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Applying AHP to Select the Best Vendor for Bio-Efficacy Trials

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Abstract

Purpose: The pesticide industry is highly regulated by various regulations and requirements. Getting a distribution permit for a pesticide depends on the results of bio-efficacy trials carried out by institutions outside the company (vendors). These vendors must be selected from a list that has been made by the Ministry of Agriculture. Choosing a vendor is quite a difficult endeavor because not all vendors have the same competencies.

Research Methodology: One method to choose a vendor among several vendors based on various criteria hierarchically that meets the requirements is to use the Analytical Hierarchy Process (AHP) method. This thesis presents the results of the trial of the use of the AHP method in the XYZ Agrochemical Company using a qualitative and quantitative approach by collecting primary data through questionnaires and interviews with a team of Research and Development experts from the XYZ Agrochemical Company.

Results: The results of the case study at the XYZ Agrochemical Company show the practical application of the AHP model in real-world vendor selection scenarios, providing an overview of the relative significance of each criterion and its impact on the overall decision-making process.

Conclusions: The study concludes that the use of the Analytical Hierarchy Process (AHP) method effectively supports the R&D team of the XYZ Agrochemical Company in determining and prioritizing the selection criteria and sub-criteria for qualified bio-efficacy trial vendors. Applying the AHP method to four vendors allowed for an objective ranking based on agreed-upon parameters, ensuring a transparent and data-driven vendor selection process.

Limitations: Secondary data was obtained from government regulations, company reports, and relevant literature to form vendor profiles, organizational capabilities, and pesticide regulations that apply specifically to Indonesia.

Contribution: Through the AHP framework, based on the results of the interview, a hierarchical structure of evaluation criteria in selecting vendors was established, including expertise, past performance, laboratory and field facilities, timely delivery, in conducting bio-efficacy trials, and vendor responsiveness in communicating.

Keywords: *Analytical Hierarchy Process (AHP), Agrochemical Company, Bio-Efficacy Trial, Pesticide Regulation, & Vendor Selection.*

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1. Introduction

The pesticide industry plays a crucial role in agricultural practices, helping to combat pests and improve crop productivity. To ensure the efficacy and safety of pesticide products, bio-efficacy trials are conducted. Bio-efficacy trials involve assessing the effectiveness of pesticides against target pests and

determining the optimal dosage and application methods. These trials are essential for pesticide companies to gain regulatory approvals and provide reliable products to farmers. In addition to benefiting farmers as consumers of pesticide products, these trials play a crucial role for pesticide companies in obtaining legal compliance by meeting the regulations set by authorized institutions in the country. According to Law No. 12 of 1992 on Crop Cultivation Systems, pesticides distributed in Indonesia are required to be registered and meet quality standards that ensure safety for humans and the environment. The Minister of Agriculture Regulation No. 43 of 2019 on the requirements and procedures for pesticide registration stipulates that efficacy testing must be conducted by accredited testing institutions or those appointed by the Minister of Agriculture, following the standard methods established by the Director General on behalf of the Minister of Agriculture.

The availability of the vendor list provided by the Government, although quite helpful, also requires caution for pesticide companies to select the right vendors because of various considerations. The XYZ Agrochemical Company realizes that based on their experience working together with several vendors enlisted in the list, not all vendors have the same competence, both in terms of technical ability, managerial, reputation, and track record in complying with test protocols and deadlines for submitting test results. For pesticide companies, choosing a vendor for bio-efficacy trial is a crucial task because it will have an impact on the entire process in pesticide management. In addition to being in accordance with the procedures set by the Government, the results must also be precise, both in the right quality, on time, and at the right cost. So far, the XYZ Agrochemical Company has applied several criteria in selecting vendors for bio-efficacy trials but has not been implemented comprehensively and systematically.

Therefore, a method is needed in selecting the right vendor. One of them is by using the Analytical Hierarchy Process (AHP) method which provides a systematic approach in making complex decisions. When applied to the selection of vendors for field efficacy trials, AHP offers a structured and transparent process that considers various factors crucial to the success of the trials. The effectiveness and safety of pesticide products heavily rely on rigorous testing, including bio-efficacy trials. However, with numerous vendors available, each with different capabilities and expertise, selecting the best vendor becomes a challenging task for the company. The absence of a structured decision-making framework exacerbates the issue, as there is a lack of a systematic approach to evaluate and prioritize the criteria for vendor selection. Traditionally, vendor selection in the pesticide industry for bio-efficacy trials often relies on individual judgment, personal preferences, or historical relationships. The absence of structured methodologies results in inconsistent outcomes and potential biases.

Selecting vendors for bio-efficacy trials involves evaluating multiple criteria, such as technical expertise, reliability, cost, compliance with environmental regulations, and past performance. Balancing these diverse criteria and making trade-offs is challenging without a systematic approach. Additionally, decision-making tends to be subjective, with stakeholders having varying opinions on the importance of different criteria. Without a transparent process, justifying vendor choices to internal and external stakeholders becomes difficult. Given that the pesticide industry directly impacts human health and the environment, choosing reliable vendors is crucial to ensure accurate bio-efficacy trials and minimize risks. A systematic framework can enhance quality assurance by objectively assessing vendor capabilities. Therefore, this thesis aims to address this problem by utilizing the Analytical Hierarchy Process (AHP) methodology to establish a comprehensive framework that enables the XYZ Agrochemical Company to select the best vendor for bio-efficacy trials.

Based on the research questions above, the objectives of this research are; To identify and analyze the key criteria that are relevant for vendor selection in bio-efficacy trials within the pesticide industry, especially at the XYZ Agrochemical Company and to apply the AHP method in selecting the best vendor for bio-efficacy trials at the XYZ Agrochemical Company.

2. Literature Review

2.1 Theoretical Foundation

2.1.1 Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) is a decision-making tool that enables the evaluation of multiple criteria. AHP utilizes Eigen values to facilitate pair-wise comparisons and establishes a methodology to assign numeric values for measuring both quantitative and qualitative performances. The scale employed in AHP ranges from 1/9 denoting "least valued than", to 1 signifying "equal" and up to 9 representing "absolutely more important than" encompassing the entire range of the comparison spectrum (Brunelli, 2014; Mu & Pereyra-Rojas, 2017; Thomas L. Saaty & Vargas, 2001).

