Advances in Tropical Biodiversity and Environmental Sciences
9(1): 20-28, February, 2025
e-ISSN:2622-0628
DOI: 10.24843/ATBES.2025.v09.i01.p04
Available online at: https://ejournal1.unud.ac.id/index.php/atbes/article/view/1178

Analysis of Weed Diversity, Density and Dominance on Rice Plants in Minahasa, South Minahasa, North Minahasa, and Tomohon Regency

Tirza Selfin Korneles, Orbanus Naharia*, Utari Satiman, Marthy Lingkan Stella Taulu, Sukmarayu Pieter Gedoan

Program Study of Magister Biology, Faculty of Mathematics, Natural and Earth Sciences, Universitas Negeri Manado
South Tondano, Minahasa, North Sulawesi, Indonesia
*Corresponding author: orbanusnaharia@unima.ac.id

Abstract. This study investigates the diversity of weeds in rice plants across Minahasa,South Minahasa, North Minahasa, and Tomohon regency, focusing on the environmental factors influencing the distribution and density of weeds. The research highlights that the diversity of weeds is significantly influenced by environmental factors such as rainfall, soil type, and water management practices applied by farmers. Species such as *Marsilea crenata* and *Panicum disticum* dominate areas with poor drainage, while *Ludwigia hexandra* and *Fimbristylis litoralis* thrive in fields with better drainage. Observations of weed density at 21 and 42 days after planting revealed that the competition between paddy and weeds changes as the paddy plants mature, with the initial dominance of weeds decreasing as the paddy plants grow stronger. The findings provide valuable insights into weed dynamics and the significant role environmental conditions play in determining their distribution. These results offer guidance for developing more effective and environmentally sustainable weed management strategies. Recommendations include selective herbicide use, mechanical soil cultivation, crop rotation, and improved water management. The study also suggests that further research is needed to assess the impact of climate change on weed diversity and the long-term effectiveness of weed management practices.

Keywords: crop rotation; herbicide; rice plants; soil cultivation; water management; weed diversity

I. INTRODUCTION

Rice farming is one of the sectors that is very important for the Indonesian economy. Rice is a staple food that meets almost the food needs of the Indonesian people, making it an irreplaceable commodity in national food security [1]. As the fourth most populous country in the world, the need for rice continues to increase in line with rapid population growth [1][2]. The increasing rice production is a big challenge that must be faced [2][3]. Rice plants also have a strategic role in the regional economy, especially in rice-producing areas such as Minahasa Regency, South Minahasa, North Minahasa, and Tomohon City in North Sulawesi Province [4]. In addition to providing domestic food needs, the rice farming sector also supports local farmers' economic activities and welfare [2][3]. Minahasa Regency, for example, is known as one of the rice production centers in North Sulawesi with a significant contribution to the region's Gross Regional Domestic Product (GDP) [4]. However, although this sector is important, major challenges in rice cultivation remain, including the problem of weeds.

Weeds or nuisance plants are one of the main limiting factors in agricultural production, including in rice cultivation. The presence of weeds on agricultural land not only reduces crop yields but also affects the quality of the grain produced [5][6]. Weeds compete with rice plants in obtaining nutrients from soil, water, and light, which ultimately inhibits the growth of rice plants [7]. Some types of weeds can grow very quickly and absorb most of the nutrients that rice plants are supposed to use. In this context, the problem of weeds in rice fields is becoming increasingly significant due to its potential impact on food security and the local economy. Crop yield decline due to weeds is already a common problem faced by farmers, and if not addressed immediately, can reduce farmers' income and affect overall food security [5][6].

Rice plants farms in Minahasa Regency, South Minahasa, North Minahasa, and Tomohon City face major challenges due to the presence of weeds, which directly

contribute to the decline in rice yields. Weeds such as *Echinochloa crus-galli* and *Cyperus rotundus* have been found to have high resistance to waterlogged conditions and even to drought [8]. This allows the weed to thrive in rice fields that often face water instability, either due to high rainfall or poorly managed irrigation systems. In the long term, this can disrupt the balance of the rice field ecosystem, which not only reduces rice productivity, but also damages soil structure and irrigation systems, leading to degradation of land quality [3]. As a result, farmers must face challenges in increasing rice production, while the cost of controlling weeds is increasing [9].

The main problem faced in this study is how to understand the diversity and composition of weeds in rice plants rice farmland, as well as how environmental factors such as temperature, rainfall, and land management affect the existence and dominance of these weeds. In this regard, it is important to identify the dominant weeds that can compete with rice plants in obtaining vital resources [10][11]. In addition, this research also focuses on understanding the factors that affect weed diversity so that farmers can design more effective and sustainable control strategies. Another challenge is weed resistance to herbicides which often leads to an increase in weed populations that are more difficult to control [12][13]. Therefore, solutions to this problem must include a more holistic and sustainable approach, which not only focuses on chemically controlling weeds, but also considers broader ecological aspects [14][15].

Some of the solutions that have been proposed in the literature to address weed problems in rice farming include the use of integrated weed management techniques involving an ecology-based approach. For example, crop rotation systems and the use of more competitive rice varieties can reduce the presence of weeds by increasing the competitiveness of the rice plants themselves [16]. In addition, a weed diversity-based approach can also help maintain a healthier balance of soil ecosystems, by introducing certain weeds that support soil fertility and reduce the predominance of harmful weeds [17]. For example, some types of weeds are known to improve soil structure by improving aeration and retaining soil moisture, which can ultimately increase rice productivity in the long run. Therefore, research on the diversity and composition of weeds in rice farmland must pay attention to environmental factors and land management systems applied by farmers.

