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The Potential of Leaf Organs from Sorghum Ratoon Plants Cultivated in Inceptisol Land as Organic Herbicides

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A B S T R A C T

The sorghum plant is a multi-functional plant, namely as food, feed, organic fertilizer, and organic herbicide. As an organic herbicide, sorghum plants contain allelopathy. Water extracts derived from the leaf organs of sorghum ratoon plants are interesting things to study related to the effect of allelopathy on test plants. The research aims to determine the potential of extracts derived from the leaf organs of ratoon plants of several sorghum varieties produced on inceptisols land as organic herbicides. The research was conducted from March to September 2022 at Kandang Mas, Kampung Melayu District, Bengkulu City (preparation of ratoon plants). In May 2023 at Bentiring Permai, Muara Bangkahulu District, Bengkulu City (bioassay test). The study used a single-factor, completely randomized design. The treatment of extracts derived from leaf organs, the level is control, leaves of ratun plant variety Numbu, leaves of ratun plant variety Super 1, and leaves of ratun plant variety Super 2. Using the bioassay method in Petri dishes repeated four times. Each petri dish was given 10 ml of extract, sown with 20 mung bean seeds of Vima 3 variety, and incubated for three days. The results showed that the water extract from the leaf organ of the ratoon plant variety Super 1 produced the highest inhibition against the test plant. The leaf organ of the sorghum ratoon plant variety Super 1 has better potential as an organic herbicide

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INTRODUCTION

In today's farming community, using chemical herbicides is still the best method because it is easy and cheap. Using synthetic chemical herbicides over a long period with improper field application and lack of knowledge can cause negative effects on the environment and inefficiency. According to Soltys *et al.,* (2013) and Heap (2019), the improper use of herbicides can impact the accumulation of active compounds in the soil and cause weeds to experience resistance to synthetic chemical herbicides.

Using organic herbicides that apply allelochemical compounds is one of the breakthroughs and solutions that can be applied in the cultivation environment. The advantages of using organic herbicides include being easy, simple, cheap, and safe for the cultivation environment. Allelochemicals are secondary metabolite compounds and, according to De Albuquerque *et al.,* (2011), classify secondary metabolites into three groups: phenolics, terpenoids, and compounds containing nitrogen and sulfur elements. Allelopathy is an environmental event in plants that directly or indirectly has a positive or negative impact on surrounding plants by releasing allelochemical compounds (Cheng & Cheng, 2015).

Exploration of certain plant allelochemical compounds as an activity for exploration as an organic herbicide material as a sustainable and environmentally safe weed control method (Nornasuha & Ismail, 2017). Allelopathy in allelochemical compounds can be found in weeds, wild plants, and cultivated plants. Many types of plants producing allelochemical compounds, including the sorghum plant, have been known. Sorghum plants have good properties, including wide adaptation to a stressed environment. Water use is very efficient in sorghum plants, so they can grow well on stressed soils (Simarmata *et al.,*, 2017). Besides being known as multi-functional plants, sorghum plants are also good organic herbicide materials because they are environmentally friendly. There are variations between organs in producing allelochemical compounds. Allelochemical compounds can be found in leaf, stem, root, rhizome, flower, fruit, and seed organs (Bhadoria, 2011). According to Macias *et al.,* (2007), the distribution of allelochemical proportions is uneven in plant organs, so their action depends on the amount of allelochemical content in the organs used as organic herbicides. Research related to the potential of sorghum plant organs in producing allelopathy has begun to be carried out. One is the potential of sorghum plant organs (roots, stems, and leaves) to produce allelopathies different from sorghum plants whose production is on marginal land (swamps). According to Susilo *et al.,* (2021), extracts from different organ sources will induce different responses to test plants. Furthermore, according to Susilo *et al.,* (2023), a good source of bioherbicide material in sorghum plants is obtained from the root organs of the main plant and the stems of ratoon plants cultivated in swamplands.

Research related to sorghum plant organs (leaves stems, and roots) as a source of organic herbicides has been carried out recently but is limited to one variety in the main plant. However, research has not been conducted on sorghum plant organs in ratoon plants cultivated in Inceptisols land. This study aims to determine the potential of water extracts derived from sorghum plant ratoon organs, especially leaf organs of several varieties produced on inceptisols land as organic herbicides.

