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# Growth Performance of Sorghum Varieties Suri 4 and Mandau with Various Irrigation Patterns and Their Potential as Bioherbicide

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A B S T R A C T

Sorghum is a drought-resistant crop that has the potential to produce allelopathic compounds as bioherbicides. Evaluation of Suri 4 and Mandau varieties under different irrigation systems is essential to assess growth adaptability and biomass potential as a natural bioherbicide ingredient. This study aimed to identify sorghum varieties with optimal growth at specific irrigation levels and evaluate biomass as a raw material for natural herbicides. The study used a two-factor Randomized Group Design with four treatment combinations and four replications, involving two sorghum varieties (Suri 4 and Mandau) and two irrigation patterns (every day and every 4 days). The results showed that Suri 4 and Mandau varieties had relatively similar growth patterns. Daily irrigation resulted in better growth, while every 4 days increased the production of secondary metabolites that could act as bioherbicides

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## INTRODUCTION

Sorghum (Sorghum bicolor L.) is one of the most essential grain food crops with high development potential in the tropics, particularly in Indonesia. One of the main advantages of sorghum is its ability to survive and adapt to dry climates and marginal lands with low soil fertility. Its tolerance to this environmental stress makes sorghum a prospective candidate for flagship status in food diversification and dryland cropping agriculture. In addition to its resilience, sorghum is also known as a multifunctional crop with various advantages. These include serving as food for human consumption, animal feed, raw materials for bioenergy (bioethanol and biomass), and a source of bioactive compounds with allelochemical properties. Sorghum plants constantly interact with the environment and can tolerate it (Abebe et al., 2021). Environmental conditions supporting optimal sorghum plant growth include high water humidity (Morales et al., 2024).

Some vegetative parts of sorghum, such as leaves, stems, and roots, are reported to contain phenolic compounds (gallic, coumaric, vanillic, and hydroxybenzoic acid), sorgoleone, and flavonoids that have bioherbicidal activity. These allelopathic properties indicate the potential of sorghum not only in production but also in environmentally friendly agriculture supported through reduced reliance on synthetic herbicides. Therefore, sorghum can be categorized as a strategic commodity to achieve the goals of sustainable agriculture in terms of productivity, efficient utilization of natural resources, and environmental conservation (Susilo et al., 2022; Weston et al., 2013; Kremer & Reinbott, 2021).

As with other cultivated crops, sorghum productivity is strongly influenced by the interaction of genetic (genotype or variety) and environmental factors. Water availability is one of the most crucial environmental factors in drier areas. Water is essential in various physiological processes, such as photosynthesis, nutrient transport, and cell elongation. Therefore, having sufficient and timely water is essential to support optimal growth and development. In the case of sorghum cultivation, irrigation regimes or water application patterns can trigger various physiological and morphological responses depending on the variety used (Tovignan et al., 2023; Alzahrani et al., 2025).

Changes in irrigation practices affect vegetative growth parameters, such as plant height, leaf number, leaf length and width, root length, and stem diameter. These growth responses reflect the adaptive ability of each variety to specific water stress or soil moisture conditions. Therefore, assessing the growth performance of several sorghum varieties under different irrigation levels is important. This evaluation aims to identify varieties that, in addition to being able to grow optimally under water deficit conditions, can also potentially produce high amounts of biomass that can be directly used as an agricultural product or as an active ingredient of bio-environmentally friendly herbicides (Reyes-Cabrera et al., 2023).

Mandau and Suri 4 varieties are two of Indonesia's most developed and cultivated hybrid sorghum varieties. These two varieties differ in morphological traits such as plant height, leaf shape, and size and environmental stress, particularly abiotic stress such as drought. These differences suggest that the varieties have different and unique strategies to adapt to environmental conditions, which thus justifies evaluating their performance under various cultivation treatments. The diverse adaptation and water efficiency among Indonesian local varieties reflect the variation in genotypic response strategies to water stress (Widiyono & Nugroho, 2023; Campos et al., 2025).

