Available at : https://ejournal.unib.ac.id/index.php/terrajournal ISSN 2621-0207
DOI : https://doi.org/10.31186/terra.8.1.50-56

TERRA
Journal of Land Restoration

Yield Performance of Sorghum Varieties Treated With Organic Fertilizer in Sumbawa Regency

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ABSTRACT

Sorghum is an ancient grain that has good performance and adaptation in extreme condition. The crop is a stress-resilient crop with highly productive NADP-ME type C4 photosynthesis and highly efficient nitrogen and water utilization. Sorghum also requires relatively less water than other important cereals such as maize and wheat. Sorghum cultivation is very suitable to be carried out in Sumbawa Regency because it has the characteristic of low rainfall. The most common obstacle that occurs in sorghum cultivation is not being able to maximize plant genetics and existing nutrients, so that plant yields are low. One of them is by applying organic fertilizer. The interest in the use of organic fertilizers is increasing due to polluting effects of chemical fertilizers in the aerial and soil environment and gradual decline in the soil fertility. The aim of this study was to determine the yield of plants with different doses of organic fertilizers and sorghum varieties in Sumbawa Regency. This research used Split Plot Design consisting of two plots. The main plot three sorghum varieties were evaluated including V_1 = Bioguma, V_2 = GBE Methane, and V_3 = Sweet-betty. The subplot is the application of solid organic fertilizer including T_0 = control, T_1 = 50 g plant^{-1}, T_2 = 100 g plant^{-1}, and T_3 = 200 g plant^{-1}. This study had 3 replications and 36 experimental units. The results show that organic fertilizer application doses can cause significant differences in root weight, dry weight, fresh weight, grain weight/plant, weight 1000 grains, productivity, panicle length, and flowering age. Then, different types of sorghum also cause significant differences in grain weight per plant, weight of 1000 grains, and productivity. The best productivity is found at 200 g plant^{-1} of organic fertilizer. Optimal fertilizer application produces better grain.

Keywords: *alternative food, dryland, grain, organic farming, sorghum*

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is a stress-resilient crop with highly productive NADP-ME type C4 photosynthesis and highly efficient nitrogen and water utilization (Xin *et al*., 2021). Sorghum is an ancient grain that has good performance and adaptation such as Africa, Asia, Australia, America, and Europe (Boyles *et al*., 2019). The nutritional content of grains sorghum in 100 g is 8.27 g protein, 3.59 g total lipid, 77.4 g carbohydrate, 9.41 g water, 66.3 g starch, 335 mg potassium (K), 262 mg phosphorus (P), 3,95 mg niacin, and others (USDA, 2025). These grains are planted in Sub-Saharan Africa and several Southern Asia regions that are used for their main food around half billion people (Mace *et al*., 2013). The crop requires relatively less water than other important cereals such as maize and wheat (Amelework *et al*., 2015). However, the crop is not just grown for harvesting of grain, sorghum is also commonly cultivated for syrup production, animal feed, bioenergy feedstock for production of biofuel and bioproducts, and biomass production.

According to FAO reports, in 2021, 40.9 million hectares of land and 61.3 million ton of production were made worldwide. In terms of production share, Africa (42.8%) ranks first, followed by America (38.5%), Asia (14.2%), Oceania (2.7%) and Europe (1.9%) (Çelik *et al*., 2024). In terms of production, the USA (11.3 million ton) is in the first place, followed by Nigeria (6.7 million ton), India (4.8 million ton), Ethiopia (4.4 million ton) and Mexico (4.3 million ton) (FAO, 2022). Indonesia has the potential to develop sorghum as an alternative food besides rice or corn because it has areas that are suitable for growing and developing such as West Nusa Tenggara Province (WNT) and East Nusa Tenggara Province (ENT). The WNT region, especially in Sumbawa Regency, has low rainfall, so only certain types of plants are suitable for growing well, such as the C4 or CAM type. Sorghum is one of the plants that is suited to the climate conditions in that area. Sorghum productivity in various regions of Indonesia has been reported by Kurniasari *et al*. (2023) which is 3.74 ton ha^{-1} using the Numbu variety and organic fertilizer. Sorghum planting also needs to pay attention to quality sorghum varieties and produce better production.

