Asian Journal of Plant Sciences

ISSN 1682-3974

science alert

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OPEN ACCESS Asian Journal of Plant Sciences

ISSN 1682-3974
DOI: 10.3923/ajps.2021.609.619

Research Article

Effectiveness and Persistence of Metsulfuron-Methyl Herbicide in Rice Fields with Compost Organic Materials

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Abstract

Background and Objective: Metsulfuron-methyl is a pre and post-emergence herbicide that can control weeds in lowland rice cultivation, but the level of persistence is not certain. This study aimed to examine the effect of giving organic matter and the dose of the herbicide Metsulfuron-methyl to weeds, rice growth and yield, as well as to determine the level of persistence. **Materials and Methods:** The trial started from January-June, 2018 which was carried out in the Rice Fields of Cinunuk Village, Cileunyi District, Bandung Regency. The experiment used a bi-factor and was carried out using a divided plot design which was repeated three times, the main plot factor was the organic matter, consisting of two levels, namely: Low C-organic content (1.86%) and High organic C content (3.5%), while, subplot factor is the dose Metsulfuron-methyl herbicide, consisting of 5 levels: No herbicide, Metsulfuron-methyl dose 0.0010 kg a.i. ha^{-1}, Metsulfuron-methyl dose 0.0020 kg a.i. ha^{-1}, Metsulfuron-methyl dose 0.0030 kg a.i. ha^{-1} and Metsulfuron-methyl dose 0.0040 kg a.i. ha^{-1}. **Results:** The results showed that the treatment of Metsulfuron-methyl herbicide from a dose of 0.0010 kg a.i. ha^{-1} to a dose of 0.0040 kg a.i. ha^{-1} could increase the growth and yield of rice plants. The persistence of the Metsulfuron-methyl herbicide starting at a dose of 0.0010-0.0040 kg a.i. ha^{-1}at each C-organic content showed a value of 0 on observations 90 days after application. **Conclusion:** The increase in C-organic content in the soil caused a decrease in the persistence of the Metsulfuron-methyl herbicide.

Key words: Metsulfuron-methyl, C-organic content, weeds, rice, persistence, soil

Citation: Sumekar, Y., D. Kurniadie, D. Widayat and A. Yuniarti, 2021. Effectiveness and persistence of metsulfuron-methyl herbicide in rice fields with compost organic materials. Asian J. Plant Sci., 20: 609-619.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Rice is an important food crop commodity in Indonesia. Indonesian people use rice as a staple food. Ninety-five percent of Indonesia's population consumes this food ingredient. Rice can meet 63% of the total energy sufficiency and 37% of protein[1]. The need for rice as one of the main food sources for the Indonesian population continues to increase because besides the population continues to increase with an increase of around 2% per year, there is also a change in the consumption pattern of the population from non-rice to rice[2]. The national average rice consumption in 2013 reached 139.15 kg/capita/year[3].The high demands for rice consumption demand that national rice production must increase in line with Indonesia's population growth.

The success of rice cultivation is determined by various factors, one of which plays an important role in the presence of plant pests, such as pests, diseases and weeds. Weeds are pests that can hinder the success of crop production because they reduce yields both quantitatively and qualitatively[4,5]. During the plant growth period, weeds are strong competitors that occupy the crop area and compete for plant growth factors[6]. Also, weeds act as hosts for plant pests and diseases[7,8]. It wasreported[9] that nearly 227 species of weeds were directly or indirectly involved in decreasing crop yields which could reach 90%.

Due to the loss and due to the presence of weeds in cultivated crops, weed control is necessary. Weed control can be carried out in various ways, namely mechanically, technically, biologically, chemically with the use of herbicides, or in an integrated manner[4]. Among the various weed controls that are most commonly done besides mechanical means, is the use of herbicides. The use of herbicides has various advantages over mechanical means, including the weeds can be controlled in a short time is more effective for large areas, the danger of erosion and root damage can be avoided. Herbicides can control weeds that are difficult to weed by hand, solve labour problems when needed, increase the quality of maintenance and produce more optimal crops. According to another study[10] besides having various advantages, the use of pesticides must also be taken into account the possible negative effects on the environment, non-target organisms and weed resistance to the herbicide.

Herbicides that are often used in lowland rice planting areas include Metsulfuron-methyl. Metsulfuron-methyl is a pre and post-growth herbicide that can control the growth of grasses, sedges and broad-leaved weeds[11]. The herbicide Metsulfuron-methyl is a herbicide that can inhibit the action of the enzyme Acetolactate synthase (ALS) which plays a role in the branch chain synthesis of the amino acids valine, leucine and isoleucine so that weed growth is disrupted[12].

Herbicides will be effective in controlling weeds if the herbicides are in the soil for a long time. The time it takes for a herbicide to remain in an active state in the soil is known as herbicide persistence which is influenced by various factors such as the content of organic matter in the soil, volatilization, photodecomposition, adsorption, leaching, degradation by microbes and absorption by plants[13].