In Indonesia, most of the existing research on weeds in rice farms focuses on their negative impact on rice yields [18][19], but little has been done in the diversity of weed species in major rice-producing areas, such as Minahasa Regency. Previous research has generally focused on specific weed species, or the impact of herbicide use on crop yields, but not many have examined how overall environmental factors play a role in shaping the composition of weeds in the region [19]. This gap is important to fill, given the different ecological conditions in each agricultural area, which affect the way weeds develop and compete with rice crops. Several previous studies conducted in other regions of Indonesia have shown that weeds can thrive with climate change and inconsistent land management [19][20][21]. Therefore, a deeper understanding of the relationship between these factors is essential to develop more effective and environmentally friendly weed management solutions.

The main objective of this study is to identify the diversity and composition of weeds in rice plants in Minahasa Regency, South Minahasa, North Minahasa, and Tomohon City, as well as to understand the influence of environmental factors on the existence and dominance of these weeds. This study aims to provide a deeper insight into the dominant weed species in the region and how factors such as rainfall, temperature, and soil type affect the presence of weeds. The hypothesis of this study is that environmental factors, along with land management systems implemented by farmers, have a significant impact on weed diversity and composition. This research is expected to make an important contribution in designing more efficient and sustainable weed management strategies, as well as providing a scientific basis for the development of weed control policies on rice farmland in North Sulawesi.

In this context, this study offers novelty with its focus on the analysis of weed diversity in areas that have not been extensively researched in depth. The results of this study are expected to provide a clearer picture of the challenges faced by farmers in weed management, as well as provide useful information for the development of more sustainable agricultural practices in the future. By understanding the composition and diversity of weeds, farmers can design more efficient and environmentally friendly control strategies, which in turn can increase rice productivity and support national food security.

II. METHODS

This research was carried out on rice farm located in Minahasa Regency, South Minahasa, North Minahasa, and Tomohon City, North Sulawesi Province, Indonesia. The selection of this location is based on the region's great potential in rice production, which plays an important role in regional and national food security. However, the challenge faced is the presence of weeds that can significantly reduce crop yields. Rice farm areas in the region also face a fairly high diversity of weeds, which is the focus of this study. Therefore, several rice field farming areas will be used as research samples to provide a more representative picture of the diversity and composition of weeds in this area.

The research method used in this study is descriptive research with a quantitative approach. The main purpose of this study is to analyze the diversity and composition of weeds in rice farms in Minahasa Regency and its surroundings. The vegetation analysis approach is used to identify existing weed species as well as to measure the diversity and dominance of weeds in rice plants farmland. Vegetation analysis is a technique commonly used in ecology to understand the distribution patterns and structure of plant communities in an area, which is very useful for studying the diversity of weeds on agricultural land.

This research will be carried out for three months, starting from January to March 2025. This period was chosen because it includes the main growing season of rice, which allows researchers to monitor the variation in weed types that emerge during the growth stages of rice crops. The main planting season is a very crucial time in the rice farming cycle, as in this phase, weeds usually appear in significant numbers, competing with rice for limited resources such as water, light, and soil nutrients.

The data collection method used in this study consists of three main stages: field observation, weed sample collection, and vegetation parameter measurement. In the first stage, field observations were carried out to identify locations that have a high prevalence of weeds in paddy fields. Each location selected is based on certain criteria such as land area, weed attack intensity, as well as relevant environmental factors such as soil type and water management system implemented by farmers. Researchers will select locations that represent different rice farming conditions to get a comprehensive picture of weed diversity.

Weed sampling is carried out using the plot sampling method, which is one of the techniques often used in vegetation analysis. In each predetermined location, a plot will be made with a size of 1 meter squared. This plot will be randomly selected (*random sampling*) at several points in the agricultural area. In each selected plot, all existing weeds will be identified and their type recorded. Weed sampling is carried out with the aim of obtaining accurate data on the dominant and subdominant weed species in the rice farmland.

All weeds found in the plot will be recorded, and species identification is carried out based on botanical literature as well as relevant weed identification guidelines. The identification process is carried out by paying attention to the morphological characteristics of the plant, such as the shape of the leaves, stems, and flowers. If needed, plant samples will be taken to the laboratory for further analysis to ensure more precise identification. Careful identification is essential to obtain accurate data on existing weed species, which in turn will provide important information regarding the diversity and composition of weeds at each study site.

After data on weed species were collected, vegetation analysis was carried out to measure the diversity and composition of weeds in rice plants rice farm. Some of the parameters analyzed include the Shannon-Wiener diversity index (H'), the dominance index, and the weed composition analysis. The Shannon-Wiener diversity index (H') is used to measure the extent to which weed species are evenly distributed in agricultural ecosystems. A high H' value indicates that weed species are more evenly distributed within the ecosystem, while a low H' value indicates dominance by a few specific weed species. The formula used to calculate the Shannon-Wiener index is as follows:

$$H' = -\sum_{i=1}^{S} \text{p}_i \cdot \ln(\text{p}_i)$$

where is H' the Shannon-Wiener diversity index, $S\text{p}_i$ is the number of weed species present and is the proportion of the number of weed individuals of the ith species to the total weed individuals.

