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# Growth and Productivity of Brown Midrib Sorghum Mutant Line Patir 3.7 (*Sorghum bicolor* L. Moench) Treated with Different Levels of Nitrogen Fertilizer

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## ABSTRACT

**The study aimed to determine the best of nitrogen fertilizer level based on growth and biomass production of brown midrib sorghum mutant line Patir 3.7. This research was conducted at the Field Laboratory in the Faculty of Animal Science, Andalas University, Padang. The experiment was assigned in a completely randomized block design with 4 levels of nitrogen fertilizer application and 3 replications. The treatments consisted of N0= 0 kg N ha$^{-1}$ as a control; N1= 50 kg N ha$^{-1}$; N2= 100 kg N ha$^{-1}$; and N3= 150 kg N ha$^{-1}$. Agronomic and production variables measured were plant height, stem diameter, leaf width length, leaf stem panicle ratio, stem Brix sugar content, as well as fresh biomass and nutrient production. Analysis of variance followed by Duncan Multiple Range Test (DMRT) was conducted. The results showed that the addition of nitrogen fertilizer produced the highest stem diameter, leaf length, leaf width, leaf ratio, and stem ratio ($p<0.05$). However, the panicle ratio and stem Brix sugar contents were not significantly affected ($p>0.05$) by the level of nitrogen fertilizer. The fresh biomass, dry matter, crude protein, ash, NFE, and TDN production increased significantly ($p<0.05$) with the increased level of nitrogen fertilizer. Based on those findings, it can be concluded that nitrogen fertilizer application at the level of 50 kg N ha$^{-1}$ produces better growth, fresh biomass, dry matter, and nutrients production.**

*Keywords: biomass production; Brown midrib sorghum; nitrogen fertilizer; nutrient production*

## INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is the cereal crop ranked fifth globally after wheat, maize, rice, and barley. It is cultivated for a variety of purposes; the vegetative parts are used as green feed for ruminants and the grain as a food for both human and animal consumptions (Koten *et al*., 2012). Sorghum is a C4 plant that grows well in dry tropical climates and can also adapt well to diverse climatic and soil conditions. One variety of sorghum plants, known as sweet sorghum, has a high sugar content and potential as an alternative for animal feed. Sweet sorghum produces greater biomass than maize and can replace it as a livestock feed (Rocateli *et al*., 2012; Yu *et al*., 2008). Sorghum does not only contribute to forage (a source of fiber) but as a cereal plant, it also produces seeds as sources of protein and starch. However, due to high lignin content, the digestibility of conventional sweet sorghum is lower than that of maize that limits its use as animal feed.

One new type of sweet sorghum that has been developed to have a lower lignin content and hence has higher digestibility is brown midrib sorghum (BMR). Developed by an induced mutation using gamma-ray irradiation, this variety has been specifically developed as an animal feed and become widely used globally (Ouda *et al*., 2005). Patir 3.7 is one of BMR mutant-sorghum lines developed in Indonesia which produces a large amount of dry matter which can be increased further with a good and optimal fertilizer (Sriagtula *et al*., 2016).

Fertilizer plays an important role in maximizing agricultural yield. Using the optimal amount and nutrient content of fertilizer can increase growth, production, and nutritional content of plants. Nitrogen is an important nutrient for plants to maximize yields, especially in developing countries where yields are often very low (Good & Beatty, 2011). The need for nitrogen is very high in feed crops, like grasses including sorghum. Sufficient nitrogen increases growth rate, production, and quality of forage plants.

Nitrogen is an essential macro-nutrient in the formation of chlorophyll and a constituent component of many essential compounds in plant tissues, for example in amino acids, proteins, and enzymes (Lakitan, 2004). The nitrogen availability is related to the use of the environment resources by the plants, such as solar radiation and water, and a further increase in dry matter production (Brambilla *et al*., 29012). Ideally, nitrogen fertilizer is an inorganic fertilizer that should be supplemented with an organic fertilizer in the form of manure which is rich in nitrogen. This form will build up the organic matter content and so improve the nature of the soil which will improve the growth of foliage plants such as sorghum.