Organic matter is an important part of the soil that can improve soil properties, physical, chemical and biological properties of soil[14]. The existence of organic matter is necessary and maintained to maintain the harmony of ecological functions in the soil, sustainable production and environmental sustainability. Author[15] reported that the soils in Indonesia which are cultivated intensively have low organic matter content. Around 73% of agricultural land in Indonesia has soil organic C content<2.00%[16]. The provision of compost organic matter can improve the physical properties of the soil as well as affect plant growth[17].

Organic matter plays an important role in the herbicide adsorption in the soil. The adsorption of herbicides by organic matter affects the behaviour of several herbicides in the soil, namely biological activity, persistence, biodegradation, washing and evaporation[18]. Information on how herbicides behave due to the application of organic matter is the basis of the effectiveness of herbicides in suppressing weed growth and the impact of herbicides on environmental health. It was reported[19] that the residual organic matter will accelerate the degradation of herbicides in the soil.

Based on the foregoing, it is necessary to search about how the effect of the application of Metsulfuron-methyl herbicide in lowland rice fields with organic straw compost on the persistence of the herbicide in lowland rice fields and weed growth, growth and yield of lowland rice plants. The purpose of this study was to obtain the right dose of the Metsulfuron-methyl herbicide by giving organic straw compost so that it would get optimal yields as well as to examine the persistence of the herbicide used at each application dose determined by giving organic straw compost so that the use of herbicide could be right on target and has no impact on subsequent crops and the environment.

MATERIALS AND METHODS

Study area: The experiment was carried out from January-June, 2018. The experiment was carried out in the rice fields of Cinunuk Village, Cileunyi District, Bandung Regency. The location of the land is located at an altitude of 660 m above sea level and the type of rainfall is type B. The laboratory analysis was carried out at the Laboratory of Soil Fertility and Plant Nutrition, Faculty of Agriculture and the Central Laboratory of Padjadjaran University, Jatinangor, Sumedang Regency.

Tools: The tools used in this research are analytical scales, oven, knapsack, knife, scissors, plastic bag, ruler/tape measure, sickle, hoe, bucket and laboratory tools to measure the persistence and activity of microorganisms.

Research protocol: The compost used in this experiment is rice straw mixed with bran. The herbicide tested in this experiment was the active ingredient herbicide Metsulfuron-methyl. The plant seeds used are Ciherang rice cultivars. Fertilization was carried out using urea fertilizer (45% N), SP-36 fertilizer (36% P_2O_5) and KCl (50% K_2O). Pest control was carried out with Dursban 1 PE and Matador 25 EC with applications adapted to conditions in the field, while bird control uses nets.

Analysis of Metsulfuron-methyl compounds was carried out at the Central Laboratory of Padjadjaran University. Materials for persistence and residue analysis using a stock solution of Metsulfuron-methyl (1,000 LG mL^{-1}) were prepared in acetonitrile with concentrations (0.001, 0.01, 0.05, 0.1, 0.5 and 5 LG mL^{-1}).

Research design: The experiment was carried out using a two-factor experiment with a split-plot design in a randomized block design.

The main plot factor is organic matter, consisting of two levels, namely:

- b1: Low C-organic content (1.86%)
- b2: High organic C content (3.5%)

The subplot factor was the dose of the Metsulfuron-methyl herbicide, which consisted of five levels:

- d0: No herbicide
- d1: Metsulfuron-methyl dose 1 g a.i. ha^{-1}
- d2: Metsulfuron-methyl dose2 g a.i. ha^{-1}
- d3: Metsulfuron-methyl dose3 g a.i. ha^{-1}
- d4: Metsulfuron-methyl dose 4 g a.i. ha^{-1}

The experiment was repeated three times.

Statistical analysis: The data from the analysis of variance were further tested with Duncan's Multiple Range Test at the 95% confidence level.

Observations include

Weed dry weight during the experiment: Observation of weed dry weight was carried out on weeds taken from sample plots with a size of 0.5×0.5 m at 7, 21 and 35 days after application. Weeds are cut above the soil surface, then dried in a drying oven at 800°C until they reach a constant weight and then weighed.

Phytotoxicity of rice plants: How to determine the level of plant poisoning by herbicides is based on the symptoms displayed, namely abnormal growth or delayed growth and chlorosis. The percentage of plant poisoning by herbicides refers to the system issued[20] as shown in Table 1. Visually observations of plant poisoning were carried out at 7, 21 and 35 HSA.

Growth and yield of rice: Observations of lowland rice plant growth included the number of vegetative tillers per hill and height of rice plants at 7, 21 and 35 days after application. The yield and yield components of rice plants observed were the number of productive tillers per clump at 98 days after application and milled dry unhulled rice.

