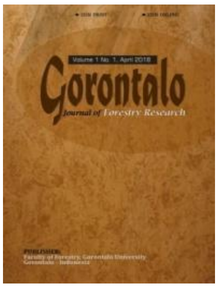

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UTILIZATION OF PINE FRUIT (Pinus mercusii) AS RAW MATERIAL FOR ENVIRONMENTALLY FRIENDLY BIOPESTICIDE FOR SPINACH PLANTS

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ABSTRACT

This study aims to determine the best formulation of pine fruit in making biopesticides by observing the number of bacteria, the number of fungi, the amount of potassium and the height of spinach plants, to find out the processing of pine waste in overcoming pest problems in spinach plants, especially the growth of spinach plants after being given biopesticides made from biopesticide solutions and pine fruit waste. Pine is a plant that functions as an ecological soil protector and wood producer, the content of compounds that have not been degraded can reduce the growth of the length of the sprout radicle, so pine has the potential as a biopesticide material to control the growth of pests that can interfere with plant growth. The study was an experimental study in RAL (Completely Randomized Design) with a 3 factorial pattern and 3 replications consisting of 4 treatments, namely the first factor (pine fruit fermentation K1 = 6 days, K2 = 12 days, K3 = 18 days), the second factor (biopesticide formulation L1 = 600 grams, L2 = 1800 grams, L3 = 3600 grams), and the third factor (application of spinach plants P0 = 0 ml / control, P1 = 250 ml, P2 = 500 ml, P3 = 750 ml). The study was analyzed by Duncan's advanced test. The parameters to be analyzed were the number of bacteria, the number of fungi, the amount of soil potassium, and plant height. The results of this study indicate that the heavier the pine fruit and the longer the fermentation used, the more significant the interaction of the treatments produced on spinach plants. The effect of interaction of pine fruit weight, fermentation time, and different doses of biopesticides applied to spinach plants resulted in the best treatment of 500 ml for the number of fungi and 750 ml for the number of bacteria, the amount of potassium, and the highest plant height, so that the results of the study are expected to be able to utilize pine fruit in everyday life into a product with economic value to ensure the fulfillment of food needs in supporting food security and independence programs.

Keywords: *Waste; Pine; Biopesticide; Friendly; Environmental.*

INTRODUCTION

One of the non-timber forest products is pine fruit. Pinus merkusii is a plant that serves multiple functions, including as an ecological soil protector and wood producer. The compounds found in undegraded pine leaves can hinder the growth of radicle length in seedlings. This suggests that the compounds in pine leaves have the potential to be used as biopesticides to control pests that may disrupt plant growth. Biopesticides are pesticides made from plant-based materials and serve as environmentally friendly pest control for plant-disturbing organisms, which aligns with research by Bayu (2021) indicating that biopesticides are made from natural ringredients that do not poison plants and do not pollute the environment. The continued use of natural extracts does not lead to pest resistance, making biopesticides a safe environmental choice for controlling Plant Disturbing Organisms (OPT).

So far, pest issues have frequently harmed crops, amounting to losses of billions of rupiah and reducing agricultural productivity by up to 20 percent. In response to this serious challenge, many Indonesian farmers excessively use chemical pesticides, which have negative impacts on the environment and human health. Natural balance is disrupted, leading to the emergence of resistant pests and threats to predators, parasites, fish, birds, and other wildlife. One reason for the negative environmental impact of pesticides is the presence of pesticide residues in the soil, which can poison non-target organisms and contaminate water sources and surrounding environments. The role of pine as a soil protector highlights its importance in soil and water conservation as well as maintaining forest ecosystem stability. This is supported by research from Markus (2023) that shows stands of pine are effective in reducing soil erosion and surface runoff. The forest floor covered by pine needle litter decomposes slowly, thereby protecting the soil surface from direct rainfall impact and surface flow.

Environmentally friendly pine will be mixed with amaranth (Amaranthus spp.) as it also contains various compounds that can be utilized as biopesticides. Some key compounds in amaranth that have the potential to control plant pests and diseases include saponins, alkaloids, flavonoids, tannins, terpenoids, and oxalic acid, making it suitable for use as an eco-friendly botanical biopesticide. Amaranth, often regarded as a weed, actually possesses potential as a base material for producing botanical pesticides. According to information from the Ministry of Agriculture (2023), compounds in amaranth can prevent yellow virus attacks on eggplant and chili plants. The method for creating botanical pesticides from amaranth involves preparing sufficient prickly amaranth plants, grinding them using a mortar or blender, straining the mixture to extract the juice, and the resulting liquid can be directly sprayed onto the plants in need.

