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Potential of Sorghum Water Extract as Bioherbicide Under Different Varieties and Water Stresses

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A B S T R A C T

The potential of sorghum plants to produce allelopathy is determined by the variety and the level of stress it receives. This study aimed to obtain information on the potential of sorghum water extract as a bioherbicide due to water stress treatment with different varieties. This study used a one-factor group randomized design. The extract source treatments were as follows: Super 2 + watering once every 1, 2, and 3 days; Suri 4 + watering once every 1, 2, and 3 days; Bioguma + watering once every 1, 2, and 3 days and control. Bioassay method experiments in petri dishes. Each petri dish was given 10 ml of aqueous extract with a concentration of 5%. A total of 25 sorghum seeds were planted and incubated for three days. The results showed that all water extracts from sorghum varieties Super 2, Suri 4, and Bioguma, combined with all water stresses, could inhibit the growth of the test plants. However, Super 2 + once every 5 days inhibited the test plants the most compared to the other treatments. Therefore, these sorghum water extracts have the potential to be used as bioherbicides to control weeds

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INTRODUCTION

With limited resources such as water, nutrients, and available growing space, weeds reduce crop yields by competing with plants for resources (Little et al., 2021). There are many challenges in crop cultivation, such as problems with improved seeds, pests and diseases, land degradation, harvest and post-harvest, and the negative impacts of climate change (Farooq et al., 2023). Weed control includes related diseases and pests. To manage weeds, farmers usually do not use effective farming strategies. This is different from the agriculture and plantation business. Farmers use manual or labor-intensive weed control Tibugari et al., (2020a) or synthetic herbicides because they do not have much labor.

Crops are usually plagued by various weeds that cause yield losses. These include weedy weeds, grass weeds, and broadleaf weeds (Tibugari et al., 2020a). Each weed control technique has good and bad effects. Manual weed control is usually costly compared to synthetic herbicide methods. In addition, synthetic herbicide methods generally require less labor than manual weed control. To manage weeds, modern farms that focus on productivity often use synthetic herbicides. The use of synthetic herbicides can cause environmental and health problems. Herbicides are a hazard to the environment, according to (Scavo et al., 2020). As a result, proper weed control methods are needed, which are essential for a sustainable agricultural system. Environmentally friendly weed management is essential for sustainable crop production.

Organic weed management methods are one way to manage weeds in crop production systems. Environmentally friendly weed management is very important to overcome the problem of weed resistance to synthetic herbicides (Tubeileh & Souikane, 2020). The use of organic herbicides derived from certain plants to overcome the problem of synthetic herbicides in weed control is necessary. Since allelopathy is one of the environmentally friendly organic herbicides, it can be used as a tool in weed management to control current and future weeds. Allelopathy is a solution to weed problems in crop production systems. Other sustainable weed control methods can also be used along with allelopaths (Kundra et al., 2023).

Bioherbicide use will benefit all parties. It will enable them to make good and environmentally friendly weed management strategies and reduce their dependence on synthetic herbicides (Iqbal et al., 2020). Allelopathy is essential for controlling weeds in a sustainable agricultural system. However, to ensure the successful use of allelopathy, this approach must be simple and economically feasible. Widespread and ever-present allelopathic plants can be used for environmentally friendly weed control of course (Nornasuha & Ismail, 2017).

Sorghum is one of the plants that has a wide growth adaptation and produces allelopathy. Sorghum plants are resistant to drought and can grow in non-ideal environments, such as dry soils with low nutrients and low rainfall (Ali et al, 2023). Bioherbicides derived from water or sorghum extracts can reduce weed weight by 29%, fresh weight by 31%, and dry weight by 27% when compared to the control in wheat crops (Ashraf & Akhlaq, 2007).

The application of sorghum genotypes as bioherbicides is an interesting phenomenon to study its potential. The allelopathic level of sorghum varieties may differ. Natural and sustainable production of allelopathic compounds can suppress weeds. A method to improve allelopathic properties is genetic modification. Allelopathy should be cheap and safe for plants and non-toxic to humans or ecosystems. Susilo et al., (2021a) showed that water extracts from Ultisol soil and water extracts made from dry cultivation patterns in swamplands can function as good bioherbicides.

