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Opportunities of Water Extracts of Sorghum Main and Ratoon Plants with Their Organs as Bioherbicides

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A B S T R A C T

Sorghum is a multipurpose crop used as food, feed, organic fertilizer, and bioherbicide. Water extracts from main and ratoon plants with leaf, stem, and root organs produced in swamplands as bioherbicides are interesting topics to research. The research aims to determine the potential of water extracts from main and ratoon plants with leaf, stem, and root organs produced in swamplands as bioherbicides. The research was conducted from November 2020 to May 2021 (stalk preparation) and October 2022 (bioassay test) in Bentiring Permai, Muara Bangkahulu, Bengkulu City. This research applied a randomized group design. The bioassay experiment was arranged factorially with two factors. The first factor is the type of plant, with two levels, namely the main plant and the ratoon plant. The second factor is the source of the extract, with three levels: leaves, stems, and roots. The experiment was repeated four times, and the experimental unit was a petri dish. Each petri dish was given 10 ml of water extract, planted 25 sorghum seeds of the Suri 3 variety were incubated for four days. The results showed a diversity of plant species and organs in producing allelopathy. Water extracts derived from ratoon plant stems and main plant roots produce good inhibition, so they have the potential to be the best bioherbicide

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INTRODUCTION

The presence of weeds in the growing environment can negatively affect fruit quality and quantity. Today's common weed control method is synthetic herbicides, especially in areas with few workers and large tracts of land. The use of synthetic herbicides can hurt the environment. The continuous use of synthetic herbicides with limited knowledge will hurt humans, animals and the environment. The negative effects caused by the use of synthetic herbicides are due to their non-selective nature, polluting the environment, affecting residues, reducing natural enemies, and reducing soil organic matter permanently or temporarily (Susanti *et al.,* 2014).

Alternative weed control is needed that has a positive impact and is environmentally friendly in terms of the environment. One effort that can be applied is to explore the potential of compounds derived from cultivated plants that can be used as bioherbicides (allelopathy). Bioherbicides derived from cultivated plants can be used as environmentally friendly herbicides because they do not contain harmful compounds, have no residual effects and do not pollute the environment, especially soil (Asmaliyah *et al.,* 2010).

Bioherbicides are plant products that have the potential as herbicides by utilizing allelochemicals produced by these plants. One of the plants that can be used as a biological herbicide is sorghum. Bioherbicides derived from sorghum plants can utilize compounds produced by plant organs such as leaves, flowers, fruits, seeds, bark, roots, and stems. However, sorghum plant organs differ in the production of allelochemicals. According to Macias *et al.,* (2007), the proportion of allelochemicals is inhomogeneously distributed in plant organs, so their effectiveness depends on the allelochemical content in the organs used as bioherbicides. Allelochemical compounds in plant organs such as leaves, flowers, fruits, stems, roots and seeds are influenced by the developmental stage of the organ and the growing environment, and the allelopathic content of the organ is different. Studies have been initiated on the potential of sorghum plant organs to produce allelochemicals.

One is the potential of sorghum plant organs (roots, stems, and leaves) to produce different allelopathic effects with sorghum plants produced on marginal land. According to Susilo *et al.,* (2021), extracts from different organ sources will respond differently to test plants. The research results recorded by Susilo *et al.,* (2022) showed that 30% sorghum extract wastewater extract has the potential as a bioherbicide. Current research on sorghum plant parts (leaves, stems, and roots) as a source of bioherbicide is still limited to one main plant type. No research has been conducted on sorghum plant organs from perennial plant species fermented at different concentrations. The research aims to determine the potential of water extracts from main and ratoon plants with leaf, stem, and root organs produced in swamplands as bioherbicides.

METHODS

The research was conducted in the swampland of Kandang Limun, Bengkulu City, Bengkulu Province, especially for preparing stover as research material from November 2020 to May 2021. This research applied the bioassay method conducted in Bentiring Permai Village, Bengkulu City, Bengkulu Province, in October 2022. This research began with planting sorghum plants of the Numbu variety on swamp land until harvest. Subsequently, the main crop was pruned to maintain the ratoon. Sorghum ratoon plants grow after the main plant produces the first sorghum seed and the stem is pruned. The ratoon plants used in this experiment were seven weeks after growth after pruning the main plant. The harvested stalks from the ratoon plants were the root, stem, and leaf organs. These organs will be used for this experiment.