The nitrogen fertilizer requirement in sorghum plants has been widely studied. Ayub *et al*. (2002) reported that in Pakistan, an increase in nitrogen fertilizer from 40-120 kg ha$^{-1}$ resulted in the increased of dry matter production in conventional sorghum. Another study applying nitrogen fertilizers at the level of 90-120 kg N ha$^{-1}$ showed an increase in the growth of sorghum production (Uchino *et al*., 2013). The response of sorghum to nitrogen fertilizer depends on genotype, climatic conditions, and the nature of the soil (Kurai *et al*., 2015). The novelty of this study is the use of new BMR sorghum mutant line material as a result of mutation technology produced in Indonesia. Information about the response of BMR sorghum mutants to nitrogen fertilizer in Indonesia is still limited. The objective of this study was to determine the best level of nitrogen fertilizer for the BMR sorghum mutant line Patir 3.7 to maximize biomass production in a sustainable state.

## MATERIALS AND METHODS

This research was conducted in the Experimental Laboratory, Faculty of Animal Science, Andalas University, Padang in July-October 2017. In this study, ultisol soil with a pH of 5.6 was used. Rainfall during the study was categorized as moderate at 100-300 mm to a high at 300-500 mm (Ishak *et al*., 2012). The soil analysis and climate condition during the study were presented in Table 1 and Figure 1. The materials used were the BMR sorghum mutant line Patir 3.7 obtained from the Silviculture Laboratory of SEAMEO-BIOTROP Bogor, manure, urea, trisodium phosphate (TSP), KCl, scales, and pruning shears. Sidametrin brand pesticide was used to prevent pests.

Fertilizers used were TSP for P and KCl for K applied at a rate of 76.7 ha$^{-1}$ and 100 kg ha$^{-1}$, respectively (Turmudhi, 2010). Urea was used as a nitrogen fertilizer with the dose varied according to the selected treatment. This study used a randomized block design with 4 levels of nitrogen fertilizer application and 3 replications. The nitrogen fertilizer levels consisted of N0= 0 kg N ha$^{-1}$, N1= 50 kg N ha$^{-1}$, N2= 100 kg N ha$^{-1}$, and N3= 150 kg N ha$^{-1}$. Harvesting was conducted at the soft-dough phase (90 days after sowing/DAS).

### Soil Processing

Organic fertilizer was applied using 10 tons ha$^{-1}$ of manure before planting. The size of the research plot was 20 m$^2$ (4 x 5 m). The planting of sorghum seeds was carried out two weeks after tillage. A range of 4-5 sorghum seeds was planted in a hole with 5 cm deep every 20 cm in straight lines placed 60 cm apart (Sahuri, 2017).

### Maintenance

N Fertilizer was applied twice during growing i.e., at 14 days and at 50 days after planting. At the first fertilizer treatment, 2/3 of the urea dose and half of the TSP and KCl were used. The remaining was applied in the second fertilizer treatment to stimulate flowering. Fertilizer was dug into the soil in the gaps between the rows of plants (Sahuri, 2017).

### Harvesting

Harvesting was conducted when the sorghum had entered the soft dough phase by cutting the sorghum stem 10-15 cm above the soil surface.

### Variables Observed

The variables measured were plant morphology (plant height, stem diameter, leaf length, leaf width), stem sugar content, fresh and nutrient production.

### Data Analysis

Data were analyzed using ANOVA for Randomized Block Design by using the SPSS 16 software program, then statistically significant differences were further tested by using Duncan's New Multiple Range Test (Steel & Torrie, 1997).

## RESULTS

### Plant Growth

Stem diameter (mm), leaf length (cm), leaf width (cm), number of leaves per plant, and plant height (cm) are presented in Table 2. Nitrogen fertilizer had highly significant effects ($p<0.01$) on stem diameter, leaf length, leaf width, and leaf number. The plants without nitrogen fertilizer (N0) had the lowest stem diameter, leaf length, leaf width, and leaf number. The stem diameters, leaf lengths, and leaf widths of sorghum treated with the levels of nitrogen fertilizer of 50, 100, and 150 kg N ha$^{-1}$ were significantly higher ($p<0.05$) compared to control sorghum without nitrogen fertilizer. Addition of