In addition, the dominance index is used to measure the extent to which one weed species dominates compared to other species within an agricultural ecosystem. This index is calculated by the formula:

$$C = \frac{N_d}{N_t}$$

where N_d is the number of weed individuals of the dominant species, and N_t is the total number of weed individuals in the plot. The dominance index provides important information about the weed species that have the greatest impact on the paddy farming ecosystem.

The composition of weeds is analyzed based on the relative proportion of the number of individuals of each weed species found in the plot. This information helps to know the most commonly found weed species (dominance) as well as the rarer weeds (subdominant). This data is also used to design more effective weed management strategies.

Environmental factors that affect the distribution of weeds will also be measured in this study. Some of the factors that will be analyzed include rainfall, soil type, soil pH, and irrigation and water management conditions. Rainfall data will be obtained from the nearest meteorological station, which is then used to analyze the effect of rainfall on weed development. Soil type and soil pH will also be analyzed through soil sampling at each research site to help understand the relationship between soil conditions and weed growth.

Irrigation conditions and water management also play an important role in the development of weeds. Therefore, the researcher will observe and record the irrigation methods used by farmers, whether the rice fields are waterlogged or have good drainage. This will provide an overview of how water management affects the growth of weeds in rice farm.

Based on the results of the analysis of weed diversity and composition, recommendations for more efficient weed management will be given. The researcher will identify the dominant weeds that need to be controlled and provide advice on appropriate control methods, be it mechanical, chemical, or biological control.

III. RESULTS AND DISCUSSION

Results

Diversity of Weed Species in Rice Plants Farmland

Rice farming in Minahasa, Minsel, Minut, and Tomohon Regencies plays an important role in the food security of North Sulawesi Province. However, one of the main problems faced is the presence of weeds that can reduce crop yields. Weeds compete with rice plants for resources such as water, light, and soil nutrients. Therefore, it is important to map the diversity of existing weed species to design more efficient and sustainable management strategies.

In this study, observations were made on the diversity of weed species found in four predetermined rice plants rice farming locations. Each location was chosen to represent the varied farming conditions. Observations were made at

several points in time, namely at the beginning of the planting season, 21 Days After Planting, and 42. Site 1 (Minahasa) was found to have 16 species of weeds, with the dominance by *Marsilea crenata* found with the highest density in the entire area. This weed has a total density of 538 individuals, making it one of the most competitive species in the fight for resources with rice crops. In addition to *M. crenata*, *Panicum disticum* and *Echinochloa crusgalli* also show a fairly high density and are weeds that need to be considered in management.

TABLE 1.
DENSITY AND ABSOLUTE FREQUENCY OF EARLY WEEDS AT LOCATION 1

Number	Species	K1	K2	K3	K4	K5	Total KM	FM Frequency	Average Density	Standard Error
1	*M. crenata*	48	39	21	28	30	166	5	33.2	4.68
2	*L. octovalvis*	2	3	8	4	3	20	5	4.0	1.05
3	*P. distichum*	35	21	20	21	28	125	5	25.0	2.88
4	*E. crusgalli*	2	2	3	2	3	12	5	2.4	0.24
5	*E. colona*	7	10	5	5	2	29	5	5.8	1.32
6	*F. litoralis*	1	1	1	1	0	4	4	0.8	0.20
7	*L. hexandra*	2	1	2	1	1	7	5	1.4	0.24
8	*S. juncoides*	21	20	10	13	2	66	5	13.2	3.58
9	*M. vaginalis*	1	1	1	2	0	5	4	1.0	0.32

TABLE 2.
DENSITY AND ABSOLUTE FREQUENCY OF EARLY WEEDS AT LOCATION 2

Number	Species	K1	K2	K3	K4	K5	Total KM	FM Frequency	Average Density	Standard Error
1	*M. crenata*	12	6	4	1	4	27	5	5.4	1.83
2	*L. octovalvis*	19	5	5	1	4	34	5	6.8	3.14
3	*P. distichum*	18	3	10	2	12	45	5	9.0	2.97
4	*E. crusgalli*	9	4	8	1	5	27	5	5.4	1.44
5	*F. litoralis*	10	5	4	2	4	25	5	5.0	1.34
6	*L. hexandra*	8	6	2	0	3	19	4	3.8	1.43
7	*S. juncoides*	7	2	1	0	3	13	4	2.6	1.21
8	*M. vaginalis*	3	0	1	3	2	9	4	1.8	0.58
9	*E. colona*	4	3	2	1	0	10	4	2.0	0.71
10	*C. iria*	0	2	3	1	0	6	3	1.2	0.58

The *weed M. crenata* shows a very strong dominance in almost all squares with a very high density. As the dominant weed, it has the potential to inhibit the growth of rice plants, reduce growing space and compete for nutrients and water. On the other hand, other weeds such as *P. disticum* and *E. crusgalli*, although not as competitive as *M. crenata*, also need attention in weed management efforts. Overall, weed management in Location 1 should be focused on controlling dominant weed species such as *M. crenata*.

In Figure 1, the distribution of weed species in Location 1 can be seen. The evenly distributed *distribution of M. crenata* throughout the area shows the adaptation of this weed to the condition of rice fields that are often flooded. The images also provide insight into areas that are prone to weeds, where more intensive management is needed, such as the use of selective herbicides or better tillage techniques.