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

This study applied a Randomized Group Design. This bioassay experiment was arranged factorially for two factors. The first factor is the type of plant with two levels: main plants and ratoon plants. The second factor is the source of the extract with three levels: leaf, stem, and root organs. The experiment was repeated four times, and the experimental unit was a petri dish.

The method of making water extracts from ratoon plant organs is as follows: Dry powder of each sorghum organ (leaves, stems, and leaves) from main and ratoon plants as much as 100 g (10% concentration) was soaked with 1,000 mL of distilled water. The extra water mixture was filtered through a cloth and continued with filter paper. Furthermore, the water extract was put in a container with a clear identity label. This water extract is ready to be used for this experiment.

The bioassay test of water extract was carried out on filter paper on a Petri dish with a diameter of 9 cm. The bioassay test aims to determine the inhibition of germination growth in the test plant as an effect of water-soluble allelochemical compounds. Filter paper was placed inside the petri dish. A total of 25 sorghum seeds of Suri 3 variety were planted in each petri dish, and 10 mL of water extract with a concentration of 10% was added to each petri dish. Susilo *et al.,* (2021), the concentration of 10% sorghum plant water extract began to show sufficient inhibition of test plant growth. 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 (%), percentage of non-sprouting seeds (%), plumula length (cm), radicle length (cm), plumula wet weight (g), radicle wet weight (g), cotyledon wet weight (g), sprout wet weight (g), plumula dry weight (g), radicle dry weight (g), and cotyledon dry weight (g). Observation data were statistically analyzed to obtain ANOVA and continued with a 5% BNT test is significantly different from the averages.

RESULTS AND DISCUSSION

This study applied the following variables: percentage of normal sprouts, percentage of abnormal sprouts, non-sprouting seeds, plumula length, radicle length, plumula wet weight, radicle wet weight, cotyledon wet weight, sprout wet weight, plumula dry weight, radicle dry weight, and cotyledon dry weight. The variance analysis shows that the treatment of plant species has no significant effect on all observation variables except the percentage of normal sprouts and non-sprouting seeds shown in Table 1. This indicates that the treatment of plant species applied in this experiment has an insignificant response to most of the observed variables and few significant responses. The extract source treatment had a significant effect on the variables of plúmula length, radicle length, plúmula wet weight, radicle wet weight, and sprout wet weight, and had no significant effect on the variables of the percentage of normal sprouts, percentage of abnormal sprouts, percentage of non-sprouting seeds, sprout sump weight, plúmula dry weight, radicle dry weight, and cotyledon dry weight. The interaction between plant species and extract source affected all observation variables, except the percentage of abnormal sprouts, percentage of non-germinated seeds, and dry weight of radicle shown in Table 1.

Table 1. Recapitulation of Test Plant Germination Due to Water Extract Treatment from Different Sources

Observation variable	Plant type (J)	Extract source (K)	Interaction (J x K)	Coefficient of variation (%)
Percentage of normal sprouts	17.13 **	3.69 ns	7.55 **	28.91
Percentage of abnormal sprouts	0.20 ns	2.22 ns	2.90 ns	38.48
Percentage of non-germinated seeds	15.89 **	0.36 ns	2.57 ns	26.07
Plumula length	0.23 ns	6.29 *	26.50 **	15.95
Radicle length	2.39 ns	4.66 *	13.12 **	22.10
Plumula wet weight	1.11 ns	4.03 *	9.89 **	22.01
Radicle wet weight	0.07 ns	4.39 *	5.57 *	23.62
Wet weight of cotyledons	0.91 ns	0.13 ns	7.56 **	10.03
Sprout wet weight	1.01 ns	4.19 *	5.90 *	14.96
Plumule dry weight	1.17 ns	3.71 ns	8.67 **	23.50
Radicle dry weight	0.00 ns	0.25 ns	0.75 ns	38.57
Dry weight of cotyledons	0.77 ns	0.06 ns	7.56 **	10.64

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

The seed germination process involves several physiological stages: water consumption, metabolism, decomposition of food reserves, transportation of decomposing substances from the endosperm to the actively growing part of the embryo, assimilation, respiration and growth. In the germination process, it also

plays an important role in supporting and activating sperm cells, softening the seed coat and promoting the development of the embryo and endosperm, allowing oxygen into the seed, diluting protoplasm and transporting nutrients. The shoot length of the test plants at the germination stage was reduced due to the limited amount of inhibitor.

