Effect of mycorrhizal provision and watering frequency on productivity and fresh material of forage sorghum (*Sorghum bicolor* (L.) Moench)

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**Abstract.** Sorghum is a cereal crop that has the potential to be developed as animal feed. Sorghum plant experiencing drought stress will decrease their productivity. Efforts to overcome this problem are by adding mycorrhizae. Mycorrhizae increase the ability of plants to adapt to the environment in the form of absorption of water and nutrients. This study aimed to determine the productivity of sorghum (plant height increase, plant length increase, number of leaves and stem diameter) and fresh weight of sorghum plant. The research treatments were mycorrhizal levels and watering frequency using a completely randomized design with a 3x3 factorial pattern. The mycorrhizal fungi provision consisted of three levels, namely without mycorrhizal (M0), mycorrhizal 10 g/polybag (M10), and mycorrhizal 20 g/polybag (M20). The frequency of watering consisted of watering everyday (A1), watering every four days (A4), and watering every eight days (A8). The provision of mycorrhizae significantly affected the productivity of sorghum and fresh weight of sorghum (p<0.05). The difference in watering frequency affected the increase in sorghum plant height (p<0.05). However, it did not significantly affect the increase in length, stem diameter, number of leaves, and fresh weight of sorghum. In conclusion, mycorrhizae can significantly improved the productivity of sorghum plants developed in areas with high drought levels.

1. Introduction
The productivity of ruminants is largely determined by the availability of sufficient and sustainable quality feed. Availability of forage feed is still an obstacle in areas with high levels of drought. Puteri et al. [1] stated that overcoming this problem requires exploratory efforts to obtain forage plants with increased productivity and stay in the dry season. One of the plants that can survive in the dry season is sorghum (*Sorghum bicolor* (L.) Moench).

Sorghum is a cereal crop that has the potential to be developed as an animal feed crop. Sorghum has the advantage that it can take regrowth after being harvested and can cultivate in marginal and dry areas such as East Nusa Tenggara (NTT). Sorghum plants with the best productivity can support the availability of feed. Several factor influencing plant productivity such as number of plants [2–5], level of fertilizer [6,7] and planting system [8–11].
Shakeri et al. [12] claimed that sorghum plant are more promising than other forages because sorghum plants are better in dry matter production, drought tolerance and can grow well after being harvested or grazed. Sorghum plant are also resistant to pests and diseases. However, excessive drought stress can reduce the productivity of sorghum plants. The impact of drought stress on sorghum plants is closed leaf stomata. It inhibits the entry of CO$_2$ and leads to decreasing photosynthetic activity, which caused the productivity of sorghum plants to drop [13,14].

The sorghum plant resistant to drought stress can be seen by the levels of watering. The water requirement of sorghum plants is 400 to 450 mm [14]. Pangesti et al. [15] reported that the watering frequency every two days with the amount of watering as much as 400 to 500 mm/season resulted in the best plant fresh weight. If the soil water content is less than the water requirement of the sorghum plant, the sorghum plant will experience drought stress. Efforts to overcome this problem are by adding environmentally friendly biological agents such as mycorrhizae.

Mycorrhizae increase the ability of plants to adapt to the environment in the form of absorption of water and nutrients. Napitupulu et al. [16] reported that giving mycorrhizae 10 g/plant and vermicompost 90 g/plant resulted in the best productivity of sorghum. The use of mycorrhizae can also reduce soil pH levels and increase the population of other microorganisms in the soil. In addition, the greater the number of mycorrhizal infected plant roots, it is directly proportional to the area of plant root uptake [17].

The research of giving mycorrhizae at different levels with watering frequencies on the productivity and fresh weight of sorghum forage has not done much. Therefore, it is necessary to conduct a study on the application of mycorrhizae at different levels and frequency of watering on the productivity of sorghum in increasing height, increase in length, number of leaves, stem diameter, and fresh weight of sorghum plant as animal feed developed in areas with high drought levels.