Some studies show that there is a relationship between allelopathic content and the growing environment of plants. Studies on the relationship between allelopathy and abiotic stress have been conducted, but there has never been a study of allelopathy in a water stress environment on Entisols or coastal land with various sorghum varieties. The purpose of this study was to obtain information on the potential of sorghum water extract as a bioherbicide due to water stress treatment with different varieties.

LITERATURE REVIEW

Sorghum is a drought-tolerant cereal crop capable of growing on marginal soils, making it a significant choice in arid climates. Under drought conditions, sorghum increases the production of secondary metabolites such as phenolics, flavonoids, and terpenoids, which serve as defense mechanisms against pathogens, herbivores, and competitors (Varela et al., 2022; Akula & Ravishankar, 2011).

Sorghum is known to have allelopathic compounds, such as sorgoleone, which is one of the most dominant bioactive compounds. Sorgoleone is a phenolic compound produced by sorghum roots and is known to be effective in inhibiting germination and growth of surrounding weeds. These compounds and other secondary metabolites can increase significantly when sorghum is under drought-stress conditions (Zuo et al., 2021).

Research shows that drought triggers the accumulation of secondary metabolites in sorghum plants as part of their stress response (Vogler et al., 2019). Drought causes oxidative stress in plants, which triggers enzymatic activity in the phenylpropanoid biosynthetic pathway, producing phenolic compounds such as sorgoleone (Khan et al., 2020). This increase in sorgoleone concentration directly impacts the allelopathic effect of sorghum on surrounding competitor plants, making it more effective as a bioherbicide agent.

The use of sorghum as a natural bioherbicide is based on its high allelopathic potential, especially in dry or marginal lands where drought stress is daily (Weston & Duke, 2003). To increase secondary metabolite production under drought, sorghum can be used in natural weed control strategies, reducing reliance on synthetic herbicides that can pollute the environment (Dayan, 2019).

Drought stress in sorghum increases the production of allelopathic secondary metabolites that can be utilized as bioherbicides. Further research is needed to identify the specific active compounds responsible for these allelopathic effects and explore their practical applications in broader agricultural systems, incredibly sustainable and environmentally friendly agriculture (Bhowmik & Inderjit, 2003).

METHODS

Plant Material

There are five types of sorghum available for use as a water extract: Super 2, Suri 4, and Bioguma. Each variety was treated with watering every day, every three days, and every five days. Entisol soil was used for this experiment. After planting, the sorghum was harvested at four weeks of age. For fourteen days, the crown and roots were dried in the sun. After that, the stover was dried for twenty-two hours in an oven at 70 degrees Celsius for 72 hours. The dried stalks are cut into 2-3 cm long pieces and pulverized with a blender or grinder.

Water Extract Preparation

For one day, 50 grams of sorghum dry powder (5% concentration) is soaked with 950 milliliters of distilled water and stirred with a secker. With a cloth, filter the mixture of extract and water before lining it with filter paper. The extracts were stored after being put into containers and labeled. This bioassay experiment used the aqueous extract on growing media in polybags with the main crop being sorghum.

Bioassay with Water Extract on Filter Paper

The purpose of this bioassay test was to determine the effect of flavonoids, a water-soluble allelochemical compound, on mung bean seed germination. In a 9 cm diameter petri dish, a two-layer filter paper was placed and 25 mung bean seeds were planted. 10 milliliters of aqueous extract at 5% concentration was added to it. Afterward, the petri dishes were incubated in a growth chamber for three days.

Measurement of Experiment Variables

Percentage of live sprouts (%), percentage of dead sprouts (%), wet weight of live sprouts (g), wet weight of dead sprouts (g), length of plumula and radicle (g), and percentage of live and dead sprouts, are included in the experimental variables.

Statistic Analysis

This experiment used a bioassay test using a single-factor completely randomized design repeated four times. After the data was statistically analyzed to generate ANOVA, LSD test was conducted to determine if there was a significant difference between means. The level of significance was assessed using a p-value of 0.05.