The effect of water extracts from different plant species on the percentage of abnormal sprouts showed no significant effect. There is a tendency for the type of ratoon plant produces a higher percentage of abnormal sprouts than the main plant. The effect of extract sources from different plant organs on the percentage of abnormal sprouts showed no significant effect. There is a tendency for the stem organ produces the highest percentage of abnormal sprouts shown in Table 2.

The effect of water extracts from different plant species on the percentage of non-germinated seeds showed a significant effect. The main plant species produced more non-germinated seeds than the ratoon plants. The effect of extract sources from different plant organs on the percentage of non-sprouting seeds showed no significant effect. There is a tendency for the stem organ produces the highest percentage of non-sprouting seeds shown in Table 2. The process of inhibiting seed germination will produce abnormal test plant sprouts. According to Susanti *et al.,* (2014), the seed germination process is caused by a decrease in cell membrane permeability, inhibition of cell division and expansion, and a decrease in the absorption process of water and nutrients.

The effect of water extracts from different plant species on radicle dry weight showed no significant effect. The effect of extract sources from different plant organs on radicle dry weight showed no significant effect, as shown in Table 2.

Table 2. Mean Percentage of Abnormal Sprouts, Percentage of Non-Sprouting Seeds, and Dry Weight of Radicle Due to the Treatment of Water Extracts from Different Sources

Treament	Abnormal sprouts (%)	Non-germinated seeds (%)	Radicle dry weight (g)
Plant type :			
Main crop	20.89	54.22 a	0.0012
Ratoon crop	22.67	32.89 b	0.0012
Extract source:			
Leaf	20.67	42.67	0.0013
Stem	27.33	46.67	0.0012
Roots	17.33	41.33	0.0012

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

The interaction effect of plant type and extract source on the percentage of normal sprouts showed a significant effect. The interaction between ratoon plants with root organs produced the highest percentage of normal sprouts (64.00%). The interaction of main plants with root organs produced the lowest percentage of normal sprouts (18.6%), shown in Table 3. This shows that the main plant with the root organ can produce the smallest percentage of normal sprouts. This value indicates the presence of sprouts experiencing pressure and inhibition due to the water extract given. This finding indicates that the water extract derived from the main plant with the root organ is the best combination as a bioherbicide material in this sorghum plant. Allelopathic content accumulates in cells and is toxic, making cells inelastic and inhibiting solute ion transport through cell membranes. These obstacles cause plant growth to be abnormal; if this event continues, it can cause death in plants (*test plants*).

Table 3. Interaction of Plant Species and Extract Source on Percentage of Normal Sprouts Normal Sprouts

Treatment	Main crop	Ratoon crop	Mean
	----------%----------		
Leaf	32.00 bc	41.33 b	36.67
Stem	24.00 bc	28.00 bc	26.00
Roots	18.67 c	64.00 a	41.33
Mean	24,89 b	44,44 a	

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

The interaction effect of plant type and extract source on the percentage of plumula length showed a significant effect. The interaction between ratoon plants with stem organs (3.79 cm) and main plants with root organs (3.48 cm) produced the lowest plumula length. The interaction of ratoon plants with root organs produced the highest plumula length (7.93 cm) and the main plants with leaves and stems shown in Table 4. This shows that the main plant with root organs and the ratoon plant with stem organs can produce the smallest plumula length. This value indicates that the sprouts experience pressure and inhibition due to the water extract given. Allelochemicals play a role in inhibiting the germination of test plants. The application of water extracts from ratoon stems and roots of the main sorghum plant resulted in a decrease in the length of the plumula. This is caused by the presence of allelopathy contained in these materials. Allelopathy causes inhibition in processes such as cell division, elongation, and enlargement, so cell size in plant organs decreases.