The Analytical Hiera"chy Process (AHP)"follows a structur"d app"oach that involves three essential steps (Thomas L Saaty, 1994); The initial step of AHP is to convert the multi-criteria decision-making problem into a hierarchical model. This model consists of three levels: the goal at the highest level, the criteria at the intermediate level, and the alternatives at the lowest level. While these three levels must be present in the hierarchy model, additional layers of sub-criteria can be incorporated between the criteria and the alternatives if necessary. In the subsequent step, the importance of one criterion over another is determined by making comparative judgments through pairwise comparisons among the n criteria. This process results in the formation of an n-order matrix based on these comparisons. It is important to note that this matrix is always positive and reciprocal in nature, meaning that all entries in the matrix are positive.

Saaty (1987) introduced a scale (refer to Figure 2.1) that facilitates a one-to-one correspondence between the set of alternatives and a subset of rational numbers. This scale assists in assigning numerical values to the alternatives, enabling a quantitative representation of their relative importance or preference.

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals	If activity i has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

ɳ the elements being compared are closer together than indicated by the scale, one can use the scale 1.1, 1.2, ..., ill finer, one can use an appropriate even finer refinement.

Figure 1. Fundamental nine-point scale proposed
Source: R. W. Saaty (1987)

In the final step, several calculations are performed to evaluate the priority vector (weights) and assess the consistency of the judgments. The Consistency Index (CI) is employed to measure the level of consistency. If the CI falls within an acceptable range, the decision can be accepted. However, if the CI exceeds the desired level of consistency, the judgments need to be re-evaluated and repeated until the desired range of consistency is achieved.

The Analytical Hierarchy Process (AHP) is a decision-making method that addresses both subjective and objective components of decision-making by simplifying complex choice issues into a series of pairwise comparisons and synthesizing the results. AHP proves helpful in various areas, such as

resource allocation, alternative selection, planning, and handling conflicting and subjective criteria. It structures problems into a hierarchical framework, starting from the goal, progressing to criteria and sub-criteria, and finally to alternatives, with an analysis of the relationships between the goal, criteria, and alternatives. AHP finds applications in diverse disciplines including Renewable Energy, Sustainable Manufacturing, Natural Hazards, Environmental Pollution, Landfill waste management, and others, often falling within the realm of Sustainable Development. However, AHP also has limitations. It is subjective in nature, as it relies on human emotions for numerical judgments. Consistency issues can arise with judgments in the AHP process, and there can be a high computational requirement associated with complex decision problems. These limitations should be considered when applying the AHP methodology.

2.1.2 Vendor Selection

Vendor selection is a complex activity that requires an appropriate method for its resolution (Wirdianto & Unbersa, 2008). According to Pujawandan and Mahendrawati (2010), supplier selection is a strategic activity, particularly when the vendor will supply critical items or will be engaged in a long-term relationship. UmaDevi et al., (2012) stated that AHP is multicriteria decision making tool that takes into account both qualitative and quantitative criterias.

According to Nydick and Hill (1992), the criteria for vendor selection are Quality, Price, Service, and Delivery. To aid in the vendor selection process, various evaluation methods and frameworks have been developed, such as multi-criteria decision-making techniques such as Analytical Hierarchy Process (Vaidya & Kumar, 2006). These methods assist in systematically assessing and comparing vendors based on multiple criteria.

2.1.3 Bio-Efficacy Trials

According to the Food and Agriculture Organization (FAO, 2006, June), efficacy evaluation refers to the assessment of a plant protection product's effectiveness against the target pest. This evaluation may encompass considerations of its agronomic sustainability and economic benefits. The primary purpose of efficacy evaluation is to assess the advantages derived from utilizing a plant protection product at its recommended minimum effective dosage and to establish the product's usage conditions. In essence, efficacy evaluation aims to verify that the trial data supports the claims and usage recommendations stated on the product label, while delivering tangible benefits to the user. The evaluation of the bio-efficacy of a plant protection product is a requirement in the registration or authorization process in many countries. Companies seeking product registration must provide efficacy data related to the relevant crops or specific uses. The purpose of requesting efficacy data is to ensure that the registration authority prevents the introduction of ineffective plant protection products or those that pose harm to plants or plant products into the market. Insufficiently effective products carry the risk of users increasing dosage or application frequency, thereby increasing human and environmental exposure to potentially hazardous compounds. In addition, efficacy evaluation trials based on the EPPO Standards should be carried out by experts who master not only about the knowledge of pesticides tested, the target organisms, statistical procedures, among others (Perry, 1999).

In Indonesia, as stipulated in Minister of Agriculture Regulation (Peraturan Menteri Pertanian/Permentan) No. 43 of 2019 concerning Pesticide Registration, Article 55 states the following; Quality testing, toxicity testing, and/or efficacy trial as referred to in Article 54 shall be conducted by accredited testing institutions. In the absence of accredited trial institutions as mentioned in paragraph (1), testing can be conducted in testing institutions designated by the Minister. The trial institution designated by the Minister as mentioned in paragraph (3) shall be determined by Ministerial Decree.

As stated in Minister of Agriculture Decree No. 282/KPTS/SR.330/M/06/2023, which was issued on June 7, 2023, there are a total of 27 registered pesticide efficacy testing institutions in the Ministry of Agriculture. These institutions include research institutions, universities, and private companies.

2.2 Conceptual Framework

This research focuses on the problem faced by the R&D division at the XYZ Agrochemical Company in selecting the best vendor for bio-efficacy trials of pesticide products based on the available qualitative data.

In choosing a vendor for pesticide bio-efficacy trials, there are 4 criteria the most expected from the vendor qualifications, namely: (1) Technical Expertise of vendors; (2) Cost of trials; (3) Project Management executed by vendors; and (4) Reputation of the vendors, all with their own sub-criteria (Figure 2.2). These criteria were selected based on a long discussion with one of the Research and Development Manager at the XYZ Agrochemical Company. These criteria were have been used in selecting vendors but not in AHP methods. Whereas the sub-criteria were developed based on the criteria developed.