The major constrain to productivity of crops in the dryland region is inadequate, unreliable and poorly distributed rainfall and low soil fertility especially (N and P). The importance of integrated use of organic nutrient sources in the dryland tropics have been reported (Muhammad *et al*., 2018). Organic sources such animal manure is an effective source of major nutrient (N, P, and K) when applied at optimum rates and can influence the temporal dynamics of nutrients availability, increase water use efficiency of crops, decrease phosphorous fixation and enhance its availability in the soils through its effects on physical and chemical properties of the soil. The interest in the use of organic fertilizers is increasing due to polluting effects of chemical fertilizers in the aerial and soil environment and gradual decline in the soil fertility. Thus, continuous use of synthetic fertilizers may deteriorate soil health affecting plants, human and any organism. Most of the nitrogenous fertilizers leach down to the root zone or pollute the groundwater causing certain diseases in plants and human being. The use of agrochemicals causes the degradation of cultivable land and increasing agricultural pollution, hence creating the unhealthy situation. In order to balance this situation organic farming might be practice in which instead of using of chemicals, natural resources such as organic matters, minerals and microbes are used (Ahmad et al., 2007).

Soil degradation is a significant global threat affecting agriculture production and human living conditions, with an estimated 19.65 million km2 of degraded soil worldwide (Singh *et al*., 2022). In 1991, the International Soil Reference and Information Centre (ISRIC), supported by the United Nations Environment Program and the Food and Agriculture Organization, assessed the status of human-induced soil degradation globally, categorizing it into five major types: soil hydraulic erosion, soil wind erosion, chemical deterioration, physical deterioration, and biological degradation (Wang *et al*., 2025). Excessive fertilization, a key driver of chemical deterioration, not only results in low fertilizer efficiency but also causes a series of issues such as reduction in soil organic matter, soil acidification, and pollution (Jiang *et al*., 2022; Song *et al*., 2022; Xue *et al*., 2020). Application of organic fertilizers on sorghum plants by considering the right dosage to support increased crop yields is certainly a good first step. Knowing plant varieties that are responsive to the provision of organic nutrients is a comprehensive study because a region has unique characteristics that need to be studied. The aim of this study was to determine the yield of plants with different doses of organic fertilizers and sorghum varieties in Sumbawa Regency.

MATERIALS AND METHODS

This research was conducted from March to August 2024 at Pernek Village, Moyo Hulu Subdistrict, Sumbawa Regency, WNT Province, Indonesia, at an altitude of 40 m asl. The solid organic fertilizer we used was good adequate for the growth and development of sorghum (Table 1). Table 1 explains the micro-climate components and soil nutrients in the research location. This research used Split-Plot of Analysis of Variance (ANOVA) model consisting of two plots. The main plot three sorghum varieties were evaluated including V_1 = Bioguma, V_2 = GBE Methane, and V_3 = Sweetbetty. The subplot is the application of solid organic fertilizer: T_0 = control, T_1 = 50 g $plant^{-1}$, T_2 = 100 g $plant^{-1}$, and T_3 = 200 g $plant^{-1}$. This study had 3 replications and 36 experimental units. The standard operating procedure for this study followed Khairi *et al*. (2024) for land cultivating, planting, fertilizing until harvesting. The authors used the method from Khairi *et al*. (2024) to make solid organic fertilizer.

The variables observed in this research include two aspects are yield components and reproductive stages. Yield components consist of fresh weight (g), dry weight (g), panicle weight/plant (g), root weight (g), grain weight per plant (g), weight 1000 grains (g), and productivity (ton ha^{-1}). Meanwhile, reproductive stages are panicle length (cm), panicle width (cm), root length (cm), flowering age (Days After Sowing (DAS)), and harvest age (Days After Sowing (DAS)). All variables have been observed after the growth stage (56 DAS). Flowering age and harvest age observations are made when all plants in the field that have flowered and are ready for harvest must reach at least 50% of the total population. The majority of variables were observed during harvesting like as fresh weight (g), dry weight (g), root weight (g), root length (cm), grain weight per plant (g), weight 1000 grains (g), panicle weight per plant (g), panicle length (cm), and panicle width (cm). The normal distribution and homogeneity were performed before Analysis of Variance (ANOVA). Furthermore, ANOVA was used for data analysis. If there was a significant difference, then post-hoc of Tukey's HSD was carried out with α 0.05, 0.01, and 0.001. SAS® OnDemand for ANOVA and post-hoc tests, then Correlogram is tested using Minitab v.22.