METHODOLOGY

The research was conducted in an inceptisols soil type in Kelurahan Kandang Mas, Bengkulu City, Bengkulu Province, as the location for planting the main sorghum plant and continued with the maintenance of sorghum plantlets. Sorghum plantlets of 5 varieties were used as extract materials which were later tested for inhibitory power against test plants—preparation of ratoon plant material from March 2020 to September 2022. Experiments in the form of inhibition tests using the bioassay method were carried out in Bentiring Permai Village, Bengkulu City, Bengkulu Province, in May 2023.

This research activity began with planting main sorghum plants of 5 varieties on inceptisols land. Subsequently, the main plants were pruned to maintain the ratoon. A ratoon plant is a plant that grows after the main plant has harvested sorghum seeds and trimmed its stems. The ratoon plants used in this experiment were ratoon plants that had grown shoots at the age of 7 weeks after pruning the main plant. The harvested stalks from these ratoon plants were roots, stems, and leaves.

Sorghum ratoon plant stalks were dried in the sun for seven days. Each organ (roots stems, and leaves) was cut into 1-2 cm pieces, then oven dried at 70^{o}C for 72 hours or constant weight. The plant organ pieces were pulverized using a grinder. The fine powder obtained was the aqueous extract material for this experiment.

This study used a completely randomized design. This bioassay test experiment was arranged as a single factor. The treatment of water extract of sorghum plant leaves, with the following levels: Control, leaves of Numbu variety, leaves of Super 1 variety, and leaves of Super 2 variety. The experiment was repeated four times, and the experimental unit was a Petri dish.

Making aqueous extracts of ratoon plant organs is as follows: 100 g dry powder of organ stalks of each sorghum variety (10% concentration) was soaked with 1,000 mL of distilled water. The extract and water mixture was filtered with a cloth and continued with filter paper. Furthermore, the water extract was put in a bottle and labeled with a clear identity. The water extract is ready to be used as an ingredient in this experiment.

The bioassay test of water extract was carried out on filter paper on a Petri dish with a diameter of 9.00 cm. The bioassay test aims to determine the inhibition of germination growth of the test plant (mung bean seed variety Vima 3) as an effect of water-soluble allelochemical compounds. Filter paper is placed in a petri dish. Twenty mung bean seeds were planted in each petri dish, and 10 mL of water extract at a concentration of 10% was added to each petri dish. Susilo *et al.,* (2021b), the concentration of 10% sorghum plant water extract began to show high enough inhibition of mung bean sprout development as a bioassay test reaction. Furthermore, incubation was carried out in the growth chamber for three days.

The observation variables consisted of the percentage of normal sprouts (%), percentage of abnormal sprouts (%), plumula length (cm), radicle length (cm), plumula wet weight (g), radicle wet weight (g), cotyledon wet weight (g), and sprout wet weight (g). Observational data were statistically analyzed to obtain ANOVA and continued with the BNT test at the 5% level if there were significant differences between the averages.

RESULTS AND DISCUSSION

The observation variables in this experiment were the percentage of normal sprouts, percentage of abnormal sprouts, plumula length, radicle length, plumula wet weight, radicle wet weight, cotyledon wet weight, and sprout wet weight. The table of variance shows that the treatment of water extracts from the leaf organs of sorghum plantlets cultivated on inceptisols land shows a very significant effect on the length of the plumula and a significant effect on the percentage of normal sprouts, percentage of abnormal sprouts, radicle length, and wet weight of the plumula. No significant effect on the variables of radicle wet weight, cotyledon wet weight, and sprout wet weight is shown in Table 1. This shows that the treatments applied in this experiment significantly respond to the core variables of germination. The germination process undergoes a sequential process starting from water absorption into the seed cells. The process of imbibition water through the micropyle into the endosperm impacts the seed's volume, increases in size, and finally causes the testa rupture in the seed (Sudjadi, 2006). Active amylase enzymes work by breaking down flour into maltose. Maltose is hydrolyzed by maltase into glucose. Proteins that are broken down become amino acids. Glucose interacts during the metabolic process that produces energy and is converted into carbohydrate compounds—amino acids as a constituent of proteins that function as constituents of cell structures and new enzymes. If the above germination process is disturbed, such as the presence of toxic water extracts, the sprouts will experience impaired organ development.

