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Research Article

Effect of Nitrogen Levels and Harvest Intervals on Dry Matter Yield of Barnyard Millet

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ABSTRACT

The aim of this study was to investigate dry matter productivity and nitrate nitrogen content in the growth stages of barnyard millet (*Echinochloa esculenta*) cultivated for feed, which was treated with different nitrogen fertilization levels. An early variety of barnyard millet (cv. Shirohie) was used for the test, and the different treatments with nitrogen fertilizer were as follows: 50% (N-40 kg/ha, T1), 100% (N-80 kg/ha, reference amount, T2), 150% (N-120 kg/ha, T3), 200% (N- 160 kg/ha, T4), 250% (N-200 kg/ha, T5), and 300% (N-240 kg/ha, T6). Sowing was done on May 13, 2021 and plants were harvested for four stage; vegetative stage, elongation stage, heading stage, and milk stage. The length of the millet increased significantly as the amount of nitrogen fertilization increased during the harvest period ($p<0.05$), but the difference was insignificant during the milk stage ($p>0.05$). Moreover, barnyard millet dry matter yield increased significantly as the levels of nitrogen fertilization increased ($p<0.05$), but there was no significant difference in dry matter yield among nitrogen fertilization levels during the heading stage ($p>0.05$). Chlorophyll also was significantly higher in T5 (250%) at all harvesting times, whereas nitrate nitrogen content was highest at the vegetative stage, gradually decreased as growth progressed, and lowest at the milk stage. Finally, as the nitrogen fertilization levels increased, the nitrate nitrogen content was significantly higher in all treatment groups ($p<0.05$). Therefore, our results suggest that the most appropriate nitrogen fertilizer levels is between 150%–200%, considering the dry matter yield, feed ingredients and nitrate nitrogen content in barnyard millet for feed.
(**Key words**: Barnyard millet, Dry matter yield, Nitrate nitrogen)

Ⅰ. INTRODUCTION

Domestic livestock farmers cultivate and use corn silage and sorghum-sudangrass as summer crops. The production of corn silage totaled 14,7000 tons in 2020, with a cultivated area of 11,000 ha, whereas sorghum-sudangrass production yielded 152,000 tons in 2020 and reached a cultivation area of 14,000 ha (MAFRA, 2021). However, corn silage can only be cultivated with the use of appropriate equipment for planting and harvesting, and it is difficult to expand the cultivation area of sudangrass used as round-packed silage due to the deterioration of fermentation quality and livestock palatability.

Unlike grain crops, barnyard millet (*Echinochloa esculenta*) for feed has low fertility, adapts well to adverse growing environments such as heat, dryness, and wet conditions, and is at no known risk of cyanide poisoning (Shin et al., 2006; Lee et al., 2009; Chun et al., 2016). Recently, as part of income diversification projects including rice supply and demand control, cultivation of barnyard millet for feed has been attempted as an alternative to rice, and its cultivation area is gradually increasing (Cho et al., 2001; Hwang et al., 2012). However, research on stable production, such as breed development, seeding amount, and fertilization levels of barnyard millet for feed is insufficient and, particularly, standards for appropriate sowing amounts and fertilization levels have not yet been established. An increase in the amount of nitrogen fertilizer in the cultivation of barnyard millet may help increase production, but it may also increase nitrate nitrogen content in the plant (Hur, 1992). In general, if nitrate nitrogen content in the plant is high, nitric acid poisoning may occur in ruminant livestock, and can cause death in severe cases. For example, as revealed by Undersander et al. (1999), grasses with nitrate content of 0.1% or less are adequate for livestock. However, when nitrate content ranges from 0.1%–0.2% in grasses, it can be dangerous for pregnant and young livestock, while when it reaches 0.4% or higher, acute toxicity symptoms appear in most animals (Undersander et al., 1999).

Nitrate levels are high when plants are young, but they

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decrease as plants grow (Lee et al., 2017). In particular, nitrate poisoning occurs frequently when extra nitrogen fertilizer is applied; excessive nitrogen fertilization during drought is fatal because it can lead to an excessive accumulation of nitrogen in the soil (Yoon and Choi, 1999). Therefore, this study was conducted to investigate dry matter productivity and nitrate nitrogen content at different growth stages of barnyard millet treated with different nitrogen fertilizer amounts, and to determine the appropriate nitrogen fertilization level for the cultivation of this crop.