Table 1. Soil characteristics

| Soil properties | Unit | Value | Information |
|---|---|---|---|
| pH | H2O | 5.6 | Medium |
| C | % | 1.8 | Low |
| Organic matter | % | 3.2 | Low |
| Cation exchange capacity | me/100g | 16.3 | Low |
| N-total | % | 0.3 | Low |
| P available | Ppm | 1.9 | Low |
| K-total | me/100g | 0.4 | Medium |

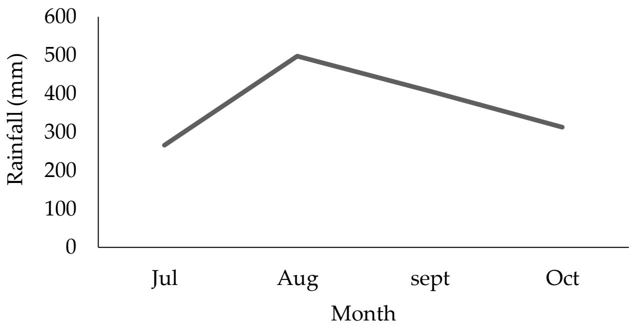


Figure 1. Rainfall (mm) in July to October 2017

50 kg N $ha^{-1}$ had similar leaf number to control without urea supplementation. However, higher dosages of nitrogen fertilizer (100 and 150 kg N $ha^{-1}$) significantly increased the number of leaves.

### Leaves, Stems, Panicles Ratio, and Stem Sugar

Percentage of the fresh weights at harvest consisted of stem, leaf or panicle along with sugar content of stem are presented in Table 3. The dose of nitrogen fertilizer had a highly significant effect ($p<0.01$) on the percentage of the green weight (consisting of leaves and stems). However, the dose of nitrogen fertilizer did not affect panicles. In this study, the addition of nitrogen fertilizer increased the proportion of the green weight consisted of leaves and decreased the proportion of stems. These results are clearly related to the increased number of leaves present in the plants receiving higher levels of N.

### Fresh and Nutrient Production

Averages of production values for fresh production, DM production, and nutrient production (tons $ha^{-1}$) are presented in Table 4. The results showed that using nitrogen fertilizer had significant effects ($p<0.05$) on fresh and dry matter productions, as well as crude protein (CP), ash, nitrogen-free extract (NFE), and total digestible nutrient (TDN) productions. However, nitrogen fertilizer did not have significant effect on crude fiber (CF) and ether extract (EE). In addition, increase in the dose of N fertilizer above 50 kg $ha^{-1}$ had no significant effect on fresh, dry matter, and nutrients yields (ton $ha^{-1}$) in BMR mutant sorghum line of Patir 3.7.

### Nutrient Content

The effect of nitrogen fertilizer application on nutrient content is presented in Table 5. The results showed that the application of N fertilizer resulted in a significant decrease in DM content of whole sorghum ($p<0.05$). However, the increase in the level of nitrogen fertilizer has no significant effect on DM content. The application of nitrogen fertilizer did not affect CP, CF, EE, ash, and NFE contents.

## DISCUSSION

The significant increase in stem diameter and leaf length and width in BMR mutant sorghum line of Patir 3.7 supplemented with nitrogen fertilizer is related to the sufficient nitrogen availability required for the growth of leaves and stems. Nitrogen is needed for the synthesis of chlorophyll that essential in the photosynthesis producing glucose that provides both the carbohydrates and energy necessary for vegetative growth through the cell division that eventually increase the cell size necessary for both leaf and stem (Almodares *et al*., 2006; Almodares *et al*., 2008; Mahdi *et al*., 2011). Almorades *et al*. (2008) find that nitrogen application also increases the stem diameter of sweet sorghum and Ayub *et al*. (2009) records a similar result in pearl millet. In this study, no significant difference was found in plant growth with the use of fertilizer above the lowest dose even though the number of leaves produced increased significantly. The increased level of N fertilizer above 50 kg $ha^{-1}$did not affect the number of the leaves, size of leaves, and stems. These results are in line with the results reported by Restelatto *et al*. (2015) that there was a decrease in efficiency with the increase in nitrogen rates in sorghum and oat.