Table 1. The values are fertilizer nutrients, micro-climate components and soil nutrients in the research location

Variables	Units	Values
Micro-Climate Components		
Temperature	°C	30.58 ± 0.97
Relative Humidity	%	76.04 ± 0.51
Sunlight Intensity	lx	39,751.20 ± 10.15
Wind Speed	m/s	2.50 ± 0.08
Soil Nutrients		
Nitrogen (N)	%	0.08 ± 0.05
Phosphorus (P)	ppm	185.72 ± 3.58
Potassium (K)	cmol(+)/kg	0.58 ± 0.01
Fertilizer Nutrients		
Water Content	%	13.24
Nitrogen (N)	%	1.35 ± 0.38
P_2O_5	%	1.60 ± 0.50
K_2O	%	3.80 ± 0.55

Note: mean ± standard error (n = 3)

Productivity was calculated using the formula as follows:

$$FY = \frac{FP}{LA}$$

where FY was productivity (ton ha^{-1}), FP was grains production (ton), and LA was land area (ha).

RESULTS AND DISCUSSION

Sorghum (*Sorghum bicolor* L. Moench) is the fifth most widely produced cereal crop globally and serves as a valuable source of nutrients and bioactive compounds for the human diet (de Morais Cardoso *et al*., 2016). In Indonesia, sorghum holds significant potential as a food commodity for further development. It can be processed into flour as a substitute for wheat flour, thereby supporting food diversification through the utilization of locally produced resources (Kurniasari *et al*., 2023). Beyond its use as food, sorghum is also widely utilized for animal feed, with its seeds, leaves, and stems being suitable components.

This study investigates the effects of various treatments on agronomic and yield-related variables of sorghum, with a particular focus on plant performance from the onset of flowering through to harvest. The analysis results for all measured variables are presented below.

Table 2. Evaluating of plant roots and dry weight with different treatments

Treatments	Root Weight (g)	Root Length (cm)	Dry Weight (g)	Fresh Weight (g)
Sorghum Varieties (V)				
V_1	5.86	24.65	295.79	522.37
V_2	6.53	25.00	282.85	510.95
V_3	6.20	27.38	276.59	514.99
Organic Fertilizer Dosage (T)				
T0	5.47 b	23.60	245.46 c	411.95 c
T1	5.97 ab	24.20	259.98 bc	496.54 b
T2	6.62 a	26.40	306.50 ab	536.85 b
T3	6.73 a	28.53	328.35 a	619.07 a
V	NS	NS	NS	NS
T	**	NS	**	***
Interaction V × T (-/+)	-	-	-	-

Note : V_1 = Bioguma; V_2 = GBE Methane; V_3 = Sweetbetty; T_0 = 0 g $plant^{-1}$; T_1 = 50 g $plant^{-1}$; T_2 = 100 g $plant^{-1}$; T_3 = 200 g $plant^{-1}$; NS = non-significant; (+) = interaction; (-) = not interaction; the number followed by the same letter in column and treatments factor of same has no significant difference based on Tukey's HSD test (* = α 0.05; ** = α 0.01; *** = α 0.001); mean ± standard error (n = 3)

No significant interaction was observed between the combination of sorghum varieties and organic fertilizer treatments. Additionally, the individual effects of variety type and organic fertilizer type did not show significant differences in most variables. However, the application of different doses of organic fertilizer alone exhibited a significant impact on several growth and yield parameters. The application of 100 g $plant^{-1}$ (T_2) and 200 g $plant^{-1}$ (T_3) of organic fertilizer produced the most favorable results compared to other treatments. Among these, the T2 treatment was considered more efficient due to the reduced input requirement with comparable performance outcomes.

Suminar *et al*. (2018) reported that dry biomass yield under a 120 kg N ha^{-1} treatment reached 359.33 g, which was higher than the 328.35 g obtained with 200 g $plant^{-1}$ of organic fertilizer in the present study. However, fresh biomass yield under the same nitrogen treatment was 611.67 g, lower than the 619.07 g obtained with the 200 g $plant^{-1}$ organic fertilizer application. According to Wahyono *et al*. (2018), longer harvesting periods contribute to an increase in dry matter content, rising from 27.55% to 29.74%, attributed to nutrient conversion and storage in seeds throughout the crop maintenance period. The increase in dry matter content in mature forage is also associated with a reduction in moisture content, as younger plants typically contain higher water content and thus have a lower percentage of dry matter.

Higher fresh biomass production of leaves and stems is influenced by an increased number of actively dividing and enlarging cells. Biomass accumulation is further enhanced by the sufficient availability of essential nutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), which support the formation of new structural plant components (Kindangen *et al*., 2024). When nutrients are adequately available, chlorophyll content in the leaves increases, promoting more efficient photosynthesis and leading to higher assimilate production, thereby improving overall plant growth (Sari & Prayudyaningsih, 2015).