On the other hand, plants subjected to mild or moderate water stress have been shown to increase the biosynthesis and accumulation of secondary metabolites, such as phenolic compounds and flavonoids. These compounds are known to have allelopathic activity and have the potential to act as active ingredients in formulating natural bioherbicides. Therefore, genetic factors (variety) and environmental factors (irrigation pattern) affect the growth and productivity of sorghum and actively modulate the crop's bioactive compounds. Water stress increases flavonoid content in tannin-free sorghum varieties. This effect varied by genotype, emphasizing the importance of the interaction between abiotic stress and genetic factors in the biosynthesis of secondary metabolites such as flavonoids (Pinheiro et al., 2021; Ni et al., 2025). The production and accumulation of sorghum allelochemicals include sorgoleone and various phenolic compounds resulting from sorghum's roots, stems, and leaves. It is known that phenolic compounds have phytotoxic properties and can be used as natural bioherbicides (Hussain et al., 2021).

Irrigation pattern is an important factor determining sorghum growth response, given the need for adaptable and water-efficient varieties. Exploration of sorghum's potential as a source of natural bioherbicides strategically contributes to developing environmentally sustainable agricultural systems and reduces dependence on synthetic inputs for weed control. The combination of Mandau and Suri 4 varieties with an irrigation interval of 4-5 days produced extracts that exhibited high levels of phytotoxicity against weeds, including the ability to reduce seed germination and root length in seedlings significantly (Susilo et al., 2025).

## LITERATURE REVIEW

This study evaluated the growth performance of two sorghum varieties, Suri 4 and Mandau, under different irrigation strategies. The main objectives were to determine the specific varieties that achieved optimal growth at specific water levels and assess the potential biomass yield as a feedstock for natural herbicides. The results from this study also provide a scientific rationale to support the development of environmentally friendly sorghum cultivation through the application of allelopathic principles for sustainable biotic weed control.

## METHODOLOGY

The research was conducted from April to July 2025 in the Greenhouse of Agronomy Laboratory, Faculty of Agriculture, Bengkulu University. The experimental materials were sorghum seeds of Suri 4 and Mandau varieties, coastal soil media, and water. The tools used were a hoe, a polybag, a bucket, a ruler, a vernier, a label, and stationery.

This experiment used a 2-factor Randomized Group Design. Factor 1 was the sorghum variety with Suri 4 and Mandau varieties. Factor 2 is the irrigation pattern, with the level of irrigation every day and the irrigation pattern every four days. The treatment combination was four treatments repeated four times. The volume of water used as treatment was 1 liter per polybag. The water used came from the well's groundwater.

Coastal soil media was prepared and stirred compositely to mix the media evenly. The polybags used were large, 40 cm x 50 cm. The soil media was put into polybags, weighing 5 kg per polybag. The media in the polybag was left for 1 week to get the perfect planting media. The distance between polybags is 30 cm x 30 cm.

Sorghum planting was carried out using the dense population method with a spacing of about 0.5 cm. The polybag planting medium that had been prepared was watered with 1 liter of water. Planting holes were made with a dense population. Seeds were planted in the planting hole and covered with soil by sprinkling soil over the surface of the planting hole. Furthermore, the planting media were watered with 1 liter of water using a paddle. Maintenance was carried out daily by watering 1 liter per polybag media for 14 days. Furthermore, an irrigation pattern was applied every day and every 4 days with a volume of 1 liter of water. At the age of 45 days, plant growth was observed and harvested. The stalks were later used as bioherbicide material.

The observation variables consisted of plant height (cm), number of leaves (strands), leaf length (cm), leaf width (cm), root length (cm), and stem diameter (mm). Observation data were analyzed statistically to produce an ANOVA and followed by a LSD test, if there were significant differences between the averages with a significance level set at $P < 0.05$.

## RESULTS AND DISCUSSION

Based on the table of variance, the treatment of varieties has a significant effect on the variable number of leaves, and has no significant effect on the variable stem diameter, and is not significantly different from the variables of plant height, leaf length, leaf width, root length, and stem diameter. The treatment of irrigation patterns had a very significant effect on the variables of plant height, number of leaves, and leaf length, had a significant effect on the variable leaf width, and had no significant effect on the variables of root length and stem diameter. The interaction effect between varieties and irrigation patterns had no significant effect on all observed variables, as shown in Table 1.