Criteria and Sub-criteria for Vendor Selection:

1. Technical Expertise:
   - Experience with similar trials
   - Scientific qualifications of personnel
   - Track record of successful trials
   - Expertise with relevant regulatory requirements
2. Cost:
   - Cost of conducting trials
   - Payment terms
   - Miscellaneous costs (e.g., additional services)
3. Project Management:
   - Proven track record of meeting deadlines
   - Effective communication and collaboration
   - Ability to handle unforeseen issues
   - Risk management capabilities
4. Reputation:
   - Industry reputation
   - Client satisfaction
   - Regulatory compliance history

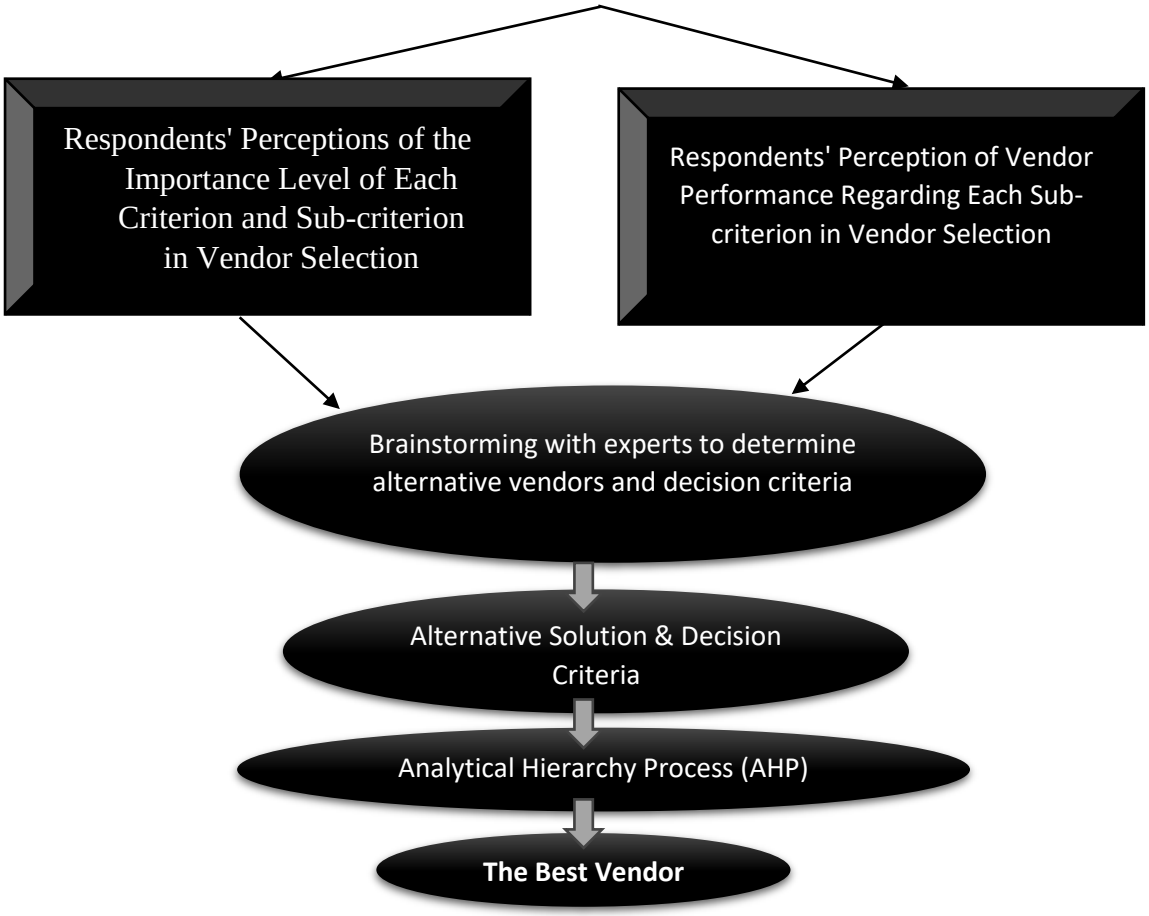

Figure 2. Conceptual Framework

3. Research Methodology

3.1 Research Design

The aim of this study is to identify the best vendor for conducting bio-efficacy trials within the XYZ Agrochemical Company. The approach employed in this research involves the utilization of the Analyticalal Hierarchy Process (AHP), a methodology that amalgamates psychological and mathematical principles. By integrating AHP, the decision-making process can be facilitated through the consideration of multiple criteria or parameters, thereby incorporating both qualitative and quantitative data. Through the quantification of qualitative data, alternatives can be effectively ranked, simplifying the decision-making process (Brunelli, 2014; Mu & Pereyra-Rojas, 2017).

The diagram below delineates the flow of the research:

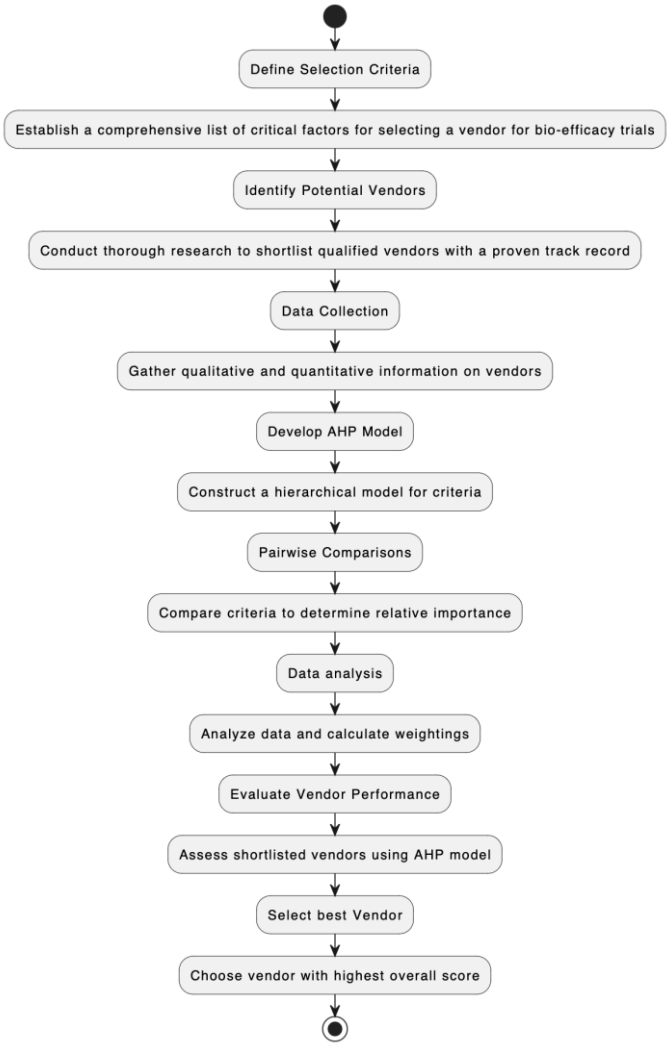

Figure 3. Workflow of the AHP implementation
Source: Author (2024)

3.2. Data Collection

This sub-chapter delves into the data collection methodologies employed to identify the optimal vendor for the bio-efficacy trial using the Analytical Hierarchy Process (AHP). AHP is a structured multi-criteria decision-making tool that facilitates the evaluation of complex choices by systematically decomposing them into hierarchical components. In the context of this research, it will be used to assess potential vendors based on a set of predetermined criteria and sub-criteria, ultimately enabling the selection of the vendor that best aligns with the project's requirements and priorities.