Herbicide persistence in soil: Herbicide concentrations in the soil were determined at 0, 30, 60 and 90 days after application. The total concentration of herbicides in the soil was measured by HPLC[21].

Observation of microorganism activity in soil: Observation of the activity of microorganisms in the soil as indicated by the respiration of microorganisms in the soil, observed at 30, 60 and 90 days after application[22].

Table 1: Percentage of plant poisoning

Damage amount (%)	Scale	Information
0-5	0	No poisoning
5-20	1	Mild poisoning
20-50	2	Moderate poisoning
50-75	3	Severe poisoning
$\geq$75	4	Very severe poisoning

RESULTS AND DISCUSSION

Total weed dry weight: The total dry weight of weeds is the total dry weight of weeds found in the experimental field. Weed dry weight indicates the level of a weed population in an experimental plot, the higher the dry weight of the weeds, the higher the weed population in the experimental plot. The dominant types of weeds that were present during the experiment were *Altenanthera sessilis*, *Ludwigia octovalvis*, *Marsilea crenata* and *Pistia stratiotes*.

Based on the data in Table 2, it can be seen that the treatment of high organic C content (3.5%) and low organic C content (1.86%) does not affect increasing the total dry weight of weeds. In observations 7 days after application, the average value of dry weeds in the treatment of low C-organic content was 7.093 g/0.25 m^2 and high organic C content was 10.427 g/0.25 m^2, observations were 21 days after the application for treatment. The low organic C content of 9.993 g/0.25 m^2, high organic C content of 10.273 g/0.25 m^2 and at 35 days of observation after application of treatment the low organic C content was 8.687 g/0.25 m^2 and high organic C content of 10.533 g/0.25 m^2. This is following the previous research[14] stated that the application of organic matter has not been able to increase the dry weight of plants because although mineralization of organic matter will completely release plant nutrients (N, P, K, Ca, Mg, S and other micronutrients), but in relatively small amounts.

All treatment doses of Metsulfuron-methyl herbicide starting from the dose of 1-4 g a.i. ha^{-1} gave an average dry weight number of total weed weeds that were significantly different than the treatment without herbicide application in observations 7, 21 and 35 days after application. The treatment of Metsulfuron-methyl herbicide dose of 4 g a.i. ha^{-1} produced the lowest average dry weight of weeds of 0 g/25 m^2 for each observation time. This shows that the use of Metsulfuron-methyl herbicide doses from 1-4 g a.i. ha^{-1} doses can control total weeds in lowland rice fields.

According to another study[23] that, the use of the Metsulfuron-methyl herbicide is effective in controlling broadleaf weeds and some grasses. Metsulfuron-methyl is the herbicide that works systemically, meaning that it is translocated and moves throughout the plant to inhibit the production of three essential amino acids needed for growth. For sensitive weeds that will cause symptoms such as chlorosis (yellowing of the leaves) and necrosis (brown or black dead leaves), these symptoms usually appear within one to two weeks after application.

Phytotoxicity of rice plants: Observation of plant phytotoxicity due to the application of the herbicide Metsulfuron-methyl was performed visually at 7, 14 and 21 days after application given in Table 3. Observations are based on some of the symptoms displayed, namely germination failure, stunted growth, abnormal growth and chlorosis.

The results of observations at 7, 14 and 21 days after application of plants in all experimental plots showed phytotoxicity symptoms due to the application of all doses of Metsulfuron-methyl herbicide with a scale of 0 (no poisoning). This shows that the application of the herbicide Metsulfuron-methyl up to a dose of 4 g a.i. ha^{-1} is safe to use for rice plants. Several types[24] of plants such as rice, corn and cotton are tolerant to herbicides because they contain enzymes that can convert toxic substances into non-toxic to plants, such as the enzyme nitrilase, glyphosate oxidoreductase, phosphinothricin acetyltransferase and 2,4-D dioxygenase. Furthermore, it was reported[25] that the use of the metsulfuron methyl herbicide is effective in controlling broadleaf weeds and is safe for plants.

Rice plant height: In Table 4, it can be seen that the dosage treatment of organic matter did not have a significant effect between treatments between low, medium and high C-organic content on the height of rice plants. In the

Table 2: Effect of various organic ingredients and doses of metsulfuron-methyl herbicide on the total dry weight of weeds

Treatment	Weed average dry weight (g/0.25 m^2) 7 DAA	21 DAA	35 DAA
C-Organic content			
b1: Low C-organic content (1.86%)	7.093[a]	9.993[a]	8.687[a]
b2: High C-organic content (3.5%)	10.427[a]	10.273[a]	10.533[a]
Doses of the metsulfuron-methyl herbicide			
d0: No herbicide	27.417[c]	42.233[c]	38.317[c]
d1: Metsulfuron methyl dose 1 g a.i. ha^{-1}	10.250[b]	6.117[b]	8.817[b]
d2: Metsulfuron methyl dose 2 g a.i. ha^{-1}	6.133[b]	1.983[a]	0.917[a]
d3: Metsulfuron methyl dose 3 g a.i. ha^{-1}	0.000[a]	0.300[a]	0.000[a]
d4: Metsulfuron methyl dose 4 g a.i. ha^{-1}	0.000[a]	0.033[a]	0.000[a]