Ⅱ. MATERIALS AND METHODS

1. Experimental design

The experiment was carried out in 2021 at the test field of the Department of Animal Resources Development, National Institute of National Science, located in Cheonan, Chungcheongnam-do, Republic of Korea. It sought to test different fertilization levels and nitrate nitrogen content in the growth stages of barnyard millet (*Echinochloa esculenta*) for feed, and one of its early varieties (cv. Shirohie) was used for the test.

The treatment comprised the following nitrogen fertilizer levels: 50% (N-40 kg/ha, T1), 100% (N-80 kg/ha, reference amount, T2), 150% (N-120 kg/ha, T3), 200% (N- 160 kg/ha, T4), 250% (N-200 kg/ha, T5), and 300% (N-240 kg/ha, T6), which followed a randomized block design method with three repetitions. Sowing was done on May 13, 2021 with a seed drill 30 cm wide, and the yield amount was 20 kg/ha. The standard P and K amounts were applied at 200 and 70 kg/ha, respectively, and the crop was harvested four times during each growth stage: vegetative stage (first harvest when plant height was 70cm, June 15), elongation stage (second harvest when plant height reached 100cm, June 25), during the heading stage (third harvest, July 6), and during the milk stage (fourth harvest, July 20). Finally, chlorophyll content was measured using a chlorophyll meter (SPAD-502 plus, Minolta, Japan) during each harvest to confirm the change in the leaves' chlorophyll levels.

2. Investigation parameters

Measured variables were soil composition (pH, T-N, OM, Av-P_2O_5 and CEC), plant height (cm), dry matter amount (kg/ha), chlorophyll (SPAD), and feed composition (DM, CP, NDF, ADF, and NO_3-N). Data on atmospheric temperature (℃) and humidity (%) during the testing period were obtained using HOBO (H21-USB, Onset, USA), and data from the Cheonan Meteorological Observatory (KMA, 2022) was used to measure atmospheric temperature, humidity, and precipitation (mm) in the last 10 years. Finally, dry matter (DM) was analyzed following AOAC (1990) to calculate the forage value of barnyard millet.

Subsequently, the collected samples were dried in a hot air dryer at 65 °C for 72 h, pulverized with a 0.7-mm mesh mill, and stored in plastic sample containers. Crude protein content was measured using an elemental analyzer (Vario Max CUBE, Elementar, Germany) following Dumas' method (AAAS, 1884), and using total nitrogen content, crude protein content (%CP = %N × 6.25) was calculated. Moreover, with the aid of an Ankom fiber analyzer (ANKOM Technology Corp., Fairport, NY, USA), NDF and ADF contents were determined according to the method described by Goering and Van Soest (1970), and nitrate was analyzed using a brucine colorimetric method (RDA, 1988).

3. Statistical analysis

A one-way variance analysis was conducted using the SAS Enterprise Guide (version 9.2), and the statistical differences in treatment intervals were tested at a 5% significance level using Duncan's multiple range test.

Ⅲ. RESULTS AND DISCUSSIONS

1. Soil and climatic conditions

Jung et al. (2001) reported that the average physicochemical characteristics of Korean field soil were as follows: pH 5.6, 24 g/kg of organic matter, and 577 mg/kg of effective phosphoric acid. In addition, Korean field soil surveyed by Kim et al. (2019) in 2017 had a pH of 6.4, 27 g/kg of organic matter, and 657 mg/kg of effective phosphoric acid. Nevertheless, the soil used in this study (Table 1) had higher acidity and effective phosphoric acid levels, as well as lower organic matter content, than what has been reported for Korean field soils, and we

Table 1. Chemical properties of experimental fields in the Cheonan-si region

pH	T-N* (%)	OM** (g/kg)	Av-P_2O_5*** (mg/kg)	CEC**** ($cmol^+$/kg)
7.58	0.10	13.88	799.84	9.15

*T-N: total nitrogen.
**OM: organic matter.
***Av- P_2O_5: Available phosphate.
****CEC: cation exchange capacity.