3.2.1 Interviews

Internal interviews were conducted with the R&D leader to gain a comprehensive understanding of the key considerations and challenges associated with vendor selection for the bio-efficacy trial. The insights gleaned from these interviews were instrumental in refining the defined criteria and sub-criteria for vendor evaluation. Following the finalization of the evaluation framework, participants completed an assessment form that included pairwise comparisons within the matrix.

3.2.2 Digital Survey

To ensure all participants possessed a common understanding of the evaluation framework, a digital survey was distributed to relevant stakeholders via a dedicated BPMSG link. The survey commenced with clear and concise definitions for each criterion and sub-criterion, ensuring all participants were on the same page when making their comparisons. The core objective of the survey was to gather data on

the relative importance of these criteria and sub-criteria through pairwise comparisons. This method involved presenting participants with two criteria or sub-criteria at a time and asking them to judge which one held greater significance for selecting the most suitable vendor for the bio-efficacy trial. Their responses were recorded in a pairwise comparison matrix, which would subsequently be used to calculate the weights assigned to each criterion and sub-criterion within the AHP framework. In figure 4. Show digital survey of criteria comparison.

3.2.2.1 Criteria comparison

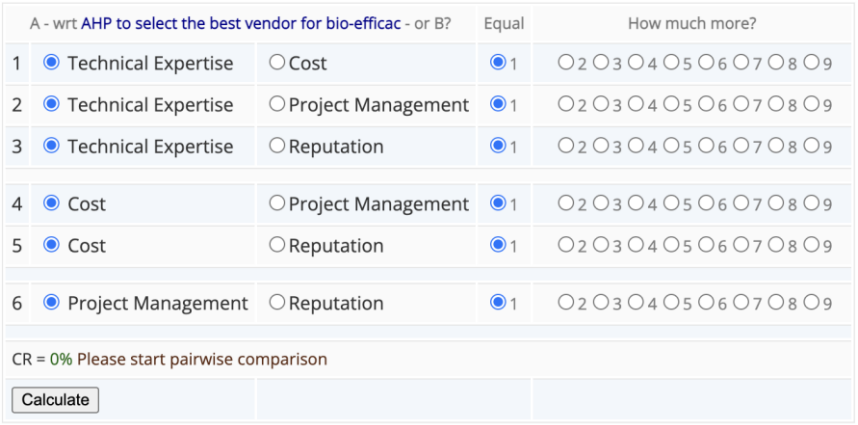

Figure 4. Digital Survey for criteria comparison
Source: Data analiyze (2024)

3.2.2.2 Technical Expertise Sub-Criteria Comparison

Figure 5. Digital Survey for Technical Expertise Sub-Criteria
Source: Data analiyze (2024)

3.2.2.3 Cost Sub-Criteria Comparison

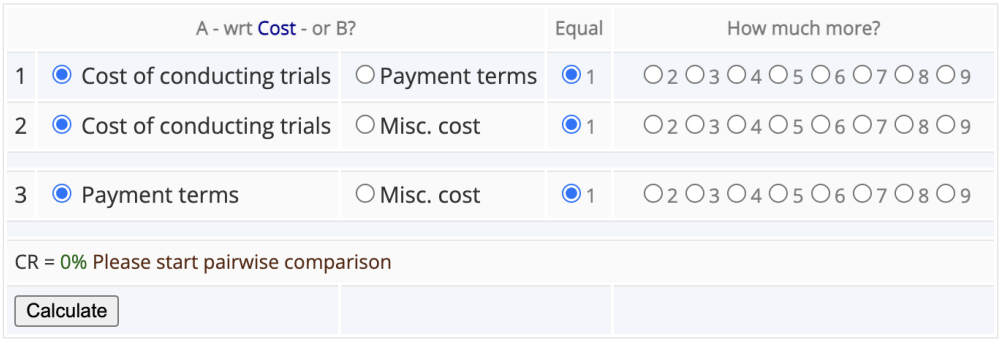

Figure 6. Digital Survey for Cost Sub-Criteria
Source: Data analiyze (2024)

3.2.2.4 Project Management Sub-Criteria Comparison

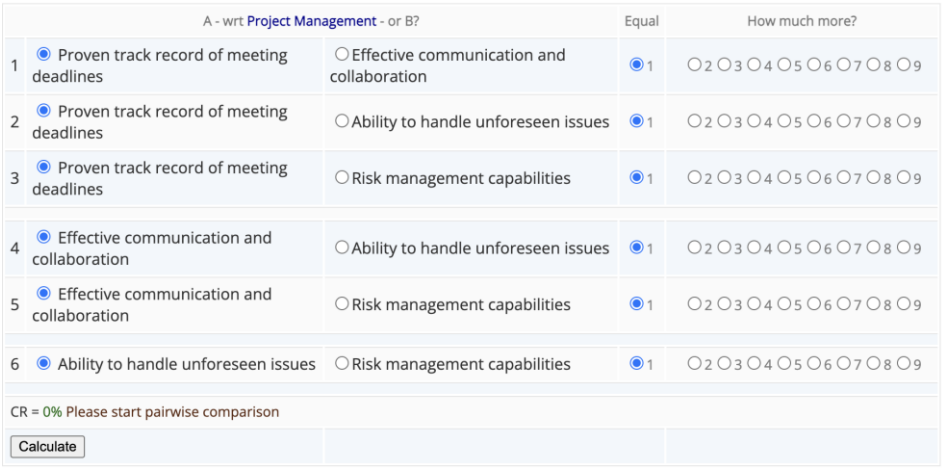

Figure 7. Digital Survey for Project Management Sub-Criteria
Source: Data analiyze (2024)