2. Materials and methods

2.1. Preparation of planting media

Media preparation included disassembling the soil, sifting with a diameter of 1 mm. mixed media with cow manure in a ratio of 9:1. Then put into polybags as much as 10 kg/polybag. The polybags used were 45 polybags. The soil nutrient content as a growing media for sorghum as shown in table 1.

| Parameter     | Unit | Test result   |
|---------------|------|---------------|
| N-total       | %    | 2.52 ± 0.08   |
| Pottasium (K) | K/Kg | 34.9 ± 2.80   |
| Phosphate (P) | Mg/L | 1.26 ± 0.01   |

2.2. Planting of sorghum

After preparing the planting media, the sorghum seed were planted. Planting holes were made a depth of ± 3 cm. After that, as many as 3 to 5 seeds of sorghum were given in each planting hole.

2.3. Plant thinning and mycorrhizal feeding

Sorghum was thinning within six days after planting, leaving one of the best plants. The type of Arbuscular mycorrhizae fungi used Glomus Claroidem, Acaulospora rogusa, A. colosica. G. fasciculatum, G. mosseae, G. etunicatum. Mycorrhizal provision was made seven days after planting, according to the treatment, namely without mycorrhizal (M0), mycorrhizal 10 g/polybag (M10), and mycorrhizal 20 g/polybag (M20).
2.4. Plant maintenance and watering treatment
Maintenance is done by cleaned weeds and controlling pests. Watering the sorghum plants according to the research treatment, namely watering everyday (A1), watering every four days (A4), and watering every eight days (A8).

2.5. Productivity measurement
2.5.1. Measurement of sorghum plant height increase. The increase in sorghum plant height was measured from the soil surface to the highest leaf tip of all plants in each clump. Height gain was obtained from height of the second week minus the first week (cm/week) and measured until the week before harvesting.

2.5.2. Measurement of the length increase of sorghum. Measuring the length of the sorghum plant utilizing a ribbon stretched from the base to the tip of the longest leaf. The increase in plant length was obtained from the length of the second week of the plant minus the first week (cm/week) and measured until the week before harvesting.

2.5.3. Measurement of stem diameter of sorghum. The stem diameter was measured every week and then the average was taken. The stem diameter was measured at the base of the sorghum stem using a caliper

2.5.4. The number of leaves of the sorghum plant. The number of leaves of sorghum plants was counted weekly and then the average was taken.

2.6. Fresh material weight of forage sorghum
The fresh weight of sorghum was obtained after harvesting by calculating the weight (g/plant)

2.7. Statistical analysis
The study results were analyzed quantitatively using the Analysis of Variance (ANOVA) based on the factorial pattern further testing was carried out with Duncan’s New Multiple Range Tests (DMRT) to data with significant differences using the SPSS version 23 application.

3. Results and discussion

3.1. Increase in the height of the sorghum plant
The average height increase of sorghum plants obtained during the study as shown in table 2.

| Mycorrhizal levels | Watering Frequency | Average  |
|--------------------|--------------------|---------|
|                    | A1                | A4      | A8      |        |
| M0                 | 20.48 ± 0.95<sup>a</sup> | 21.86 ± 0.71<sup>y</sup> | 19.14 ± 0.62<sup>z</sup> | 20.49 ± 1.35<sup>a</sup> |
| M10                | 22.14 ± 0.87<sup>x</sup> | 21.76 ± 0.58<sup>y</sup> | 22.24 ± 1.37<sup>x</sup> | 22.05 ± 0.89<sup>b</sup> |
| M20                | 23.05 ± 0.36<sup>a</sup> | 23.29 ± 0.66<sup>a</sup> | 20.04 ± 0.79<sup>a</sup> | 22.13 ± 1.66<sup>b</sup> |
| Average            | 21.89 ± 1.31<sup>i</sup> | 22.30 ± 0.93<sup>i</sup> | 20.48 ± 1.61<sup>k</sup> | 21.55 ± 1.49 |

M0 = without mycorrhizal, M10 = mycorrhizal 10 g/polybag and M20 = mycorrhizal 20 g/polybag
A1 = watering everyday, A4 = watering every four days, and A8 = watering every eight days
<sup>a,b</sup> different superscripts on the same column showed significant differences (p<0.05) in the mean treatment
<sup>k,l</sup> different superscripts on the same line showed significant differences (p<0.05) in the mean treatment
<sup>x,y,z</sup> different superscripts in the same row and column showed significant differences (p<0.05) in the mean treatment
The provision of mycorrhizal fungi can increase the height of sorghum plants. The analysis of variance showed that the administration of mycorrhizal fungi had a significant effect (p<0.05) on the increase in sorghum plant height. The more the number of mycorrhizae given to the plant, the more nutrients are available for plant growth. Napitupulu et al. [16] stated that mycorrhizal plants grow better than non-mycorrhizal plants.