The observation variables of this experiment were the percentage of live sprouts, percentage of dead sprouts, wet weight of live sprouts, weight of dead sprouts, wet weight of plumula and radicle, length of plumula and radicle. Based on the variance analysis, it showed that the treatment of water extract treatment from a combination of sorghum varieties and the level of water stress had a significant effect on all variables shown in Table **1.**

Table 1. Recapitulation of Test Plant Germination Due to Water Extract Treatment of Different Combinations of Sorghum Varieties and Water Stress Levels

No	Observation variable	Treatment	Coefficient of variation (%)
1	Percentage of live sprouts	22.75 **	26.34
2	Percentage of dead sprouts	22.75 **	14.18
3	Wet weight of live sprouts	6.66 **	56.88
4	Wet weight of dead sprouts	38.59 **	13.28
5	Wet weight of plumula and radicle	110.68 **	17.92
6	Length of plumula and radicle	240.81 **	13.27

Description : ** = Significantly Different

The water extract treatment derived from the sorghum variety Suri 4 + watering 5 days at a time produced the lowest percentage of live sprouts which was 0.00% shown in Table 2. This shows that the water extract treatment derived from a combination of sorghum varieties and the level of water stress is able to provide the highest level of inhibition when compared to other treatments and the control. The treatment with the lowest level of test plant inhibition or no inhibition is the control treatment because there are no toxic compounds. This is thought to be caused by differences in allelopathic levels at the level of water stress received by each variety. The physiological processes of sorghum plants will be affected by differences in their growth under various conditions of water stress. In addition, water stress in sorghum plants reduces the activity of sorghum preparation enzymes (Bing et al, 2014). As a result, sorghum plants are disrupted, which has an impact on the production of secondary metabolites and the formation of allelopathic compounds.

The water extract treatment derived from the sorghum variety Suri 4 + watering 5 days at a time produced the highest percentage of sprouts that did not grow, namely 100.00%, although it was not significantly different from the Bioguma variety + watering every day (90.00%) shown in Table 2. This shows that the water extract treatment derived from a combination of sorghum varieties and the level of water stress is able to provide the highest level of inhibition when compared to other treatments and the control. The treatment with the lowest level of inhibition against test plants or no inhibition is the control treatment because there are no toxic compounds. Each variety shows differences in allelopathic levels and the level of water stress received. Since there were no toxic compounds, the control treatment had the lowest level of inhibition of the test plant against germination. According to Ibrahim et al., (2022), drought stress affects wheat seedling growth due to its biochemical characteristics, including low activity of antioxidant enzymes.

Table 2. Effect of Water Extracts Derived from a Combination of Sorghum Varieties and Water Stress Levels on the Percentage of Live Sprouts, Percentage of Unsprouted Seeds, and Live Sprout Weight

Treatment	Live sprouts (%)	Seeds not sprouted (%)	Live sprout weight (g)
Control	90.00 a	10.00 e	2.460 a
Super 2 + watering once a day	40.00 c	60.00 c	0.656 bcd
Super 2 + watering once every 3 days	40.00 c	60.00 c	0.611 bcd
Super 2 + watering once every 5 days	60.00 b	40.00 d	0.864 bc
Suri 4 + watering once a day	25.00 cd	75.00 b	0.517 cd
Suri 4 + watering once every 3 days	30.00 c	70.00 b	0.693 bcd
Suri 4 + watering once every 5 days	0.00 e	100.00 a	0.000 d
Bioguma + watering once every 1 days	10.00 de	90.00 a	1.340 b
Bioguma + watering once every 3 days	25.00 cd	75.00 b	0.329 cd
Bioguma + watering once every 5 days	30.00 c	70.00 b	0.551 cd

Note: Numbers Followed by the Same Letter in the Same Column are not Significantly Different in the 5% LSD Test

The water extract treatment derived from the sorghum variety Suri 4 + watering 5 days at a time produced the lowest live sprout weight of 0.00 g shown in Table 2. This shows that the water extract treatment derived from a combination of sorghum varieties and the level of water stress is able to provide the highest level of inhibition when compared to other treatments and the control. The treatment with the lowest level of inhibition against the test plant was the control treatment. Phytotoxicity caused by phenolic compounds from allelopathy in sprouts will interfere with plant growth due to changes in water status, increased ABA content, and osmotic stress and oxidative stress (Araniti et al., 2020).