The effect of variety treatment on plant height variables showed no significant effect. There was a tendency for the Suri 4 variety (79.34 cm) to produce higher plant heights than the Mandau variety (72.68 cm). The effect of varietal treatment on plant height variables did not show statistically significant differences, indicating that the genetic factors of the varieties have not fully exerted a significant influence in the environment where the research was conducted. However, there was a trend that the Suri 4 variety was better, with an average plant height of 79.34 cm, while Mandau was 72.68 cm. Although the difference was insignificant, it could indicate that the Suri 4 variety provides some competitive advantages related to physiological processes during resource utilization, including light and nutrients, which ultimately affect agronomic performance. These findings suggest that variety selection, as the primary focus of research, is still a crucial factor to consider in the development of sorghum cultivation, primarily to obtain adaptable varieties that have the potential to produce higher biomass. According to Mrubata et al. (2024) and Abriham (2022), varietal differences did not guarantee significant differences in plant height, suggesting that environmental conditions strongly influence varietal responses.

Table 1. Recapitulation of the Growth of Sorghum Varieties with Various Waterings

| **Observation variables** | **Variety (V)** | **Irrigation pattern (P)** | **Interaction (V x P)** | **Coefficient of variation (%)** |
|---|---|---|---|---|
| Plant height | 3,06 tn | 56,96 ** | 6,43 tn | 8,69 |
| Number of leaves | 7,20 * | 37,93 ** | 0,59 tn | 7,43 |
| Leaf length | 0,64 tn | 40,78 ** | 7,67 tn | 9,56 |
| Leaf width | 4,56 tn | 8,47 * | 1,44 tn | 11,67 |
| Root length | 0,02 tn | 4,56 tn | 1,58 tn | 35,62 |
| Stem diameter | 0,14 tn | 0,30 tn | 4,76 tn | 10,72 |

| | | |
|---|---|---|
| ** = significantly different | | |
| * = significantly different | | |

| | | |
|---|---|---|
| Tn = not significantly different | | |

The effect of irrigation patterns on plant height showed significant differences on a statistical scale. This indicates that the availability of irrigation water significantly affects plant growth. With the daily irrigation system, the average plant height reached 90.39 cm. This was significantly higher than the seventy-four-day treatment with irrigation every 4 days. In this case, the plants reached an average height of 61.61 cm. These results indicate that a higher irrigation frequency facilitates a more stable plant water supply, thus favoring the optimal physiological processes of photosynthesis, cell division, and elongation.

On the other hand, restriction of water supply through infrequent irrigation leads to water stress. This resulted in stunted vertical growth of these plants. These findings reinforce the significant role of irrigation management on crop production, especially during the early vegetative phase when water is critical for biomass accumulation and morphological development. According to (Ciftci et al., 2025), increasing irrigation levels significantly increased plant height, dry matter, and other yield components. Furthermore, according to Ghalkhan et al. (2023), using a drip irrigation system with 100% soil moisture supply resulted in the best vegetative growth and biomass yield, including greater plant height compared to lower irrigation levels.

The effect of variety treatment on the variable number of leaves showed a significant effect. The Mandau variety produced the highest number of leaves at 7.11 strands, significantly different from the sorghum variety Suri 4 (6.34 strands). The effect of irrigation pattern treatment on the variable number of leaves showed a real effect. The pattern of irrigation every day produced the highest number of leaves, namely 7.61 strands, and was significantly different from the pattern of irrigation every 4 days (5.84 strands) shown in Table 2. The effect of treatment variation on the number of leaves statistically showed a very significant difference. This suggests that genetic factors of the variety contribute to the development of the plant canopy, especially regarding the number of leaves. The Mandau variety was reported to have the highest number of leaves with an average of 7.11 per plant. It was statistically different from the Suri 4 variety, which produced an average of 6.34 leaves. Mandau's superiority in this parameter indicates significant potential for lush vegetative growth, which contributes to the expansion of photosynthetic area and increased plant productivity.According to Ciftci et al (2025), irrigation with higher frequency and quantity significantly increased the number of leaves and LAI of plants. Furthermore, Ghalkhani et al. (2023), treatments with 100% soil moisture supply produced the best vegetative characteristics (number of leaves and plant height) compared to 75% and 50% moisture treatments. Likewise, the effect of irrigation pattern on leaf number showed a highly significant effect. Leaf production for daily irrigation was the highest at 7.61 leaves, much higher than the once every 4 days irrigation pattern which only produced 5.84 leaves. This finding confirms the important role of high watering frequency in maintaining water levels in the root zone. This supports plant metabolism and plant tissue formation, including leaf differentiation. Reduced irrigation frequency limits plant physiological activities due to water stress, which in turn inhibits optimum leaf production.