Biopesticides are a type of pesticide made from plant materials. Plants are rich in active compounds that function as inducers, antifeeding attractants (deterrents), and lethal agents. The total production of botanical biopesticides exceeds 3,000 metric tons (MT) per year. Biopesticides control pests through non-toxic mechanisms, making them an alternative pest control method with low potential danger to humans and the environment. This aligns with research from Astusi (2019) stating that biopesticides play a role as a component in integrated pest and disease management. In Indonesia, biopesticides are still relatively unpopular, and knowledge about them is often confused with organic farming. In fact, biopesticide technology is already widely available, including plant-based pesticides made from extracts of various herbs or spices that are abundant, such as galangal, neem, and ginger. The effectiveness of biopesticides cannot reach 100%, making them better suited for preventive purposes.

Efforts can be made to utilize pine waste in the production of biopesticides, which can reduce the use of chemical pesticides and promote a shift toward various types of biological pesticides by applying them directly to amaranth, which also has environmentally friendly properties. Based on this, research on utilizing pine waste as a raw material for eco-friendly biopesticides will be easier to implement in communities, especially in agricultural and forestry practices in Indonesia.

LITERATURE REVIEW

Biopesticides

Based on their origin, biopesticides can be classified into two categories: plant-based pesticides and biological pesticides. Plant-based pesticides are the result of extracting specific parts of plants, whether from leaves, fruits, seeds, or roots, containing compounds or secondary metabolites that are toxic to certain pests and diseases. Generally, plant-based pesticides are used to control pests (insecticidal properties) and diseases (bactericidal properties). Biopesticides made from natural materials do not poison plants or pollute the environment. The continuous use of natural extracts is also believed to not cause resistance in pests, as is often the case with synthetic pesticides. Some types of plants capable of controlling pests include the Meliaceae family (neem, Aglaia) and the Anonaceae family (seeds of soursop, cherimoya, and other fruits). According to Novizan (2022), biopesticides are agents for controlling pests and plant diseases derived from natural materials, such as microorganisms, plant extracts, or specific minerals. The use of biopesticides is considered more environmentally friendly compared to synthetic chemical pesticides, as they tend to have lower toxicity and are more specific to target pests or pathogens. Balitbangtan (2019) reported that the use of insecticides is not the only effective way to combat pests. Biopesticides are a natural alternative that can be used, which are plant-based pesticides with natural active ingredients capable of acting as pest repellents. Biopesticides have various roles, such as repellents, attractants, antifertility, insecticides, and other forms. The application of biopesticides does not cause negative impacts on the environment and is more environmentally friendly than pesticides made from hazardous chemical compounds. Plant-based pesticides or biopesticides are formulated from plant materials. Based on these organic materials, the use of biopesticides can reduce environmental pollution and is more cost-effective because it does not use synthetic chemicals. One of the raw material sources for biopesticides is coconut shell, which has high lignin levels and low cellulose.

Research by Nia (2024) examined the impact of biopesticide technology application in controlling plant pests, as well as its implications for agricultural ecosystems, human health, and sustainable food production. The use of biopesticides has many advantages, including higher selectivity towards target pests, thus not disturbing important non-target organisms in the ecosystem, such as pollinating insects and soil microbes. Additionally, biopesticides have good biodegradability, leaving no harmful residues in the environment. Their application is also considered safer for consumers, as the agricultural products produced are free from toxic chemical residues. However, the application of biopesticides still faces several challenges, such as higher production costs compared to chemical pesticides, and their effectiveness can depend on specific environmental conditions.

Pinus (Pinus merkusii)

Pinus is a plant that can be used for reforestation, as it has several functions, including serving as an ecological soil protector and a wood producer. Additionally, pine has a high competitive ability against other nearby plants, allowing it to thrive. Pine trees have resin channels that can produce secondary metabolites with allelopathic properties. The allelochemicals in this resin belong to the terpenoid compound group, which includes the monoterpenes α-pinene and β-pinene. These compounds are known to be toxic to both insects and other plants. Moreover, these compounds are the primary ingredients in the production of turpentine. Monoterpenes (C-10) are among the most important plant oils, which also possess toxic properties (Rifaldy, 2019).