Table 4. Interaction of Plant Species and Extract Source on Plumula Length

Treatment	Main crop	Ratoon crop	Mean
	----------%----------		
Leaf	8.21 a	6.19 b	7.20 a
Stem	6.87 ab	3.79 c	5.33 b
Roots	3.48 c	7.93 a	5.70 b
Mean	6.19	5.97	

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

The interaction effect of plant type and extract source on the percentage of radicle length showed a significant effect. The interaction between ratoon plants with stem organs (4.01 cm) and main plants with root organs (2.51 cm) produced the lowest radicle length. The interaction of ratoon plants with root organs produced the highest radicle length (7.12 cm), as well as the main plants with leaves and ratoon plants with leaf organs shown in Table 5. This shows that the main plant with root organs and the ratoon plant with stem organs can produce the smallest radicle length. This value indicates the presence of sprouts experiencing pressure and inhibition due to the water extract given. In general, in test plants that are in direct contact with water extracts of sorghum plants, the radicle will experience abnormalities, namely stunted, thick, dark and twisted. Pebriani (2013) states that some allelochemical compounds prevent cell division, which slows the growth of germination organs due to the action of flavonoid and phenolic compounds.

Table 5. Interaction of Plant Species and Extract Source on Radicle Length

Treatment	Main crop	Ratoon crop	Mean
	----------%----------		
Leaf	7.01 a	5.39 ab	6.20 a
Stem	4.54 b	4.01 bc	4.27 b
Roots	2.51 c	7.12 a	4.81 ab
Mean	4.68	5.50	

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

The interaction effect of plant type and extract source on plumula wet weight showed a significant effect. The interaction between ratoon plants with stem organs (0.041 g) and main plants with root organs (0.039 g) produced the lowest plumula wet weight shown in Table 6. This indicates that the main plants with root organs and ratoon plants with stem organs can produce the smallest plumula wet weight. This value indicates that the sprouts experience pressure and inhibition due to the water extract given. Inhibition occurs due to the role of allelopathy contained in the material. There is a diversity of inhibition in plant species and sorghum plant organs.

Table 6. Interaction of Plant Species and Extract Source on Plumula Wet Weight

Treatment	Main crop	Ratoon crop	Mean
	----------%----------		
Leaf	0.083 a	0.073 a	0.078 a
Stem	0.083 a	0.041 b	0.062 ab
Roots	0.039 b	0.071 a	0.055 b
Mean	0.069	0.062	

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

The interaction effect of plant type and extract source on radicle wet weight showed a significant effect. The interaction between ratoon plants with stem organs (0.0133 g) and main plants with root organs (0.0073 g) produced the lowest radicle wet weight shown in Table 7. This shows that the main plant with root organs and the ratoon plant with stem organs can produce the smallest radicle wet weight. This value indicates the presence of sprouts experiencing pressure and inhibition due to the water extract given. The effect of water extract on the test plants is the first thing that is affected, namely the root morphology of the test plants. This abnormal root morphology is one of the signs of shock induced by this water extract. The reduced mass of plant organs in both shoots and roots is caused by damage such as chlorophyll and water absorption processes. According to Kristanto (2006), plant dry weight is reduced due to chlorophyll damage, water absorption, and stomatal closure, slowing down photosynthesis. It affects the rate of organic matter formation, reducing plants' dry weight.

Table 7. Interaction of Plant Species and Extract Source on Wet Weight of Radicle Radicle

Treatment	Main crop	Ratoon crop	Mean
	----------%----------		
Leaf	0.0180 a	0.0160 a	0.0170 a
Stem	0.0180 a	0.0133 ab	0.0157 ab
Roots	0.0073 b	0.0153 a	0.0113 b
Mean	0.0144	0.0149	

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

The interaction effect of plant type and extract source on cotyledon wet weight showed a significant effect. The interaction between ratoon plants with root organs (0.0327 g) and main plants with root organs (0.0447 g) produced the lowest cotyledon wet weight shown in Table 8. This shows that the main plant with root organs and the ratoon plant with stem organs can produce the highest cotyledon wet weight. This value indicates the presence of sprouts experiencing

pressure and inhibition due to the water extract given. Test plants that get the water extracted from sorghum plants will experience inhibition of activity in the process of seed germination. Seeds have reduced germination activity so that the endosperm or cotyledons do not undergo much overhaul so that the weight of the cotyledons remains high and relatively does not decrease. While seeds that do not get the water extracted from sorghum plants (control), the seeds will remain normal in the germination process; this impacts reducing the weight of the cotyledons or endosperm is higher. A common symptom caused by allelopathic effects on plants is the inhibition of plant seed germination. During seed germination, allelopathy can affect enzyme activity, and allelopathic compounds can also inhibit enzyme activity, making germination difficult even if the seeds do not germinate.