3.2.2.5 Reputation Sub-Criteria Comparison

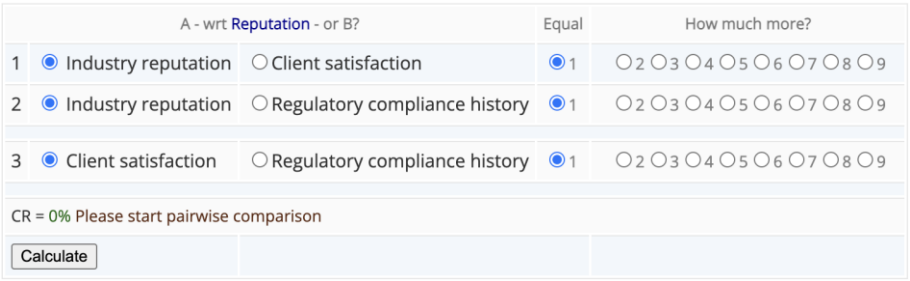

Figure 8. Digital Survey for Reputation Sub-Criteria
Source: Data analiyze (2024)

3.2.3. Respondent Profile

This study utilized a mixed-methods approach, surveying internal R&D staff from the XYZ Agrochemical Company (Technical Supervisor, Disease Control, SAT, and Weeds Control). These respondents were carefully selected based on experience in the pesticide industry, relevant expertise, and decision-making authority to ensure a comprehensive understanding of bio-efficacy trials perceptions and practices from various stakeholders. The detailed profile of each respondent is outlined below.

Table 1. Details of the respondents

Respondent Initial	Role	Job Description	Reason

ABW	R&D Leader (Technical supervisor)	Supervises a basic unit of research, technical, or information professionals/scientists, monitoring and evaluating progress and results, and determining necessary improvements or changes to achieve goals. Manages research and development in a core technology area and evaluates fundamental scientific and technical knowledge within that field. Additionally, responsible for overseeing group safety efforts.	His expertise is ideal for defining criteria and sub-criteria due to his in-depth knowledge of trial requirements, understanding of the XYZ Agrochemical Company's specific needs, and experience in evaluating vendors. His decision-making authority and alignment with industry standards ensure that the criteria are practical, relevant, and meet regulatory requirements, ultimately contributing to the company's success in the product registration process, particularly for bio-efficacy trial requirements
IR	Field Scientist for Disease Control	Bridging technical expertise with commercial success, this role provides field testing and technical product support to sales and marketing. It involves collecting, summarizing, and communicating data and recommendations to ensure regulatory compliance and empower the sales team and customers with product knowledge. Training program development, project plan creation aligned with technical and business goals, and data package contribution for specific products and markets may also be included. Additionally, collaboration with internal and external partners supports product label development, regulatory processes, and bio-efficacy trials for product registration requirements.	They have direct experience as executors and technical knowledge in their field of bio-efficacy trial, understand operational and logistical requirements, and ensure quality and compliance with regulatory standards and company needs. They also liaise directly with vendor collaborators to ensure bio-efficacy trials are conducted according to protocols approved by the Ministry of Agriculture and adhere to the detailed criteria outlined in the agreements between the company and vendor institutions.
WW	Field Scientist for Seed Applied Technology		
RR	Field Scientist for Weeds Control and Technical Educator		

Source: Data research (2024)

3.3 Data analysis method

This section details the data analysis method employed in this research. The Analyticalal Hierarchy Process (AHP) is utilized, which integrates both qualitative and quantitative data analysis techniques. Qualitative data, in the form of selection criteria and sub-criteria, forms the foundation of the AHP model. These criteria and sub-criteria are then evaluated qualitatively to determine their relative importance (weights). These weights play a crucial role in comparing different alternatives, represented by the projects under consideration for prioritization.

Following data collection, the obtained qualitative data undergoes processing and calculation using specialized software like BPMSG (Business Performance Management Singapore). This process focuses on deriving the weights of the criteria and sub-criteria, as well as determining the local priorities for each alternative. Local priorities represent the relative preference of each alternative based solely on a specific criterion or sub-criterion.

4. Results and Discussions

4.1. Analysis

This section details the data analysis process employed in this research. The data collection leverages BPMSG (Geopel, 2018), a user-friendly online platform built on the Analyticalal Hierarchy Process (AHP) framework. BPMSG facilitates not only the distribution of questionnaires but also the subsequent data processing, offering several key functionalities crucial for AHP analysis. One of its strengths lies in enabling multi-participant input, allowing researchers to incorporate diverse perspectives from experts or stakeholders with varied knowledge and experience. This is particularly valuable for AHP, which often relies on subjective judgments about the relative importance of criteria impacting decision-making.

Furthermore, BPMSG manages weight and consensus effectively. Participants utilize the platform to express their judgments about the relative importance of each criterion and sub-criterion using a predefined scale. The tool then calculates a consensus ratio to evaluate the consistency of these judgments among participants. This ensures the reliability of the collected data and identifies potential outliers or areas where additional discussion or clarification of criteria might be necessary. Another crucial feature is the automatic calculation of consistency ratios. As AHP relies heavily on consistent judgments, BPMSG analyses each participant's input and provides a consistent ratio. This metric helps identify inconsistencies, ensuring data validity for further analysis. A high consistency ratio (typically above 0.1) indicates reliable judgments, while a low ratio suggests potential inconsistencies that might require revisiting the data or clarifying the criteria for participants.

i. Weight Analysis of Criteria

Following the pairwise comparison of all criteria using the AHP online system, the calculated weights for each criterion are presented in the table below. These weights represent the relative importance of each criterion in the decision-making process. The survey results on the Table 2, showed that respondents place the technical proficiency criterion as the main criterion in selecting a vendor for pesticide efficacy trials, followed by project management, and cost, while the reputation criterion ranks the lowest.

Given its top rank and substantial weight, technical expertise is evidently the most valued criterion. Ensuring that the chosen option excels in technical expertise will likely have the greatest impact on the overall success. Meanwhile, strong project management is also highly valued. Efficient and effective project management practices are crucial for the smooth execution and timely completion of the project. The respondents consider that cost of pesticide efficacy trials has a lower weight compared to technical expertise and project management but still holds some importance. While cost is a factor, it is less critical than technical expertise and project management. Decisions should not overly compromise on quality or project management efficiency just to minimize costs.

Table 2. Weight of Criteria Result

Criteria	Weight	Rank
Technical Expertise	42.3%	1
Cost	19.6%	3
Project Management	21.8%	2
Reputation	16.3%	4

CR	5.0%
AHP Consensus	70.5%

Source: Data analiyze (2024)

The least weighted criterion is the reputation of the vendors. Apparently, reputation, although important, is considered the least critical among the criteria. However, it should not be entirely disregarded as it can provide insights into the reliability and past performance of the options considered. In summary, for optimal results of pesticide efficacy trials, the respondents of the XYZ Agrochemical Company consider that the vendors should excel in technical expertise and have strong project management practices, even if it comes at a higher cost or if the reputation is slightly lower.