Table 1. Recapitulation of Test Plant Germination as a Result of Treatment with Aqueous Extracts of Leaf Organs from Sorghum Ratoon Cultivated in Inceptisol Soil

Observation Variable	Treatment	Coefficient of variation (%)
Percentage of normal sprouts	4.84 *	21.92
Percentage of abnormal sprouts	4.84 *	81.22
Plumula length	9.83 **	13.87
Radicle length	5.76 *	22.73
Plumula wet weight	6.47 *	12.93
Radicle wet weight	0.29 ns	46.14
Wet weight of cotyledons	0.42 ns	26.86
Sprout wet weight	0.46 ns	21.37

** = very significant effect
* = significant effect
ns =Not significantly affect

The effect of extracts from leaf organs of ratoon sorghum plants cultivated in inceptisols land on the percentage of normal germination showed a significant effect. The control produced the highest germination percentage. These data show that the application of water extracts derived from the leaf organs of sorghum plantlets produces a response in the form of growth inhibition on the test plant in the form of green beans. The impact of inhibition on germination will produce abnormal sprouts.

Sorghum plants in the growth phase experience the formation of root, stem, and leaf organs. During the growth phase, the plant will experience growth from small to large and become a complete individual organ. According to Susilo *et al.,* (2021), different responses (test plants) in water extracts derived from different organ sources exist. Inhibition of water absorption causes low water content so that the stomata close, which impacts photosynthesis, is inhibited, and ultimately, the growth of the target plant is disrupted. The disruption of this physiological process inhibits the elongation of shoots, roots, and passive endosperm. Normal development of plant organs causes organs to absorb more water and store photosynthetic products, resulting in increased wet weight. The germination of a seed can be explained as the growth and development of the vital parts of the embryo inside the seed, which shows its ability to grow normally in the right environment. Normal germination usually shows good and normal growth of seed sprouts (Ance, 2003).

Table 2. Mean Percentage of Normal Sprouts, Percentage of Abnormal Sprouts, Plumula Length, and Radicle Length as a Result of Treatment with Aqueous Extracts of Leaf Organs from Sorghum Ratoon Plants Cultivated on Inceptisol Land

Treatment	Normal sprouts (%)	Abnormal sprouts (%)	Plumula length (cm)	Radicle length (cm)
Control	100.00 a	0.00 b	5.29 a	3.70 b
Leaf variety Numbu	80.00 ab	20.00 ab	3.27 b	4.29 b
Leaf variety Super 1	48.33 b	51.67 a	3.27 b	3.27 b
Leaf variety Super 2	86.67 a	13.33 b	4.79 a	6.41 a

Note: Numbers followed by the same letter in the same column are not significantly different in the LSD test at the 5% level.

The effect of extracts from leaf organs of ratoon sorghum plants cultivated in inceptisols land on the percentage of abnormal sprouts showed a significant effect. The control produced the lowest germination percentage. The Super 1 variety produced the highest percentage of abnormal germination, which was 51.67%, as shown in Table 2. These data show that the application of water extracts derived from the leaf organs of sorghum plantlets of the Super 1 variety produced a response in the form of growth inhibition to the highest test plant. The impact of this inhibition on germination will produce abnormal sprouts. The high number of abnormal sprouts shows that the allelopathy produced by the leaf organs of the Super 1 variety is the highest. This shows that the effect of water extracts derived from the leaf organs of ratoon plants produces inhibition of test plants in this experiment—test plants experience inhibition in the process of sprout growth which results in sprouts having abnormal sprout organs. The control achieved the lowest percentage of abnormal sprouts, which was 0.00%, as shown in Table 2. This shows that no water extract was derived from sorghum plants in the control treatment, resulting in a higher normal sprout component and the least abnormal sprouts.

