Sorghum germination inhibition using its water extract cultivated in swampland with different irrigation patterns

E Susilo\(^1\), N Setyowati\(^2\)*, U Nurjanah\(^2\), Riwandi\(^3\) and Z Muktamar\(^3\)

\(^1\) Student of Doctoral Program for Agricultural Sciences, University of Bengkulu, Jl. WR. Supratman Kandang Limun Bengkulu 38371, Indonesia.
\(^2\) Department of Crop Production, Faculty of Agriculture, University of Bengkulu, Jl. WR. Supratman Kandang Limun Bengkulu 38371, Indonesia.
\(^3\) Department of Soil Science, Faculty of Agriculture, University of Bengkulu, Jl. WR. Supratman Kandang Limun Bengkulu 38371, Indonesia.

*Email: nsetyowati@unib.ac.id

Abstract. One of the allelopathic uses is the application of sorghum water extract for weed control. Drought-shaped abiotic stress plays an important role in the plant contribution of allelopathy. This study aimed to examine the inhibition of sorghum water extracts grown in swampland with different irrigation patterns. The study employed a randomized complete block designed with two factors. The first factor was irrigation patterns, i.e., four weeks of dry and saturated water, alternating weekly saturated and dry water for four weeks, and alternating weekly dry and saturated water for four weeks. The second factor was water extract concentration, consisting of 0%, 2.5%, 5%, 7.5% and 10%. Dry Ultisol was assigned as a control treatment. The bioassay procedure was set up with 25 sorghum seeds per petri dish. Each petri dish was solved and incubated for four days with a 10 ml sorghum water extract from each of the above treatments.

The results showed the highest germination inhibition levels were in the interaction between the dry patterns (dry swampland and dry Ultisol) at 7.5% of water extraction. Sorghum extract, grown in dry swampland, is a potential for good bioherbicide production.

1. Introduction

Weeds reduce crop yields, utilizing available resources such as water, nutrients, and growing space [1] and synthetic herbicides to manage weeds often done in modern productivity-oriented agriculture. The use of synthetic herbicides that are less profitable can cause environmental and health problems. According to [2], herbicides harm the environment. Thus, an appropriate weed control method in organic farming is needed.

Organic weed management is one way of controlling weeds in crop production systems. Environmentally friendly weed management is needed to overcome the problem of weed resistance to herbicides [3]. Furthermore, [4] the use of organic herbicides in plant derivatives is an alternative inorganic herbicide for weed control. Allelopathy is an environmentally friendly organic herbicide as an implication of weed management that can be as a tool to control weeds. Allelopathy is a way out to overcome weed problems in agricultural cultivation systems [1]. The allelopathic method can be used with allelochemicals to suppress weeds (as natural herbicides) and allelopathic plants as cover crops or mulch [5].
Reducing the dose of synthetic herbicides or replacing them with bioherbicides will lessen the impact on the environment and human health and minimize the expansion of herbicide-tolerant weeds. Using bioherbicides will benefit all stakeholders such as researchers, industry, extension workers, and growers to develop effective and environmentally friendly weed management strategies and lower the dependency on synthetic herbicides [6]. The application of allelopathy as a strategy for controlling weed in sustainable agricultural systems in developing countries is needed. However, to ensure that the allelopathic approach is successful, it must be simple and economically feasible. Weed control strategies that are environmentally friendly can be achieved by utilizing widely distributed and readily available local plants with an allelopathic potential [7]. Sorghum is a plant that produces allelopathy and has wide growing adaptations.

Sweet sorghum is a C4 plant [8]. Sweet sorghum could grow and easily adapted to various environmental conditions with limited inputs [9]. Sorghum plants have the potential as an alternative to replacing plants with low economic value. Sorghum also may be used as environmentally friendly energy sources, and for food needs [10].

Apart from being able to produce and adapt to a wide range of environments, sorghum also has allelopathy. According to [11], sorghum and sunflower are highly allelopathic plants capable of inhibiting other species’ plants. Sorghum and sunflower have allelopathic compounds that are environmentally friendly and can suppress weed growth in cotton plants. There is an allelopathic content in various types of plants. Such an experiment [12] revealed different concentrations of aqueous extracts (5, 10, and 15 g/l) of three weeds significantly reduced the percentage of germination, but 15 g/l of M. officinalis extract resulted in Pirisabaq breeding failure. Bioherbicides in the form of sorgaab (sorghum water extract) can reduce weed density, fresh weight, and dry weight by 29%, 31%, and 27% compared to controls on wheat cropping. Spraying extracts derived from sorghum stems and leaves can increase wheat yield by 8% and 19% but causes inhibition of weed species Anagallis arvensis L., Fumaria indica L., and Medicago polymorpha L. [13].