Average value marked with the same letter in the same column shows no significant difference at the 5% level according to Duncan's Multiple Range Test. DAA: Days After Application

Table 3: Observation results of rice plant phytotoxicity percentage due to herbicide application at 7, 14 and 21 days after application

Treatments		Observation		
		7 DAA	14 DAA	21 DAA
b1d1	Low C-organic content+metsulfuron methyl dose 1 g a.i. ha^{-1}	0	0	0
b1d2	Low C-organic content+metsulfuron methyl dose 2 g a.i. ha^{-1}	0	0	0
b1d3	Low C-organic content+metsulfuron methyl dose 3 g a.i. ha^{-1}	0	0	0
b1d4	Low C-organic content+metsulfuron methyl dose 4 g a.i. ha^{-1}	0	0	0
b2d1	High C-organic content+metsulfuron methyl dose 1 g a.i. ha^{-1}	0	0	0
b2d2	High C-organic content+metsulfuron methyl dose 2 g a.i. ha^{-1}	0	0	0
b2d3	High C-organic content+metsulfuron methyl dose 3 g a.i. ha^{-1}	0	0	0
b2d4	High C-organic content+metsulfuron methyl dose 4 g a.i. ha^{-1}	0	0	0

DAA: Days After Application

Table 4: Effect of various organic ingredients and doses of metsulfuron-methyl herbicide on rice plant height in observations 7, 21 and 35 days after application

Treatments	Observation of rice plant height (cm)		
	7 DAA	21 DAA	35 DAA
C-Organic content			
b1: Low C-Organic content (1.86%)	35.30[a]	53.246[a]	70.582[a]
b2: High C-Organic content (3.5%)	37.773[a]	56.065[a]	72.988[a]
Doses of the metsulfuron-methyl herbicide			
d0: No herbicide	34.512[a]	52.617[a]	67.032[a]
d1: Metsulfuron methyl dose 1 g a.i. ha^{-1}	35.952[a]	54.022[a]	72.293[a]
d2: Metsulfuron methyl dose 2 g a.i. ha^{-1}	36.218[a]	53.955[a]	73.277[a]
d3: Metsulfuron methyl dose 3 g a.i. ha^{-1}	37.923[a]	54.993[a]	73.273[a]
d4: Metsulfuron methyl dose 4 g a.i. ha^{-1}	38.402[a]	57.692[a]	73.050[a]

Average value marked with the same letter in the same column shows no significant difference at the 5% level according to Duncan's Multiple Range Test. DAA: Days After Application

observation, 7 days after the application of low C-organic content treatment resulted in a rice plant height of 35.430 cm and high organic C content treatment resulted in a rice plant height of 37.773 cm, 21 days after application of low organic C content treatment resulted in rice plant height 53.246 cm and treatment of high C-organic content resulted in rice plant height of 56.065 cm and at observation 35 days after the application of the treatment, low organic C content resulted in rice plant height of70.582 cm and treatment of high organic C content resulted in rice plant height of 72.988 cm. It was reported[26] that giving straw compost did not affect the height of rice plants. The same thing was conveyed by another study[27] in research conducted on paddy fields, that giving straw compost did not show a difference in the height of rice plants. Furthermore, it was suggested[28] that organic matter added to the soil undergoes a decomposition process which results in simpler organic compounds and unstable inorganic compounds. Besides, organic matter is also a source of various plant nutrients, especially nitrogen and phosphorus in small amounts and can affect soil pH and cation exchange capacity.

The same thing also happened to the treatment of the herbicide Metsulfuron-methyl dose, where the dose of the herbicide Metsulfuron-methyl was not significantly different from the treatment without herbicide application to the height of rice plants. In observations 7 days after application of treatment without herbicide, Metsulfuron-methyl herbicide at a dose of 1, 2, 3 and a dose of 4 g a.i. ha^{-1} resulted in rice plant heights of 34.512, 35.952, 36.218, 37.923 and 38.402 cm. Observations 21 days after application of treatment without herbicide, Metsulfuron-methyl herbicide at a dose of 1, 2, 3 and a dose of 4 g a.i. ha^{-1} resulted in rice plant heights of 52.617, 54.022, 53.955, 54.993 and 57.692 cm. In the observation 35 days after the application of the treatment without herbicide, the Metsulfuron-methyl herbicide at a dose of 1, 2, 3 and a dose of 4 g a.i. ha^{-1} resulted in rice plant heights of 67.032, 72.293, 73.277, 73.273 and 73.050 cm. This is possible because plant height is not only influenced by environmental factors but also by genetic factors. According to another study[2], the similarity of genetic makeup is one of the causes of the uniform appearance of plants. Genetic programs are expressed in various plant traits that include the form and function of plants that produce diversity.

