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Effect of chemical and mechanical weed control on weed seed banks in rice field

Abstract. Weed control is essential for ensuring the diversity of weeds on agricultural land. A study was conducted in rice fields in Subang and Cianjur districts, where 24 fields were observed to have varying weed management approaches. The research employed descriptive methods, including surveys to identify weed types and destructive methods to analyze weed seed banks at different depths. The descriptive methods included surveys to identify weed types and destructive methods to analyze weed seed banks at different depths. Each district contained twelve rice fields that reflected diverse environmental conditions and weed control techniques, yet shared a similar age range of 1-5 weeks. The study examined the weed vegetation, community coefficients, weed diversity, weed dominance, and variations in seed banks at various depths. The results indicated that fields without herbicide-based weed control had a higher number of weed species than those using herbicides. Herbicide use effectively decreased weed populations, subsequently altering the seed bank composition. The dominant weeds in herbicide-treated fields were *Cynodon dactylon*, *Pistia stratiotes*, and *Ludwigia adscendens*, whereas *Ludwigia adscendens, Cynodon dactylon*, and *Pistia stratiotes* were dominant in fields without herbicides.

Keywords: Diversity · Population · Seedbank · Vegetation · Weed control

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Introduction

The traditional tillage and fertilizer systems are gradually being replaced by no-till and no-fertilizer systems because they are more environmentally friendly and economical. Problems found with this method include the presence of weed populations before planting, resulting in much higher herbicide use (Putra et al., 2018). Herbicide use in the world is increasing rapidly due to high labor costs and a declining labor force. About 33% of agricultural products produced are accompanied by the use of pesticides. Herbicides make up more than 80% of the total consumption of pesticides used to protect crops (Sitaramaraju et al., 2014). When applied, the majority of herbicides have an impact on non-target plants and animals in addition to weeds. One of the threats to agricultural and natural ecosystems is the overuse of chemicals, which can hasten the loss of biodiversity. Overexploitation and chemicalization are the main drivers of accelerated biodiversity loss and one of the greatest global threats to ecosystem function and agriculture (Wanger, et. al., 2020).

The density of seedbanks is impacted by the application of weed control techniques either before or subsequent to weed establishment. It has been demonstrated that there exists a positive linear correlation between the initial seed bank density and the weed density stored in the deepest soil layer with the application of post-emergence herbicide and mechanical weed control (Norsworthy et al., 2016) The development of effective management strategies that reduce weed diversity and the use of herbicides early in flower or pod formation can reduce the potential for weed seed storage in the soil. Furthermore, reduced seed weight, seed viability, and seedling recruitment can affect the presence of crop species in the following season, as the stored seed bank consists of several dominant weed species (Bagavathiannan et al., 2018).

The timing of sowing and crop management systems are the most important factors that affect weed density. Many studies have shown that no-tillage systems and crop rotation in subsequent seasons reduce weed seed survival over time. Herbicides can shift the weed seed bank to species that are less susceptible to the herbicides used (Norsworthy et al., 2018). The main factors that influence the weed seed bank in the soil are: 1) crop rotation systems; 2) tillage techniques; 3) different fertilizer treatments; 4) weed control techniques; and 5) soil water availability (Caroca et al., 2014). This study aims to determine how weed control can affect the weed seed bank on rice farms.

Materials and Methods

The research was conducted in farmers' paddy fields in Subang and Cianjur districts, where 24 fields were observed to have varying weed management approaches..The experimental sites are located at an altitude of about 10 m above sea level for Subang district and Cianjur district at about 400 m above sea level. The average rainfall in Subang District is 1526.3 mm/year, climate type C3 according to Oldeman Classification. The average rainfall in Cianjur Regency is 3087.1 mm/year, climate type B2 according to the Oldeman Classification. This research started in May - July 2023.

The materials used in this research include weeds growing in rice fields, questionnaires, soil samples, and maps of West Java. **Tools**: meter, raffia rope, bamboo stakes, scissors, label paper, plastic bags, shovels, plastic cups, paper envelopes, drying oven, and electric scales; 10 cm diameter, 30 cm long marked pipes; watering tools; seed bank trays (food containers).