Table 2. Mean Plant Height, Number of Leaves, and Leaf Length of Suri 4 and Mandau Varieties as A Result of Different Irrigation Treatments

| Treatment | Plant height (cm) | Number of leaves (leaflets) | Leaf length (cm) |
|---|---|---|---|
| Sorghum variety: | | | |
| Suri 4 | 79,34 | 6,34 b | 44,95 |
| Mandau | 72,68 | 7,11 a | 43,00 |
| Watering pattern : | | | |
| Every day | 90,39 a | 7,61 a | 51,72 a |
| every 4 days | 61,61 b | 5,84 b | 36,22 b |

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

The effect of variety treatment on the leaf length variable showed no significant effect. There is a tendency for the Suri 4 variety (44.95 cm) to produce a leaf length higher than that of the Mandau variety (43.00 cm). The effect of irrigation pattern treatment on leaf length variables showed a significant effect. The daily irrigation pattern produced the highest leaf length of 51.72 cm and significantly differed from the once every 4 days irrigation pattern (36.22 cm) shown in Table 2. The effect of various varieties of treatment on leaf length did not show statistical significance. This means that genetic differences between varieties have not had a sufficient impact on leaf morphological traits, even with similar environmental factors. However, there is a trend that Suri 4 has a higher leaf length growth of 44.95 cm compared to Mandau, which reached 43 cm. Due to this difference, Suri 4 is suspected to have vegetative vigor, although it is not statistically significant. This variety has the potential to outperform Suri 4 in leaf organ development, but it is still not statistically significant. In contrast, irrigation pattern treatment had a highly significant effect on leaf length. Daily irrigation still had the maximum leaf length of 51.72 cm compared to irrigation every 4 days, which had an average of 36.22 cm. This distinction emphasizes the importance of regulated water amounts and a continuous water supply to support growth. Under daily irrigation systems, the water content in the soil can help support sufficient turgor and cell elongation, as well as photosynthesis necessary for optimal leaf development. In contrast, under water stress conditions, minimal water supply inhibits turgor, cell division, and cell elongation, as well as leaf elongation. According to Wang et al. (2024), increased irrigation frequency and volume significantly increased the leaf area index and leaf number of plants.

Table 3. Mean Leaf Width, Root Length, and Stem Diameter of Suri 4 and Mandau Varieties Due to Different Irrigation Treatments

| Treatment | Leaf width (cm) | Root length (cm) | Stem diameter (mm) |
|---|---|---|---|
| Sorghum variety: | | | |
| Suri 4 | 2.01 | 8.36 | 3.45 |
| Mandau | 2.32 | 8.13 | 3.53 |
| Watering pattern : | | | |
| Every day | 2.38 a | 10.06 | 3.43 |
| every 4 days | 1.96 b | 6.43 | 3.55 |

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

The effect of variety treatment on leaf width variables showed no significant effect. There is a tendency for the Mandau variety to produce a higher leaf width than the Suri 4 variety. The effect of irrigation pattern treatment on leaf width variables showed a significant effect. The daily irrigation pattern can produce the highest leaf width (2.38 cm) and significantly differs from the irrigation pattern every 4 days (1.96 cm) shown in Table 3. The impact of variety treatment on leaf width did not show a significant statistical effect. This indicates that genetic differences between varieties have not significantly impacted the development of leaf width under uniform growth conditions. Nonetheless, there is a tendency for the Mandau variety to have wider leaves than the Suri 4 variety. This indication may support variety selection based on vegetative characteristics that can help increase surface area for photosynthesis, although the difference is not statistically significant. In contrast, the effect of irrigation treatment on leaf width was significant. Daily irrigation produced the widest leaves with an average of 2.38 cm, statistically significantly different from the 4-day interval irrigation pattern that produced a width of 1.96 cm. These results support the hypothesis that water availability at optimal levels is important to maintain the cell turgor pressure required for maximal leaf tissue expansion. More frequent watering allows greater space for physiological processes such as photosynthesis, transpiration, and cell division, which positively impacts vegetative organ size, especially leaf width. On the other hand, infrequent watering can cause water stress that restricts cell growth and results in stunted leaf organs.