Experiments carried out in the field, proving the role of allelopathy affects the agricultural ecosystem. According to [1], corn planted after sorghum has a significantly lower weed density (23.1%) and biomass (23.6%) than corn produced after fall. The application of environmentally friendly weed control involving two methods is better than a single. According to [1], the application of sorghum-based treatment (mulch and sorghum water extract) is most effective and significantly reduces the weed infestation of corn after the sorghum harvest. Furthermore, [11] reported that powder and water extract of sorghum and sunflower suppressed weed growth better than cotton plants’ control treatment. In terms of allelopathic efficiency, sorghum plants are superior when compared to sunflower plants. Shoot and root water extract of Parthenium hysterophorus L at 5% concentration suppress weed growth. The higher the extract concentration, the higher the seed germination inhibition [14].

Allelopathy is environmentally friendly weed control in organic agriculture. One strategy to increase allelopathic traits is through genetic modification. The resulting allelopathy must be safe or non-toxic for both humans and the ecosystem and increase plant productivity at an affordable cost [15]. Some experiments reported that there was a relationship between the growing environment and the plant allelopathy content. Research related to the relationship between allelopathy with biotic and abiotic stress environment has been done; however, research on allelopathy in settings stress, especially in the marginal swamplands, has not been carried out. The research will evaluate the water extract of sorghum grows in swamps with different irrigation patterns. This study aims to test the inhibition of sorghum water extract on seed germination under different irrigation patterns.

2. Materials and methods

2.1. Plant material

Water extract of sorghum var. Numbu planted in swampland four-week-olds that have undergone treatment namely wet for four weeks; wet one week and dry one week, repeated once; dry one week wet one week, repeated one; dry for four weeks; and Ultisol dry for four weeks (control). The leaves, stems, and roots were harvested air-dried for seven days, then in a hot air oven at 70°C for 72 hours. The dried plant were chopped 1-2 cm and grounded, and the powder used as an extraction material.
2.2. Water extract preparation

Dry powder of sorghum as much as 100 g (or 10% treatment) is immersed in a 1000 mL flask of distilled water and stirred for 24 hours using a shaker at room temperature. The extract then filtered through Whatman No. filter cloth and paper. The extract was then put into a labeled beaker glass and stored in the refrigerator in dark conditions. Further concentrations (i.e., 2.5%, 5%, and 7.5%) of this extract were also prepared.

2.3. Bioassay with water extract on filter paper

The purpose of the study was to determine sorghum water extract on sorghum seed growth. Petri dishes with a diameter of 9 cm are coated with filter paper as a medium for germination. Sorghum seeds of 25 grains are planted in each petri dish with regular spacing and added with 10 mL extract at different concentrations (2.5%, 5%, 7.5%, and 10%) added per petri dish. Petri dishes then incubated in the growth chamber for four days. Each treatment was repeated 5 times.

2.4. Measurement of experiment variables

The variables observed were normal sprouts (%), abnormal sprout (%), plumula length (cm), radicles length (cm), sprout with cotyledons (g), sprout dry weight with no cotyledons (g), plumula fresh weight (g), radicle fresh weight (g), cotyledon fresh weight (g), plumula dry weight (g), radicle dry weight (g), and cotyledon dry weight (g).

2.5. Statistic analysis

The research design used in the bioassay test in the laboratory was a complete randomized block design with five replications. Data collected were analyzed statistically with SAS software. ANOVA analysis was continued by the Duncan test if there were significant differences between the means with P <0.05.

3. Results and discussions

The results of an analysis of variance, the growth of sorghum sprouts are in Table 1. The results of the study show that the treatment of irrigation patterns and the treatment of sorghum water extract concentration significantly affected all observational variables. There was an interaction between the irrigation pattern and the water extract concentration except for the dry weight of sprouts + cotyledons. The control treatment (extract concentration 0%), both in swampland and ultisols, produced higher regular sprouts than other interaction treatments (Table 2). This result indicated that without the addition of sorghum extract, there was no seed germination inhibition.

In general, the higher the extract concentration, resulted in the lower the normal sprouts. At 2.5%, seed germination was inhibited, but normal germination was higher than 50%. In the 5% extract concentration treatment, seed germination was increasingly inhibited. At this concentration, the normal sprouts produced are below 50%. The aqueous extract at a concentration of 10% from all irrigation patterns inhibited sorghum seed germination. All sprouts produced were abnormal. Irrigation patterns in swampland land, mainly dry and dry Ultisol, have the highest seed inhibition than other irrigation patterns. These results indicate that to produce extracts with high inhibition, sorghum should be planted in swampland or in Ultisols with a dry irrigation pattern. These results indicate that sorghum planted in swampland or in Ultisols with a dry irrigation pattern produced high allelopathic content. However, the biomass produced from swampland with dry irrigation patterns was lower than other treatments.