The increase in sorghum plant height was 23.29 cm/week, given 20 gram/polybag mycorrhiza. The mycorrhizae provision to plants can positively impact plant root conditions so that it has a positive effect on plant height. Better root conditions certainly cause the nutrients available in the soil to be easily absorbed by plants with the help of mycorrhizae. Wardhika [18] stated that the increase in plant height given mycorrhizal fungi was caused by improved plant's improved root conditions.

The frequency of watering every day and every four days resulted in the best increase in sorghum plant height. The highest increase in sorghum was 22.30 cm/week, with the frequency of watering every four days. The frequency of watering had a significant effect on the rise in sorghum plant height (p<0.05) because the water was able to dissolve soil nutrients for plant needs. Pervez et al. [19] stated that plants that did not experience stress produced the highest plant height compared to those that experienced drought stress. The frequency of watering every day and every four days showed that the better the soil moisture content also led to the higher plant material height. Marzoukh et al. [20] explained that the better the soil water content, the higher the increase in plant height caused by shoot formation, cell division, and plant cell enlargement.

The results of the analysis of variance showed that the interaction between mycorrhizae and watering frequency gave a significant effect on the increase in plant height of sorghum (p<0.05). The treatment of giving mycorrhizae 20 g/polybag and the frequency of watering every four days increased in plant height, reaching 23.29 cm/week. Mycorrhizae help plants absorb nutrients, while water dissolves nutrients so plants can absorb them. The combination of mycorrhizae and water can increase the increase in plant height.

### 3.2. Increase in the length of the sorghum plant

Table 3 shows the increase in the length of sorghum plants in the treatment of mycorrhizal fungi and different watering frequencies.

| Mycorrhizal levels | Watering Frequency | Average |
|--------------------|--------------------|---------|
|                    | A1                 | A4      | A8      |         |
| M0                 | 25.33 ± 0.94       | 26.38 ± 1.07 | 25.81 ± 0.43 | 25.84 ± 0.87<sup>a</sup> |
| M10                | 27.33 ± 0.71       | 26.33 ± 0.21 | 26.71 ± 0.37 | 26.79 ± 0.60<sup>b</sup> |
| M20                | 26.52 ± 0.32       | 26.61 ± 0.43 | 25.81 ± 0.43 | 26.31 ± 0.51<sup>ab</sup> |
| Average            | 26.39 ± 1.06       | 26.44 ± 0.60 | 26.11 ± 0.58 | 26.31 ± 0.76 |

M0 = without mycorrhizal, M10 = mycorrhizal 10 g/polybag and M20 = mycorrhizal 20 g/polybag
A1 = watering everyday, A4 = watering every four days, and A8 = watering every eight days
<sup>ab</sup> different superscripts on the same column showed significant differences (p<0.05) in the mean treatment

The results of the analysis of variance showed that the mycorrhizal factor affected the increase in plant length. The application of mycorrhizal fungi with different levels had a significant effect (p<0.05) on the increase in length of sorghum plants. The best sorghum plant length growth on plants gave mycorrhizal fungus 10 g/polybag was 27.33 cm/week. Mycorrhizae can absorb soil nutrients, thereby increasing the length of the sorghum plant. One of the nutrients that increase the size of sorghum is phosphorus. Maryeni and Hervani [21] stated that hyphae absorb nutrients, especially phosphorus, to be greater than non-mycorrhizae plants.
Mycorrhizae help plants absorb phosphorus to promote the growth of sorghum plants. Bonvante and Genre [22] stated that mycorrhizal hyphae also have phosphatase enzymes that can hydrolyze bound phosphorus compounds into available and soluble phosphorus so that plants can absorb them. Nutrients such as phosphorus are essential for increasing plant length. Phosphorus is needed because phosphorus plays a role in various processes such as photosynthesis, assimilation, and respiration [23,24].

The analysis of variance showed that the frequency of watering did not affect the length of sorghum plants. The benefits of water for plants are not only as a solvent for nutrients but also as a raw material for photosynthesis. The availability of groundwater is sufficient, but the lack of sunlight will reduce plant growth. Gardner et al. [23] stated that the rate of photosynthesis and respiration in plants is also affected by light.