The research method uses descriptive research methods, through the survey method. In each district will be studied 12 rice plant areas spread in a variety of different environmental conditions, but with a relatively similar age of rice plants between the age of 1 - 5 weeks. In the rice plant area that has been determined to be studied, vegetation analysis is made diagonally (5 observations) with the quadrat method (1 x 1 m). In each vegetation analysis, all weed species, percentage of weed cover, weed density, weed frequency, weed dominance, Summed Dominance Ratio (SDR), community coefficient, and weed dry weight will be determined. In addition, 84 soil samples were taken to be used for the seed bank, which were coded with an infraboard with details of 7 plots and soil depths (0-5 cm, 5-10 cm, 10-15 cm, 15-20 cm) in each field. Observation made includes:

A. SDR (Summed Dominance Ratio)
   Summed Dominance Ratio value is calculated using formula (1) and (2) based on Satriawan & Fuady (2019).

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$$SDR = \frac{Importance\ value\ index\ (IVI)}{\text{Number of species}} \ldots\ldots\ldots\ldots (1)$$

IV = Relative Density + Relative Frequency + Relative Dominance .... (2)

B. Community Coefficient **(C)**
The Community Coefficient (C) was measured using the formula by Tjitrosoedirjo. (1984) shown in (3):

$$C = 2\frac{W}{A+B} \times 100\%$$

Description:
C: Community Coefficient
W: the sum of the two lowest quantities for species from each community
A: the sum of all the quantities in the first community
B: the sum of all the quantities in the second community.

Results and Discussion

Seed bank characteristics of weeds in paddy fields. Seed bank was conducted after the soil in all observation areas was collected. The soil was taken with different depths, namely: 0 - 5 cm, 5 - 10 cm, 10 - 15 cm, 15 - 20 cm, and 20 - 25 cm in each area. The soil was sown in plastic cups according to the depth for 4 weeks. Each week, it was observed which weed classes grew at the various depths. The results of the seed bank in Subang and Cianjur districts can be seen in Table 1.

Differences in seed banks are also caused by different weed management and agroecological factors. In general, Subang District controls weeds with herbicides, while in Cianjur District, weeds are controlled with non-herbicides. Subang and Cianjur districts have differences in altitude, temperature, soil type, and fertilizer use. This increases the number of weed seeds stored in the soil. Subang district has an alluvial soil type; the air temperature ranges from 26° to 27°C; the altitude is around 10 m above sea level; and the common fertilizers used by farmers are compost and urea fertilizer. Cianjur District has a latosol soil type; the air temperature ranges from 20° to 21°C; the altitude is around 400 m above sea level; and the common fertilizer used by farmers is manure. Another factor that influences differences in the seed bank in the soil is soil chemical factors such as cation exchange capacity (Ma et al., 2017). These differences cause differences in the number of weed seeds stored in the soil (seed bank).

The results also showed that the use of herbicides significantly reduced the number and diversity of weed seedbanks in the field. Herbicides inhibit the germination and growth of seedbanks of dominant weed species in the topsoil, thus reducing the number of weed eedbanks in the soil. The diversity and number of weeds growing in the 0 - 10 Cm depth is more than the depth of more than 10 m, because most weed seedbanks are scattered on the soil surface, the disturbance of cultivation on the soil surface will affect the viability and depth of seeds in the soil (Khan et al., 2012). As soil depth increases, the number and diversity of weeds decreases which may be due to weed seeds close to the soil surface losing viability and mortality faster due to herbicide application compared to weed seeds buried in the soil (Mohler, 1993).

The diversity of weed seeds in soil varies greatly depending on the composition of what grows on it and the history of the soil itself. Soils that were originally used as agricultural land will have seed populations associated with agricultural weeds. According to Lal, et al. (2016), soil contains weed seeds that can

Table 1. Number of seed banks in Subang Regency and Cianjur Regency.