Germination is a very important part of the plant life cycle, characterized by the emergence of prospective roots and shoots. Elisa (2006) germination is the process of reactivating the activity of the embryonic axis in the seed, which is stopped to form a sprout. During the process of seed growth and maturation, the embryonic axis also grows. Morphologically, germinating seeds are characterized by radicle or plumula protruding from the seed. Inhibition of sprout length growth by allelopathic compounds contained in aqueous extracts can occur through inhibition of cell division and elongation activities. Fitter and Hay (1991) suggested terpenoids, flavonoids, and phenols inhibit cell division. Wattimena (1987) states that phenolic compounds inhibit the metaphase phase in mitosis. Disruption of the metabolic phase causes inhibition of mitosis, which leads to cell division and elongation inhibition.

Extract materials derived from the leaf organs of ratoon plants have the potential as candidates for the best organic herbicide materials. Tetelay (2003) states that the inhibition caused by allelopathy can be in the form of inhibition of plant growth through disturbances in the root system or radicle. Root disturbance can be seen from the root length parameter. The presence of phenolic compounds disrupts auxin transport from shoots to roots and disrupts cytokinin synthesis in the roots. Cytokinin is known to function as root cell division and differentiation, and auxin is a compound that stimulates root elongation (Gardner *et al.,* 1991). Allelopathic compounds absorbed by the roots will inhibit growth, especially in the part of the root that is in direct contact with the water extract.

The effect of extracts from leaf organs of ratoon sorghum plants cultivated in inceptisols land on the length of the plumula showed a real effect. The control produced the highest plumula length (5.29 cm), although it was not significantly different from the extract derived from the Super 2 variety (4.79 cm). Super 1 and Numbu varieties produced the lowest plumula length, as shown in Table 2. These data show that the application of aqueous extracts derived from leaf organs of sorghum plantlets produced a response in the form of growth inhibition on the test plant. The impact of inhibition on germination will result in a shorter plumula length. This shows that the effect of the treatment of water extracts derived from leaf organs of sorghum ratoon plants of the Super 1 variety produces a higher inhibition of sprout growth, especially the length of the plumula.

The series of physiological processes that take place in germination before there is a response as above is the first absorption of water either by imbibition or osmose, the second breakdown of smaller, simpler, water-soluble, and transportable molecular compounds, the third distribution of the results of the breakdown, the fourth rearrangement of the compounds of the breakdown, the fifth respiration which is the breakdown of food reserves, and the sixth growth at the growing point. The activity of the hormone gibberellin influences stem elongation. Gibberellins play a role in stimulating cell division, cell enlargement, and stem elongation. Einhellig (1995), the mechanism of allelochemicals in plant growth inhibition is one of them by inhibiting the activity of phytohormones. Allelopathic compounds in sorghum extract are thought to inhibit gibberellin activity. This causes disruption of cell division in the interlayer meristem, inhibiting sprout development.

The effect of extracts from leaf organs of sorghum plantlets cultivated in inceptisols land on radicle length showed a real effect. Super 1 variety produced the lowest radicle length of 3.27 cm, although it was not significantly different from the extract from Numbu or the control shown in Table 2. Based on these data, the extract from the leaf organ of the ratoon plant does not always produce inhibition of the test plant, especially on the radicle length variable.

The effect of extracts from leaf organs of sorghum plantlets cultivated in inceptisols land on the wet weight of the plumula showed a real effect. The control produced the highest plumula wet weight (0.131 g) compared to the other treatments, although it was not significantly different from the extract of the Super 1 variety (0.108 g). Numbu and Super 2 extracts produced the lowest plumula wet weight, although not significantly different from Super 1, as shown in Table 3. This shows that the effect of treating aqueous extracts derived from leaf organs of ratoon plants of several sorghum varieties resulted in the inhibition of sprout growth. This shows that extracts derived from leaf organs of sorghum ratoon plants produce inhibition even though it varies between sorghum varieties. The water extract treatment always produced inhibition against the test plant in this experiment, although the inhibition power was different.