The metabolic activities are not normal resulted in the lower regular sprout. High number of regular sprouts, on the other hand, indicate that seeds can carry out normal germination processes. Sorghum aqueous extract allelopathy plays an essential role in seed germination. According to [5], allelopathic compounds are released by plants into the environment through decomposition, washing, volatilization, and root exudates.
Table 1. Recapitulation of sorghum water extract inhibition test on different irrigation patterns and extract concentrations.

| No | Variable                              | Irrigation Pattern (A) | Extract Concentration (B) | Interaction (A x B) | Coefficient of diversity (%) |
|----|---------------------------------------|------------------------|---------------------------|---------------------|-----------------------------|
| 1  | Normal sprout                         | 4.19 **                | 984.02 **                 | 5.31 **             | 13.56                       |
| 2  | Abnormal sprout                       | 7.30 **                | 156.40 **                 | 3.10 **             | 28.05                       |
| 3  | Plumula length                        | 25.08 **               | 1540.55 **                | 5.88 **             | 9.75                        |
| 4  | Radicle length                        | 11.33 **               | 1740.48 **                | 5.65 **             | 13.75                       |
| 5  | DW germination + cotyledons           | 3.98 **                | 74.17 **                  | 1.28 ns             | 2.79                        |
| 6  | DW germination without cotyledons     | 31.81 **               | 1039.83 **                | 3.67 **             | 10.25                       |
| 7  | Plumula fresh weight                  | 22.43 **               | 1007.84 **                | 4.65 **             | 11.27                       |
| 8  | Radicle fresh weight                  | 96.92 **               | 281.92 **                 | 41.28 **            | 28.57                       |
| 9  | Cotyledon fresh weight                | 53.21 **               | 90.09 **                  | 4.71 **             | 4.03                        |
| 10 | Plumula dry weight                    | 28.41 **               | 725.65 **                 | 4.14 **             | 10.65                       |
| 11 | Radicle dry weight                    | 12.88 **               | 523.64 **                 | 3.86 **             | 20.68                       |
| 12 | Cotyledon dry weight                  | 3.89 **                | 485.74 **                 | 2.67 **             | 3.15                        |

** = significantly
ns = no significant
DW = dry weight

The interaction of irrigation patterns and sorghum water extract concentration significantly affected the abnormal sprout variables (Table 2). Interaction of dry irrigation patterns in the swamp and dry soil in Ultisol with 7.5% water extract concentration produced the highest abnormal sprout of 73% and 74%. The interaction of irrigation patterns with 0% extract concentration (control) resulted in lower abnormal sprouts than other treatments (Table 2). These results indicate that the presence of allelopathy negatively affects seed germination. In general, the higher the concentration of water extract, the higher the normal germination rate. A water extract concentration of 7.5% with a dry irrigation pattern in swampland and dry Ultisol soil resulted in the highest abnormal sprouts. These results indicate that the irrigation pattern affects the efficacy of allelopathy. Allelopathy at a concentration of 7.5% had the most effect on sorghum seed germination. Sorghum water extract contains allelochemical compounds that affect the root growth of the target plant. According to [16], allelopathy is a secondary metabolite derived in the form of allelochemicals in donor plants and will affect root growth and development of recipient plants.

The interaction of irrigation patterns and concentration of water extracts showed a significant effect on plumula’s length (Table 2). The highest plumula length obtained from control plants (0% extract concentration) in all irrigation pattern treatments. These results indicate that the allelopathic compounds affect seed germination. The interaction of dry irrigation patterns in swampland land and concentrations of water extracts of 7.5% and 10% produced the lowest length of the plumula, which were 0.938 cm and 0.038 cm. These results indicate that sorghum grown in drought stress conditions in swamps and Ultisols produced biomass with the highest seed inhibition, namely at a water extract concentration of 7.5% and 10%.
Table 2. The interaction effect of irrigation pattern and extract concentration on normal sprouts, abnormal sprouts, plumule length, radicle length, sprouts dry weight with no cotyledon, and sprouts dry weight with cotyledon.