3.3. The stem diameter of the sorghum plant

Table 4 shows the average stem diameter of sorghum in the treatment of mycorrhizal fungi and different watering frequencies.

| Mycorrhizal levels | Watering Frequency | Average     |
|-------------------|--------------------|-------------|
|                   | A1                 | A4          | A8          |
| M0                | 1.46 ± 0.47        | 1.17 ± 0.56 | 1.88 ± 0.06 |
| M10               | 1.88 ± 0.17        | 1.91 ± 0.14 | 1.87 ± 0.16 |
| M20               | 1.88 ± 0.14        | 1.87 ± 0.02 | 1.76 ± 0.08 |
| Average           | 1.74 ± 0.33        | 1.65 ± 0.46 | 1.84 ± 0.10 |

M0 = without mycorrhizal, M10 = mycorrhizal 10 g/polybag and M20 = mycorrhizal 20 g/polybag. A1 = watering everyday, A4 = watering every four days, and A8 = watering every eight days. 

\[ a,b \] different superscripts on the same column showed significant differences (p<0.05) in the mean treatment.

The analysis of variance showed that the administration of mycorrhizal fungi had a significant effect on the increase in stem diameter of sorghum plants (p<0.05). The average diameter of the largest sorghum plant stems was found in the treatment of 10 grams of mycorrhizae/polybag which was 1.89 cm. The application of mycorrhizae to sorghum plants affects the diameter of the stems of sorghum plants. Thangadurai et al. [25] stated that mycorrhizae could increase the uptake of N, P, and K nutrients as well as the efficiency of use groundwater. Plants absorb sufficient N elements to help the process of cell division. According to Made [26] statement, adequate N in meristem tissue triggers cell division, elongation, and enlargement to form cell walls and protoplasm. The process of cell division and growth impacts increasing the diameter of the stem of sorghum plants.

The frequency of watering did not affect the stem diameter of the sorghum plant. The superiority of sorghum plants that can live in areas with high drought stress causes the frequency of watering does not affect the stem diameter of sorghum plants. In addition, mycorrhizal hyphae can absorb water, and even though under drought stress the plants do not experience stress which causes a decrease in plant growth [27] stated that mycorrhizae have high water absorption capabilities. The impact is that plant water needs are still met and can reduce drought stress on sorghum plants cultivated in areas with high drought stress.

3.4. Number of leaves of sorghum plant

Table 5 shows the average number of leaves of sorghum plants in the treatment of mycorrhizal fungi and different watering frequencies.
Table 5. The average number of leaves of sorghum in the treatment of Arbuscular mycorrhizae fungi and different watering frequencies.

| Mycorrhizal levels | Watering Frequency | Average   |
|--------------------|--------------------|-----------|
| M0                 | A1: 11.00 ± 0.00   | 10.77 ± 0.67 |
|                    | A4: 10.33 ± 0.58   | 11.55 ± 0.72 |
|                    | A8: 11.00 ± 1.00   | 10.89 ± 0.78 |
| M10                | A1: 11.33 ± 0.58   | 11.33 ± 0.58 |
|                    | A4: 11.00 ± 1.00   | 11.33 ± 0.58 |
|                    | A8: 10.67 ± 0.57   | 11.07 ± 0.78 |
| M20                | A1: 11.00 ± 1.00   | 11.00 ± 0.70 |
|                    | A4: 11.00 ± 1.00   | 11.00 ± 0.70 |
|                    | A8: 11.00 ± 1.05   | 11.00 ± 0.70 |
| Average            | A1: 11.11 ± 0.60   | 11.11 ± 1.05 |
|                    | A4: 11.11 ± 1.05   | 11.11 ± 1.05 |
|                    | A8: 11.00 ± 0.70   | 11.00 ± 0.70 |

M0 = without mycorrhizal, M10 = mycorrhizal 10 g/polybag and M20 = mycorrhizal 20 g/polybag
A1 = watering everyday, A4 = watering every four days, and A8 = watering every eight days

The analysis of variance showed that the application of mycorrhizal fungi and different watering frequencies had no significant effect on the number of leaves of sorghum plants. Another factor that affects the increase in the number of leaves in plants is genes. Following the statement Faizi and Purnaasari [28], in general, the response of fertilizer to the number of leaves does not provide a clear picture because leaf growth has a close relationship with genetic factors.