The reasons behind the prioritization of criteria likely reflect the company's strategic priorities and the nature of pesticide efficacy trials, such as: (1) Pesticide efficacy trials require precise and accurate scientific measurements to determine the effectiveness of pesticides. Vendors with high technical expertise are more likely to provide reliable and accurate results; (2) High technical expertise ensures compliance with regulatory standards and protocols, which is crucial for the approval and marketability of pesticides, and (3) Advanced technical skills enable vendors to handle complex issues that may arise during trials and to innovate in trial methodologies, which can lead to better and more insightful results. The results of this survey revealed that Project Management is ranked secondly (21.8%). The reasons for this may be due to the consideration by the respondents that: (1) a pesticide efficacy trial should meet the completion timely. Effective project management of the vendors ensures that trials are conducted within the stipulated timelines, which is critical for timely product development and market entry; and (2) Efficient project management of the vendors helps in the optimal allocation of resources (time, personnel, equipment), which is crucial for conducting high-quality trials.

Therefore, it can be concluded that for the XYZ Agrochemical Company focusing on technical expertise and project management, the company is likely aiming to achieve: (1) Accurate and reliable trial results; (2) Compliance with regulatory standards; (3) Efficient and timely completion of trials; and (4) Optimal resource utilization.

4.1.2 Weight Analysis of Sub-Criteria (Technical Expertise)

The result of the survey (Table 4.2.) showed that of the technical expertise criteria, the respondents placed track record of successful trials by vendor as the highest priority.

Table 3. Weight of Technical Expertise Sub-Criteria

Criteria	**Weight**	**Rank**
Experience with similar trials	19.5%	3
Scientific qualifications of personnel	13.2%	4
Track record of successful	30.0%	2
Expertise with relevant regulatory requirements	37.3%	1
CR	3.6%	
AHP Consensus	90.1%	

Source: Data analiyze (2024)

Pesticide efficacy trials is highly regulated by the government, which issue a protocol based on the highly regulated standard, both in experimental design, statistical procedures, and biological considerations of the target organisms to be treated by the pesticide tested. Compliance by the vendors

to this regulation is an obligation. Ensuring that trials meet all regulatory requirements is crucial for the approval and marketability of pesticides. Vendors with high expertise in this area are more likely to navigate the regulatory landscape effectively, avoiding potential legal and compliance issues. Vendors that are expert in meeting the regulatory requirements can prevent delays in the approval process, ensuring that the product reaches the market in a timely manner.

The second rank sub criteria of technical expertise (weights 30.0%) based on this survey is Track Record of Successful Trials. The respondents consider that a strong track record indicates that the vendor has consistently delivered successful outcomes in past trials, which increases confidence in their ability to produce reliable results. By choosing vendors with a proven track record reduces the risk of trial failures or issues (risk mitigation), as past performance is often indicative of future success.

The third rank sub-criteria of technical expertise (weights 19.5%) based on this survey is Experience with Similar Trials. The reasons for this may be due to: (1) Relevant Experience. Vendors with specific experience in similar trials are likely to understand the unique challenges and requirements, leading to more efficient and effective trial execution; and (2) Specialized Knowledge. Experience with similar trials suggests that the vendor possesses specialized knowledge that can be critical for the success of the current trials.

The last sub-criteria selected by the respondents of technical expertise is the Scientific Qualifications of Personnel (13.2%). The reasons behind this may be due to assumption that highly qualified personnel ensure that the trials are conducted with scientific rigor and integrity, producing reliable and credible results, and well-qualified personnel are likely to bring innovative approaches and deep expertise to the trials, enhancing the overall quality of the outcomes.

In summary, the most critical factor in the decision-making process is Expertise with Relevant Regulatory Requirements, followed by the Track Record of Successful Trials. These two criteria should be the primary focus. While Experience with Similar Trials and Scientific Qualifications of Personnel are also important, but they are secondary to ensuring regulatory compliance and a proven track record. Regulatory Expertise ensures compliance with regulatory standards, as failure to meet these standards can result in delays, additional costs, or outright rejection of the product. Expertise in this area is vital for smooth and timely approval processes. A strong track record of successful trials provides assurance that the vendor can deliver reliable and effective results, which is crucial for the credibility and success of the pesticide efficacy trials. Experience with similar trials is important because it indicates that the vendor understands the specific requirements and challenges, leading to more effective and efficient trial execution. While the scientific qualifications of personnel are essential, they are considered slightly less critical than regulatory expertise and a proven track record. This criterion ensures that the trials are conducted with high scientific standards. This approach underscores the company's focus on regulatory compliance and proven success, which are essential for the successful approval and market entry of their pesticide products.

Table 4. Weight of Cost Sub-Criteria

Criteria	Weight	Rank
Cost of conducting trials	45.7%	1
Payment terms	32.4%	2
Misc. Cost	21.9%	3
CR	0.3%	
AHP Consensus	81.2%	

Source: Data analiyze (2024)

The results of the survey on respondents at the XYZ Pesticide Company in regard to the Cost Subcriteria (Table 4.3.) found that the cost of testing trials ranked firstly (45.7%), followed by Payment terms (32.4%) and Miscellaneous Cost (21.9%). The cost subcriterion for the implementation of the bio-efficacy trial is an important criterion. This is a concern for respondents from XYZ Agrochemical Company because the amount of costs is part of the company's budget arrangement. Regarding the cost of bio-efficacy trials, there is no standard because it is very determined, among others, by the type of plant (seeds and seedlings), and the location of the experiment.

Meanwhile, favorable payment terms are crucial for managing cash flow and financial planning. By prioritizing this criterion, the company aims to negotiate terms that allow for better financial stability and flexibility.

Project Management Sub-Criteria

Table 5. Weight of Project Management Sub-Criteria

Criteria	Weight	Rank
Proven track record of meeting deadlines	26.8%	2
Effective communication and collaboration	31.3%	1
Ability to handle unforeseen issues	20.8%	4
Risk management capabilities	21.1%	3
CR	0.7%	
AHP Consensus	93.8%	

Source: Data analiyze (2024)

The high weight assigned to the cost of conducting trials suggests that the company is heavily focused on minimizing the primary expenses associated with conducting the trials (Tabel 4.4.). This approach helps in maintaining financial discipline and ensuring that the projects remain within budget. Meanwhile, favorable payment terms are crucial for managing cash flow and financial planning. By prioritizing this criterion, the company aims to negotiate terms that allow for better financial stability and flexibility.