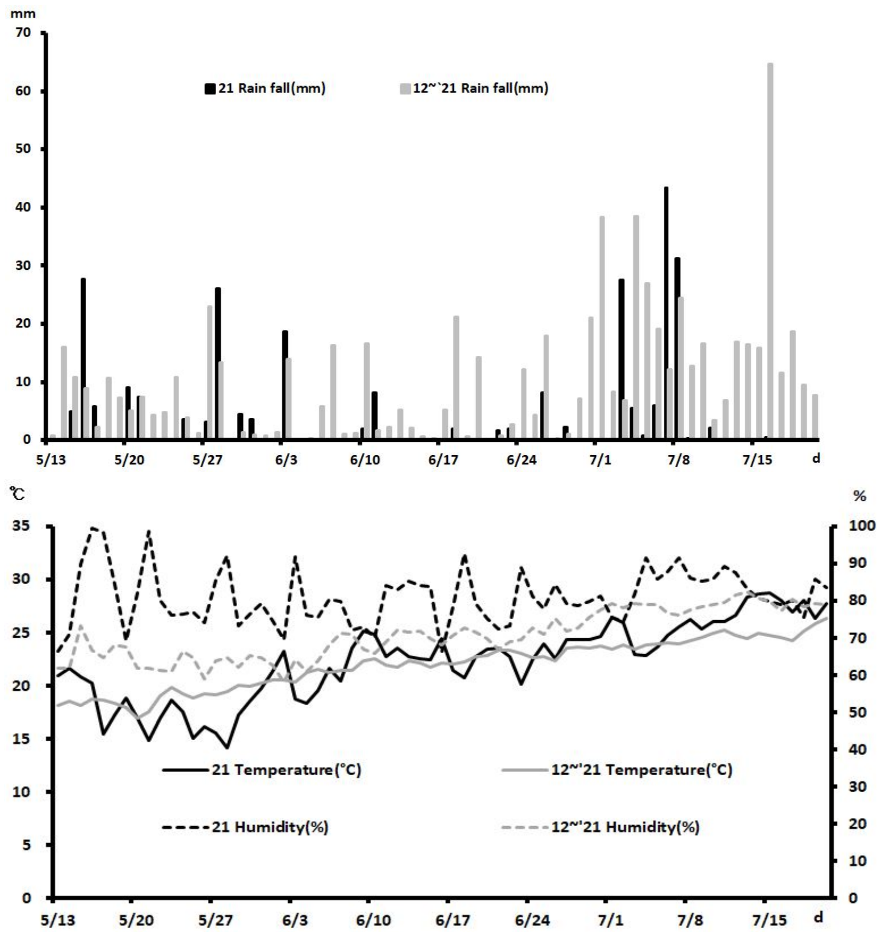

Fig. 1. Temperature, humidity, and rainfall at the experimental sites during the cultivation period and 10 years prior.

infer that these differences can be explained by the fact that the test soil used a large amount of chemical fertilizer.

Moreover, the climate characteristics at Cheonan-si, Chungcheongnam-do during the test period is shown in Fig. 1, which shows that the air temperature and humidity had similar trends compared to the 10-year average. Precipitation during the test period was 258 mm, which was lower than the average of 314 mm for the last 10 years, and was overall low during the vegetative growth period.

2. Barnyard millet growth characteristics

Barnyard millet length showed a significant increasing trend, similar to the amount of nitrogen fertilization, during each harvest period ($p<0.05$), except for the milk stage, where no significant differences were observed ($p>0.05$, Fig. 2). In addition, treatment group T4 (200%) appeared shorter than the nitrogen fertilization standard treatment group (T2, 100%). Furthermore, when compared to T1 (50%), plant height was similar, which can be due to soil condition and poor growth. However, Lee et al. (2013) found barnyard millet lengths ranging from 167 to 179 cm, about 50