| Treatment | Normal sprout (%) | Abnormal sprout (%) | Plumule length (cm) | Radicle length (cm) | Sprout dry weight dry with no cotyledon (g) | Sprout dry weight dry with cotyledon (g) |
|-----------|------------------|-------------------|--------------------|-------------------|--------------------------------|----------------------------------|
| Irrigation pattern (A) | | | | | | |
| W | 44.20 a | 29.80 b | 2.35 c | 3.40 a | 0.0029 c | 0.0265 b |
| WD | 43.80 a | 27.80 b | 2.60 b | 3.26 a | 0.0032 b | 0.0262 b |
| DW | 46.40 a | 33.60 b | 2.76 a | 3.24 a | 0.0036 a | 0.0270 a |
| D | 45.00 a | 33.80 b | 2.09 d | 2.76 b | 0.0027 c | 0.0266 ab |
| UD | 39.20 b | 42.60 a | 2.29 c | 2.70 b | 0.0027 c | 0.0263 b |
| Prob. F > 5 % | 0.0040 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0056 |
| Concentration (B) | | | | | | |
| 0% (0) | 91.80 a | 2.60 e | 5.25 a | 9.40 a | 0.0059 a | 0.0247 e |
| 2.5% | 81.80 b | 12.00 d | 3.84 b | 4.40 b | 0.0047 b | 0.0256 d |
| 5% | 35.60 c | 52.60 b | 1.71 c | 1.20 c | 0.0024 c | 0.0266 c |
| 7.5% | 9.40 d | 64.80 a | 1.04 d | 0.36 d | 0.0016 d | 0.0276 b |
| 10% | 0.00 e | 35.60 c | 0.25 e | 0.01 e | 0.0004 e | 0.0281 a |
| Prob. F > 5 % | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| Interaction A x B | | | | | | |
| W x 0% | 94.00 a | 2.00 k | 5.4600 a | 9.7975 ab | 0.0061 ab | 0.0247 a |
| WD x 0% | 89.00 abcd | 4.00 jk | 5.5225 a | 10.0950 a | 0.0059 bc | 0.0247 a |
| DW x 0% | 91.00 abcd | 0.00 k | 5.5000 a | 9.6925 ab | 0.0065 a | 0.0249 a |
| D x 0% | 92.00 abc | 2.00 k | 4.8550 b | 8.0050 c | 0.0055 cd | 0.0245 a |
| UD x 0% | 93.00 ab | 5.00 ijk | 4.8925 b | 9.3900 b | 0.0053 d | 0.0248 a |
| W x 2.5% | 74.00 e | 20.00 hi | 3.6000 d | 4.8100 d | 0.0045 e | 0.0254 a |
| WD x 2.5% | 86.00 abcd | 5.00 ijk | 4.5075 c | 5.1825 d | 0.0055 cd | 0.0250 a |
| DW x 2.5% | 83.00 cd | 9.00 ij | 4.4650 c | 4.6475 d | 0.0054 d | 0.0263 a |
| D x 2.5% | 84.00 bcd | 14.00 hijk | 3.1025 e | 3.8850 e | 0.0044 ef | 0.0263 a |
| UD x 2.5% | 82.00 de | 12.00 hijk | 3.5225 d | 3.4775 e | 0.0040 f | 0.0249 a |
| W x 5% | 29.00 g | 53.00 cde | 1.3075 hi | 1.4900 f | 0.0019 ij | 0.0269 a |
| WD x 5% | 38.00 f | 53.00 cde | 1.7075 g | 0.7625 gh | 0.0027 gh | 0.0261 a |
| DW x 5% | 45.00 f | 49.00 def | 2.3175 f | 1.3150 fg | 0.0031 g | 0.0269 a |
| D x 5% | 45.00 f | 43.00 def | 1.5425 gh | 1.7925 f | 0.0023 hi | 0.0262 a |
| UD x 5% | 21.00 gh | 65.00 abc | 1.6575 g | 0.6150 hi | 0.0021 ij | 0.0269 a |
| W x 7.5% | 24.00 g | 49.00 def | 1.1575 ij | 0.8375 gh | 0.0017 kl | 0.0274 a |
| WD x 7.5% | 6.00 ij | 58.00 bcd | 0.9625 ij | 0.2825 hi | 0.0017 jk | 0.0272 a |
| DW x 7.5% | 13.00 hi | 70.00 ab | 1.1775 ij | 0.5275 hi | 0.0021 ij | 0.0282 a |
| D x 7.5% | 4.00 j | 73.00 a | 0.9275 j | 0.0950 i | 0.0013 kl | 0.0277 a |
| UD x 7.5% | 0.00 j | 74.00 a | 0.9775 ij | 0.0400 i | 0.0014 kl | 0.0276 a |
| W x 10% | 0.00 j | 25.00 gh | 0.2025 k | 0.0425 i | 0.0002 n | 0.0279 a |
| WD x 10% | 0.00 j | 19.00 hij | 0.2800 k | 0.0000 i | 0.0003 n | 0.0282 a |
| DW x 10% | 0.00 j | 40.00 ef | 0.3550 k | 0.0000 i | 0.0010 ln | 0.0289 a |
| D x 10% | 0.00 j | 37.00 fg | 0.0375 k | 0.0000 i | 0.0001 n | 0.0285 a |
| UD x 10% | 0.00 j | 57.00 bcd | 0.3875 k | 0.0000 i | 0.0006 mn | 0.0272 a |
| Prob. F > 5 % | 0.0001 | 0.0005 | 0.0001 | 0.0001 | 0.0001 | 0.2332 |

