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The Effect of Zinc (Zn) Micronutrient Supplementation through Seed Priming and Foliar Spray on the Growth and Grain Yield of Several Sorghum Varieties

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ABSTRACT
Sorghum (Sorghum bicolor L.) is known for its resistance to marginal land conditions, but optimal production requires proper crop management, particularly fertilization. This study aims to determine the effect of the application of Zn micronutrients given through seed priming and foliar spray on several varieties of sorghum carried out on the Ultisol sour dry land in Central Lampung. The trial was carried out in May - September 2024 using a three-replication factorial group random design (RAK). The first factor is the type of sorghum varieties, namely Numbu, Samurai 2, Super 2, and Suri 1. While the second factor is Zn treatment in the form of: control, ZnSO4.7H2O 0.5% seed priming application, ZnSO4.7H2O 0.5% seed priming and foliar spray application in the vegetative phase, ZnSO4.7H2O seed priming and foliar spray application 0.5% in the generative phase and seed priming and foliar spray ZnSO4.7H2O 0.5% application in the vegetative + generative phase. The results of the study showed that the difference in varieties had a real effect on vegetative growth and leaf growth. Micronutrient Zn has a significant impact on increasing plant height, leaf width, greenness/chlorophyll level of leaves and seed yield per plant.
Keywords: sorghum, varieties, zinc, seed priming, foliar spray, biomass, crop yield,

INTRODUCTION

Sorghum (Sorghum bicolor L.) is an alternative commodity for food and a source of feed and agro-industrial materials that is very prospective when viewed from all components of crop crops that can be used (Macedo et al., 2020; Widowati & Luna, 2022). The advantage of sorghum over other cereals is its tolerance to drought and the ability to grow on marginal land (Mwamahonje et al., 2021; Njinju et al., 2022). Although genetically sorghum has resistance to extreme conditions, plant cultivation technology, especially fertilization, plays an important role in producing optimal production (Khalifa & Eltahir, 2023). The provision of proper and balanced fertilizers or nutrients is the basis for plants to reach their maximum potential (Menna, 2021). Fertilization not only provides macronutrients such as nitrogen, phosphorus, and potassium, but also important micronutrients such as iron, zinc, and manganese (Cole et al., 2016; Delgado et al., 2024). Micronutrient fertilization provides significant benefits in improving the efficiency of photosynthesis, increasing disease resistance, and strengthening plant cell structure (Jeevanraj et al., 2025). Nutrient Zn is one of the micronutrients that plays an important role in plant growth so that it often restricts crop yields (Suganya et al., 2020).

Micronutrients zinc (Zn) are essential elements for plants that act as enzyme cofactors, a tryptophan constituent in auxin biosynthesis, and are important in the formation of chlorophyll and membrane stability (Solanki, 2021). Rudani (2018) explained that the sufficient availability of Zn in plants has a positive effect on increasing the efficiency of photosynthesis, especially through the important role of carbonic enzyme anhydrase. The activity of this enzyme can accelerate the accumulation of glucose in the leaves, which is subsequently converted into sucrose as the main form of photosynthate translocation to other organs which can ultimately increase the growth and production of biomass (Li et al., 2017). The adequacy of Zn for plants has been shown to increase vegetative growth, photosynthesis efficiency, and biomass accumulation (Andrejić et al., 2018; Wang et al., 2016). It was mentioned by Chen (2025) that sorghum plants are a type of cereal with high sensitivity to Zn deficiency. Therefore, the application of Zn is an important strategy to increase the growth and productivity of sorghum in suboptimal land (Dimkpa et al., 2019).

Research on the provision of Zn micronutrients in cereal plants has been widely reported, especially related to increased vegetative growth, yield, and nutritional value. Various Zn application methods have been studied, including through soil fertilization, seed priming, and foliar spray. Cakmak and Kutman explained that the application of Zn through the soil often faces obstacles due to low mobility of Zn and various other conditions that reduce the availability of Zn to be absorbed by plants. Research shows that the provision of Zn micronutrients through a combination of seed priming with foliar spray has the potential to increase the efficiency of Zn absorption and support the physiological growth of plants. However, studies that systematically compare the effectiveness of a combined seed priming and foliar spray approach, with specific timing during different growth phases (vegetative and generative), are still limited, particularly for sorghum cultivated in acidic, nutrient-poor Ultisol soils typical of Indonesia's dryland areas. This study aims to fill that gap by evaluating the effect of Zn micronutrient application through seed priming and foliar spray at different growth phases on the growth and grain yield of several sorghum varieties in an Ultisol dryland of Central Lampung. The novelty of this research lies in the comprehensive evaluation of combined application methods and timing on multiple local sorghum varieties under specific acidic soil conditions. The findings are expected to provide practical recommendations for efficient Zn fertilization strategies to enhance sorghum productivity in similar marginal agro-ecosystems..