Depth (cm)	Subang Regency						Cianjur Regency					
	Grass		Sedges		Broadleave		Grass		Sedges		Broadleave	
	NH	H	NH	H	NH	H	NH	H	NH	H	NH	H
0-5	4	11	1	4	23	19	4	20	1	-	6	28
5-10	9	4	-	1	34	24	2	17	1	-	5	19
10-15	3	13	-	4	24	6	5	17	1	-	4	17
15-20	-	1	-	-	13	8	6	10	1	-	6	10
20-25	1	2	1	-	14	17	7	4	-	-	3	3

Description: NH= Non herbicide; H= Herbicide

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germinate at any time resulting from previous years. Seeds that under favourable conditions can germinate and grow as competitors of the main crop are called seed stores. This seed bank may consist of seeds of different ages, some of which are in a dormant state, ready for favourable conditions. Seeds located several metres deep in the soil are still classed as seed stores because they can be brought to the surface at any time by tillage, excavation, or digging animals. In general, it is the seeds in the cultivation layer (up to 25cm deep) that need special attention in relation to weed management as they will play an important role in terms of the type and amounts of seeds that will cause disturbance each year. Weed seeds can be stored and survive for decades in dormant conditions, and will germinate when environmental conditions break the dormancy. The lifting of weed seeds to the top layer of the soil surface and the availability of suitable moisture for germination encourage weeds to grow and develop.

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Weed Vegetation Analysis. Herbicides had no significant effect on species abundance in most treatments except with deep tillage and fertilizer used (see Table 3). As is known, the use of herbicides can inhibit the density and growth of target weeds, reduce their seed yield, and then cause a decrease in the seed density of the weed soil seed bank by affecting its filling. In this study, the species composition of the weed seed bank tested was simple and the two dominant species were both sensitive to Atrazine, an effective herbicide in Maize farming.

Table 2 shows that at the observation of 15 Days After Plant (DAP), the dominant weed in Subang District (non-herbicide weed control) was *Ludwigia adscendens* with an SDR value of 27.3 while the dominant weed in Subang District (herbicide control) was *Cynodon dactylon* with an SDR value of 28.6 %. In Cianjur District (non-herbicide weed control) the dominant weed was *Ludwigia adscendens* with an SDR value of 19.2 % while the dominant weed in Cianjur District (herbicide control) was *Pistia stratiotes* with an SDR value of 45.5 %.

The dominance of broadleaf weeds is because broadleaf weeds have a higher competition for light absorption than grass and weed species. Broadleaf weed species are generally known to be able to produce an abundant amount of seeds so it is difficult to control, besides that at the age of 15 DAP rice tillers are not many so that the crown of rice leaves has not covered each other.

Table 3 shows that the dominant weed in Subang District (non-herbicide weed control) is *Cynodon dactylon* with an SDR value of 23.7. while the dominant weed in Subang District (herbicide control) was *Cynodon dactylon* with an SDR value of 29.1. In Cianjur District (non herbicide weed control) the dominant weed was *Pistia stratiotes* with an SDR value of 18.9 while the dominant weed in Cianjur District (herbicide control) was *Ludwigia adscendens* with an SDR value of 25.3. The dominance of *Cynodon dactylon* occurs because this weed is difficult to control during weeding.

This weed is difficult to control during weeding. In addition, *Cynodon dactylon* can dominate rice fields in each of the villages sampled because *Cynodon dactylon* is a weed that has a sturdy, upright stem and is one of the annual weeds that reproduce by seeds and have many seeds and long seed dormancy so that they can last a long time on the land and will grow in the next planting season.

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Table 2. SDR value of each weed type in Subang District and Cianjur District at 15 DAP.