Number of vegetative tillers of rice plants per clump: Based on the data in Table 5, it can be seen that the dosage treatment of organic matter did not have a significant effect between treatments between low and high C-organic content on the number of vegetative tillers of rice plants per hill. Observation 7 days after application of low C-organic content treatment resulted in the number of vegetative rice tillers per

Table 5: Effect of various organic ingredients and doses of metsulfuron-methyl herbicide on the number of vegetative tillers of rice plants per clump at observations 7, 21 and 35 days after application

	Number of vegetative tillers clump		
Treatments	7 DAA	21 DAA	35 DAA
C-Organic content			
b1: Low C-Organic content (1.86%)	8.267[a]	17.267[a]	21.067[a]
b2: High C-Organic content (3.5%)	9.400[a]	19.400[a]	21.267[a]
Doses of the metsulfuron-methyl herbicide			
d0: No herbicide	7.500[a]	15.000[a]	18.333[a]
d1: Metsulfuron methyl dose 1 g a.i. ha^{-1}	9.000[a]	17.833[b]	20.500[b]
d2: Metsulfuron methyl dose 2 g a.i. ha^{-1}	9.000[a]	18.333[b]	21.333[bc]
d3: Metsulfuron methyl dose 3 g a.i. ha^{-1}	8.500[a]	20.167[c]	22.333[bc]
d4: Metsulfuron methyl dose 4 g a.i. ha^{-1}	10.167[a]	20.333[c]	23.333[c]

Average value marked with the same letter in the same column shows no significant difference at the 5% level according to Duncan's Multiple Range Test. DAA: Days After Application

Table 6: Effect of various organic ingredients and doses of metsulfuron-methyl herbicide on the number of productive tillers of rice plants per clump

Treatment	Number of productive tillers of rice plants per clump
C-Organic content	
b1: Low C-Organic content (1.86%)	13.133[a]
b2: High C-Organic content (3.5%)	13.800[a]
Doses of the metsulfuron-methyl herbicide	
d0: No herbicide	10.167[a]
d1: Metsulfuron methyl dose 1 g a.i. ha^{-1}	12.667[ab]
d2: Metsulfuron methyl dose 2 g a.i. ha^{-1}	14.333[b]
d3: Metsulfuron methyl dose 3 g a.i. ha^{-1}	14.500[b]
d4: Metsulfuron methyl dose 4 g a.i. ha^{-1}	15.667[b]

Average value marked with the same letter in the same column shows no significant difference at the 5% level according to Duncan's Multiple Range Test

clump of 8.267 and treatment of high organic C content resulted in the number of vegetative rice tillers per clump of 9.400, observations 21 days after application of the C-organic content treatment low yielded the number of vegetative tillers per clump of 17.267 and treatment of high C-organic content resulted in the number of vegetative tillers per clump of 19.400 and at observation 35 days after application of treatment the low C-organic content resulted in the number of vegetative tillers per clump of 21.067 and treatment of high organic C content resulted in the number of vegetative tillers per clump of 21.267. This is in line with the previous research[29] that giving straw compost does not have a different effect than other treatments on the growth of lowland rice plants. It was explained earlier[30] that most fertilizers that are given to the soil cannot be used by plants because they react with other soil materials so that the fertilization efficiency value is generally low to very low.

Meanwhile, the independent effect of the herbicide dose treatment of Metsulfuron-methyl showed that in the observation of 7 days after application, the herbicide dose treatment was not significantly different than the treatment without herbicide on the number of vegetative tillers of rice plants per clump. On observations 21 and 35 days after application of all Metsulfuron-methyl herbicide treatments starting at a dose of 1-4 g a.i. ha^{-1}showed an effect on increasing the number of vegetative tillers of rice plants per clump. The highest number of vegetative tillers on observations 21 and 35 days after the application was produced by the treatment of Metsulfuron-methyl herbicide dose 4 g a.i. ha^{-1}, namely 20.333 and 23.333. This means that the treatment of the Metsulfuron-methyl herbicide dose which can suppress weed growth has a good effect on increasing the number of vegetative tillers of rice plants. With the reduced weed population in the cultivation area, the competition with plants to fight for water, sunlight and nutrients can be suppressed so that plant growth and yield will be optimal[31]. Other authors[32] argued that in terms of nutrient competition, the absorption rate and efficiency of nitrogen use for rice weed biomass production were higher than rice plants, so to get good plant growth and yield, weed control, especially in critical periods is very necessary[33].