METHOD

The research was carried out in Bumi Aji Village, Anak Tuha District, Central Lampung at the location points of 4°57'16''LS and 105°04'16''E with an altitude of ± 51 meters above sea level. The condition of the research land has an ultisol soil type with a sand texture of 16.0%, dust 40.0% and clay 44.0% with the following soil fertility levels: C-organic 1.67%, N-total content 0.20%, P potential 53.90 ppm, K potential 73 ppm, Zn 44.0 ppm, cation/CEC exchange capacity 795 cmol/kg and soil pH 4.90 which is classified as sour. The research was conducted from May 2024 to September 2024.

The experiment was carried out using a Group Random Design (RAK) which was factorially arranged with two treatment factors and each treatment was repeated three times.

The first factor is the sorghum (V) variety which consists of 4 types, namely V1 = Numbu variety, V2 = Samurai 2 variety, V3 = Super 2 variety and V4 = Suri 1 variety. The second factor is the administration of Zn (P) micronutrients consisting of 5 treatments, namely P0 = Control, P1 = Seed Priming 0.5% ZnSO4.7H20 for 12 hours, P2 = P1 + Foliar Spray 0.5% ZnSO4.7H20 Vegetative Phase, P3 = P1 + Foliar Spray 0.5% ZnSO4.7H20 Generative Phase, P4 = P1 + Foliar Spray 0.5% ZnSO4.7H20 Vegetative Phase + Foliar Spray 0.5% ZnSO4.7H20 Generative Phase. To determine the effect of treatment on the observation variables, a variety of fingerprint analysis was carried out and on the treatment that had a real effect, a middle value test was carried out with the Least Significant Difference (LSD) at the level of 5%.

Soaking sorghum seeds (Seed Priming) in a solution of ZnSO4.7H2O with a concentration of 0.5% was carried out for 12 hours with ± 60% of the seeds submerged in the solution. Before planting, sorghum seeds according to the variety that have been primed are dried and ventilated in the open. Planting according to treatment is carried out manually with a planting distance of 80 cm x 20 cm, 2 plants per hole in a treatment plot measuring 3 m x 3 m. Spraying Zinc solution on plant leaves (foliar spray) using a hand sprayer given according to the treatment, namely in the vegetative phase two (2) times when the age of 30 HST and 50 HST and in the generative phase as many as two (2) times when the plant age is 70 HST and 80 HST. Before starting spraying, a calibration is carried out the spray time and the treatment plot to be sprayed is given a plastic barrier with the aim that the spray solution does not contaminate other plots with different treatment. The application of N, P and K fertilizers is given with a dose of urea fertilizer of 200 kg / ha, SP 36 100 kg / ha and KCl fertilizer as much as 50 kg/ha of KCl fertilizer is given two applications, namely at the age of 2 weeks after planting as much as 100 kg of urea / ha, 100 kg SP 36 / ha and then at the age of 1 month urea fertilizer is given with a dose of 100 kg / ha. Observations were carried out on vegetative growth (plant height, number of leaves, stem diameter) which was carried out at the age of 30 HST, 45 HST, 60 HST and 75 HST, leaf length, leaf width, leaf greenness level (SPAD unit) and seed yield per plant.

RESULTS AND DISCUSSION

The results of the analysis of the -F Test in Table 1 show that the variation of varieties has a significant effect on all components of vegetative growth measured from the age of the plant from 30 HST to 75 HST, except for the stem diameter variable at the age of 60 HST and 75 HST. Meanwhile, the application of Zn micronutrients has a significant effect on plant height (30 HST to 75 HST) and stem diameter at the age of 30 HST. In the leaf width variable, leaf length and leaf greenness level measured at the age of 75 HST showed that the variety difference only had a real effect on leaf length and leaf greenness (SPAD Unit), while the application of Zn micronutrients had a real effect on leaf width and leaf greenness. The provision of Zn micronutrients also has a real impact on the components of seed yield per plant. No significant interaction was found between the cultivated varieties and the nutrient application of mkro Zn to all the observed variables.

Table 1. Recapitulation of F-Test on the Effect of Zn Micronutrient Provision on Growth and Seed Yield of Several Sorghum Varieties.