In relation to the Project Management sub-criteria, these four factors have an important role in the successful implementation of bio-efficacy trials. Respondents had a high level of agreement in giving their answers (93.8%). The reason is allegedly based on the consideration that: Meeting deadlines is essential for the timely completion of trials, which can impact the company's competitive edge and profitability. A vendor with a proven track record ensures that the trial will be completed on schedule, minimizing delays and potential losses. Effective communication and collaboration are vital for the smooth conduct of trials. A vendor that can communicate effectively and collaborate well with the company's team ensures that all aspects of the trial are managed efficiently, reducing the risk of misunderstandings and errors. Unforeseen issues can arise during trials, and a vendor that can handle them effectively ensures that the trial remains on track. This capability is critical for maintaining the integrity of the trial and minimizing potential losses. Risk management is essential for ensuring the success of trials. A vendor with robust risk management capabilities can identify and mitigate potential risks, reducing the likelihood of trial failures and ensuring compliance with regulatory requirements.

In summary, the XYZ Agrochemical Company prioritizes these factors to ensure that the vendor selected for bio-efficacy trials has a proven track record of meeting deadlines, effective communication and collaboration, the ability to handle unforeseen issues, and robust risk management capabilities. These factors are critical for the success of trials and the company's overall competitiveness in the market.

Table 6. Weight of Reputation Sub-Criteria

Criteria	Weight	Rank
Industry reputation	23.2%	3
Client satisfaction	24.6%	2
Regulatory compliance history	52.2%	1
CR	0.3%	
AHP Consensus	83.6%	

Source: Data analiyze (2024)

Based on the data in Table 4.5., the XYZ Agrochemical Company gave an assessment of the Vendor Reputation sub-criteria, that Regulatory Compliance History is the most important (52.2%) followed by Client Satisfaction (24.6%) and finally Industry Reputation (23.2%). Industry reputation here is the reputation of the vendors.

Thus, for the XYZ Agrochemical Company, regulatory compliance is essential for the success of bio-efficacy trials. A vendor with a strong regulatory compliance history is likely to have the necessary expertise and experience to ensure compliance with relevant regulations and guidelines, which is critical for the approval and marketing of pesticides.

4.1.3 Deriving Local Priorities for Alternatives

To assess and evaluate the available options or alternatives, the weighted sum method is utilized. Local priorities for each alternative are determined, leading to the calculation of global priorities. The resulting global priorities are presented in the table below. A higher value in the group result indicates a higher priority for the selected vendor.

Based on the results of the survey (Table 4.6 and Fig. 4.1.) it is known that when tested to determine the best vendor order against four vendors who have been vendors in the bio-efficacy trials of The XYZ Agrochemical Company, the use of the AHP method succeeded in obtaining the best vendor order based on the criteria and subcriteria used. The Vendor D was the best vendor, followed by the Vendor A, B, and C as the least competence. The results prove that the quality of vendors is not uniform. This is proven by combining various criteria and subcriteria, the most competent vendors in various aspects will be obtained.

Table 7. Local Priorities of Alternatives

Criteria	Sub-Criteria	Alternatives Vendor				
		Glb Prio.	Vendor A	Vendor B	Vendor C	Vendor D
Technical Expertise	Experience with similar trials	8.2%	27.7%	19.5%	14.7%	38.1%
	Scientific qualifications of personnel	5.6%	29.2%	15.7%	12.5%	42.7%
	Track record of successful trials	12.7%	33.3%	17.6%	13.8%	35.2%
	Expertise with relevant regulatory requirement	15.8%	33.9%	17.3%	11.8%	37.0%
Cost	Cost of conducting trials	9.0%	25.0%	24.7%	13.3%	36.9%
	Payment terms	6.3%	35.1%	23.9%	14.8%	26.2%
	Miscellanous Cost	4.3%	35.8%	24.1%	14.5%	25.6%
Project Management	Proven track record of meeting deadlines	5.8%	40.7%	17.4%	13.9%	27.9%
	Effective communication and collaboration	6.8%	31.3%	20.6%	13.7%	34.3%
	Ability to handle unforeseen issues	4.5%	33.2%	20.7%	15.7%	30.4%
	Risk management capabilities	4.6%	30.7%	15.5%	13.8%	40.0%
Reputation	Industry reputation	3.8%	30.0%	16.3%	11.5%	42.2%
	Client satisfaction	4.0%	32.1%	19.6%	13.0%	35.3%
	Regulatory compliance history	8.5%	30.3%	24.7%	17.7%	27.3%
		Group Result	31.9%	19.8%	13.8%	34.4%

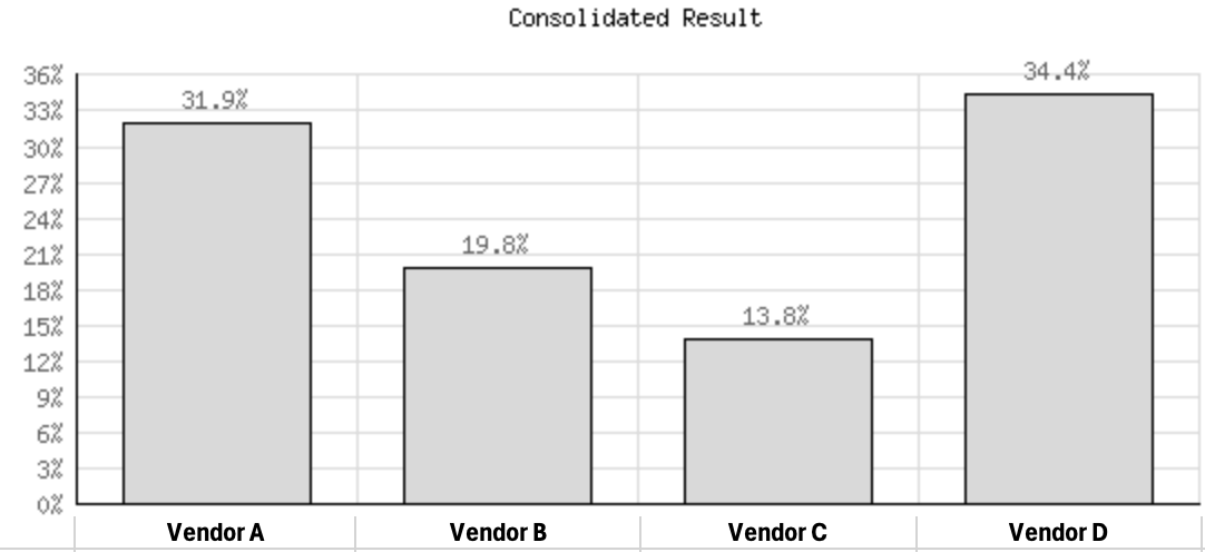

Figure 9. Consolidated result scores (%) of 4 vendors selected by the R&D respondents of the XYZ Agrochemical Company using AHP method

