the policy priorities that must be taken in disseminating biopesticides. The higher the priority value, the more a criterion becomes a priority in determining the policy. Priority determination is accompanied by a consistency test to determine the validity or non-validity of priority decision-making criteria. The consistency ratio in the paired comparison of the priority of the disseminating biopesticide policy was 0.005. This decision-making can be considered valid because the consistency ratio value was <0.1.

The priority value in Table 4 shows that the knowledge criterion has the highest priority value (55%), followed by the effectiveness and efficiency criteria (27%), and availability and affordability (17%). The priority of the knowledge policy in disseminating biopesticides was related to the ease of access to information about biopesticides, the intensity and quality of counseling on biopesticides, and the development of research and innovation regarding biopesticides. Understanding biopesticides is the basis for farmers to use these products. One of the reasons why knowledge is a top priority is that the application of biopesticides is a prerequisite for the effective control of pests and diseases. A lack of in-depth understanding of biopesticides has led to these prerequisites hindering their use in the field. Some of the prerequisites expressed by respondents include the response and effects of pests and diseases, which are relatively long compared to synthetic chemical pesticides. Alawiyah (2018) said that the low use of biopesticides is also since farmers find it difficult to see the impact of biopesticide applications visually, in other words, the observability factor is low. Compared to the use of chemical pesticides, the effect of biopesticides on pests and disease attacks is visually invisible.

Biopesticide users need to have a good understanding of agroecosystems so that they can not only make the observability factor the basis for using biopesticides in replicating pests and diseases. An understanding of agroecosystems is usually obtained from the IPM Field School Program (SL-PHT). According to Nanta (2019), farmers' participation in the SL-PHT program had a significant effect on the use of IPM technology that uses biopesticide products.

Knowledge Policy Priorities on Biopesticides

Knowledge criteria are a priority for disseminating biopesticides. The knowledge criteria were divided into three sub-criteria: (1) ease of access to information, (2) the level of intensity and quality of counseling, and (3) product research and innovation. Priority in the knowledge sub-criteria was determined by conducting a paired comparison between the three, so that the priority value of the criteria and the percentage of priority were obtained (Table 5). The consistency ratio value of the paired comparison between the knowledge sub-criteria was 0.0742. This decision-making could be considered valid because the consistency ratio value was <0.1.

The priority value of the sub-criteria showed that the intensity and quality of counseling were a policy priority with a percentage of 39%. The second and third priorities in a row were product research and innovation, as well as ease of information. The intensity and quality of counseling was a priority, considering that most farmers' knowledge and understanding of biopesticides were obtained from field officers, either plant pest control officers or field agricultural extension officers. Some of the programmes brought by officers were often related to disseminating biopesticides, both in terms of knowledge and infrastructure. Kamaruzaman *et al*. (2012) suggested that farmers who have higher knowledge can acquire adequate knowledge and awareness about the potential benefits of biopesticides, which then influences farmers to use biopesticides. Likewise, according to Nanta (2019), farmers' participation in the IPM field school program affects the adoption rate of IPM, which includes the use of biopesticides.

Access to knowledge had the lowest policy priority score. Knowledge of biopesticides is now easier to obtain as technology develops. However, the validity of information or knowledge circulating on the Internet needs to be a concern so that it does not become misleading. The sub-criteria for research and innovation were the second priority. According to the respondents, research and innovation need to be

Table 5 Priority and weight of the subcriteria of the knowledge policy on biopesticides

Criterion	Priority criteria	Percentage
Ease of access to information	0.245	25
Intensity and quality of counseling	0.427	39
Product research and innovation	0.328	36

completed downstream so that existing innovations could be directly felt by farmers.

Priority of Biopesticide Effectiveness and Efficiency Policy

The effectiveness and efficiency of biopesticides have four sub-criteria: (1) control effectiveness, (2) environmental and natural enemy preservation, (3) time, labor, and cost efficiency, and (4) product quality. Decision making was considered valid when the consistency ratio value was 0.005 or <0.1.

The highest priority value for the effectiveness and efficiency criteria was 61% for the sub-criterion of effectiveness on pest and disease control. Next, in a row are the sub-criteria of product quality, time, effort, and cost efficiency, and the preservation of natural enemies (Table 6). For stakeholders, the effectiveness of controlling plant pest and disease is the most important variable compared to others. Even when compared to the time, labor, and cost efficiency variables, the priority level was much lower. This is also related to the behavior of farmers in controlling plant pest and disease, who are willing to spend more to obtain products that effectively control plant pest and disease. Garane *et al.* (2023) stated that there is a positive and significant relationship between the willingness to pay and the perception of the effectiveness of biopesticides on tomato pests. This shows that farmers choose pest and disease control products among biopesticides and synthetic chemical pesticides based on considerations of effectiveness and efficiency. Farmers tend not to risk losing their yield even though the production costs incurred are greater. Even in China, Li *et al.* (2023) stated that the effectiveness of biopesticides in controlling plant pest and disease is the main variable affecting the level of their use in the field. Biopesticide products that are not effective in controlling plant pest and disease, are the cause of inhibition in the use of biopesticides in China.

Policy Priorities for Biopesticide Availability and Affordability

The availability and affordability criteria consist of three sub-criteria: (1) ease of access to products, (2) price, and (3) availability of infrastructure. Decision-making was valid because the consistency value was 0.007 or <0.1.

The product accessibility policy sub-criterion was a top priority compared to price availability, with a percentage of 50% (Table 7). Biopesticide products circulating in the market and among farmers were still relatively few, in contrast to synthetic chemical pesticide products that were available in various trademarks, types, and active ingredients. The trend at the global level also shows the same tendency, where the circulation of biopesticide products covers only 5% of the total market for plant protection products (Damalas 2018). Most biopesticide products available at the farmer level were obtained from agricultural shops and farmer groups that reproduce themselves from government programs. Therefore, the availability of propagation infrastructure at the farmer group level wwas a second priority. Government programs related to the dissemination of biopesticides are directed toward farmers or farmer groups to produce their own biopesticides. On the other hand, the commercialization efforts of biopesticides were still low, one of which is due to low investor interest in biopesticide products. Some of the things that companies consider investing in were as follows: (1) the working power of biopesticides is not as fast as that of synthetic chemical pesticides, (2) shelf life is not long as that of synthetic chemical pesticides, and (3) the registration and licensing process is relatively difficult (Ratnaningrum 2019). In addition, it is necessary to identify certain compounds from biopesticides to ensure their effectiveness and to assemble formulations that are right on target and last a long time so that they can be applied to agricultural land (Tampubolon 2018). The availability and affordability of biopesticide products affect the level of their use by farmers in the field. Constantine *et al.* (2020) revealed that the availability and affordability of biopesticides were important factors that caused the low use of biopesticides in Kenya.

CONCLUSION

The low concentration of biopesticides requires policy priorities in terms of increasing knowledge of biopesticides. The variables of knowledge improvement policies that must be prioritized are the level of intensity and quality of counseling from officers. Increasing the effectiveness of pests and disease control is a priority in developing biopesticide products. In addition, ease of access to products must be a priority in terms of the availability and affordability of biopesticides. Farmers can ensure the effectiveness and efficiency of biopesticide products through increased knowledge through both extension services and research institutions. The connection between research innovation and commercialization plays an important role in providing quality-guaranteed products for farmers.

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