Table 3. Mean Wet Weight of Plumula, Wet Weight of Radicle, Wet Weight of Cotyledon, and Wet Weight of Sprouts as a Result of Treatment with Aqueous Extracts of Leaf Organs From Ratoon Sorghum Plants Cultivated on Inceptisol Land

Treatment	Plumula wet weight (g)	Radicle wet Weight (g)	Wet weight of cotyledons (g)	Sprout wet weight (g)
Control	0.131 a	0.039	0.077	0.211
Leaf variety Numbu	0.083 b	0.032	0.090	0.201
Leaf variety Super 1	0.108 ab	0.031	0.087	0.237
Leaf variety Super 2	0.099 b	0.042	0.073	0.198

Note: numbers followed by the same letter in the same column are not significantly different in the LSD test at the 5% level.

The effect of extracts from leaf organs of sorghum plantlets cultivated in inceptisols land on radicle wet weight showed no significant effect. There was a tendency for the water extract derived from the leaf organs of the Super 1 variety of ratoon plants to produce the lowest radicle wet weight of 0.031 g, as shown in Table 3. This indicates that the water extract derived from the leaf organ of the ratoon plant variety Super 1 has a greater allelopathic content when compared with water extracts from other varieties.

The effect of extracts from leaf organs of sorghum plantlets cultivated in inceptisols land on cotyledon wet weight showed no significant effect. There was a tendency for the water extract derived from the leaf organs of ratoon plants of Super 1 and Numbu varieties to produce the highest cotyledon wet weights of 0.087 g and 0.090 g, respectively. This indicates that the water extract derived from leaf organs of Super 1 and Numbu plant ratoon plants have a greater allelopathic content, thus inhibiting sprout growth, especially the wet weight of cotyledons. The wet weight of cotyledons that experienced inhibition due to water extract is characterized by a higher wet weight of cotyledons than those that experienced less inhibition. This indicates that cotyledons that experience inhibition do not experience the breakdown of seed endosperm or inactive seeds in the germination process, so the seed weight remains high.

Conversely, if the seeds do not experience inhibition due to water extract, the germination growth is normal, so the cotyledon weight is low. The wet weight of cotyledons that remains high indicates that the sprouts have minimal germination metabolic processes so that the cotyledons experience less embryo breakdown, and, ultimately, the weight remains high. According to Tanner and Sumayku (2009), allelopathic compounds with a growth-inhibitory effect are one of the main environmental factors affecting germination. While Trenggono (1990), the effect of allelochemicals occurs on water transportation in seeds. Water mixed with extracts containing allelochemicals will interfere with the work of the hormone gibberellin acid (GA). GA cannot produce the enzyme α-amylase, which interferes with germination.

The effect of extracts from leaf organs of sorghum plantlets cultivated in inceptisols land on the wet weight of sprouts showed no significant effect. There is a tendency for the water extract derived from the leaf organs of the ratoon plant variety Super 2 to produce the lowest sprout wet weight of 0.198 g, shown in Table 3. The wet weight of sprouts is obtained from the contribution of plumula, radicle, and cotyledon components. For sprouts that experience inhibition due to water extracts, the value of sprout weight is obtained from the low weight of radicle and low plumula and cotyledon weight which remains high, contrary to sprouts that do not experience inhibition. The decrease in wet weight indicates that the growth process is inhibited. This occurs because of the disruption of the water absorption process and the inhibition of the photosynthetic preparation process. Wet weight is the total water content and photosynthesis products in the plant. The inhibition of water absorption and the photosynthesis process causes the total water content, and photosynthesis results to decrease in plants. Sitompul and Guritno (1995) stated that the difference in genetic makeup is one of the factors causing the diversity of plant appearance. The diversity of plant appearance due to differences in genetic makeup can occur even though the plant material used comes from the same species.

CONCLUSIONS AND RECOMMENDATIONS

The aqueous extract derived from the leaf organ of the sorghum ratoon plant variety Super 1 produced the highest inhibition against the test plant. The leaf organ of the sorghum ratoon plant variety Super 1 has better potential as a source of organic herbicide. Therefore, for this water extract, it is recommended to use the leaf organ of the Super 1 variety ratoon plant.

FURTHER STUDY

The limitation of this study is that allelochemical analysis on the extracted material has not been carried out. Therefore, allelochemical analysis of the extracted material will be carried out in future studies.

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