No	Spesies	SDR mean value			
		Subang district		Cianjur district	
		NH	H	NH	H
1	*Alternanthera philoxeroides*	9.3	8.4	9.7	4.3
2	*Amaranthus* sp.	-	-	4.5	-
3	*Axonopus compressus*	5.2	-	1.1	-
4	*Bacopa monnieri*	-	-	4.6	5.8
5	*Brachiaria* sp.	-	-	-	2.1
6	*Commelina diffusa*	8.2	-	-	-
7	*Cynodon dactylon*	10.2	28.6	6.2	9.1
8	*Cynodon* sp.	-	-	-	5.1
9	*Cyperus rotundus*	-	-	2.1	1.2
10	*Digitaria* sp.	-	-	0.8	2.8
11	*Echinochloa crus-galli*	7.2	8.1	7.7	-
12	*Eleusine indica*	-	-	1.3	-
13	*Fimbristylis miliacea*	9.6	15.9	9.4	4.8
14	*Galinsoga parviflora*	-	-	3.4	-
15	*Hedyotis* sp.	-	-	2.1	-
16	*Leersia hexandra*	1.6	-	11.7	12.4
17	*Limnocharis flava*	1.1	-	-	-
18	*Ludwigia adscendens*	27.3	24.2	19.2	6.4
19	*Ludwigia perennis*	-	-	1.1	-
20	*Monochoria vaginalis*	13.6	6.1	6.5	-
21	*Panicum repens*	1.8	-	-	-
22	*Paspalum conjugatum*	-	8.2	-	-
23	*Pistia stratiotes*	4.2	-	7.9	45.5
	Total Domination Value	99.3	99.5	99.3	99.5
	Number of species	12	7	17	11

Description: NH= Non herbicide; H= Herbicide

Factors that influence weed dominance and diversity can vary from one region to another. The difference in the Summed Dominance Ratio (SDR) values of the two districts has increased and decreased, according to Rahmadi & Rochman (2020) that this is due to differences in weed control methods. In general, Subang Regency weeds are controlled by herbicides, while in Cianjur Regency weeds are controlled by non-herbicides. In this study, it can be seen that the dominant weeds are from the broad leaf group, while the grass and teki weeds are relatively fewer. The results of research by Zarwazi, et al. (2016) showed that the presence of weeds is influenced by the cultivation system, the presence of weeds in the cultivation system technology without herbicides, and using organic fertilizer is higher than in the conventional cultivation system which still uses herbicides as weed control. This reinforces that cultivation systems without the use of herbicides as weed control and the use of organic fertilizers have weaknesses in overcoming potential weed problems compared to conventional cultivation systems, but in terms of food safety and environmental health, organic cultivation systems are very superior (Rachma & Umam, 2021).

Table 3. SDR value of each weed type in Subang District and Cianjur District at 30 DAP.

No	Spesies	SDR Mean Value			
		Subang District		Cianjur District	
		NH	H	NH	H
1	*Alternanthera philoxeroides*	16.7	3.8	17.7	7.4
2	*Alternanthera sessilis*	-	1.5	-	-
3	*Axonopus compressus*	3.1	-	5.9	12.7
4	*Bacopa monnieri*	-	-	4.1	2.9
5	*Commelina diffusa*	-	-	1.1	-
6	*Cynodon dactylon*	23.7	29.1	7.7	4.2
7	*Cyperus difformis*	2.1	8.6	-	-
8	*Cyperus rotundus*	-	-	-	0.8
9	*Digitaria ciliaris*	5.1	-	-	-
10	*Digitaria* sp.	2.2	-	1.1	-
11	*Eclipta prostrata*	-	6.8	-	-
12	*Emilia sonchifolia*	-	-	-	1.8
13	*Fimbristylis miliacea*	18.7	28.1	13.6	14.0
14	*Hedyotis* sp.	2.3	-	2.6	3.5
15	*Leersia hexandra*	-	-	1.3	17.1
16	*Ludwigia adscendens*	15.0	15.3	13.1	25.3
17	*Ludwigia perennis*	-	3.3	-	-
18	*Monochoria vaginalis*	3.1	-	3.6	-
19	*Oxalis barrelieri*	1.4	-	-	-
20	*Oxalis corniculata*	-	-	-	2.5
21	*Panicum repens*	2.7	2.8	-	-
22	*Pistia stratiotes*	-	-	18.9	-
23	*Synedrella nudiflora*	3.3	-	8.9	7.1
	Total Domination Value	99.4	99.3	99.6	99.3
	Number of species	13	9	13	12

Note: NH= Non herbicide; H= Herbicide

Community Coefficient of Weed Population. The value of the population community coefficient in the observation areas in Subang and Cianjur Regencies can be seen in Table 4 and Table 5.