Stem diameters obtained were in the range of 14.90-17.83 mm, leaf widths were in the range of 7.03-8.33 cm, and leaf lengths were in the range of 90.18-101.29 cm. These values are very similar to those reported by Sriagtula *et al*. (2016) that ranges of stem diameters, leaf widths, and leaf lengths were 16.93-17.35 mm, 7.56-8.04

Table 2. Growth variables of BMR sorghum mutant line Patir 3.7 with different levels of nitrogen fertilizer

| Treatments | Growth variables | | | | |
|---|---|---|---|---|---|
| | Stem diameter (mm) | Leaf length (cm) | Leaf width (cm) | Number of leaf | Plant height (cm) |
| N0 | 15.21±1.98$^{A}$ | 91.76±5.82$^{A}$ | 7.20±0.98$^{A}$ | 6.05±0.70$^{A}$ | 166.54±9.39$^{A}$ |
| N1 | 17.89±2.26$^{B}$ | 98.32±5.44$^{B}$ | 8.40±0.88$^{B}$ | 6.63±0.92$^{AB}$ | 181.77±12.59$^{B}$ |
| N2 | 17.56±2.20$^{B}$ | 101.29±12.07$^{B}$ | 8.27±1.00$^{B}$ | 6.76±0.85$^{AB}$ | 183.35±11.60$^{B}$ |
| N3 | 17.41±2.04$^{B}$ | 98.78±12.39$^{AB}$ | 8.25±0.92$^{B}$ | 7.18±0.68$^{C}$ | 171.07±7.64$^{A}$ |

Note: Means in the same column with different superscripts differ significantly ($p<0.01$). N0= 0 kg N $ha^{-1}$, N1= 50 kg N $ha^{-1}$, N2= 100 kg N $ha^{-1}$, and N3= 150 kg N $ha^{-1}$

Table 3. Leaves, stems, and panicles ratio (fresh weight basis) as well as stem sugar (% Brix) on BMR sorghum mutant line Patir 3.7 with different levels of nitrogen fertilizer

| Treatments | Variables | | | |
|---|---|---|---|---|
| | Stem ratio (%) | Leaf ratio (%) | Panicle ratio (%) | Stem sugar (% Brix) |
| N0 | 58.84±3.76$^{C}$ | 21.88±2.99$^{A}$ | 19.28±2.16 | 10.60±2.44 |
| N1 | 56.57±3.05$^{B}$ | 24.80±3.32$^{B}$ | 18.63±1.84 | 10.09±2.65 |
| N2 | 55.97±5.06$^{B}$ | 24.31±4.98$^{B}$ | 19.72±2.32 | 10.35±1.83 |
| N3 | 52.03±3.75$^{A}$ | 28.81±2.67$^{C}$ | 19.15±2.56 | 10.78±1.84 |

Note: Means in the same column with different superscripts differ significantly ($p<0.01$). N0= 0 kg N $ha^{-1}$, N1= 50 kg N $ha^{-1}$, N2= 100 kg N $ha^{-1}$, and N3= 150 kg N $ha^{-1}$

Table 4. Biomass and nutrient production of BMR sorghum mutant line Patir 3.7 with different levels of nitrogen fertilizer

| Variables (ton ha$^{-1}$) | Treatments | | | | |
|---|---|---|---|---|---|
| | N0 | N1 | N2 | N3 | Mean |
| Fresh production | 24.75±0.50$^a$ | 35.77±3.71$^b$ | 34.23±1.76$^b$ | 35.10±3.32$^b$ | 33.16±4.82 |
| Dry matter production | 6.70±0.35$^a$ | 8.30±0.33$^b$ | 8.70±0.02$^b$ | 7.91±0.40$^b$ | 7.92±0.73 |
| Crude protein production | 0.46±0.14$^a$ | 0.69±0.12$^b$ | 0.70±0.07$^b$ | 0.66±0.87$^b$ | 0.65±0.12 |
| Crude fiber production | 1.46±0.01 | 1.62±0.10 | 1.53±0.15 | 1.64±0.10 | 1.57±0.12 |
| Ether extract production | 0.21±0.00 | 0.28±0.02 | 0.25±0.09 | 0.29±0.01 | 0.26±0.05 |
| Ash production | 0.24±0.23$^a$ | 0.44±0.09$^b$ | 0.42±0.05$^b$ | 0.43±0.09$^b$ | 0.39±0.10 |
| Nitrogen-free extract production | 4.33±0.28$^a$ | 5.49±0.37$^b$ | 5.40±0.42$^b$ | 4.89±0.38$^{ab}$ | 5.09±0.55 |
| Total digestible nutrient production | 4.14 ±0.21$^a$ | 5.41±0.45$^b$ | 5.39±0.21$^b$ | 4.96±0.17$^b$ | 5.05±0.55 |