Research by Chayroel (2024) indicates that pine trees have significant benefits, both from their wood and non-wood products. Pine wood is used for various purposes, such as lightweight construction, furniture, pulp, matches, chopsticks, and can be processed into charcoal briquettes. Non-wood products include resin that produces valuable goods like gum rosin and turpentine. Turpentine oil, which contains terpene compounds, is commonly used as a solvent for thinning oil paints, a mix for varnish, floor fragrance, disinfectants, and as a raw material for perfumes, oils, aromatherapy massage oils, and as an additive in making chewing gum to make it chewy and flexible.

Several ecological studies in areas with pine tree growth have shown a lack of herbaceous plant growth, presumably due to the leaf litter from pine trees releasing allelopathic substances that inhibit herb growth. This is supported by research on the ability of undecomposed pine leaves to reduce the growth of radicle length in mustard seedlings. This indicates that the compounds found in Pinus merkusii leaves have the potential to serve as bioherbicides to control weed growth that can interfere with food crop production, such as rice. One of the weeds that disrupt rice plant growth is E. colonum and A. viridis (Suluh et al., 2023).

Various studies related to pine forests generally outline the benefits and roles of pine resin in improving community welfare (Suwaji et al., 2022). Additionally, there is research discussing the role of pine forests in carbon absorption and techniques for tapping pine resin.

Spinach Plant

Spinach (Amaranthus spp. L.) has around 60 species, each with a very wide distribution area because it can thrive in diverse ecosystems. From a layman's perspective, spinach is a simple commodity, meaning it is easy to obtain at any time at a low price, and its processing for food is straightforward. The spinach plant can survive in various habitats and can produce a large number of seeds. Spinach seeds tend to drop easily, and many of its members can act as weeds, competing with main cultivated plants or growing in vacant lands. One type of spinach, A. spinosus Linn., has thorns and can be a very annoying weed for farmers. On the other hand, spinach has comparative advantages, such as being able to grow vigorously and quickly in marginal ecosystems, and its leaves and seeds have very high nutritional value. Many varieties have the potential to be developed as ornamental plants, medicinal herbs, natural dyes, sources of fibrous materials for livestock feed, and organic soil enhancers (Kristiyani, 2021).

Widianto (2020) states that although Indonesia can achieve food self-sufficiency in quantity, the quality of food consumed by most of the population is still relatively low. The health status of much of the Indonesian population still needs continuous improvement to enhance the quality of human resources in facing globalization. Malnutrition, both in the form of vitamin and mineral deficiencies, still occurs, particularly among low-income populations. Vegetables, including spinach, are a source of vitamins and minerals that can be produced cheaply and in unlimited quantities, with a continuous supply. These vegetables also contain fiber, which is very useful for aiding the digestive process in the stomach, helping to prevent gastrointestinal diseases, particularly stomach cancer.

The nutritional advantages of spinach as a vegetable mainly lie in its content of vitamin A (beta-carotene), vitamin C; riboflavin, and amino acids thiamine and niacin. The most important minerals found in spinach are calcium and iron, the latter being essential for addressing anemia. Additionally, spinach is rich in other minerals like zinc, magnesium, phosphorus, and potassium. The protein content in spinach proves to be superior compared to water spinach, especially when it comes to easily digestible protein composition. The carbohydrate content in spinach is quite high, mainly in the form of indigestible cellulose fiber. This indigestible fiber plays a crucial role in aiding the digestive process in the stomach, helping to prevent all forms of stomach disturbances, especially stomach and intestinal cancer (Rahmani, 2022).

RESEARCH METHODOLOGY

Time and Location

This research will be conducted from March to December 2024 in Majene Regency, West Sulawesi Province (2°57′0″ S, 119°6′0″ E) for the application of spinach. The Forest Product Utilization and Processing Laboratory at the Faculty of Forestry, Universitas Hasanuddin (5°8'30" S, 119°29'47" E) will focus on pine fruit processing from September to October. The Soil Fertility Laboratory at the Faculty of Agriculture, Universitas Hasanuddin will conduct potassium soil analysis from October to November. The Karst Microbial Research Collaboration Center will perform analyses of fungi and bacteria from October to November, and sampling will take place from July to September in Sasakan Village, Sumarorong District, Mamasa Regency, West Sulawesi Province (2°55′0″ S, 119°24′0″ E).