The effect of variety treatment on the root length variable showed no significant impact. There was a tendency that the Suri 4 variety (8.36 cm) was able to produce a higher root length than the Mandau variety (8.13 cm). The effect of irrigation pattern treatment on the root length variable showed no significant impact. There is a tendency that the daily irrigation pattern (10.06 cm) can produce higher root length than the every 4 days irrigation pattern (6.43 cm) shown in Table 3. The effect of variety treatment on root length showed no significant difference at the statistical level. This suggests that genetic differences between varieties cannot yet significantly impact root system development under uniform environmental conditions. However, it is still reasonable to expect that the Suri 4 variety tends to have a longer average root length of 8.36 cm, while the Mandau variety averages 8.13 cm. This slight difference suggests that Suri 4 may have better root system adaptability, although this has not been proven significant. Meanwhile, the impact of irrigation pattern on root length growth does not have a substantial effect at the statistical level. However, it is reasonable to conclude that daily watering stimulated root growth, which averaged 10.06 cm compared to 6.43 cm for the irrigation pattern every 4 days. This trend suggests that sufficient and continuous amounts of water allow for optimal root growth and development as the plant attempts to absorb water and nutrients from the soil. On the other hand, low-frequency watering treatments can result in water stress conditions, reducing cell division and elongation activities in root tissues, thus inhibiting root elongation.

The effect of variety treatment on the stem diameter variable showed no significant effect. There was a tendency that the Mandau variety (3.53 mm) was able to produce a higher stem diameter than the Suri 4 variety (3.45 mm). The effect of irrigation pattern treatment on the stem diameter variable showed no significant effect. There is a tendency that the once every 4 days irrigation pattern (3.55 mm) can produce a higher stem diameter than the daily irrigation pattern (3.43 mm) shown in Table 3. The impact of treatment variation on stem diameter did not show a significant statistical impact. Genetic differences between variants did not significantly contribute to plant stem thickness under the uniform environmental conditions provided. However, there was a trend that the Mandau variant had a slightly larger stem diameter of 3.45 mm, compared to the Suri 4 variant, which had an average stem diameter of 3.43 mm. This slight difference may indicate that the Mandau variant potentially has greater morphological stem vigor, although not enough to show a statistically significant difference. In the same way, the impact of irrigation pattern treatment on stem diameter also showed no statistically significant difference. However, there was a trend that irrigation every 4 days resulted in a larger stem diameter of 3.55 mm compared to daily irrigation of 3.43 mm. This finding is interesting because interval irrigation's mild water stress conditions may stimulate the development of a reinforcing mechanical support network in the stem as a form of plant morphological adaptive response. However, since this trend was not statistically significant, further exploration is needed through studies that consider plants' growth phase and physiological response to water availability. Furthermore, according to Ndlovu et al. (2021), drought stress on sorghum growth triggers increased accumulation of secondary metabolites such as flavonoids and phenolics. As a result, physiological processes such as photosynthesis and cell division are inhibited.

## CONCLUSION AND RECOMMENDATION

Sorghum varieties Suri 4 and Mandau have relatively the same type of growth. The daily irrigation pattern produced superior growth; in contrast, the irrigation pattern every four days had the potential to produce higher secondary metabolites, making it a good bioherbicide material.

## FUTHER STUDY

This research is still at an early stage, focusing on morphological studies, especially the growth of sorghum plants as a basis for their utilization as a bioherbicide material. In the future, the research will continue with the analysis of secondary metabolite content as an allelopathic compound, which is expected to open up opportunities for more in-depth and comprehensive studies.

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**REFERENCES**

Abebe, T., Belay, G., Tadesse, T., & Keneni, G. (2021). Stay-green genes contributed for drought adaptation and performance under post-flowering moisture stress on sorghum (Sorghum bicolor L. Moench). Journal of Plant Breeding and Crop Science, 13(4), 190-202.

Abriham, A. (2022). Response of midland sorghum varieties to different intra-row spacing at kaffa zone south western Ethiopia. Ukrainian Journal of Ecology, 12(12), 1-7.

Alzahrani, Y., Abdulbaki, A. S., & Alsamadany, H. (2025). Genotypic variability in stress responses of Sorghum bicolor under drought and salinity conditions. Frontiers in Genetics, 15, 1502900.

Campos, M. L. D., Aspiazú, I., Magalhães, P. C., Carvalho, A. J. D., Alves, P. F. S., & Portugal, A. F. (2025). Morphophysiological indicators of drought tolerance in sorghum hybrids. Revista Ciência Agronômica, 56, e202394282.