Note: Means in the same row with different superscripts differ significantly ($p<0.05$). N0= 0 kg N ha$^{-1}$, N1= 50 kg N ha$^{-1}$, N2= 100 kg N ha$^{-1}$, and N3= 150 kg N ha$^{-1}$

Table 5. Nutrients content of BMR sorghum mutant line Patir 3.7 (ton ha$^{-1}$) with different levels of nitrogen fertilizer

| Nutrients (%) | Treatments | | | | |
|---|---|---|---|---|---|
| | N0 | N1 | N2 | N3 | Mean |
| Dry matter | 27.08±0.84$^b$ | 23.32±2.01$^a$ | 24.41±1.19$^a$ | 22.66±2.37$^a$ | 24.12±2.21 |
| Crude protein | 6.84±0.12 | 8.37±1.18 | 8.40±0.27 | 8.39±1.48 | 8.10±1.06 |
| Crude fiber | 21.83±0.88 | 19.65±2.25 | 18.29±0.77 | 20.27±1.23 | 26.02±1.75 |
| Ether extract | 3.16±0.17 | 3.38±0.21 | 2.85±1.07 | 3.64±0.31 | 3.31±0.50 |
| Ash | 3.54±0.23 | 5.23±0.96 | 4.98±0.35 | 5.42±1.00 | 4.91±0.95 |
| Nitrogen-free extract | 64.65±0.93 | 64.52±0.95 | 64.67±0.69 | 61.78±1.72 | 63.77±1.69 |
| Total digestible nutrient | 61.81±0.09 | 63.03±1.59 | 64.62±3.75 | 62.68±1.21 | 63.16±2.22 |

Note: Means in the same row with different superscripts differ significantly ($p<0.05$). N0= 0 kg N ha$^{-1}$, N1= 50 kg N ha$^{-1}$, N2= 100 kg N ha$^{-1}$, and N3= 150 kg N ha$^{-1}$

cm, and 100.62-101.72 cm, respectively. However, the range of plants heights in this study was 164.86-184.18 cm that was lower than that reported by Sriagtula *et al*. (2016) i.e., 214.38 cm. The relatively low heights of plants in this study appear to be related to the differences in either climatic or soil type. In the present study, the type of soil used was red clay soil (ultisol soil). This soil is classed as marginal and is relatively acidic. In addition, this study was conducted in dry conditions with low rainfall while the study of Sriagtula *et al.* (2016) was conducted in the rainy season.

Addition of nitrogen fertilizer did not have a significant effect on the sugar contents of the stems. Previous studies also reported that the addition of nitrogen fertilizer did not significantly affect the sugar content in sweet sorghum stems (Maw *et al*., 2016; Almodares *et al*. 2008). Sugar content is known to be more influenced by the phosphorus and potassium levels (Ali & Anjum, 2017) as well as the genetic factors.

The increase in the fresh production of sorghum biomass in this study is contributed by the increased stem diameter, leaf length, leaf width, number of leaves, and plant height with the increased levels of nitrogen fertilizer (Table 1). The increase in dry matter in this study was related to the high photosynthesis rate with the increased nitrogen fertilizer addition similar to mineral uptake in the plant to grow. Mahdi *et al*. (2011) reported that nitrogen fertilizer in maize could increase plant height, stem thickness, accumulation of dry matter, and production per hectare. Latifmanesh *et al*. (2018) stated the net photosynthetic rates increased the dry matter accumulation.