W = wet swampland, WD = wet-dry swampland, DW = wet-dry swampland, D = dry swampland, UD = dry Ultisol; the numbers followed by the same letters in the same column are not significantly different in the Duncan's Multiple Range Test (DMRT) level of 5%
The interaction between irrigation patterns and water extract concentration significantly affected the radicle length (Table 2). At concentrations extract of 0% (control), all irrigation patterns produced the highest radicle length. This result showed that the interaction of all irrigation patterns with 0% extract concentration (control) has no inhibitory effect on recipient plants. Interaction of dry irrigation patterns in swamp and Ultisol with a concentration of 7.5% water extract produced the lowest radicle length of 0.095 cm and 0.040 cm. Thus, sorghum planted in drought stress in both swampland and Ultisols with a water extract concentration of 7.5% produced the highest seed inhibition. The higher the water extract, the shorter the length of the radicles. The dry irrigation pattern in swampland soil and Ultisol resulted in the shortest radicle length. Data analysis results showed that the reduction in radicle length was higher than the reduction in plumule length at all extract concentrations tested.

Thus, the radicle is more responsive and sensitive to aqueous extract of sorghum than the plumule. In general, the highest concentration of sorgoleone compounds is in the sorghum root component. According to [5], a high concentration of sorgoleone and some phenolic acids in the root exudate of sorghum var Enkath was higher than that of var. Rabeh. Thus, it is necessary to get the right sorghum cultivars for controlling environmentally friendly weeds.

The interaction between irrigation patterns and concentration of water extracts showed a significant effect on the dry weight of sprouts with no cotyledons (Table 2). The dry irrigation pattern in wetlands and dry land in Ultisol with 0% extract concentration (control), resulting in the lowest sprout dry weight without cotyledons. Interaction dry irrigation pattern of swamp and dry soil in Ultisol with 7.5% water extract concentration produced the lowest dry weight of sprout without cotyledon, 0.0013 g, and 0.0014 g. The results showed that sorghum planted in dried swamp soils and ultisols was toxic to germination of seeds at a concentration of 7.5 percent. Furthermore, the higher the extract concentration applied, the smaller the dry weight of sprouts without cotyledons was produced. This result means that the higher the concentration of water extracts, the seeds tend to experience disruption of germination metabolism because of higher allelopathic potential in water extracts. The dry irrigation pattern on swamp and ultisol soil produced the lowest seed (with no cotyledon) dry weight. Therefore, cultivating sorghum on marginal swampland lands and Ultisols with drought stress produced biomass with high allelochemical content and high efficacy on seed germination.

Table 2 shows the highest average sprouts dry weight with cotyledons resulted from the treatment of dry irrigation patterns on swampland and dry-wet on swampland. This result showed that the pattern of dry irrigation in swampland, as well as dry-wet in swampland, produced sorghum biomass with the highest seed inhibition. The sorghum extract concentration treatment showed that the highest extract concentration resulted in the highest dry weight of sprouts with cotyledons. The germination seed metabolism process could not be effective and led an increased dry weight of the sprout. The result of this study showed, the higher the water extract applied, the higher the cotyledon weight. The higher the water extract concentration, the greater the inhibition of seed germination (Table 2). According to [5], allelopathic plants either have positive or negative effects on the surrounding plants. In this study, water extracts tended to produce inhibition of recipients.

There was an interaction between the irrigation pattern and the water extract concentration on the fresh weight of plumules (Table 3). The dry irrigation pattern in the swampland with an extract concentration of 10%, resulting in the lowest plumula fresh weight, 0.0006 g, however it was not significantly different from other interactions, especially at 10% concentration. This study showed that the interaction of dry irrigation patterns in swampland with an extract concentration of 10% produces the highest drought and allelopathic stress and has a role in the inhibition of the plumula’s fresh weight.

The interaction between irrigation patterns and water extract concentration significantly affected the fresh weight of radicles (Table 3). Dry irrigation patterns in swampland with a water extract concentration of 7.5% yielded the lowest fresh weight of radicles, although not significantly different from other interactions, especially at a concentration of 7.5%. This result shows that the interaction of dry irrigation patterns in swampland with an extract concentration of 7.5% resulted in the highest drought stress, therefore inhibiting radicle fresh weight. According to [5], the allelopathic effect of plants depends on biotic and abiotic factors. The allelopathic approach will reduce dependence on chemical pesticides, which are proven to be environmental contaminants. The higher the concentration of aqueous extract, the lower the radicles’ fresh weight. When compared between the plumula’s fresh weight, the
radicle’s fresh weight was more affected by an extract. This was due to the radicles were in direct contact with the water extract in the growing media.

The interaction between irrigation patterns and water extract concentration significantly affected the fresh weight of cotyledons (Table 3). The dry irrigation pattern in the swamp and dry land in Ultisol with 10% extract concentration yielded the highest fresh cotyledon fresh weight of 0.0421 g, 0.0416 g, and significantly different from other interactions, especially the concentration of 10%. This result shows that the interaction of dry irrigation patterns in the swamp and dry soil in Ultisol with an extract concentration of 10% produces the highest stress. Allelopathic water extracts affect the metabolic activities of seed germination.