At Site 2, observations at 21 and 42 showed significant changes in weed counts, with some species showing a decrease in density, while others, such as *E. crusgalli*, remained stable or even slightly improved at 42 HST observations. This indicates that even though rice crops have begun to develop, the competition between weeds and rice continues with high intensity. The dominant *E. crusgalli* weed in this location shows the ability to survive in better drainage conditions, demonstrating its superiority in fighting for space and resources with rice plants. Therefore, sustainable weed management in Site 2 should be focused on controlling these dominant species with appropriate approaches, such as the use of selective herbicides and mechanical tillage to reduce the potential for weeds in the next growing season.

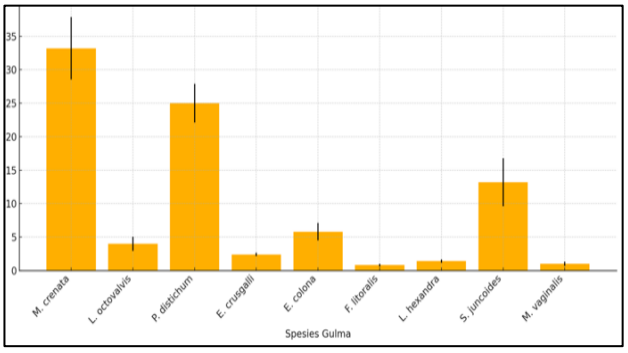

Fig. 1. Distribution of Weed Species in Location 1 (Minahasa)

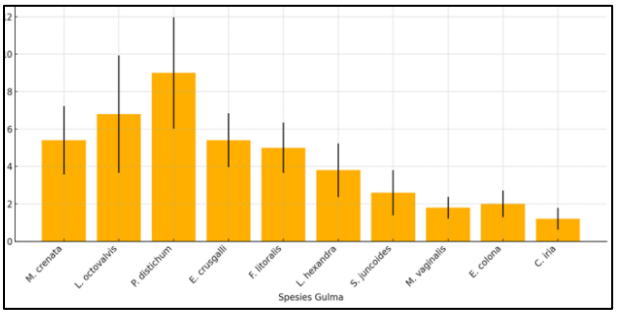

Fig. 2. Distribution of Weed Species in Location 2 (South Minahasa)

At Site 2, 14 species of weeds were found, dominated by *E. crusgalli* and *L. octovalvis*. Both species exhibit high levels of density throughout the observation area, signaling their excellent adaptability to lower humidity land conditions and better drainage systems. Other weeds, although of lower density, still affect agricultural yields and need to be considered in management. At Location 3, *the weed E. crusgalli* became the dominant species, with very high densities throughout the observation area. These weeds show good adaptability to waterlogged soil conditions, which provides a competitive advantage in competing for resources with rice crops. Proper management needs to be done to reduce the impact of these dominant weeds, such as the use of appropriate tillage techniques and crop rotation that can reduce dependence on certain species.

TABLE 3.
DENSITY AND ABSOLUTE FREQUENCY OF EARLY WEEDS AT LOCATION 3

Number	Species	K1	K2	K3	K4	K5	Total KM	FM Frequency	Average Density	Standard Error
1	*M. crenata*	9	6	0	1	5	21	3	4.2	1.66
2	*L. octovalvis*	12	6	3	0	4	25	4	5.0	2.00
3	*P. distichum*	8	6	2	0	3	19	2	3.8	1.43
4	*E. crusgalli*	2	2	3	1	3	11	5	2.2	0.37
5	*F. litoralis*	3	3	1	0	4	11	2	2.2	0.73
6	*L. hexandra*	15	9	4	3	6	37	3	7.4	2.16
7	*S. juncoides*	7	4	2	0	4	17	4	3.4	1.17
8	*M. vaginalis*	3	1	2	3	4	13	2	2.6	0.51
9	*E. colona*	4	0	1	3	2	10	2	2.0	0.71
10	*C. iria*	3	2	3	0	4	12	2	2.4	0.68

TABLE 4.
DENSITY AND ABSOLUTE FREQUENCY OF EARLY WEEDS AT LOCATION 4

Number	Species	K1	K2	K3	K4	K5	Total KM	FM Frequency	Average Density	Standard Error
1	*M. crenata*	29	8	2	3	6	48	5	9.6	4.97
2	*L. octovalvis*	2	1	3	1	4	11	5	2.2	0.58
3	*P. distichum*	6	5	2	4	3	20	5	4.0	0.71
4	*E. crusgalli*	15	12	3	7	4	41	5	8.2	2.31
5	*F. litoralis*	12	14	8	6	10	50	5	10.0	1.41
6	*L. hexandra*	18	13	9	7	5	52	5	10.4	2.32
7	*S. juncoides*	10	9	3	1	2	25	5	5.0	1.87
8	*M. vaginalis*	5	3	4	3	4	19	5	3.8	0.37
9	*E. colona*	3	2	1	1	4	11	5	2.2	0.58
10	*C. iria*	4	1	2	3	1	11	5	2.2	0.58