Based on Table 4, the value of the community coefficient (C) in all areas in Subang Regency is on average below 75%, except in the comparison village of Jayamukti with Blanakan at the age of 30 DAP which shows a community coefficient value of 80.8%. This means that the weeds between the villages are homogeneous or not so different.

Table 4. Comparative Value of Community Coefficient (C) in Observation Areas in Subang Regency

No.	Comparison Region	Community Coefficient (%)	
		15 DAP	30 DAP
1	Ciasem Girang: Ciasem Baru	51.0	36.8
2	Ciasem Girang: Jayamukti	35.9	39.8
3	Ciasem Girang: Blanakan	40.4	39.6
4	Ciasem Baru: Jayamukti	38.3	62.3
5	Ciasem Baru: Blanakan	29.0	54.3
6	Jayamukti: Blanakan	69.9	80.8

Table 5, shows that the value of the community coefficient (C) in all areas in Cianjur District is below 75%, this means that the value of C in the region A - B and so on do not have the same population. According to Tjitrosoedirdjo (1984), if the value of C is smaller than 75% then the area does not have population similarity. Comparison of other areas in the two districts also showed an average community coefficient (C) value below 75%. This shows that the observation areas in Subang and Cianjur districts have weed population dissimilarity or it can be said that the weed populations in the observation areas are not similar. The existence of a high level of population inequality is due to the different environmental conditions in the two areas of paddy rice cultivation.

Subang and Cianjur districts have differences in altitude, temperature, soil type, and fertilizer use. Subang District has an alluvial soil type, the air temperature ranges from 26° to 27° C, the altitude is about 10 m above sea level, and the fertilizers commonly used by farmers are compost and urea fertilizer. Cianjur district has a latosol soil type, the air temperature ranges from 20° - 21° C, the altitude is about 400 m above sea level, and the common fertilizer used by farmers is manure. Jiang, et al. (2014) reported that the application of organic fertilizer increased the diversity index of the weed community, thereby, stabilising the community structure. Nutrient-poor environments have high weed species diversity (Everaarts, 1992).

Table 5. Comparative Value of Community Coefficient (C) in Observation Areas in Cianjur Regency

No.	Comparison Region	Community Coefficient (%)	
		15 DAP	30 DAP
1	Sindanglaka: Babakan Caringin	51.0	31.0
2	Sindanglaka: Ciranjang	29.2	52.3
3	Sindanglaka: Cibiuk	28.5	44.0
4	Babakan Caringin: Ciranjang	26.3	56.0
5	Babakan Caringin: Cibiuk	40.9	50.8
6	Ciranjang: Cibiuk	17.9	60.2

Many factors influence weed community diversity including light. The length of time light shines on seeds also greatly affects the germination of some weed species. Cultivation techniques also influence weed community diversity. Cultivation techniques that influence the nature of the weed community include the presence of ground cover vegetation (legumes), weed control methods, drainage, plant spacing, and others. The effects of legume cover crops can be both beneficial and detrimental but the losses are very small compared to the benefits. The presence of legume cover crops can suppress weed growth, especially during the early stages of crop growth where the canopy has not yet closed so weed control costs can be reduced.

Weeding is based on the weed growth phase. Weeding before weeds enter the generative phase can prevent the development and spread of weeds through seeds and also prevent the addition of weed seeds in the soil (seed bank).

Conclusion

1. Weed diversity in lowland rice plantations is caused by different weed management and agroecology.
2. The population of weed seeds in the soil (weed seed bank) varies greatly depending on the composition of what grows on it and also the history of the soil itself. Land that was originally used as agricultural land will have a population of seeds related to agricultural weeds.

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