The interaction between the irrigation pattern and the water extract concentration showed a significant effect on the plumula’s dry weight (Table 3). The pattern of dry irrigation in swampland with an extract concentration of 10%, resulting in the lowest plumula’s dry weight, 0.0001 g. This result shows that the interaction of dry irrigation patterns in swampland with an extract concentration of 10% produces drought stress with the highest allelopathic activity.

The concentration of extract significantly affected the dry weight of radicles (Table 3). This experiment showed that the dry irrigation patterns in swampland and Ultisols soil at 7.5% extract concentration treatment, resulting in the lowest radicle dry weight, 0.0001 g. This result shows the irrigation pattern’s interaction with the extract concentration of 7.5% produces drought stress with the highest allelopathic activity and suppressing the radicle dry weight. The higher the concentration of sorghum extract, the smaller the dry weight of the radicles. Radicular dry weight is more sensitive compared to the dry weight of the plumula. This result was due to the radicle was in direct contact with the bioassay media. According to [14], roots are more sensitive to allelopathic than the shoots.

The interaction between irrigation patterns and water extract concentrations significantly affected the dry weight of cotyledons (Table 3). The higher dry weight of cotyledons resulted from all irrigation patterns in swampland (10% extract concentration) and dry irrigation patterns in swamps, and dry irrigation patterns in Ultisols (with extract concentration 7.5%). Therefore, the interaction between the irrigation pattern and the extract concentrations of 10% and 7.5% reduced dry weight of cotyledons higher than the other treatment combinations. The higher the concentration of the extract, the greater the dry weight of the cotyledons. The results of the experiments show that water extract of sorghum can inhibit seed germination. According to [5], sorghum and sunflower have allelopathic compounds that inhibit plant growth. Root growth disrupted due to decreased activity of the root meristem. Allelopathic can, moreover, also reduce the cell length of the root [16].

**Table 3.** Effect of interaction of irrigation patterns and extract concentration of sorghum on plumula fresh weight, radicle weight, cotyledon fresh weight, plumula dry weight, radicle dry weight, and cotyledon dry weight

| Irrigation Pattern (A) | Plumula Fresh Weight (g) | Radicle Fresh Weight (g) | Cotyledon Fresh Weight (g) | Plumula Dry Weight (g) | Radicle Dry Weight (g) | Cotyledon Dry Weight (g) |
|------------------------|--------------------------|--------------------------|---------------------------|------------------------|------------------------|--------------------------|
| W                      | 0.0169 c                 | 0.0011 bc                | 0.0334 cd                 | 0.0021 c               | 0.0007 b               | 0.0236 a                 |
| WD                     | 0.0188 b                 | 0.0010 c                 | 0.0333 d                 | 0.0024 b               | 0.0008 b               | 0.0230 b                 |
| DW                     | 0.0211 a                 | 0.0013 b                 | 0.0342 b                 | 0.0027 a               | 0.0009 a               | 0.0234 ab                |
| D                      | 0.0176 bc                | 0.0012 bc                | 0.0355 b                 | 0.0020 c               | 0.0007 b               | 0.0239 a                 |
| UD                     | 0.0224 a                 | 0.0037 a                 | 0.0388 a                 | 0.0021 c               | 0.0005 c               | 0.0236 a                 |
| Prod. F > 5 %          | 0.0001                   | 0.0001                   | 0.0001                   | 0.0001                 | 0.0001                 | 0.0063                   |

| Concentration (B) | Plumula Fresh Weight (g) | Radicle Fresh Weight (g) | Cotyledon Fresh Weight (g) | Plumula Dry Weight (g) | Radicle Dry Weight (g) | Cotyledon Dry Weight (g) |
|-------------------|--------------------------|--------------------------|---------------------------|------------------------|------------------------|--------------------------|
| 0 %               | 0.0394 a                 | 0.0036 a                 | 0.0310 e                 | 0.0041 a               | 0.0018 a               | 0.0188 e                 |
| 2.5 %             | 0.0310 b                 | 0.0033 b                 | 0.0333 d                 | 0.0034 b               | 0.0013 b               | 0.0209 d                 |
| 5 %               | 0.0151 c                 | 0.0009 c                 | 0.0354 c                 | 0.0020 c               | 0.0005 c               | 0.0242 c                 |
| 7.5 %             | 0.0091 d                 | 0.0002 d                 | 0.0368 b                 | 0.0015 d               | 0.0001 d               | 0.0260 b                 |
| 10 %              | 0.0021 e                 | 0.0000 d                 | 0.0387 a                 | 0.0004 e               | 0.0000 e               | 0.0277 a                 |
| Prod. F > 5 %     | 0.0001                   | 0.0001                   | 0.0001                   | 0.0001                 | 0.0001                 | 0.0001                   |
Sorghum bicolor L. (Moench) cultivars

4. Conclusions
Sorghum at a water extract concentration of 7.5% in a dry irrigation pattern on swampland and dry on Ultisol soil inhibit seed germination better than the other treatments. Sorghum cultivated in swampland or Ultisols with a dry irrigation pattern produced high allelopathic content.