Table 3. Evaluating of plant seeds, harvest age, and productivity with different treatments

Treatments	Grain Weight per Plant (g)	Weight 1000 Grains (g)	Harvest Age (DAP)	Productivity (ton ha^{-1})
		Sorghum Varieties (V)		
V_1	67.25 b	31.44 b	123.83	4.80 b
V_2	77.84 a	36.56 a	123.43	5.56 a
V_3	69.38 b	30.79 b	124.09	4.96 b
		Organic Fertilizer Dosage (T)		
T_0	56.63 c	25.83 b	124.64	4.05 c
T_1	67.55 bc	29.30 b	123.21	4.83 b
T_2	73.37 ab	36.78 a	122.09	5.24 b
T_3	88.42 a	39.82 a	125.19	6.32 a
V	**	*	NS	**
T	***	***	NS	***
Interaction V × T (-/+)	-	-	-	-

Note V_1 = Bioguma; V_2 = GBE Methane; V_3 = Sweetbetty; T_0 = 0 g plant^{-1}; T_1 = 50 g plant^{-1}; T_2 = 100 g plant^{-1}; T_3 = 200 g plant^{-1}; NS = non-significant; (+) = interaction; (-) = not interaction; DAP = days after planting; the number followed by the same letter in column and treatments factor of same has no significant difference based on Tukey's HSD test (* = α 0.05; ** = α 0.01; *** = α 0.001); mean ± standard error (n = 3)

Sorghum grain consists of three primary components: the bran layer (comprising the pericarp and testa), the endosperm, and the germ (Birhanu, 2021). Sorghum continues to be an important cereal for both human and livestock consumption. In the present study, statistical analysis showed that harvest age did not differ significantly across treatment combinations or between individual treatment factors. This indicates that neither sorghum variety nor organic fertilizer dosage had a substantial influence on the crop's maturation period.

Susilo *et al*. (2021) reported that the grain weight per plant for the Numbu variety was 62.48 g, which is lower than the 77.84 g observed for the GBE Methane variety in this study. The highest recorded weight of 1000 grains was previously reported by Suwardi & Suwarti (2020) in sweet sorghum var. Super-1 with the application of 75 kg ha^{-1} ammonium sulfate (ZA) fertilizer, yielding 28.98 g. However, in this study, application of 200 g plant^{-1} organic fertilizer (T_3) resulted in a higher value of 39.82 g. Among the tested varieties, GBE Methane demonstrated the highest productivity at 5.56 tons ha^{-1}, whereas the application of 200 g plant^{-1} organic fertilizer resulted in the highest yield among all fertilizer treatments, reaching 6.32 tons ha^{-1}.

Kurniasari *et al*. (2023) reported that the productivity of the Numbu variety with manure application was 3.74 tons ha^{-1} and 3.30 tons ha^{-1} without manure, both of which were lower than the yields obtained in this study. The current findings are supported by Bertham *et al*. (2020), who found that the application of organic fertilizers on coastal soils improved nutrient uptake and enhanced the biological properties of the soil, thereby increasing crop yields. Optimal crop production is achieved when essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K) are available in appropriate quantities and forms, contributing to enhanced plant growth and root development.

According to Ghimire *et al*. (2021), each genotype possesses unique genetic potential, and the ability of a plant to produce high grain yields is largely determined by its inherent genetic makeup. Furthermore, Panjaitan *et al*. (2015) noted that yield variability among genotypes is also influenced by their physiological responses to environmental factors and nutrient availability throughout the growth phases. Telleng *et al*. (2016) emphasized that varietal differences in growth and productivity are shaped by the genotype's adaptability to specific environmental conditions. A more adaptive variety typically exhibits superior productivity, as observed in the GBE Methane variety under the given agroecological conditions.

Table 4 explains that genetics do not affect the occurrence of significant differences, but providing nutrients in the form of organic fertilizer can accelerate the flowering process. The higher the dose of fertilizer given, the faster the flowering process.