Variabel Observation	*Central Lampung*		
	V	**P**	**V x P**
Plant Height 30 HST	**	*	tn
Plant Height 45 HST	**	**	tn
Plant Height 60 HST	**	*	tn
Plant Height 75 HST	**	**	tn
Number of Leaves 30 HST	**	tn	tn
Number of Leaves 45 HST	**	tn	tn
Number of Leaves 60 HST	**	tn	tn
Number of Leaves 75 HST	**	tn	tn
Diameter Batang 30 HST	**	*	tn
Diameter Batang 45 HST	*	tn	tn
Diameter Batang 60 HST	tn	tn	tn
Diameter Batang 75 HST	tn	tn	tn
Leaf Length 75 HST	**	tn	tn
Leaf Width 75 HST	tn	*	tn
Leaf Greenness Level (SPAD Unit) 75 HST	**	**	tn
Yield Seeds per Plant	tn	**	tn

Source: Data processed, 2024

Description: * = real at the level of 5%; ** = real at the level of 1%; tn = not real.

In Table 2, it can be seen the effect of different varieties of sorghum on plant height growth, stem diameter and number of leaves according to age phases. It appears that at the beginning of growth until the age of 45 HST, the plant height of the Numbu variety exceeds the Samurai 2, Super 2 and Suri 1 varieties. However, starting at the age of 60 HST, the Samurai 2 variety is noticeably able to exceed the height of the Numbu, Super 1 and Suri 1 varieties. In the stem diameter variable, at 30 HST age shows that the Numbu variety has the highest diameter. However, at the age of 75 HST, the stem diameter between the planted sorghum varieties does not show any noticeable difference. Meanwhile, the number of leaves variable shows that the Samurai 2 and Super 2 varieties actually have more leaves than Numbu and Suri 1 starting from the plant age of 60 HST. Based on the results of the above observations, the Samurai 2 and Super 2 varieties showed the best growth in terms of plant height and number of leaves at 60 and 75 HST. This indicates that both varieties genetically have a stronger vegetative growth potential than Numbu and Suri 1. The difference in vegetative growth between varieties in this study is in accordance with the opinion of Rengel and the results of Sihono research which explains that genetic factors affect the agronomic appearance of plants.

Table 2. Effect of Variety Differences on Vegetative Growth of Sorghum Plants

Variabel Observation	Varietas sorgum (V)*			
	V 1	V 2	V 3	V 4
	30 HST			
Plant Height (cm)	42.16a	36.71b	33.38c	36.65b
Diameter Batang (mm)	11.53a	10.30b	9.49c	10.10bc
Number of Leaves	6.43a	6.33a	6.20b	6.13b
	45 HST			
Plant Height (cm)	96.82a	95.63a	94.23a	84.61b
Diameter Batang (mm)	17.99b	18.78a	18.33from	18.24b
Number of Leaves	7.33a	7.29a	7.00b	6.97b
	60 HST			
Plant Height (cm)	214.93c	266.53a	249.11b	171.44d
Diameter Batang (mm)	19.02	19.54	19.31	19.03
Number of Leaves	10.07c	10.85a	10.41b	9.33d
	75 HST			
Plant Height (cm)	214.57c	266.11a	248.47b	172.52d
Diameter Batang (mm)	19.11	19.29	19.43	19.13
Number of Leaves	9.99b	10.71a	10.19b	9.20c

Source: Data processed, 2024

Remarks: Numbers on the same line followed by the same letter do not differ significantly at the 5% test level with LSD. Unlettered numbers are not significantly different from the F test.
*V1= Numbu; V2= Samurai 2; V3 = Super 2; V4= Suri 1.