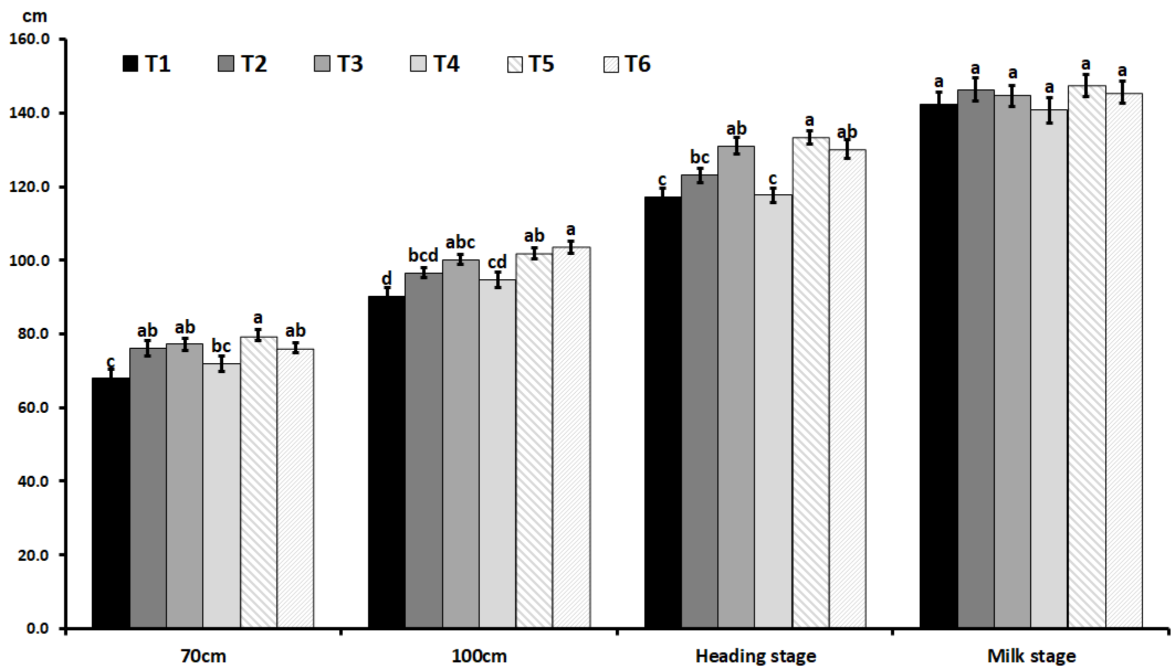

Fig. 2. Effect of nitrogen fertilization on the height of barnyard millet during different harvest intervals.
[a,b,c,d]Means in the column with different superscripts are significantly different(p<0.05).
T1: 50%, T2: 100%, T3: 150%, T4: 200%, T5: 250%, T6: 300%.

cm longer than the 117–133 cm reported herein, which might be influenced by the fact that the heading stage in our study began about 15 days earlier than that reported by Lee et al. (2013). Meanwhile, Park et al. (2022) found that plant height during early heading was 138 cm, which was similar to that reported in the present study.

Barnyard millet dry matter yield became significantly higher as nitrogen fertilization amounts increased (p<0.05), but there were no significant differences in terms of nitrogen fertilization amounts during the heading stage (p>0.05, Table 2). However, dry matter yield was higher in treatment areas with a high nitrogen fertilization rate; the T5 (250%) treatment showed the highest dry matter yield. At the heading stage, dry matter yield was close to 7.6 ton/ha, as reported by Park et al. (2022); however, Lee et al. (2013) reported a dry matter yield during the heading stage of 11.4–13.2 ton/ha, which was similar to the 10.5–15.8 ton/ha of dry matter yield at the milk stage in this study. Furthermore, dry matter yield during the heading stage for the T6 (300%) treatment was 119% compared to T2 (100%).

Lastly, as the amount of nitrogen fertilization increased, the CP content significantly increased (p<0.05; Table 3). Nonetheless, after the heading stage, there were no significant differences in CP content (p>0.05), although it tended to be higher in the treatment groups with high levels of nitrogen fertilization amount. The contents of NDF and ADF tended to be low in the treatment with high nitrogen fertilization. In addition, as the growing period increased, the NDF and ADF contents were higher.

3. SPAD values and nitrate nitrogen content

The chlorophyll levels of barnyard millet were significantly higher in T5 (250%) at all harvesting times (p<0.05; Table 4). Moreover, as nitrogen fertilization increased, the value of SPAD also tended to increase, However, as they grew from the vegetative stage, the chlorophyll content decreased. This is similar to previous results that showed that SPAD value decreased as the nitrogen fertilization amount increased (Kang, 1999; Kim et al., 2002).