In addition to gene factors, factors that affect plant growth are external factors, namely temperature, light, and humidity. The intensity of the light also affects the formation of leaves of sorghum plants. In this study, all sorghum plants received the same light intensity and temperature due to sorghum cultivation in a greenhouse. Erlita and Hariani [27] started that environmental factors such as temperature and light significantly affect plant growth. Both of these factors play an essential role in the production and transportation of foodstuffs so that with the same light intensity, the resulting plant growth is also relatively the same.

3.5. Fresh weight of sorghum plant

Table 6 shows the average fresh weight of forage sorghum in the treatment of mycorrhizal fungi and different watering frequencies.

Table 6. The average fresh weight of sorghum in the treatment of Arbuscular mycorrhizae fungi and different watering frequencies.

| Mycorrhizal levels | Watering Frequency | Average   |
|--------------------|--------------------|-----------|
| M0                 | A1: 337.67 ± 6.42  | 333.33 ± 7.37 |
|                    | A4: 340.33 ± 5.50  | 346.67 ± 5.67 |
|                    | A8: 337.11 ± 6.39  | 349.67 ± 5.28 |
| M10                | A1: 348.33 ± 7.63  | 346.00 ± 1.73 |
|                    | A4: 349.67 ± 3.78  | 346.00 ± 1.73 |
|                    | A8: 348.22 ± 5.28  | 345.33 ± 4.41 |
| M20                | A1: 346.00 ± 6.55  | 344.66 ± 5.89 |
|                    | A4: 344.00 ± 5.29  | 344.00 ± 1.73 |
|                    | A8: 345.33 ± 4.41  | 342.00 ± 8.04 |
| Average            | A1: 344.00 ± 6.79  | 344.66 ± 5.89 |
|                    | A4: 344.00 ± 5.89  | 344.00 ± 5.29 |
|                    | A8: 342.00 ± 8.04  | 343.55 ± 7.08 |

M0 = without mycorrhizal, M10 = mycorrhizal 10 g/polybag and M20 = mycorrhizal 20 g/polybag
A1 = watering everyday, A4 = watering every four days, and A8 = watering every eight days

a, b different superscripts on the same column showed significant differences (p<0.05) in the mean treatment

Analysis of variance showed that the application of mycorrhizal fungi at different levels and watering frequency had a significant effect (p<0.05) on the fresh weight of sorghum forage. The highest fresh weight of forage sorghum was found in the treatment of 10 grams of mycorrhiza/polybag, which was 349.67 gram/polybag. The lowest fresh material of forage sorghum in the treatment without mycorrhizae was 333.33 grams/polybag. Haryadi et al. [29] stated that the ability of plants to absorb nutrients in the soil could stimulate the development of plant organs which causes the increase of forage fresh weight.

The fresh weight of plants treated with mycorrhizae was higher than plants without mycorrhizae. The mycorrhizae provision to plants can help plants absorb nutrients and water [30]. Turk et al. [31] stated that mycorrhizal hyphae intensively increase the capacity of plants to absorb nutrients and water. The more nutrients and water absorbed by the plant, the higher the fresh weight of the plant. Line with the
statement. Rahma et al. [32] stated that plants increase in fresh material is caused by plants absorbing large amounts of nutrients and water. Fresh weight can provide a measure of the quality of plant growth and crop yield and is associated with photosynthesis as well as nutrient assimilation [10].

Analysis of variance showed that the frequency of watering did not affect the fresh weight of forage sorghum. The superiority of the sorghum plant’s resistance to drought causes no decrease in the fresh matter of sorghum even though the frequency of watering the plants is once every eight days. The superiority of sorghum that is resistant to drought has the opportunity to be developed as ruminant feed. Some literature states that the development of sorghum on marginal lands with high drought levels has considerable potential.

4. Conclusions
The mycorrhizae provision at different levels can increase the increase in height, length, stem diameter, and fresh material of sorghum plants. The frequency of watering did not affect the growth in stem diameter length, number of leaves, and fresh material of sorghum plants, but it did affect the length increase of sorghum plants. The mycorrhizae provision of 10 g/polybag can increase the productivity of sorghum plants and fresh sorghum forage materials, and the frequency of watering every four days can increase the increase in the height of sorghum plants.

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