Potential Future Research Directions

The research findings reviewed in this literature provide valuable insights into the benefits of using AHP in selecting vendors by pesticide companies. Although the data obtained in this research is only based on the results of the opinions of respondents in the XYZ Agrochemical Company (see the limitation of this study), considering that the problems faced by all pesticide companies can be said to be similar, the use of AHP can provide a justification in choosing the best vendor for bio-efficacy trials. However, there are several knowledge gaps and potential future research directions that warrant further exploration. These include:

1. Investigating the adaptability of AHP in accommodating diverse sustainability criteria and evolving environmental regulations in vendor selection processes. - Exploring the integration of AHP with emerging technologies, such as artificial intelligence and machine learning, to enhance the efficiency and accuracy of vendor evaluation and selection.
2. Examining the application of AHP in addressing social and ethical considerations in vendor selection, particularly in the context of supply chain transparency and responsible sourcing practices.

Comprehensive literature review has demonstrated the significance of AHP in vendor selection processes and identified potential areas for future research to further enhance the applicability and effectiveness of the AHP method in addressing the complexities of modern supply chain management. AHP has been successfully implemented in selecting vendors of construction (Darko et al., 2019); tenders selection in public office buildings (Hsieh et al., 2004); electric vehicle selection (Guler & Yomralioglu, 2020); selection of future hospital sites (Sahin et al., 2019), and others.

4.1.4 Data Validation

Data analyzed in this study were valid as can be seen from values of AHP consensus and the consistency rate (CR). The CR of all criteria and sub-criteria presented in Tables 4.1. to 4.5. showed that the values range from 0.3% to 3.6%. These indicated that all respondents are consistent with their priorities about the criteria and the subcriteria. The value of AHP consensus were also high (ranged from 70.5% the lowest to 93.8% the highest), indicated that all of the respondents considering similar view regarding the priorities of the criteria and subcriteria being presented for selecting the best vendors for bio-efficacy trials.

4.2 Business Solution

According to the respondents from the XYZ Agrochemical Company, they have been using the criteria and sub criteria compiled in this AHP for many years in selecting vendors for bio-efficacy trials. However, in its implementation, it is still often biased, not comprehensive, and unstructured and does not go through consistent priority weighting as done through the AHP method.

With the use of AHP, the respondents from the XYZ Agrochemical Company's R&D proved to be successful in identifying vendors based on measurable competencies (Table 4.6. and Figure 4.1.) it can be a business solution for the project in selecting the best vendors that the XYZ Agrochemical Company has been facing so far.

4.3 Implementation Plan & Justification

Based on this findings, it can be proposed that the XYZ Agrochemical Company should implement the use of AHP method in selecting the best vendors for bio-efficacy trials in the near future. The adoption of AHP method will answer all discrepancies and doubts in choosing the best vendors for pesticide bio-efficacy trials.

The Agrochemical company XYZ will leverage the Analytic Hierarchy Process (AHP) to select a vendor for crucial bio-efficacy trials. These trials are mandated by the Indonesian Ministry of Agriculture for pesticide registration (new products, expanded uses, re-registration etc.) as outlined in Regulation Number 43 of 2019. Based on the AHP analysis result, Vendor D emerges as the top choice with following Vendor A for the R&D pilot team's upcoming collaborations on key projects involving new products and pipelines. This selection is particularly important due to the Ministry's stringent evaluation process for new product registrations. Furthermore, the highly anticipated new pipeline promises to empower farmers with solutions against crop pests, while minimizing the risk of resistance development.

Additionally, they will consider collaborating with the other two vendors (B and C) for projects aimed at maintaining the registration of existing products, such as re-registration and label expansion. This approach ensures that the company does not rely solely on the selected vendor but can also utilize alternative vendors. Moreover, they will continue to explore expanding partnerships with other vendors who are listed in the Ministry of Agriculture regulation.

5. Conclusion

Pesticides are products that are highly regulated by various regulations, from their manufacture to their trade and distribution. Pesticides have a beneficial impact because they can protect agricultural production, prevent pest and disease epidemics in plants, animals and humans, but they can also endanger life, because pesticides are basically poisons. Pesticides also have a certain active period, and certain target organisms as well. The use of pesticides must be in accordance with the rules, both dosage, concentration, and how to use them. Therefore, bio-efficacy trial is one of the requirements that must be met by pesticide companies before obtaining their distribution permits.

Therefore, bio-efficacy trial must be carried out precisely, carefully and in accordance with the testing protocol set by the Government c.q Pesticide Commission of the Ministry of Agriculture of the Republic of Indonesia. Bio-efficacy trial must be carried out by expert personnel of an institution is recognized as professional bio-efficacy testers according to the assessment of the Ministry of Agriculture of the Republic of Indonesia.

Agrochemical companies such as the XYZ Agrochemical Company, rely heavily on the results of bio-efficacy trials carried out by vendors. Selecting the best qualified vendors is one of the main tasks of agrochemical companies.

Based on the results of this study in answering the problems faced by the XYZ Agriochemical Company when selecting vendors for bio-efficacy trials, it can be concluded that the use of AHP method helps the R&D of the XYZ Agrochemical Company determine and agree upon the priority of criteria and sub-

criteria of best vendors of bio-efficacy trials. Exercising the use of AHP methods to 4 vendors has resulted in finding the best rank of vendors that meet the criteria and sub-criteria to which the R&D of the XYZ Agrochemical Company determined and agreed upon.

Limitations and Future Study

This study is limited by the relatively small sample size of only four vendors, which may not represent the full range of potential service providers in the market. Additionally, the criteria used were based solely on the internal consensus of the R&D team, which may not fully capture external stakeholder perspectives. Future studies should expand the sample size, include cross-functional evaluation teams, and explore the integration of other decision-making tools, such as fuzzy logic or machine learning, to further enhance vendor selection accuracy and robustness.

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