Tools and Materials

The tools used will include a blender, Erlenmeyer flask, shaker, measuring flask, sieve, balance, stirrer, stationery, and bucket. The materials required are pine fruit, acetone solution, filter paper, label paper, polybags, clean water, and spinach plants.

Data Collection Technique

This study is an experimental research using a Completely Randomized Design (RAL) with a 3-factorial pattern and 3 replications, consisting of 4 treatments:

1. The first factor is the fermentation of pine fruit:
   a. K1 = 6 days
   b. K2 = 12 days
   c. K3 = 18 days
2. The second factor is the biopesticide formulation:
   a. L1 = 600 grams
   b. L2 = 1800 grams
   c. L3 = 3600 grams
3. The third factor is the application of spinach plants:
   a. P0 = 0 ml (Control)
   b. P1 = 250 ml
   c. P2 = 500 ml
   d. P3 = 750 ml

Data Analysis

This research will be analyzed using Duncan's advanced test. The parameters to be analyzed include the number of bacteria, number of fungi, soil potassium content, and plant height. The biopesticide will be applied to the spinach plants by soaking the spinach seeds in warm water for 15-20 minutes. Next, fill 8 polybags measuring 25 cm in height and 20 cm in diameter with soil, making a 1 cm deep hole. Plant 3 spinach seeds in each polybag (1 seed per hole), cover with soil, and water until moist. After one week, fertilization, maintenance, and weeding will be carried out. Observations will be made on plant height (cm), number of leaves (sheets), and root length (cm). Harvest will be conducted simultaneously for all plants at four weeks after planting by uprooting the entire plant down to the roots.

RESULTS AND DISCUSSION

Biopesticides are a type of pesticide made from plant-based materials that can control pests through non-toxic mechanisms due to their low potential danger to humans and the environment. Pine waste can be used as a raw material for producing biopesticides, which can reduce the use of chemical pesticides and shift towards types of biological pesticides. The amount of raw materials (plants) and the duration of fermentation are significantly influential in the production of biopesticides (Hidayat, 2021). In addition, the dosage of biopesticides also affects their application.

Bacterial Count

The results of the Duncan test in Table 4 show that the bacterial count with a fermentation period of 6 days and a biopesticide dosage of 250 ml exhibits the lowest bacterial count (155 grams) and is significantly different. In contrast, the bacterial count with a fermentation period of 18 days and a biopesticide dosage of 750 ml shows the highest bacterial count (22000 grams).

Table 4. Average number of bacteria (grams) with different biopesticide doses and fermentation durations.

Treatment	Biopesticide Dose			
	0 ml (P_0)	**250 ml (P_1)**	**500 ml (P_2)**	**750 ml (P_3)**
L1K1	500^{d}	6000^{s}	3400^{o}	1450^{j}
L1K2	155^{a}	7500^{u}	4400^{q}	350^{b}
L1K3	1395^{i}	7000^{t}	2500^{m}	10700^{w}
L2K1	580^{d}	185^{a}	4500^{q}	4950^{r}
L2K2	900^{g}	1955^{l}	4050^{p}	1550^{k}
L2K3	300^{b}	435^{c}	4800^{r}	3000^{n}
L3K1	8350^{v}	735^{e}	850^{f}	13400^{x}
L3K2	1550^{k}	900^{g}	1150^{h}	16000^{y}
L3K3	3000^{n}	700^{e}	1110^{h}	22000^{z}

Note: Numbers followed by the same letter in the same column indicate no significant difference at the 5% Duncan test level.

As the weight of the pine fruit and the duration of fermentation increase, the number of bacterial colonies produced also increases. This is due to the ongoing fermentation process that causes bacterial colonies to reach stationary phase (Azhari, 2021).

The best biopesticide dosage is 750 ml. This is because an excessive amount of ethanol solution applied to the plants leads to an incomplete decomposition process of the pine and ethanol solution, resulting in poor bacterial development. According to Yaman (2021), biopesticides made from pine will have antimicrobial or antibacterial effects from the active compounds present in pine, especially its resin and essential oil. Pine resin extracts, essential oils, or specific active compounds (such as pinene, limonene, or camphene) have been tested against various types of bacteria, both pathogen and neutral to plants. After incubation, the bacterial colonies are counted to observe the effect of biopesticide exposure on the reduction of colony numbers. Research according to [7] tested biopesticides against plant pathogenic bacteria such as Pseudomonas syringae, Xanthomonas campestris, or Erwinia amylovora. Pine demonstrated significant antibacterial activity, primarily due to terpenoid content such as α-pinene and β-pinene, which can inhibit bacterial growth.