On the other hand, nitrate nitrogen content was the highest in the vegetative stage, gradually decreased as growth progressed, and was the lowest in the milk stage(Table 5). In addition, as nitrogen fertilization amounts increased, nitrate nitrogen content became significantly higher in all treatment groups (p<0.05). Block (2020) reported that it is safe to feed livestock when nitrate nitrogen content found in forage is less than 1,000 ppm, and that when the nitrogen nitrate content is

Table 2. Barnyard millet dry matter yield at different nitrogen levels and harvest intervals

Nitrogen levels	Vegetative stage (70cm)		Elongation stage (100cm)		Heading stage		Milk stage	
	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha
T1 (50%)	10.3±0.6^{a}	1,060.2±141.3^{b}	12.7±0.1^{a}	3,466.2±143.3^{b}	17.1±0.9^{a}	6,907.5±720.1^{a}	25.9±1.9^{a}	10,470.8±584.8^{a}
T2 (100%)	9.8±0.4^{a}	1,284.3±155.9^{b}	12.9±0.4^{a}	3,665.0±441.9^{ab}	17.4±0.5^{a}	7,479.0±512.5^{a}	24.9±1.5^{a}	11,660.3±847.1^{a}
T3 (150%)	9.3±0.3^{ab}	1,169.7±101.4^{b}	12.0±0.3^{a}	3,775.6±85.7^{ab}	15.9±0.2^{a}	7,925.8±604.6^{a}	26.0±1.1^{a}	14,120.0±834.2^{a}
T4 (200%)	9.3±0.6^{ab}	1,375.0±117.8^{ab}	12.2±0.2^{a}	3,852.4±205.0^{ab}	16.2±0.5^{a}	6,188.5±995.2^{a}	25.4±2.3^{a}	10,959.2±1,956.6^{a}
T5 (250%)	9.0±0.2^{ab}	1,937.0±140.7^{a}	11.8±0.7^{a}	4,729.9±255.2^{a}	15.9±0.5^{a}	8,681.0±96.3^{a}	29.6±3.7^{a}	15,837.2±2,448.5^{a}
T6 (300%)	8.3±0.2^{b}	1,393.2±131.8^{ab}	11.9±0.1^{a}	4,392.6±58.9^{ab}	16.9±0.7^{a}	8,874.3±526.0^{a}	26.1±.3^{a}	15,079.8±1,342.7^{a}

Mean±standard error.
[a,b]Means in the column with different superscripts are significantly different(p<0.05).

Table 3. Barnyard millet chemical composition at different nitrogen levels and harvest intervals

Nitrogen levels	Vegetative stage (70cm)			Elongation stage (100cm)			Heading stage			Milk stage		
	CP[1)]	NDF[2)]	ADF[3)]	CP	NDF	ADF	CP	NDF	ADF	CP	NDF	ADF
	% of DM											
T1 (50%)	19.3±1.5^{c}	55.0±1.3^{ab}	29.8±1.2^{a}	10.8±0.6^{c}	56.7±0.1^{a}	29.8±0.1^{a}	7.7±0.6^{a}	61.6±0.3^{a}	34.4±0.4^{a}	6.5±0.8^{a}	62.6±0.2^{a}	36.4±0.5^{a}
T2 (100%)	21.1±2.5^{c}	56.2±0.5^{a}	29.7±0.5^{a}	12.1±0.9^{c}	56.0±0.2^{ab}	28.6±0.2^{b}	7.7±1.0^{a}	61.4±0.4^{a}	34.4±0.8^{a}	5.9±0.8^{a}	62.2±0.9^{a}	36.5±0.8^{a}
T3 (150%)	23.4±0.5^{bc}	57.0±0.4^{a}	28.5±0.5^{a}	13.9±1.3^{bc}	57.0±0.5^{a}	29.9±0.5^{a}	9.6±0.4^{a}	60.5±1.1^{ab}	35.7±0.7^{a}	5.9±0.1^{a}	61.7±1.3^{a}	36.3±1.0^{a}
T4 (200%)	22.2±2.0^{c}	56.0±0.5^{a}	30.0±0.4^{a}	15.8±0.5^{abc}	56.1±0.6^{ab}	29.2±0.4^{ab}	11.2±2.9^{a}	60.3±0.8^{ab}	34.2±0.3^{a}	5.3±0.2^{a}	62.5±1.1^{a}	36.3±0.5^{a}
T5 (250%)	28.0±1.7^{ab}	54.5±0.4^{ab}	28.0±0.5^{a}	20.8±3.4^{a}	54.7±0.8^{b}	28.3±0.3^{b}	10.7±0.9^{a}	58.6±0.5^{b}	34.3±0.1^{a}	6.5±0.2^{a}	62.6±0.4^{a}	36.1±0.2^{a}
T6 (300%)	29.4±0.9^{a}	52.2±0.9^{b}	27.7±1.2^{a}	18.0±0.6^{ab}	54.8±0.6^{b}	28.2±0.3^{b}	9.8±0.1^{a}	60.6±0.4^{ab}	35.6±0.6^{a}	5.9±0.6^{a}	60.8±.7^{a}	35.1±0.2^{a}