The increase in nutrient production with nitrogen fertilizer treatment is caused by the increased of dry matter production. The nutrient productions (CP, CF, EE, ash, NFE, and TDN) were calculated from the percentage content of nutrients and then multiplied by the average dry matter (DM) production of biomass (tons ha$^{-1}$). Balabanli *et al*. (2010) state that the nutrient production of feed crops depend on DM production and nutrients content of plants. The fresh, dry matter, and nutrient productions in this study were lower than those reported by Sriagtula *et al*. (2016b) and these differences were related to different locations and climate conditions. The study was carried out from July to October 2017 with low to medium rainfall in the range of 100-300 mm.

The lower DM content in the BMR mutant sorghum line of Patir 3.7 receiving nitrogen fertilizer was due to the higher plant growth as was reflected by the higher fresh weight production than the control sorghum without the addition of nitrogen fertilizer. The level of water and nutrients uptakes in plants for metabolism is the combination effects of development and increase in plant tissue such as the number of leaves, leaf area, and plant height as are reflected in the increased fresh weight. The application of nitrogen fertilizer at the levels of 50, 100, and 150 kg N ha$^{-1}$ produced the lower DM content in this study similar to the results reported by Saini (2012) that the increased application of nitrogen fertilizer increased moisture content by 75.9% (24.1% DM). Nitrogen plays a role in vegetative growths of stem, leave, and root. Saini (2012) states that nitrogen functions to increase the root growth due to the increased area for absorbing water on the soil profile that eventually increases the water content in the plant.

Even though the content of DM sorghum biomass in control or BMR mutant sorghum line of Patir 3.7 without N fertilizer (N0) was higher, the other nutrients such as CP, CF, EE, ash, NFE, and TDN were not significantly affected by the addition of nitrogen fertilizer at the levels of 50, 100, and 150 kg N $ha^{-1}$ (N1, N2, and N3) because nutrients availabilities in the soil were still sufficient to assimilate nutrient compounds. The results of soil analysis (Table 1) indicate that the soil has a moderate acidity (pH 5.6) so that the soil factor supports the growth and production of sorghum plants. Ishak's *et al.* (2012) states that the zone of land suitability for sorghum ranges from pH 5.5 to 8.5. At pH 5.5, the nutrient content is sufficiently available for plant growth in the tropics, and the growth of soil microorganisms that play roles in the process of nutrient supply is also quite good (Hardjowigeno, 2003). This result is in line with the research of Khalil *et al*. (2015) stating that cultivation of sweet sorghum requires a relatively low nutrient input.

In this study, the application of nitrogen fertilizer gave an increase in growth parameters (Table 1) and biomass production (fresh and dry matter productions). In general, nitrogen is a limiting nutrient in crop production, and especially in sorghum, nitrogen is the most responsive nutrient for production. This assumption is in line with the statement of Almodares *et al*. (2006) that the application of nitrogen fertilizer generally increases leaf area, total dry matter, and production of sweet sorghum varieties. However, the nutrient content in this study was not affected by the application of nitrogen fertilizer, except DM content. This result is contradictive with the report of Almodares *et al*. (2009) that the application of nitrogen fertilizer increases the CP, NFE, and CF content. Olugbemi (2017) states that the different effects of the application of nitrogen in sorghum plants can be due to differences in climate, soil, genotypic factors, season, and location. The DM, CP, and ash contents of BMR sorghum mutant line Patir 3.7 in this study were similar to those reported by Telleng *et al*. (2016) i.e., 25.26%, 9.76%, and 6.76%, respectively.

## CONCLUSION

The nitrogen fertilizer increased the growth of BMR sorghum Patir line 3.7; it increased the ratio of leaves to stems and increased the production of fresh and dry matter biomass. The nutrients production increased with the addition of nitrogen fertilizer except for CF and EE. The best level of nitrogen fertilizer was 50 kg N $ha^{-1}$. Therefore, while the use of nitrogen fertilizer is important, there appears to be no advantage in using higher levels of nitrogen fertilizer when BMR mutant sorghum line Patir 3.7 are planted on ultisol soil.

## CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial, personal, or other relationships with other people or organization related to the material discussed in the manuscript.

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