Number of Fungi

The results of the Duncan test in Table 5 show that the amount of potassium with the treatment of fermentation duration of 18 days and a biopesticide dose of 500 ml shows the highest number of fungi, which is 500 grams, and is significantly different.

Table 5. Average number of fungi (grams) with different biopesticide doses and fermentation durations.

Treatment	**Biopesticide Dose**			
	0 ml (P_0)	**250 ml (P_1)**	**500 ml (P_2)**	**750 ml (P_3)**
L1K1	0[a]	2[a]	0,5[a]	2,5[a]
L1K2	0[a]	5[a]	5[a]	15[ab]
L1K3	0[a]	0[a]	0[a]	100[d]
L2K1	1[a]	3[a]	6[a]	7[a]
L2K2	5[a]	15[ab]	145[e]	55[c]
L2K3	0[a]	250[f]	350[g]	100[d]
L3K1	1[a]	0,5[a]	2,5[a]	12[ab]
L3K2	0[a]	25[b]	110[d]	145[e]
L3K3	0[a]	50[c]	500[i]	450[h]

Note: Numbers followed by the same letter in the same column indicate no significant difference at the 5% Duncan test level.

According to Kusnendar (2020), the heavier the pine fruit and the longer the fermentation, the greater the number of fungal colonies produced. This is due to the fact that pine trees often have a symbiotic relationship with certain types of fungi, especially those that form mycorrhiza (for example, fungi from the genera Rhizopogon or Suillus). Mycorrhizae help the roots of pine trees in nutrient absorption, particularly phosphorus and nitrogen, from the soil. Fungi thrive better in environments with organic substrates such as pine leaf litter, which contains organic compounds that support fungal growth. However, the number of fungal colonies is also influenced by environmental factors such as humidity, soil pH, and nutrient content.

The best biopesticide dose is 500 ml. This is because ethanol solution is often used as a disinfectant or as an agent to inhibit microbial growth, including fungi. At certain concentrations, ethanol can kill or inhibit the development of fungal colonies. If the ethanol solution is used at low concentrations, the effect may not be significant, but at high concentrations, ethanol can significantly reduce the number of fungal colonies by damaging the cell membrane or causing dehydration of fungal cells (Nugroho, 2022).

Potassium (K)

The results of the Duncan test in Table 6 show that the amount of potassium with the treatment of fermentation duration of 6 days and a biopesticide dose of 500 ml shows the lowest amount of potassium (0.26%) and is significantly different. Meanwhile, the amount of potassium with the treatment of fermentation duration of 18 days and a biopesticide dose of 750 ml shows the highest amount of potassium (0.84%).

According to Yuliani (2023), the heavier the pine fruit and the longer the fermentation, the higher the amount of potassium produced. This is because the fermentation time of the biopesticide from pine extract for use on plants like spinach usually takes about 7 to 14 days. This fermentation period allows the microorganisms in the solution to decompose the organic materials from the pine and produce active compounds that function as pesticides. Based on the average results, the highest potassium test was found in the treatment with a fermentation period of 18 days. This is suspected to be influenced by several factors, including the type of microorganisms involved in fermentation (bacteria, fungi) that can affect the process speed. According to one source, the factors affecting fermentation duration include the optimal temperature ranging from 25°C to 35°C; suitable pH for microorganism growth; the types of microorganisms including bacteria, fungi, or yeast used in fermentation; and the availability of sufficient nutrients for microorganisms to thrive.

Table 6. Average percentage of soil potassium (%) with different biopesticide doses and fermentation durations.

Treatment	**Biopesticide Dose**			
	0 ml (P_0)	**250 ml (P_1)**	**500 ml (P_2)**	**750 ml (P_3)**
L1K1	0,38[cd]	0,35[b]	0,26[a]	0,27[a]
L1K2	0,35[b]	0,36[bc]	0,41[ef]	0,33[b]
L1K3	0,55[k]	0,51[ij]	0,42[f]	0,39[de]
L2K1	0,39[d]	0,41[ef]	0,48[gh]	0,46[g]
L2K2	0,50[hij]	0,51[ij]	0,52[j]	0,49[hi]
L2K3	0,60[lm]	0,57[kl]	0,68[o]	0,63[n]
L3K1	0,41[ef]	0,43[f]	0,52[j]	0,49[hi]
L3K2	0,67[o]	0,64[n]	0,58[kl]	0,61[mn]
L3K3	0,75[p]	0,75[p]	0,81[q]	0,84[r]

Note: Numbers followed by the same letter in the same column indicate no significant difference at the 5% Duncan test level.