The water extract treatment derived from sorghum variety Suri 4 + watering every 5 days, and Bioguma variety + watering every day produced the lowest dead seed weight of 1.468 g and 1.448 g shown in Table 3. This shows that the water extract treatment derived from a combination of sorghum varieties and water stress levels was able to provide the highest level of inhibition when compared to other treatments and the control. The treatment with the lowest level of inhibition against the test plant was the control treatment. According to Weston & Czarnota, (2021), allelochemicals increase plant growth at low concentrations while suppressing growth at high levels of stress.

The water extract treatment derived from sorghum varieties Suri 4 + watering every 5 days, and Super 2 + watering every 5 days produced the lowest plumula and radicle weights of 0.000 g and 0.011 g shown in Table 3.

This shows that the water extract treatment derived from a combination of sorghum varieties and water stress levels was able to provide the highest level of inhibition when compared to other treatments and the control. The treatment with the lowest level of inhibition against the test plant was the control treatment. These results are in line with research conducted by Susilo et al., (2020), which found that because sorghum extract produces high allelopathic compounds, it can inhibit shoot growth.

Table 3. Effect of Water Extract Derived from a Combination of Sorghum varieties and Water Stress Levels on Dead Seed Weight, Plumula + Radicle Weight, and Plumula + Radicle Length

Treatment	Seed weight dead (g)	Plumule weight + radicle (g)	Length of plumula + radicle (g)
	0.1	0.1	7.31
Control	65 e	48 a	1 a
	0.6	0.0	1.20
Super 2 + watering once a day	86 c	29 cd	7 b
Super 2 + watering once every 3 days	0.6	0.0	1.28
	31 c	19 de	3 b
Super 2 + watering once every 5 days	0.3	0.0	1.22
	99 d	11 ef	3 b
	1.0	0.0	1.16
Suri 4 + watering once a day	30 b	28 d	0 b
Suri 4 + watering once every 3 days	1.0	0.0	1.20
	68 b	47 b	0 b
Suri 4 + watering once every 5 days	1.4	0.0	0.00
	68 a	00 f	0 c
Bioguma + watering once every 1 days	1.4	0.0	1.15
	48 a	40 bc	0 b
Bioguma + watering once every 3 days	1.0	0.0	1.16
	19 b	27 d	0 b
Bioguma + watering once every 5 days	0.9	0.0	1.26
	09 b	28 d	3 b

Note: Numbers Followed by the Same Letter in the Same Column are Not Significantly Different in the 5% LSD Test

The water extract treatment derived from the sorghum variety Suri 4 + watering every 5 days produced the lowest plumula and radicle length of 0.000 g shown in Table 3. This shows that the water extract treatment derived from a combination of sorghum varieties and the level of water stress is able to provide the highest level of inhibition when compared to other treatments and the control. The treatment with the lowest level of inhibition against the test plant was the control treatment. Sorgoleone, a compound in allelopathy, consists of 85 to 90% of sorghum root exudate, according to (Weston & Czarnota, 2021). Plants stop developing due to the phytotoxicity of allelopathy; photosynthesis and respiration stop, and chlorosis in seedlings stops growth.

CONCLUSIONS AND RECOMMENDATIONS

It was concluded that the highest inhibition of test plant germination was in the sorghum variety Suri 4 + watering every 5 days. This was indicated by the lowest percentage of live sprouts, wet weight of live sprouts, wet weight of plumula and radicle, and length of plumula and radicle, and the highest percentage of dead sprouts and wet weight of dead sprouts. These findings indicate that the sorghum variety Suri 4 has the potential to produce the highest allelopathic compounds when combined with 5-day watering.

FURTHER STUDY

Further research can apply flavonoid content analysis that can describe water-soluble chemical compounds.

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