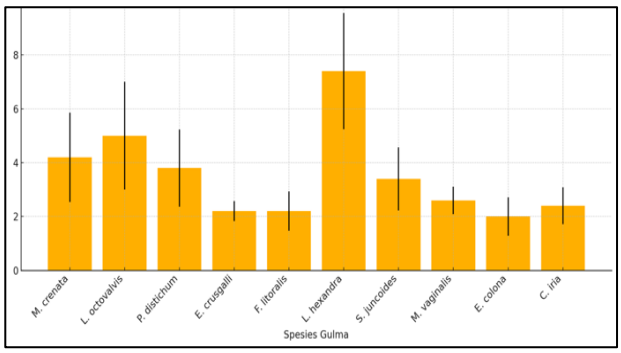

Fig. 3. Distribution of Weed Species in Location 3 (North Minahasa)

Location 4 has a higher diversity of weeds compared to some other locations, with 16 species of weeds found. The dominant weeds include *Ludwigia hexandra*, *Fimbristylis litoralis*, *Mikania crenata*, and *Panicum disticum*, with *L. hexandra* and *F. litoralis* showing very significant dominance across planting areas.

Table 4 shows the density and frequency of weeds observed in various squares, where *L. hexandra* shows the highest density in squares 1 and 2, while *F. litoralis* is more dominant in areas with higher soil moisture. *M. crenata* and *P. disticum* are found with fairly high density, but their distribution is more limited.

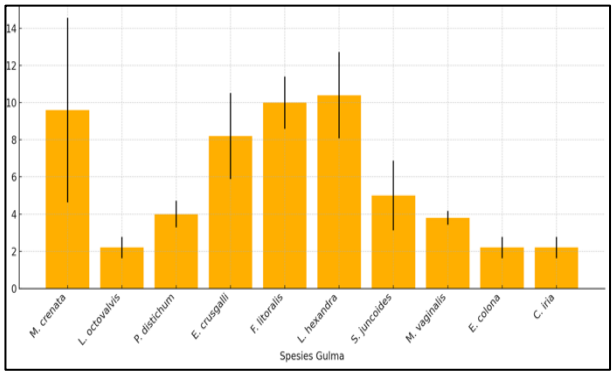

Fig. 4. Distribution of Weed Species in Location 4 (Tomohon)

The distribution of weeds in Location 4 showed an uneven pattern, with weeds such as *F. litoralis* and *L. hexandra* more commonly found in well-drained areas, while weeds such as *Echinochloa crusgalli* and *Panicum disticum* dominated areas with high humidity. This study shows that environmental factors, such as soil drainage and moisture, affect weed diversity and distribution, providing important insights for more effective weed management in rice farmland.

Analysis of Environmental Factors Affecting Weed Diversity

Environmental factors that affect weed diversity are very important in understanding the distribution of weeds in rice farm. Rainfall, soil type, and water management are the main factors that affect the growth and diversity of weeds. For example, in locations with high rainfall and fertile soils, such as in Location 1, weeds such as *M. crenata* and *P. disticum* thrive and dominate. In contrast, in locations with better drainage and lower soil moisture, such as in Location 2, weeds such as *E. crusgalli* and *L. octovalvis* are more dominant.

TABLE 5.
THE RELATIONSHIP BETWEEN RAINFALL AND WEED DIVERSITY

Location	Rainfall (mm)	Soil Type	Gulma Dominant
1	2500	Fertile Soil	*M. crenata*, *P. disticum*
2	2200	Drained Soil	*E. crusgalli*, *L. octovalvis*
3	2400	Clay	*E. crusgalli*, *M. vaginalis*
4	2300	Drained Soil	*L. hexandra*, *F. litoralis*

This study shows that high rainfall and soil types that support high humidity greatly influence the development of weeds more tolerant to moisture. Conversely, good drainage conditions provide an advantage for weeds that are more tolerant of dry conditions, demonstrating the importance of environmental management in designing more effective weed control strategies.

In Figure 5, it can be seen that higher rainfall is associated with an increase in the population of some types of weeds that are more tolerant to moisture. This shows a clear relationship between climatic conditions and the dynamics of weed growth on farmland.

Weed Management Recommendations to Increase Rice Productivity

Based on the results of the study, dominant weeds such as *M. crenata*, *E. crusgalli*, and *P. disticum* require serious attention in their management. Effective weed control can be done by combining mechanical and chemical techniques, such as the use of selective herbicides, tillage, and crop rotation. Proper water management is also very important in influencing weed development and increasing rice agricultural yields sustainably.

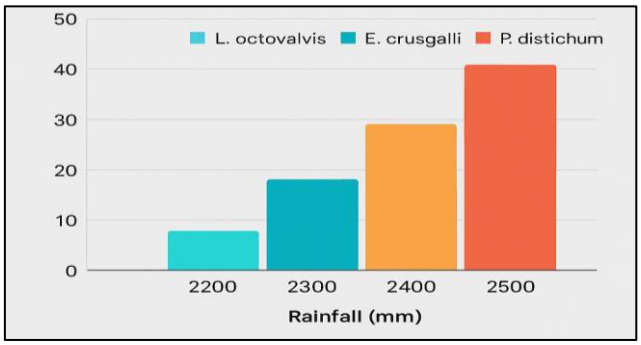

Fig. 5. The Impact of Rainfall on Weed Growth

This research is expected to provide a solid foundation for designing more effective and efficient weed management strategies, as well as supporting more sustainable rice farming productivity in Minahasa Regency.