The best dosage of biopesticide is 750 ml. This is because this dosage has a very significant effect compared to other dosage treatments, where potassium has a positive effect on spinach, including optimal growth, as potassium aids in the transport of water, nutrients, and carbohydrates in plants. This supports healthy and optimal spinach growth. It enhances photosynthesis as potassium is involved in the opening and closing of stomata (leaf pores), allowing gas exchange for photosynthesis. Good photosynthesis results in healthier leaf growth. It strengthens plant resilience as potassium increases the plant's resistance to diseases, drought, and other environmental stresses, allowing spinach to grow better under various conditions. It regulates protein formation, as potassium plays a role in the synthesis of proteins and enzymes necessary for various physiological functions of the plant. It improves harvest quality, as spinach receiving adequate potassium will have greener, fresher leaves and better harvest quality (Nugroho, 2022).

Plant Height (cm)

The Duncan test results in Table 7 show that the plant height with the treatment of 6 days of fermentation and a biopesticide dosage of 250 ml recorded the lowest plant height (10 cm) and was significantly different. Meanwhile, the plant height with the treatment of 6 days of fermentation and a biopesticide dosage of 750 ml recorded the highest plant height (30.33 cm).

The heavier the pine cones and the longer the fermentation period, the greater the height of the plants produced. This is due to the significant relationship between the height of spinach (Spinacia oleracea) and the duration of fermentation, which is crucial in the context of using soil material that has undergone fermentation. The duration of fermentation has a significant impact on the quality of the soil used for planting spinach. Properly conducted fermentation for the right duration produces fertilizer that is rich in nutrients, balanced in pH, and free from anti-plant compounds, all of which support healthy and tall spinach growth. However, if the fermentation is too short or not optimal, it can result in ineffective fertilizer or even harm plant growth. Therefore, it is important to control and adjust the fermentation time according to the type of material used and the needs of spinach plants (Siti, 2021).

Table 7. Average plant height (cm) with different biopesticide doses and fermentation durations.

Treatment	Biopesticide Dose			
	0 ml (P_0)	250 ml (P_1)	500 ml (P_2)	750 ml (P_3)
L1K1	17,00^{fgh}	16,67^{efgh}	11,50^{abc}	17,00^{fgh}
L1K2	12,00^{abc}	19,67^{hijk}	22,50^{jkl}	21,83^{ijkl}
L1K3	17,00^{fgh}	14,67^{bcdef}	14,83^{bcdef}	23,67^{lm}
L2K1	19,50^{hijk}	26,50^{m}	18,50^{hi}	22,67^{kl}
L2K2	22,50^{jkl}	26,50^{m}	13,33^{abcde}	18,67^{hij}
L2K3	21,50^{ijkl}	17,83^{ghi}	12,17^{abc}	16,83^{efgh}
L3K1	14,50^{bcdef}	10,00^{a}	16,00^{defgh}	30,33^{n}
L3K2	14,50^{bcdef}	12,67^{abcd}	19,33^{hijk}	23,83^{lm}
L3K3	24,00^{lm}	11,33^{ab}	15,00^{cdefg}	19,00^{hijk}

Note: Numbers followed by the same letter in the same column indicate no significant difference at the 5% Duncan test level.

The optimal dose of biopesticide is 750 ml. This is because a good biopesticide contains a concentration of materials that meet the necessary threshold. If the concentration applied is too high, the effectiveness of the biopesticide will decrease; however, if the concentration is appropriate for the needs, the effectiveness of the biopesticide will increase. According to Andi (2020), a concentration that is too high will yield poor results, and nutrients will perform well when used in optimal amounts for the growth of the plants.

CONCLUSION

The heavier the pine cones and the longer the fermentation period used, the more significant the interaction effects on the spinach plants. The interaction effects of the weight of the pine cones, fermentation duration, and varying doses of biopesticides applied to the spinach plants resulted in the best treatment with 500 ml for the number of fungi and 750 ml for the number of bacteria, potassium content, and the highest plant height.

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