Reference
[1] Farooq M, Khan I, Nawaz A, Cheema M A and Siddique K H M 2020 Using sorghum to suppress weeds in autumn planted maize. *Crop Protection* **133** (May 2019), 105162. https://doi.org/10.1016/j.cropro.2020.105162
[2] Scavo A, Pandino G, Restuccia A and Mauronicale G 2020 Leaf extracts of cultivated cardoon as potential bioherbicide *Scientia Horticulturae* **261** (November) 109024. https://doi.org/10.1016/j.scientia.2019.109024
[3] Tubeileh A M and Souikane R T 2020 Effect of olive vegetation water and compost extracts on seed germination of four weed species. *Current Plant Biology*, **22** (March), 100150. https://doi.org/10.1016/j.cpb.2020.100150
[4] Arif M, Cheema Z A, Khaliq A and Hassan A 2015 Organic weed management in wheat through allelopathy. *International Journal of Agriculture and Biology* **17** (1) pp 127–34
[5] Alsaadawi I S, Al-Khateeb T A, Hadwan H A and Lahmood N R (2015) A chemical basis for differential allelopathic potential of root exudates of Sorghum bicolor L. (Moench) cultivars on companion weeds *Journal of Allelochemical Interactions* **11** pp 49–55

| Treatment  | Plumula fresh weight (g) | Radicle fresh weight (g) | Cotyledon fresh weight (g) | Plumula dry weight (g) | Radicle dry weight (g) | Cotyledon dry weight (g) |
|------------|--------------------------|-------------------------|----------------------------|------------------------|------------------------|--------------------------|
| W x 0 %    | 0.0402 ab                | 0.0023 cd               | 0.0296 i                  | 0.0044 a               | 0.0017 bc              | 0.0186 h                 |
| WD x 0 %   | 0.0353 c                 | 0.0022 cd               | 0.0311 hi                | 0.0040 b               | 0.0018 ab              | 0.0188 h                 |
| DW x 0 %   | 0.0409 a                 | 0.0025 cd               | 0.0300 i                 | 0.0045 a               | 0.0020 a               | 0.0184 h                 |
| D x 0 %    | 0.0377 bc                | 0.0024 cd               | 0.0311 hi                | 0.0038 bc              | 0.0017 bc              | 0.0189 h                 |
| UD x 0 %   | 0.0431 a                 | 0.0085 a                | 0.0331 fgh               | 0.00358 cd             | 0.0017 bc              | 0.0195 h                 |
| W x 2.5 %  | 0.0291 d                 | 0.0018 d                | 0.0330 gh                | 0.0033 de              | 0.0012 e               | 0.0209 g                 |
| WD x 2.5 % | 0.0319 d                 | 0.0019 d                | 0.0310 i                 | 0.0040 b               | 0.0015 cd              | 0.0195 h                 |
| DW x 2.5 % | 0.0315 d                 | 0.0025 cd               | 0.0326 gh                | 0.0038 bc              | 0.0016 bc              | 0.0209 g                 |
| D x 2.5 %  | 0.0260 e                 | 0.0027 cd               | 0.0336 fg                | 0.0031 e               | 0.0013 de              | 0.0229 g                 |
| UD x 2.5 % | 0.0367 c                 | 0.0075 b                | 0.0367 bcd               | 0.0032 e               | 0.0008 f               | 0.0209 g                 |
| W x 5 %    | 0.0079 i                 | 0.0010 e                | 0.0350 cdef              | 0.0014 ij              | 0.0005 g               | 0.0250 cd                |
| WD x 5 %   | 0.0158 g                 | 0.0007 ef               | 0.0330 fg                | 0.0022 fg              | 0.0005 g               | 0.0234 f                 |
| DW x 5 %   | 0.0179 fg                | 0.0009 e                | 0.0335 fg                | 0.0025 f               | 0.0006 g               | 0.0238                   |
| D x 5 %    | 0.0149 h                 | 0.0009 e                | 0.0344 efg               | 0.0019 gh              | 0.0005 g               | 0.0239 ef                |
| UD x 5 %   | 0.0191 f                 | 0.0008 e                | 0.0413 a                 | 0.0020 gh              | 0.0002 hi              | 0.0248 de                |
| W x 7.5 %  | 0.0063 ij                | 0.0005 ef               | 0.0348 cdefg             | 0.0014 ij              | 0.0004 gh              | 0.0257 bcd               |
| WD x 7.5 % | 0.0096 hi                | 0.0001 f                | 0.0344 efg               | 0.0017 hi              | 0.0000 i               | 0.0255 bcd               |
| DW x 7.5 % | 0.0115 h                 | 0.0006 ef               | 0.0368 bcd               | 0.0019 gh              | 0.0002 hi              | 0.0261 bc                |
| D x 7.5 %  | 0.0087 hi                | 0.0000 f                | 0.0364 bcde              | 0.0013 jk              | 0.0000 i               | 0.0264 b                 |
| UD x 7.5 % | 0.0096 hi                | 0.0000 f                | 0.0415 a                 | 0.0014 ij              | 0.0000 i               | 0.0263 b                 |
| W x 10 %   | 0.0011 k                 | 0.0001 f                | 0.0346 defg              | 0.0002 m               | 0.0000 i               | 0.0277 a                 |
| WD x 10 %  | 0.0017 k                 | 0.0000 f                | 0.0370 bc                | 0.0003 lm              | 0.0000 i               | 0.0280 a                 |
| DW x 10 %  | 0.0036 jk                | 0.0000 f                | 0.0384 b                 | 0.0010 l              | 0.0000 i               | 0.0280 a                 |
| D x 10 %   | 0.0006 k                 | 0.0000 f                | 0.0421 a                 | 0.0001 m              | 0.0000 i               | 0.0284 a                 |
| UD x 10 %  | 0.0035 jk                | 0.0000 f                | 0.0416 a                 | 0.0006 l              | 0.0000 i               | 0.0266 b                 |