Table 3 shows the effect of Zn micronutrient application on plant height, stem diameter and leaf count. It appears that the application of Zn micronutrients has a real effect on the height variables of plants throughout the age phase and the diameter of the stem at the age of 30 HST. Micronutrient Zn had a positive impact on plant height through the treatment of Seed Priming + Foliar Spray Vegetative Phase (P2) and Seed Priming + Foliar Spray Vegetative and Generative Phase (P4) compared to control (P0), Seed Priming (P1) and Seed Priming + Foliar Spray Generative Phase (P3). In the table, it can be seen that at the age of 75 HST, plants with P2 and P4 treatments have heights of 232.41 cm and 234.02 cm, which are significantly different from P0 = 220.21 cm, P1 = 218.19 cm and P3 = 221.54 cm. Based on the above data, it can be concluded that the application of Zn micronutrients through P2 (seed priming + foliar Zn in the vegetative phase) and P4 (seed priming + foliar Zn in the vegetative and generative phase) treatment is able to increase vegetative growth which is consistently higher than the control (P0), especially at the age of 60 and 75 HST. In Table 2, it can also be seen that the micronutrient application of Zn (P1, P2, P3, P4) has a significant effect on the diameter of the stem during the initial phase of growth (30 HST). The increased vegetative growth due to Zn application can be explained physiologically that Zn plays a role in the formation of chlorophyll, enzyme activation, and protein synthesis, which is important in the division and enlargement of plant cells. The application of foliar Zn in the vegetative phase (P2) has been shown to increase Zn uptake directly in photosynthetic active tissues, thereby promoting faster vegetative growth (Cakmak; Alloway; Broadley). It is explained by Rudani (2018) that the sufficient availability of Zn in plants has a positive effect on increasing the efficiency of photosynthesis, especially through the important role of carbonic enzyme anhydrase. The activity of this enzyme can accelerate the accumulation of glucose in the leaves, which is then converted into sucrose as the main form of photosynthetic translocation to other organs which can ultimately promote plant growth.

Table 3. Effect of Micronutrient Provision of Zn on Vegetative Growth of Sorghum Plants

Variabel Observation	Micro Nutrient Provider Zn (P)*				
	P 0	**P 1**	**P 2**	**P 3**	**P 4**
			30 HST		
Plant Height (cm)	34.92c	37.12bc	37.93from	36.40bc	39.76a
Diameter Batang (mm)	9.64b	10.42a	10.43a	10.48a	10.81a
Number of Leaves	6.18	6.32	6.30	6.22	6.35
			45 HST		
Plant Height (cm)	89.67b	90.15b	96.60a	94.23a	96.40a
Diameter Batang (mm)	18.06	18.23	18.58	18.33	18.48
Number of Leaves	7.07	7.17	7.17	7.12	7.23
			60 HST		
Plant Height (cm)	220.18b	220.40b	232.85a	220.40b	233.68a
Diameter Batang (mm)	19.16	19.15	19.24	19.27	19.32
Number of Leaves	10.10	10.17	10.23	10.03	10.30
			75 HST		
Plant Height (cm)	220.21b	218.91b	232.41a	221.54b	234.02a
Diameter Batang (mm)	19.22	19.17	19.26	19.26	19.31
Number of Leaves	9.97	9.98	10.12	9.97	10.07

Source: Data processed, 2024

Description: The numbers on the same line followed by the same letter are not significantly different at the 5% test level with LSD. Unlettered numbers are not significantly different from the F test.
*P0 = Control; P1 = Seed Priming Zn; P2 = P1+Foliar Spray Zn vegetative phase; P3 = P1+Foliar Spray Zn generative phase; P4= P1+Foliar Spray Zn vegetative and generative phases.

Leaf morphology such as leaf length, leaf width, and leaf chlorophyll content play a major role in determining the photosynthetic capacity of plants and is directly correlated with plant growth and yield. Table 4 shows the results of observation of leaf length, leaf width, and greenishness level of leaves with the provision of Zn micronutrients in several varieties of sorghum observed at the age of 75 HST. The measurement results showed that the longest leaves were owned by the Numbu variety and the widest leaves were owned by Samurai 2, while the greenery level of plant leaves measured with the SPAD 502 plus Konica Minolta tool, the highest index was owned by the Numbu variety with an index value of 50.99 but was not significantly different from the Samurai 2 (50.49) and Suri 1 (49.79) varieties. The Numbu and Samurai 2 varieties show the best performance in variable leaf length and width as well as the greenness of the leaves. This indicates that both varieties genetically have high leaf morphology and photosynthetic efficiency.

Table 4. The Effect of Variety Differences and Micronutrient Provision of Zn on the Length, Width and Greenness Level of Leaves

Treatment	Leaf Length (cm)	Leaf Width (cm)	Greening Leaves (units)
Varietas Sorgum			
Numbu (V1)	91.55a	8.85	50.99a
Samurai 2 (V2)	90.11a	8.87	50.49a
Super 2 (V3)	87.50b	8.77	48.27b
Suri 1 (V4)	90.62a	8.75	49.79a
Zn Applications			
Control (P0)	88.86	8.61b	43.47d
Seed priming (P1)	88.96	8.51b	44.90c
Seed priming + Foliar spray vegetative phase (P2)	91.53	9.05a	52.64b
Seed priming + Foliar spray generative phase (P3)	90.03	8.80from	53.32b
Seed priming + Foliar spray vegetative and generative phase (P4)	90.36	9.08a	55.10a

Source: Data processed, 2024

Note: The numbers in the same column followed by the same letters show no significant difference at the 5% test level with LSD. Unlettered numbers are not significantly different from the F test.