Discussion

Weed Diversity in Rice Fields

The results of this study show that the diversity of weeds in rice farm in Minahasa, Minsel, Minut, and Tomohon districts is greatly influenced by local environmental conditions, with a total of 16 species of weeds found in various locations. The varied distribution pattern of weeds suggests that weed diversity depends not only on the type of weed itself, but also on existing environmental factors. At the first location, the dominant weed species is *Marsilea crenata* (*M. crenata*), which is found with high densities in almost the entire observation square. These weeds are highly competitive in the competition for resources with rice plants, according to the findings of Haris et al. [22] who stated that high-density weeds such as *M. crenata* can reduce the light received by rice plants and absorb nutrients from the soil, inhibiting rice growth and significantly lowering crop yields.

In addition to *M. crenata*, other weeds that are dominant in the first location are *Panicum disticum* (*P. disticum*) and *Echinochloa crusgalli* (*E. crusgalli*). Both also exhibit high density, which indicates that they are competing with rice plants for water, light, and soil nutrients. *E. crusgalli*, which is highly adaptive to waterlogged soils, has the ability to survive even in wet rice field conditions, which makes it highly competitive in the fight for resources that rice plants should use. This finding is supported by Zhang et al. [23], who state that *E. crusgalli* is a highly competitive weed due to its ability to utilize water and soil nutrients.

In the second location, the dominant weeds are *E. crusgalli* and *P. disticum*, which exhibit very high density, creating intense competition in the early phases of rice growth. The decline in crop yields in the early stages of rice growth is indeed greatly influenced by competition between weeds and rice plants in obtaining limited resources, which leads to a decrease in the quality and quantity of crops. These findings are also in line with Zhang et al. [23], who revealed that weeds such as *E. crusgalli* can absorb more soil nutrients compared to rice

plants, disrupt rice photosynthesis processes, and lower overall crop yields.

In the third and fourth locations, weeds with adaptation to high humidity, such as *L. hexandra* and *F. litoralis*, dominate rice farm, especially in the rainy season. This condition shows that weeds with a deeper root system and the ability to survive in waterlogged conditions are more likely to thrive in well-drained rice fields. This finding is in line with Jiang et al. [24][25], who stated that soil moisture has a major influence on weed distribution, with waterlogging-tolerant species becoming more dominant in well-drained rice paddies.

The pattern shows that the diversity of weeds in the study site is greatly influenced by environmental factors, such as rainfall, soil type, and water management systems applied by farmers. As revealed by Nunes et al. [25], climatic factors and soil management directly affect weed composition, where weeds that are more tolerant to high humidity tend to be dominant in poorly drained land, while weeds that are more drought-tolerant are more developed in well-drained land.

Comparison of Weed Density at 21 hst and 42 hst Observations

Observations conducted at 21 Days After Planting and 42 revealed significant differences in weed density, reflecting the dynamics of competition between weeds and rice crops. At the observation of 21 HST, weeds such as *P. disticum* and *E. crusgalli* dominated with very high densities. In the observation of 42 HSTs, although some weed species experienced a decrease in numbers, other weeds showed stability or increased density. This shows that changes in environmental conditions throughout the growing season affect the composition and dynamics of weed populations in rice farmland.

In the early phase of rice growth, which is 21 HST, rice plants are still in a fragile vegetative stage, so weeds such as *P. disticum* and *E. crusgalli* that have the ability to grow rapidly can take advantage of this condition to develop quickly. This is in accordance with the research of Lal et al. [27], which stated that weeds such as *E. crusgalli* that have high adaptability to flooded soil will be more dominant in the early phase of the planting season, when rice plants have not fully developed.

At the observation of 42 HSTs, there was a decrease in density in some weed species, such as *P. disticum* and *E. crusgalli*, although their numbers remained quite high in some locations. This decline is likely due to rice plants that have entered a more advanced growth phase and are starting to control the area better. With an increasingly strong root system, rice plants are starting to be able to overcome competition and absorb more water and nutrients, so there is less room for weeds to develop. These findings are in line with Hoesain et al. [28][29], who stated that in the late phase of rice growth, competition with weeds tends to decrease as rice plants begin to dominate the area more effectively.

However, although there was a decrease in some weed species at 42 HST, other weeds, such as Ludwigia hexandra and Fimbristylis litoralis, still showed stability or even increased density. This suggests that although competition with rice plants is reduced, some weeds that are more adaptive to certain environmental conditions can still survive. For example, *L. hexandra*, which is more tolerant of flooded soil conditions, can survive in well-drained rice fields, while *F. litoralis* shows adaptability to high humidity.

The Influence of Environmental Factors on Weed Diversity

Environmental factors, such as rainfall, soil type, and water management, play an important role in influencing the diversity and distribution of weeds in paddy farmland. In locations with high rainfall, such as locations 1 and 3, moisture-tolerant weeds such as *E. crusgalli* and *P. disticum* predominate. Research by Wendra et al. [30] revealed that weeds that can survive in waterlogged conditions are more likely to thrive in soils that have high humidity, such as rice fields that often experience waterlogging. This shows that weeds with adaptation to high humidity conditions can thrive in flooded rice fields.

In contrast, in locations with better drainage, such as location 2, weeds such as *L. octovalvis* become dominant. This weed is more adaptive to drier conditions and more resistant to well-drained soils. Research by Zhang et al. [23] shows that good drainage can reduce the excess moisture required by some types of weeds, allowing weeds that are more tolerant to dry conditions to thrive better.