Number of productive tillers of rice plants per clump: In Table 6, it can be seen that the treatment of the dosage of organic matter did not have a significant effect between the treatments of low and high organic C content on the number of generative tillers of rice plants per clump. In the treatment of low C-organic content, the number of productive tillers per clump was 13.133 and the treatment of high organic C content resulted in the number of productive tillers per clump

Table 7: Effect of various organic ingredients and doses of metsulfuron-methyl herbicide on the weight of dry grain milled rice per 1 m^2

Treatments	Dry grain weight of rice (g m^{-2})	Dry grain weight of rice (t ha^{-1})
C-Organic content		
b1: Low C-Organic content (1.86%)	446.595^a	4.466
b2: High C-Organic content (3.5%)	461.269^a	4.613
Doses of the metsulfuron-methyl herbicide		
d0: No herbicide	351.862^a	3.519
d1: Metsulfuron methyl dose 1 g a.i. ha^{-1}	426.714^{ab}	4.267
d2: Metsulfuron methyl dose 2 g a.i. ha^{-1}	450.022^b	4.500
d3: Metsulfuron methyl dose 3 g a.i. ha^{-1}	483.925^{bc}	4.839
d4: Metsulfuron methyl dose 4 g a.i. ha^{-1}	557.135^c	5.571

Average value marked with the same letter in the same column shows no significant difference at the 5% level according to Duncan's Multiple Range Test

of 13.800. The same thing was reported previously[34] that the application of organic matter can not directly increase agricultural yield, but after continuous application can increase the N content in the soil. The increased N content in the soil due to the N supply from organic matter can lead to an increase in the vegetative growth of rice plants[35]. Furthermore[36], to replenish seeds required photosynthate products from leaves and photosynthate flow from other plant parts.

The independent effect of Metsulfuron-methyl herbicide treatment at a dose of 2-4 g a.i. ha^{-1} showed an average number that was significantly different than treatment without herbicide on the number of productive tillers of rice plants per clump. The treatment was of Metsulfuron-methyl herbicide 4 g a.i. ha^{-1} resulted in the highest number of productive tillers per clump of 15.667. This means that the dose of Metsulfuron-methyl herbicide treatment which can suppress weed growth has a good effect on increasing the number of generative tillers of rice plants. It was revealed[37] that Metsulfuron-methyl is a systemic and selective herbicide, which can be used pre and post-growth. The herbicide can stop plant cell division by blocking the action of the enzymes Aceto Lactase Synthase (ALS) and AcetoHydroxy Synthase (AHAS) to inhibit the conversion of α-ketoglutarate to 2 acetohydroxybutyrate and pyruvate to 2-acetolactate which produces the amino branch chains of valine, leucine and isoleucine. It was[38] revealed that the use of the Metsulfuron-methyl herbicide can suppress weed growth and can increase rice production with an effective application dose.

Milled dry grain weight: Base on Table 7 it can be seen that the independent effect of the treatment of organic matter content, both low and high, does not provide a significant difference between treatments on the observation of the weight of milled dry grain. Treatment of low organic C content resulted in milled dry grain weight of rice as much as 446.595 g m^{-2} and treatment of high organic C content resulted in milled dry grain weight of rice as much as 461,269 g m^{-2}. Another study[27] reported that the provision of organic matter cannot directly affect the increase in rice yields. According to another study[39] that, the appropriate organic substitution under the same N conditions is a good method for maintaining soil nutrient balance, improving soil physical properties and reducing fertilizer leaching.

All methyl metsulfuron herbicide treatments at a dose of 2, 3 and 4 g a.i. ha^{-1}gave an average number of observations of the weight of milled dry grain which was significantly different than without the application of herbicide. The Metsulfuron-methyl herbicide treatment was effective in reducing the dry weight of weeds and based on the data in Table 2 and 3, the treatment of Metsulfuron-methyl herbicide at a dose of 4 g a.i. ha^{-1} gave the highest yield of milled dry grain weight of 557.135 g m^{-2} (5,571 t ha^{-1}). This shows that the competition between rice plants and weeds becomes small, which in turn increases plant growth and the photosynthetic partition used for panicle formation will increase. It was revealed[19] that the metsulfuron methyl herbicide dose 4 g a.i. ha^{-1} was able to control broad-leaved weeds and grass in rice so that the yield was optimal.

Based on the research that has been done that the presence of weeds is very disturbing the productivity of the rice plant and now weeds can not only be controlled mechanically but can also be done chemically with the use of herbicides which are chemical weed control steps but are relatively safe both for the user and for the main crop itself[40]. Rice productivity depends on the interaction of various physiological and biological functions in plants. A higher percentage of filled grains are an indication of higher photosynthetic of plants that produce higher yields[41]. This shows that the application of herbicides does not create a negative impact on the photosynthesis of rice plants[36].