Table 4. Evaluating of panicles and flowering age with different treatments

Treatments	Panicle Length (cm)	Panicle Width (cm)	Panicle Weight/ Plant (g)	Flowering Age (DAP)
Sorghum Varities (V)				
V_1	33.16	9.76	55.35	74.57
V_2	30.92	9.22	56.02	75.02
V_3	31.74	9.59	55.08	75.16
Organic Fertilizer Dosage (T)				
T_0	22.99 d	8.23	54.49	78.25 a
T_1	28.87 bc	8.95	55.59	76.25 ab
T_2	35.11 ab	9.76	56.25	73.88 ab
T_3	40.79 a	11.15	55.59	71.29 b
V	NS	NS	NS	NS
T	***	NS	NS	*
Interaction V × T (-/+)	-	-	-	-

Note V_1 = Bioguma; V_2 = GBE Methane; V_3 = Sweetbetty; T_0 = 0 g plant^{-1}; T_1 = 50 g plant^{-1}; T_2 = 100 g plant^{-1};T_3 = 200 g plant^{-1}; NS = non-significant; (+) = interaction; (-) = not interaction; DAP = days after planting; the number followed by the same letter in column and treatments factor of same has no significant difference based on Tukey's HSD test (* = α 0.05; ** = α 0.01; *** = α 0.001); mean ± standard error (n = 3)

This occurred at 200 g plant^{-1} of organic fertilizer compared to the control which was significantly different. A different case occurred in Panjaitan *et al*. (2015) who reported that sorghum var. Patir (61.66 DAS) had a faster flowering process than var. Pahat and var. Kawali (68.33 DAS). Panicle width and panicle weight per plant did not produce significant differences in all tests. This is because different varieties or higher organic fertilizer administration did not significantly affect the effects of changes. The best results for panicle length have been reported by Suwardi & Suwarti (2020) on sweet sorghum var. Super-1 with the provision of 50 kg ha^{-1} of ZA fertilizer of 30.37 cm. However, when compared to 200 g plant^{-1} of organic fertilizer (T_3), the results were higher at 40.79 cm. The panicle is where the sorghum seeds are located. In the middle of the panicle there is a panicle axis where the panicle branches are attached. The seeds are located on the panicle branches. The longer the panicle, the more panicle branches, and the number of seeds that will increase seed production, according to Meng *et al*. (2016). Eniola *et al*. (2019) stated that panicle length will determine the number of seeds per panicle.

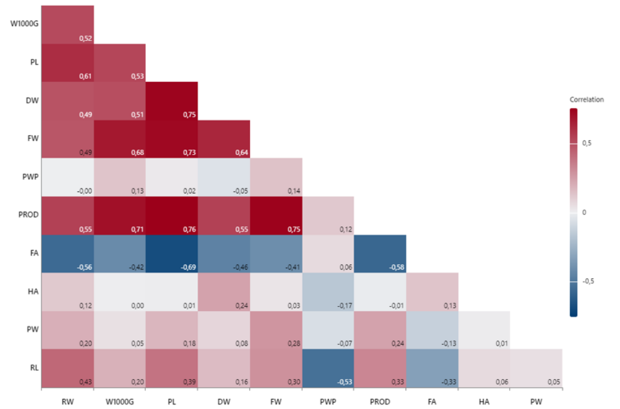

Figure 1. Correlogram on observation variable with RW = root weight; W1000G = weight 1000 grains; PL = panicle length; DW = dry weight; FW = fresh weight; PWP = panicle weight/plant; PROD = productivity; FA = flowering age; HA = harvest age; PW = panicle width; RL = root length

The darker red color in Figure 1 indicates a weaker level of correlation between the variables, and vice versa. The values of productivity with panicle length (0.76) and fresh weight (0.75) are relatively strong, compared to flowering age and panicle length of -0.69. Positive correlation values and having a coefficient >0.5 indicate a strong correlation between observation variables (Wardana *et al*., 2015).

CONCLUSION

The combination of sorghum varieties and organic fertilizer treatments did not result in significant differences across all measured variables. However, the application of different organic fertilizer doses significantly affected several parameters, including root weight, dry weight, fresh weight, grain weight per plant, weight of 1000 grains, productivity, panicle length, and flowering age. Additionally, variation among sorghum varieties led to significant differences in grain weight per plant, weight of 1000 grains, and overall productivity. These findings underscore the importance of identifying and utilizing sorghum genotypes that are responsive to organic nutrient sources. Future research should focus on evaluating sorghum genetic potential under higher levels of organic nutrient inputs to optimize yield performance.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia (KEMENRISTEKDIKTI) for providing the research grant through the Afirmasi

Beginner Lecturer Research Program (Penelitian Dosen Pemula Afirmasi), under contract number 110/E5/PG. 02.00.PL/2024.

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