Mean±tandard error.
[a,b,c]Means in the column with different superscripts are significantly different(p<0.05).
[1)]CP: crude protein, [2)]NDF: neutral detergent fiber, [3)]ADF: acid detergent fiber.

Table 4. Barnyard millet SPAD at different nitrogen levels and harvest intervals

Nitrogen levels	Vegetative stage (70cm)	Elongation stage (100cm)	Heading stage	Milk stage
	SPAD			
T1 (50%)	27.7±0.9^{c}	27.2±0.8^{b}	28.1±1.5^{b}	25.2±1.6^{b}
T2 (100%)	29.3±1.0^{ab}	29.1±1.2^{ab}	26.9±1.3^{b}	24.9±1.3^{b}
T3 (150%)	30.8±0.5^{ab}	29.1±0.5^{ab}	28.5±1.1^{b}	26.2±1.7^{b}
T4 (200%)	31.0±0.8^{ab}	28.6±0.8^{ab}	28.2±1.7^{b}	25.4±1.2^{b}
T5 (250%)	34.8±0.9^{a}	31.6±1.2^{a}	34.5±1.1^{a}	31.9±1.5^{a}
T6 (300%)	31.9±1.1^{ab}	30.2±1.0^{ab}	30.3±0.9^{ab}	26.0±1.0^{b}

Mean±standard error.
^{a,b,c}Means in the column with different superscripts are significantly different(p<0.05).

Table 5. Nitrate nitrogen content at different nitrogen levels and harvest intervals

Nitrogen levels	Vegetative stage (70cm)	Elongation stage (100cm)	Heading stage	Milk stage
	ppm			
T1 (50%)	591.8±22.8^{b}	204.1±103.9^{b}	51.4±8.0^{b}	23.7±3.7^{a}
T2 (100%)	997.6±422.1^{ab}	486.6±210.7^{b}	89.6±42.4^{b}	19.3±2.1^{a}
T3 (150%)	1,238.1±104.0^{ab}	906.1±252.1^{a}	203.2±72.4^{b}	16.7±0.4^{a}
T4 (200%)	1,161.6±246.2^{ab}	1,018.4±76.9^{a}	244.0±8.8^{b}	13.7±0.7^{a}
T5 (250%)	1,607.0±12.8^{a}	1,263.9±274.6^{a}	840.9±212.4^{a}	20.1±7.5^{a}
T6 (300%)	1,609.2±24.5^{a}	1,115.9±182.2^{a}	356.4±32.8^{b}	23.0±11.0^{a}

Mean±standard error.
^{a,b}Means in the column with different superscripts are significantly different(p<0.05).

1,000–1,500 ppm, it is safe to limit the feeding amount to 50% for pregnant animals. Barnyard millet had a nitrate nitrogen content <1,000 ppm in all treated groups at the heading stage, indicating that it was safe for livestock feeding. However, it is noteworthy that T5 (250%) had lower nitrate nitrogen levels in the heading stage than in the elongation stage, but these levels were significantly higher than those reported for T6 (300%) (p<0.05). Therefore, this treatment group can be deemed as an outlier when comparing the nitrate nitrogen content of the rest of the treatment groups.

Ⅳ. CONCLUSIONS

This study was conducted to test the change in dry matter yield and nitrogen nitrate content with changing nitrogen fertilization levels during barnyard millet cultivation for feed. Under the condition of good soil fertility, the increase in dry matter production was smaller than the increase in the amount of nitrogen fertilizer, and CP content tended to be higher in treatment groups with larger amounts of nitrogen fertilizers. Moreover, nitrate nitrogen content in barnyard millet during the heading stage proved to be safe for feeding, as previously reported, and therefore, we could conclude that 150%–200% of nitrogen fertilization is appropriate considering dry matter yield, feed ingredients, and nitrate nitrogen content.

Ⅴ. ACKNOWLEDGEMENT

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