Soil type also affects the distribution of weeds. In location 3, with heavier clay, weeds such as *E. crusgalli* and *M. vaginalis* thrive. Clay has a high-water retention capacity, which supports weeds that can survive in flooded conditions. In contrast, in location 4 with well-drained soils, weeds such as *L. hexandra* and *F. litoralis* were more dominant, as well-drained soils allowed the weeds to thrive better in drier conditions.

Weed Management Recommendations to Increase Rice Productivity

Based on the results of this study, several effective weed management strategies can be applied to increase rice productivity in Minahasa, South Minahasa, North Minahasa, and Tomohon Regencies. One strategy that can be applied is weed control through selective mechanical and chemical approaches. Selective use of herbicides is essential to reduce populations of dominant weeds such as *M. crenata* and *P. disticum* without damaging rice crops. Judicious use of herbicides with attention to the proper time of application can minimize damage to rice plants and increase yields.

In addition, mechanical tillage such as plows and weed removal can reduce weed populations in the early stages of rice plant growth. This tillage will disrupt the weed's root system and reduce its ability to thrive. This mechanical processing technique also improves soil aeration, which is beneficial for the growth of rice plants.

Crop rotation is also a very effective strategy in reducing the dominance of certain weeds. Crop rotation with legume crops such as peanuts or soybeans can weaken competitive weeds, such as *E. crusgalli* and *M. vaginalis*. Legume crops can improve soil structure and fertility, which in turn creates less than ideal conditions for weed development. In

addition, crop rotation reduces dependence on herbicides, which can improve the balance of soil ecosystems and reduce pressure from weeds.

Efficient irrigation management is also very important in reducing the growth of weeds that require high humidity. By improving drainage systems, farmers can reduce excessive moisture and reduce growing space for weeds that are more tolerant of high humidity. Techniques such as *alternate wetting and drying* (AWD) can be applied to reduce waterlogging time, which can also help reduce weed growth and increase rice yields.

Overall, an integrated weed management approach based on local environmental conditions is essential to increase rice productivity. Selective use of herbicides, crop rotation, mechanical tillage, and good irrigation management will help reduce the negative impact of weeds, increase rice yields, and support the sustainability of agricultural production.

Conclusion

The weed diversity in rice farm in Minahasa, South Minahasa, North Minahasa, and Tomohon Districts is greatly influenced by environmental conditions, such as rainfall, soil type, and water management systems implemented by farmers. Weeds such as *M. crenata* and *P. disticum* dominate rice fields with poor drainage conditions, while weeds such as *L. hexandra* and *F. litoralis* thrive better on land with better drainage. Observation of the difference in weed density at 21 HST and 42 HST also revealed that the growth phase of rice affects the competitive interaction between rice plants and weeds.

Recommendation

These findings can be used to design more effective and environmentally friendly weed management strategies. Recommended weed management strategies include the use of selective herbicides, mechanical tillage, crop rotation, and more efficient irrigation management. Further research is needed to explore the effects of climate change on weed diversity and the effectiveness of long-term weed management methods.

REFERENCES

[1] Pramunadipta, S., Widiastuti, A., Wibowo, A., Suga, H. & Priyatmojo, A., 2020. Short communication: *Sarocladium oryzae* associated with sheath rot disease of rice in Indonesia. *Biodiversitas*, 21, pp.1243–1249.

[2] Hidayat, R.A., Iskandar, J., Gunawan, B. & Partasasmita, R., 2020. Impact of green revolution on rice cultivation practices and production system: A case study in Sindang Hamlet, Rancakalong Village, Sumedang District, West Java, Indonesia. *Biodiversitas*, 21, pp.1258–1265.

[3] Mulyani, A., Darwanto, D., Widodo, S. & Masyuri, 2020. Production efficiency of Inpago Unsoed-1 and Situbagendit rice farming in Central Java, Indonesia. *Biodiversitas*, 12, pp.3276–3286.

[4] Rahayu, S.E. & Febriaty, H., 2019. Analisis perkembangan produksi beras dan impor beras di Indonesia. In: *Prosiding Seminar Nasional Kewirausahaan*, 1(1), pp.219–226.

[5] Sugiono, D. & Saputro, N.W., 2016. Respon pertumbuhan dan hasil beberapa genotip padi (*Oryza sativa* L.) pada berbagai sistem tanam. *Jurnal Agrotek Indonesia*, 1(2).

[6] Kusumawati, D.E., Istiqomah, I. & Arnanto, D., 2022. Efektivitas macam pestisida nabati dan pupuk organik padat untuk mengendalikan serangan organisme pengganggu tanaman pada tanaman padi. *Buana Sains*, 22(3), pp.13–22.

[7] Baker, H., 2016. Weed management in paddy fields: A sustainable approach. *Journal of Agriculture*, 45(2), pp.134–145.

[8] Naharia, O., Setyanto, P., Arsyad, M., Burhan, H. & Aswad, M., 2018. The effect of water regime and soil management on methane (CH_4) emission of rice field. *IOP Conference Series: Earth and Environmental Science*, 157(1), p.012012.

[9] Hanim, Z. & Nurdin, I.P., 2024. Perubahan sosial akibat modernisasi pada komunitas petani padi di Gampong Lingom Kabupaten Aceh Besar. *RESIPROKAL: Jurnal Riset Sosiologi Progresif Aktual*, 6(2), pp.151–162.