Ciftci, B., Varol, I. S., Akcura, S., Kardes, Y. M., Karaman, S., & Kaplan, M. (2025). Morphological and nutritional responses of sorghum to variable irrigation levels and nitrogen doses. PLoS One, 20(5), e0323901.

Ghalkhani, A., Golzardi, F., Khazaei, A., Mahrokh, A., Illés, Á., Bojtor, C., ... & Széles, A. (2023). Irrigation management strategies to enhance forage yield, feed value, and water-use efficiency of sorghum cultivars. Plants, 12(11), 2154.

Hussain, M. I., Danish, S., Sánchez-Moreiras, A. M., Vicente, Ó., Jabran, K., Chaudhry, U. K., ... & Reigosa, M. J. (2021). Unraveling sorghum allelopathy in agriculture: Concepts and implications. Plants, 10(9), 1795.

Kremer, R. J., & Reinbott, T. M. (2021). Allelopathy of sorghum residues on weed establishment is affected by hybrid, phenolic acid contents and environment. Journal of Plant Sciences, 9(1), 25-31.

Morales, M. M., Hoshide, A. K., Carvalho, L. M. P., & Tardin, F. D. (2024). Sorghum biomass as an alternative source for bioenergy. Biomass, 4(3), 1017-1030.

Mrubata, K., Nciizah, A. D., & Muchaonyerwa, P. (2024). Planting date and tillage effects on yield and nutrient uptake of two sorghum cultivars grown in sub-humid and semi-arid regions in South Africa. Frontiers in Agronomy, 6, 1388823.

Ndlovu, E., Van Staden, J., & Maphosa, M. (2021). Morpho-physiological effects of moisture, heat and combined stresses on Sorghum bicolor [Moench (L.)] and its acclimation mechanisms. Plant Stress, 2, 100018.

Ni, X., Long, W., Gong, L., Zheng, J., Li, Y., & Kang, Z. (2025). Metabolomics analysis of five cultivars of Sorghum bicolor reveals the contribution of flavonoid pathway to tannin content. PloS one, 20(4), e0321649.

Pinheiro, S. S., de Morais Cardoso, L., Anunciação, P. C., de Menezes, C. B., Queiroz, V. A. V., Martino, H. S. D., ... & Sant’Ana, H. M. P. (2021). Water stress increased the flavonoid content in tannin-free sorghum grains. Journal of Food Composition and Analysis, 100, 103892.

Reyes-Cabrera, J., Adams, C. B., Nielsen, J., & Erickson, J. E. (2023). Yield, nitrogen, and water-use efficiency of grain sorghum with diverse crown root angle. Field Crops Research, 294, 108878.

Susilo, E., Parwito, P., Sari, D. N., Togatorop, E. R., Raisawati, T., Handayani, S., ... & Pujiwati, H. (2022, December). Potensi Batang Ratun Tanaman Sorgum Terfermentasi yang Diproduksi di Lahan Rawa sebagai Bioherbisida. In Prosiding Seminar Nasional Perlindungan Tanaman (Vol. 1, pp. 42-47).

Susilo, E., Setyowati, N., & Supriyanti, Y. I. (2025). Effect of water stress and varieties on the bioherbicidal effectivity of sorghum aqueous extracts. International Journal of Agricultural Technology, 21(1), 317-326.

Tovignan, T. K., Basha, Y., Windpassinger, S., Augustine, S. M., Snowdon, R., & Vukasovic, S. (2023). Precision phenotyping of agro-physiological responses and water use of sorghum under different drought scenarios. Agronomy, 13(3), 722.

Wang, Z., Nie, T., Lu, D., Zhang, P., Li, J., Li, F., ... & Waller, P. M. (2024). Effects of different irrigation management and nitrogen rate on sorghum (Sorghum bicolor L.) growth, yield and soil nitrogen accumulation with drip irrigation. Agronomy, 14(1), 215.

Weston, L. A., Alsaadawi, I. S., & Baerson, S. R. (2013). Sorghum allelopathy—from ecosystem to molecule. Journal of Chemical Ecology, 39(2), 142-153.

Widiyono, W., & Nugroho, S. (2023). Physiological characteristics to indicate water use efficiency and drought tolerance of 30 indonesian sorghum [Sorghum bicolor (L.) Moench] accessions. HAYATI Journal of Biosciences, 30(1), 171-181.