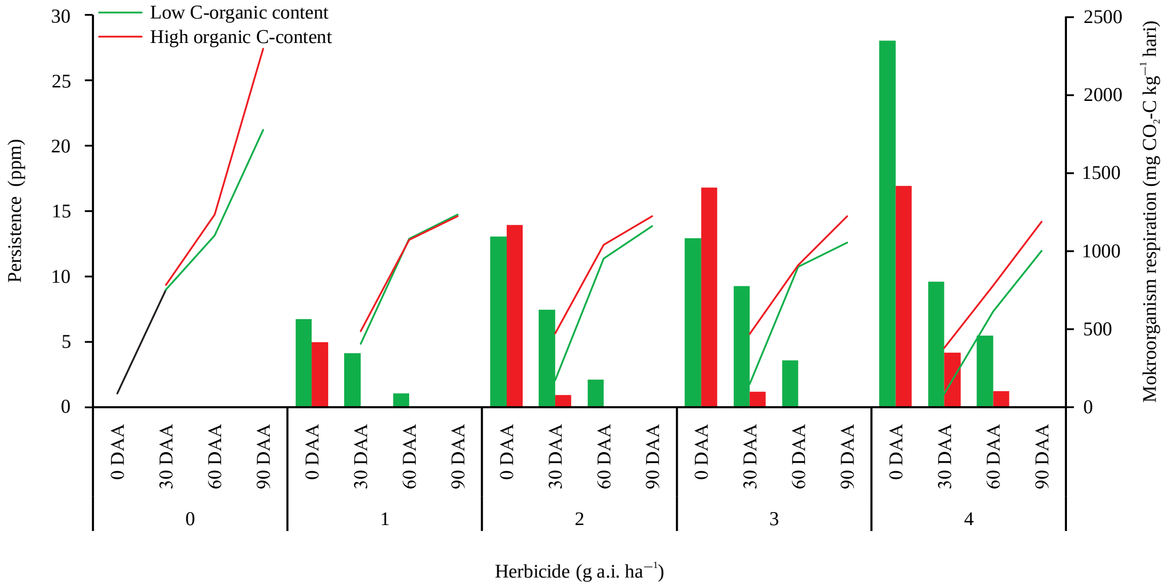

Fig. 1: Persistence graph of metsulfuron-methyl herbicide at doses of 1, 2, 3 and 4 g a.i. ha^{-1} and respiration of microorganisms with different c-organic contents in soil observations 0, 30, 60 and 90 days after application
Persistence: Bar chart, Respiration: Line chart, DAA: Days After Application

Persistence of metsulfuron-methyl herbicide and respiration of microorganisms in the soil: The concentration of herbicide Metsulfuron-methyl in the soil at 0, 30, 60 and 90 days after application and respiration of microorganisms at 30, 60 and 90 days after application with low, medium and high organic-C content. The concentration of herbicides in the soil and 30 daily respiration of microorganisms for three periods given different organic matter content and herbicides applied with each dose ranging from 1-4 g a.i. ha^{-1} can be seen in Fig. 1. Figure 1 shows that the herbicide concentration in the soil for each dose of herbicide application showed a lower number along with the increase in C-organic content, the higher the organic C content, the faster the herbicide degradation in the soil. Respiration of microorganisms from 30, 60 and 90 days after application showed a rapid increase, this means that the activity of microorganisms develops rapidly in line with the C-organic content.

Observation of 30 days after application, the highest persistence value of Metsulfuron-methyl herbicide was found in the treatment of low C-organic content (1.86%)+ Metsulfuron-methyl dose 4 g a.i. ha^{-1}, which was 9.64 ppm and the lowest persistence was in the treatment of high C-organic content (3.5%)+a Metsulfuron-methyl dose1 g a.i. ha^{-1} is 0 ppm. Observation of 30 days after application, the highest respiration rate was found in the treatment of high organic C-content (3.5%)+without herbicide application, namely 783 mg CO_2-C kg^{-1} day^{-1}, the lowest respiration rate was in the treatment of low organic C-content (1.86%)+a dose of Metsulfuron-methyl 4 g a.i. ha^{-1}, which is 85 mg CO_2-C kg^{-1}day^{-1}.

Observation of 60 days after application, the highest persistence value of Metsulfuron-methyl herbicide was found in the treatment of low C-organic content (1.86%)+dose of Metsulfuron-methyl 3 g a.i. ha^{-1}, namely 5.62 ppm and the lowest persistence with a value of 0 (undetectable there is persistence in the soil) is found in the treatment of high C-organic content (3.5%)+dose of Metsulfuron-methyl 1 g a.i. ha^{-1}, treatment of high C-organic content (3.5%)+dose of Metsulfuron-methyl 2 g a.i. ha^{-1} and treatment of high C-organic content (3.5%)+dose of Metsulfuron-methyl 3 g a.i. ha^{-1}. Observation of 60 days after application, the highest respiration rate was found in the treatment of high organic C content (3.5%)+without the application of herbicides, namely 1236 mg.CO_2-C kg^{-1}day^{-1}, the lowest respiration rate was in the treatment of low organic matter content (1.86%) + the dose of Metsulfuron-methyl 4 g a.i. ha^{-1} is 612 mg.CO_2-C kg^{-1}day^{-1}.