Table 8. Interaction of Plant Species and Extract Source on Wet Weight of Cotyledons

Treatment	Main crop	Ratoon crop	Mean
	----------%	----------%	
Leaf	0.0380 ab	0.0413 a	0.0397
Stem	0.0380 ab	0.0413 a	0.0397
Roots	0.0447 a	0.0327 b	0.0387
Mean	0.0402	0.0384	

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

The interaction effect of plant type and extract source on the wet weight of sprouts showed a significant effect. The interaction between ratoon plants with stem organs (0.0960 g) and main plants with root organs (0.0913 g) produced the lowest wet weight of sprouts (although not significantly different from other interactions) shown in Table 9. This shows that the main plants with root organs and ratoon plants with stem organs can produce the smallest wet weight of sprouts. This value indicates that the sprouts experience pressure and inhibition due to the water extract given.

Table 9. Interaction of Plant Species and Extract Source on Wet Weight of Sprouts

Treatment	Main crop	Ratoon crop	Mean
	----------%	----------%	
Leaf	0.1393 a	0.1300 ab	0.1347
Stem	0.1393 a	0.0960 b	0.1177
Roots	0.0913 b	0.1187 ab	0.1050
Mean	0.1233	0.1148	

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

The fresh weight of sprouts is the sum of several organs or components of shoots, such as radicle, hypocotyl and cotyledon. Shallow sprouts, hypocotyls, and cotyledon organs contribute to low shoot emergence. When water absorption occurs in seeds, gibberellins are released from the embryo and code the seeds that dormancy has ended, and they are ready to germinate (Campbell *et al.*, 2003). If water, as an activating material for the germination process, contains inhibiting substances, the subsequent germination process will be disrupted. According to Tiwari (2011), plant growth inhibited by allelopathy will decrease wet plant weight.

Table 10. Interaction of Plant Species and Extract Source on Dry Weight of Plumula

Treatment	Main crop	Ratoon crop	Mean
	----------%----------		
Leaf	0.0083 a	0.0073 a	0.0078
Stem	0.0083 a	0.0040 b	0.0062
Roots	0.0040 b	0.0070 a	0.0055
Mean	0.0069	0.0061	

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

The interaction effect of plant type and extract source on plumula dry weight showed a significant effect. The interaction between ratoon plants with stem organs (0.0040 g) and main plants with root organs (0.0040 g) produced the lowest plumula dry weight shown in Table 10. This shows that the main plants with root organs and ratoon plants with stem organs can produce the smallest plumula dry weight. This value indicates the presence of sprouts experiencing pressure and inhibition due to the water extract given.

Table 11. Interaction of Plant Species and Extract Source on Dry Weight of Cotyledons

Treatment	Main crop	Ratoon crop	Mean
	----------%----------		
Leaf	0.0170 ab	0.0187 a	0.0178
Stem	0.0170 ab	0.0187 a	0.0178
Roots	0.0203 a	0.0147 b	0.0175
Mean	0.0181	0.0173	

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

The interaction effect of plant type and extract source on cotyledon dry weight showed a significant effect. The interaction between ratoon plants with root organs (0.0147 g) and main plants with leaf and stem organs produced higher cotyledon dry weights (although not significantly different from other

interactions), as shown in Table 11. This value indicates the presence of sprouts experiencing pressure and inhibition due to the water extract given.

CONCLUSIONS AND RECOMMENDATIONS

There is diversity, both in plant species and plant organs, in producing inhibition against test plants. This shows a diversity of plant species and organs in producing allelopathy. Water extracts derived from ratoon plant stems and main plant roots produce good inhibition, so they have the potential to be the best bioherbicide.

FURTHER STUDY

This study has limitations, namely that no allelochemical analysis has been carried out on the extracted material; therefore, in the future, it is necessary to carry out an allelochemical analysis to complement the information of this study.

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