Table 4 above also shows that the application of Zn micronutrients has a real effect on leaf width and greenness level but does not have a real effect on leaf length although there is a tendency to increase with the application of Zn micronutrients. It appears that the widest leaves belong to sorghum plants which are treated P2 (9.05 cm) and P4 (9.08 cm) which are significantly different from the P0 (8.61 cm) and P1 (8.51 cm) treatments, but not significantly different from the P3 (8.80 cm) treatment. Meanwhile, the highest level of plant leaf greenery (SPAD unit) was owned by sorghum plants with a P4 treatment of 55.10, followed by the P 2 and P3 treatments of 52.64 and 53.32 respectively, the three of which differed significantly with the control / P0 (43.47) and P1 treatment (44.90). Based on the results of the observations above, it indicates that the application of Zn, especially the P2 and P4 treatment, has a real positive impact on the growth of leaf area and chlorophyll.

Zinc plays a role in the activation of carbonic enzyme anhydrase, chlorophyll, and stabilization of chloroplast membrane structure (Alloway; Broadley), so that plants that receive Zn have longer and wider leaves, as well as a higher chlorophyll content, It is further explained that plants with high crown area and chlorophyll are able to capture more light energy thereby increasing assimilate production in support of optimal growth (Alloway; Bhatla and Lal). Seed yield per plant is one of the important agronomic parameters in assessing crop productivity. The provision of Zn micronutrients, both through seed priming and foliar spray, affects the physiological efficiency of plants in absorbing and allocating photosynthates to the seed organs, so that it has a direct impact on the weight of seeds produced per plant.

This is reflected in the yield of seeds per plant with the provision of Zn micronutrients to sorghum plants listed in Table 5. The impact of Zn micronutrient application showed that the P2 and P4 treatments produced the highest seed weight per plant and were significantly different from the control (P0) and other treatments. In the table, it can be seen that the highest seed yield per plant was obtained from P2 treatment with a yield of 93.64 g and P4 treatment with a yield of 93.53 g which is significantly different from the yield of seeds per plant with P0, P1 and P3 treatment. The increase in seed yield in the P2 and P4 treatments showed that Zn application through leaves was more effective than through seed priming alone (P1). This is because the absorption of Zn through the foliar can avoid Zn fixation problems in acidic soils and ensure the immediate availability of Zn to plant tissues (Toor et al., 2020; Abdelgadir et al., 2021; Sewhag et al., 2023). In the context of acidic land at the site of this study, according to Alloway's explanation, the availability of Zn in the soil tends to be low and it is possible to have negative interactions with nutrients P or with other micronutrients such as Fe. Therefore, foliar application of Zn is an important agronomic strategy because it is able to avoid barriers to Zn availability in the soil and can increase the Zn uptake of plants (Sewhag et al., 2023).

Table 5. The Effect of Variety Differences and Zn Micronutrient Yields on Seed Yield per Plant

Treatment	Grain Yield (g/tan.)
Varieties	
Numbu (V1)	88.27
Samurai 2 (V2)	87.85
Super 2 (V3)	85.12
Suri 1 (V4)	86.12
Zn Applications	
Control (P0)	83.11b
Seed priming (P1)	81.71b
Seed priming + Foliar spray vegetative phase (P2)	93.64a
Seed priming + Foliar spray generative phase (P3)	83.41b
Seed priming + Foliar spray vegetative and generative phase (P4)	92.53a

Source: Data processed, 2024

Note: The numbers in the same column followed by the same letters show no significant difference at the 5% test level with LSD. Unlettered numbers are not significantly different from the F test.

CONCLUSION

Micronutrient zinc (Zn) is an important micronutrient in the metabolic process through its function and role as a cofactor of various enzymes for plant growth. The results of this study show that the application of micronutrients Zn significantly increases vegetative growth, leaf length and width, leaf greenness and seed yield per plant in sorghum plants. The application of Zn micronutrients in the form of ZnSO4.7H2O solution with a concentration of 0.5% through seed priming and foliar spray during the vegetative phase given two (2) times at the age of 30 HST and 50 HST (P2) is sufficient and proven to increase plant height, leaf width, leaf greenness and seed yield per plant. The difference in varieties shows that the Samurai 2 and Super 2 varieties have a higher average plant height and seed yield per plant than Numbu and Suri 1. There was no interaction between the varieties tested and the Zn micronutrient treatment in this experiment.

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