Prob. F > 5 %: 0.0001, 0.0001, 0.0001, 0.0001, 0.0023

W = wet swampland, WD = wet-dry swampland, DW = dry-swampland, D = dry Ultisol; the numbers followed by the same letters in the same column are not significantly different in the Duncan's Multiple Range Test (DMRT) level of 5%
[6] Iqbal N, Khaliq A and Cheema Z A 2020 Weed control through allelopathic crop water extracts and S-metolachlor in cotton. *Information Processing in Agriculture* 7 (1) pp 165–72. https://doi.org/10.1016/j.inpa.2019.03.006

[7] Nornasuhu Y and Ismail B S 2017 Sustainable weed management using allelopathic approach. *Malaysian Applied Biology* 46 (2) pp 1–10

[8] Appiah-Nkansah N B, Li J, Rooney W and Wang D 2019 A review of sweet sorghum as a viable renewable bioenergy crop and its techno-economic analysis. *Renewable Energy* 143 pp 1121–32. https://doi.org/10.1016/j.renene.2019.05.066

[9] Maw M J W, Houx J H and Fritschi F B 2016 Sweet sorghum ethanol yield component response to nitrogen fertilization. *Industrial Crops and Products* 84 pp 43–49. https://doi.org/10.1016/j.indcrop.2016.01.038

[10] Maw M J W, Houx J H and Fritschi F B 2017 Maize, sweet sorghum, and high biomass sorghum ethanol yield comparison on marginal soils in Midwest USA. *Biomass and Bioenergy* 107 (March) pp 164–71. https://doi.org/10.1016/j.biombioe.2017.09.021

[11] Kandhro M, Memon H-R, Laghari M, Baloch A, and Ansari M 2016 Allelopathic Impact of Sorghum and Sunflower on Germinability and Seedling Growth of Cotton (*Gossypium hirsutum* L.). *Journal of Basic & Applied Sciences* 12 pp 98–102. https://doi.org/10.6000/1927-5129.2016.12.15

[12] Siyar S Majeed A, Muhammad Z, Ali H and Inayat N 2019 Allelopathic effect of aqueous extracts of three weed species on the growth and leaf chlorophyll content of bread wheat. *Acta Ecologica Sinica* 39 (1) pp 63–68. https://doi.org/10.1016/j.chinaes.2018.05.007

[13] Ashraf M and Akhlaq M, 2007 Effects of sorghum leaves, roots and stems water extract, hand weeding and herbicide on weeds suppression and yield of wheat *Sarhad J Agric* 23 (2) pp 321–27

[14] Wakjira M, Berecha G and Tulu S 2009 Allelopathic effects of an invasive alien weed *Parthenium hysterophorus* L. compost on lettuce germination and growth *African Journal of Agricultural Research* 4 (11) pp 1325–30

[15] Amb M K and Ahluwalia A S 2016 Allelopathy : Potential Role to Achieve New Milestones in Rice Cultivation *Rice Science* 23 (4) pp 165–83 https://doi.org/10.1016/j.rsci.2016.06.001

[16] Huang C zhen, Xu L, Jin-jing S, Zhang Z hua, Fu M lan, Teng H ying and YI K ke 2020 Allelochemical p-hydroxybenzoic acid inhibits root growth via regulating ROS accumulation in cucumber (*Cucumis sativus* L.). *Journal of Integrative Agriculture* 19 (2) pp 518–27. https://doi.org/10.1016/S2095-3119(19)62781-4