Observation 90 days after application of all treatments in combination with C-organic content with all doses of herbicide application showed a persistence number of 0 (undetectable). Observation of 90 days after application, the highest respiration rate was found in the treatment of high organic C content (3.5%)+without the application of herbicides, namely 2296 mg.CO_2-C kg^{-1}day^{-1}, the lowest respiration rate was in the treatment of low organic matter content (1.86%)+the dose of Metsulfuron-methyl 4 g a.i. ha^{-1} is 1003 mg.CO_2-C $kg^{-1}day^{-1}$.

Based on Fig. 1, it can be seen that the respiration rate of microorganisms is directly proportional to the provision of C-organic content for each observation time, the higher the C-organic content, the higher the activity of microorganisms. Meanwhile, the provision of C-organic content causes a decrease in the persistence of the Metsulfuron-methyl herbicide in the soil faster. This shows that the C-organic content can increase the activity of microorganisms as well as play a very important role in the degradation process of herbicides in the soil. Organic matter[42] is a source of energy for soil macro and micro-fauna, the addition of organic matter in the soil will increase the activity and microbiological population in the soil, especially those related to decomposition and mineralization of organic matter. Some of the microorganisms that play a role in the decomposition of organic matter are fungi, bacteria and actinomycetes. According to another study[43], the decrease in herbicide concentrations in the soil is compensated by the increase in microbial activity, so that the reduced concentration of the Metsulfuron-methyl herbicide is inversely proportional to the activity of soil microorganisms.

It wasstated[44] that the very important factors in the degradation of sulfonylurea herbicides in the soil are chemical hydrolysis and microbial decomposition, while photolysis and volatilization have very little effect. Each of these herbicide degradation processes can be affected differently by environmental conditions and soil properties. Herbicide persistence increases with low organic matter content and high soil pH[45].

The herbicide[42] Metsulfuron-methyl residue in the soil was gradually reduced and after 60 days after application the residue was found to be below the detection limit (<0.001 µg g^{-1}) for the application dose of 3-5 g a.i. ha^{-1}, while for the application dose of 8 g a.i. ha^{-1} and 0.0039 µg g^{-1}. There are several factors[46] that determine the persistence of a herbicide, namely soil factors, climatic conditions and herbicide properties. Soil factors that affect herbicide persistence consist of soil composition, soil chemistry and microbial activity. Apart from organic matter, soil pH also plays an important role in the degradation of the herbicide sulfonylurea. Soil pH[46] can affect the persistence of some herbicides, the rate of chemical degradation of the triazine and sulfonylurea herbicides family slows down as the soil pH increases especially above 7.0, while for lower pH 7 the rate of herbicide degradation is faster.

The respiration rate of microorganisms in Fig. 1 showed that for each observation time the increase in the highest respiration rate for each C-organic content is found in the treatment without herbicides, the higher the herbicide dose given, the lower the rate of increase in the respiratory rate. It is suspected that the herbicide Metsulfuron-methyl can poison some soil microorganisms. In line with the opinion of another study[46] giving herbicides can cause toxic effects on non-target bodies such as microorganisms, so that microorganisms that can grow and develop are those that are resistant to herbicides.

CONCLUSION

The treatment of herbicide Metsulfuron-methyl starting at a dose of 1-4 g a.i. ha^{-1}affects decreasing the dry weight of weeds, increasing the number of vegetative tillers, increasing the number of productive tillers and dry weight of milled rice. The herbicide treatment of Metsulfuron-methyl dose of 4 g a.i. ha^{-1} was able to produce the highest growth and rice yield of 5.57 t ha^{-1}. The persistence value of herbicides in the soil for each dose of herbicide Metsulfuron-methyl showed a decrease along with the increase in organic C content, the higher the organic C content, the faster the herbicide degradation in the soil. The highest persistence value of Metsulfuron-methyl herbicide was found in the treatment of low C-organic content (1.86%)+4 g a.i. ha^{-1} dose of Metsulfuron-methyl herbicide with a value on 30 days after application observations of 9.64 ppm and 60 days after application observations of 5, 52 ppm. The lowest persistence value of Metsulfuron-methyl herbicide was found in the treatment of high C-organic content (3.5%)+a dose of 1 g a.i. ha^{-1}. Metsulfuron-methyl herbicide with a value on 30 days after application observations of 0 ppm.

SIGNIFICANCE STATEMENT

Application of Metsulfuron-methyl herbicide starting at a dose of 2 g a.i. ha^{-1} can suppress weed growth so that it can increase the growth and yield of lowland rice. The increase in C-organic content has an effect on increasing the activity of microorganisms in the soil, causing the persistence of herbicides to decrease.

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