[10] Hakim, M.A., Juraimi, A.S. & Ahmad-Hamdani, M.S., 2020. Recent developments of weed management in rice fields. *Crop Protection*, 132, pp.105–118.

[11] Sarr, P.S. et al., 2020. Taxonomic diversity and abundance of weed flora in upland rice fields of Southern Groundnut Basin, Senegal. *Weed Science*, 68(3), pp.234–245.

[12] Aditiya, D.R., 2021. Herbisida: risiko terhadap lingkungan dan efek menguntungkan. *Sainteknol: Jurnal Sains dan Teknologi*, 19(1), pp.6–10.

[13] Rustom, S.Y. et al., 2025. Investigation of barnyardgrass (*Echinochloa crusgalli*) resistance to multiple herbicides in Mississippi rice fields. *Weed Technology*, 39(1), pp.89–101.

[14] Marambe, B., 2020. Sustainable weed management practices in direct seeded rice: A review. *Weed Biology and Management*, 20(2), pp.45–58.

[15] Raza, A. et al., 2025. Improving weed control in sustainable agro-ecosystems: Role of cultivar and termination timing of rye cover crop. *Agriculture, Ecosystems & Environment*, 315, pp.1–12.

[16] Rizza, M.A., Monasari, R., Emzain, Z.F. & Agustriyana, L., 2020. Pertanian tanaman jagung dengan alat penyiang bagi petani jagung Desa Pulungdowo Kabupaten Malang. *JPKMI: Jurnal Pengabdian Kepada Masyarakat Indonesia*, 1(4), pp.262–271.

[17] Putra, W., Widayati, D., Dardanila, D. & Amanda, S., 2021. Leksikon kegulmaan pada masyarakat Jawa di Perkebunan Fajar Agung, Kecamatan Pegajahan, Kabupaten Serdang Bedagai: Kajian ekolinguistik. *KEMBARA: Jurnal Keilmuan Bahasa, Sastra, dan Pengajarannya*, 7(1), pp.198–215.

[18] Suryanto, A., Kusumawati, R. & Wibowo, H., 2024. Analisis vegetasi dan indeks keragaman gulma pada lahan padi sawah di Kelurahan Mauliru, Sumba Timur. *Jurnal Ilmu Pertanian Indonesia*, 29(3), pp.345–356.

[19] Hakim, M.A., Juraimi, A.S. & Ahmad-Hamdani, M.S., 2021. Komposisi vegetasi dan keragaman gulma di lahan padi sawah: Sebuah tinjauan. *Jurnal Agroteknologi*, 15(2), pp.112–125.

[20] Rice, E.L., 2018. *Ecology of weeds and invasive plants: Theory and application*. New Jersey: Wiley.

[21] Wibowo, H., Suryanto, A. & Kusumawati, R., 2024. Pengaruh perubahan iklim terhadap pola konsumsi rumah tangga petani padi di Kabupaten Demak. *Jurnal Ekonomi Pertanian*, 18(4), pp.234–245.

[22] Haris, A., Utami, S. & Murningsih, 2019. Struktur komunitas gulma pada lahan pertanian padi sawah di Desa Bulusari, Kecamatan Sayung, Kabupaten Demak. *Journal of Physics: Conference Series*, 1217(1), p.12177.

[23] Zhang, Z., Bu, D. & Qiang, S., 2022. Investigasi lapangan tentang pengendalian gulma jangka panjang melalui berbagai jenis pola budidaya padi-aquakultur terintegrasi. *Journal of Plant Protection*, 49(2), pp.693–704.

[24] Jiang, M., Shen, M.-X., Shen, X.-P. & Dai, Q.-G., 2014. Pengaruh pola pemupukan jangka panjang terhadap keragaman komunitas gulma di lahan sawah. *Chinese Journal of Ecology*, 33(7), pp.1748–1756.

[25] Jiang, J., Chen, J. & Zhang, Z., 2014. The effects of soil type and moisture on the growth of paddy field weeds. *Field Crops Research*, 163, pp.124–131.

[26] Nunes, A., Lima, A. & Carvalho, J., 2018. Gulma dominan pada lahan sawah: Pengaruh curah hujan dan pengelolaan air. *Jurnal Ilmu Pertanian*, 33(2), pp.74–80.

[27] Lal, R., Suwarno, E. & Purwanto, B., 2014. Weed competition in rice: Influence on growth and yield under different soil and water conditions. *Journal of Sustainable Agriculture*, 31(2), pp.243–251.

[28] Hoesain, M., Hasjim, S., Widodo, N. & Harsita, P.A., 2019. Analisis nilai penting gulma pada tanaman padi dalam rangka pemilihan pengendalian ramah lingkungan. *AGRIMETA: Jurnal Pertanian Berbasis Keseimbangan Ekosistem*, 9(17).

[29] Hoesain, M., Hasjim, S., Widodo, N. & Harsita, P.A., 2019. Analisis nilai penting gulma pada tanaman padi dalam rangka pemilihan pengendalian ramah lingkungan. *AGRIMETA: Jurnal Pertanian Berbasis Keseimbangan Ekosistem*, 9(17).

[30] Wendra, Y., Alwendi, A., Ardi, A. & Aldo, D., 2020. Metode Case Based Reasoning untuk identifikasi penyakit tanaman padi. *Jursima*, 8(2), pp.103–110.