Productivity and morphology of Benggala grass Riversdale cultivar (*Panicum maximum* cv Riversdale) on acid soils

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**Abstract.** Benggala grass is one of the forages everyday use by farmer livestock, it's usually cultivated at suboptimal land. Acid dry land has the potential for forage development. The study aimed to determine the tolerance of Benggala grass (*Panicum maximum* cv Riversdale) in acid soils. The study was conducted in the greenhouse of the Research Institute of Animal Production, using a completely randomized design, ten replication for ten months. The study used acid (pH 4.5 and $\text{Al}^{3+} 0.27 \text{ cmol kg}^{-1}$) and non-acid soils (pH 7.1). The seeds were planted in pots (40 cm in diameter and 30 cm height). The observed variables were morphological characters, productivity and reproduction. The results showed that the stem and internode diameters, internode lengths and plant height in non-acid soil were higher ($P < 0.05$) than in the acid soil. The fresh and dry shoot weights, number of tillers, fresh and dry shoot weights, and seed weight in acid soils were lower ($P < 0.05$). The times of booting, flowering started and length in the acidic soil was longer ($P < 0.05$). The study concluded that the Riversdale cultivar did not exhibit tolerance on acid soil; therefore, further research is required to improve its tolerance to acid soils.

1. **Introduction**

Forage needs for livestock, especially ruminants, must be available all year round. Forage has the most considerable portion in the ruminant ration and the primary energy source for ruminants. Farmers meet their forage by utilizing local grass, which has low nutritional value. Besides that, the superior forage varieties were not cultivated by farmers, it causes the low quality of forage for livestock. Farmers rarely do cultivation of forage because knowledge of ideal forage lacks and limited land for forage development. Land for forage development, usually directed to sub-optimal land.

Benggala grass (*Panicum maximum*) is one of the superior grasses that have been cultivated by farmers for their livestock. This grass has many tillers, relatively short production cycles, high leaf production, contributing to high biomass [1]. Dry matter (DM) production of Benggala grass is 13.8 to 21.4 t$^1$ ha$^1$ year$^{-1}$ dry DM. The yield is lower than elephant grass, but has a higher percentage of leaf weight than elephant grass [2].

The Riversdale cultivar is one of the cultivars of Benggala grass. This cultivar, obtained through selection on the pasture population at the South Johnstone Research Station of the Queensland Department of Primary Industries, has higher dry matter than the Makueni cultivar. This cultivar has a leaf N value of around 2.7 to 3.0% and produces more animal weight gain of 600 kg ha$^1$ year$^{-1}$ [3].
Acid dry land in Indonesia is around 108.8 million ha and 62.6 million ha, potentially as agricultural land, so it is very potential for forage development. The main limiting factor for forage cultivation in acid soils is the occurrence of Al (aluminum) root poisoning (rhizome-toxicity) so that it can reduce yields [4]. The development of plant genotypes, including tolerant forages on acid soil conditions, is an environmentally friendly, energy-efficient and economical solution for farmers who have limited resources [5]. Benggala grass cultivars show varying tolerance on acid soils, Chen et al. [6] reported that the Benggala grass cultivars are mostly less tolerant of acid soils, whereas according to Almeida et al. [7] most of the Benggala grass genotypes have good tolerance to aluminum stress. Plant selection on acid soil should be made by combining field selection and screening techniques in greenhouses based on Al tolerant plants [8]. The study aimed to determine the tolerance of *Panicum maximum* cv Riversdale in acid soils.

2. Materials and methods
The experiment was carried out in the RIAP greenhouse using a completely randomized design with ten replications. The study was conducted for ten months. The treatments were soil type, namely acid dry soil (pH 4.5, P₂O₅ 68 ppm, Al³⁺ 2.70 cmol kg⁻¹) from the oil palm plantation area of the Sei Putih-North Sumatra and non-acid soils (pH 7.10, P₂O₅ 464 ppm, Al³⁺ 0.00 cmol kg⁻¹) from the Ciawi Experimental Garden, Indonesian Research Institute for Animal Production (IRIAP). The Benggala grass cultivar used was the Riversdale cultivar from the IRIAP collection. Planting material using polybags, after the plants were one month old, then transferred to pots. The basic fertilizers applied were 100 kg ha⁻¹ urea, 100 kg ha⁻¹ TSP and 100 kg ha⁻¹ KCl and given only once at one-month-old. The plant was splashed with water every two days at the amount of the field capacity level.

Before planting, the seeds were sown in polybags, after the plants were one month old, then transferred to pots. The basic fertilizers applied were 100 kg ha⁻¹ urea, 100 kg ha⁻¹ TSP and 100 kg ha⁻¹ KCl and given only once at one-month-old. The plant was splashed with water every two days at the amount of the field capacity level.

The variables observed were leaf length and width, internode length, stem diameter, node diameter, plant height, number of tillers, fresh and dry weight, flag leaf length and green leaf color. During the generative phase, the observed characters were boot age, age at flowering, age at full bloom, panicle length, number of spikelets and seed weight. The observations in this phase were taken from an average of 3 panicles/clumps. All variables observed were carried out after three months of pruning. The forages were harvested at the age of 40 days after pruning and the forage harvest was made two times. Forage harvesting was done by cutting the grass as high as 10 cm from the ground, then weighing it to find its fresh weight. Data were analyzed using the SAS 9.4 program. If there are differences, it will be followed by the Tukey test.

3. Results and discussion
The morphology of the Riversdale cultivar showed that soil type had a significant effect (P < 0.05) on stem diameter, node diameter, plant height, internode length and flag leaf width (table 1). Soil types influenced morphological characters and showed lower characters in acid soils than morphological characters in non-acid soils. Al poisoning in acid soils caused abnormal root morphology. It directly impact on nutrient uptake and water absorption, resulting in deficiencies of magnesium, potassium, iron, molybdenum and phosphorus [10]. The study showed that the morphological characters of plant height, stem diameter and length and width of flag leaf in acid soils lower. A decrease in plant morphological characters such as plant height and the number of tillers was also reported in rice [11].

The length and width of the flag leave on acid soils were lower than on non-acid soils. The flag leaves length and width resembled the potential yield of seeds of a plant, mostly cereal plants. There was a relationship between the quantitative properties of flag leaves and leaf yield. More than 20% of the metabolites in flag leaves were significantly correlated with the same metabolites in seed development [12]. Stem characters were closely related to plant rigidity; the weaker the stems, the easier to fall. Internode length would affect plant height. Therefore, the Riversdale cultivar higher internode length in acidic soil was not directly proportional to plant height (table 1).
Table 1. The morphological characters of Benggala Riversdale cultivar planted on acidic and non-acid soils

| Variable                  | Type of Soil | Acid Soil | Non-Acid Soil | CV (%) |
|---------------------------|--------------|-----------|---------------|--------|
| Leaf Width (cm)           |              | 1.21a     | 1.54b         | 15.80  |
| Leaf Length (cm)          |              | 54.5a     | 61.7a         | 16.44  |
| Stem diameter (mm)        |              | 0.21b     | 0.29a         | 17.53  |
| Node diameter (mm)        |              | 0.15b     | 0.29a         | 15.16  |
| Internode Length (cm)     |              | 7.45b     | 13.72a        | 18.17  |
| Initial plant height (cm) |              | 91.30a    | 96.30a        | 10.30  |
| Plant Height (after pruning) (cm) | | 87.00b | 100.60a | 16.56 |
| Flag Leaf Length (cm)     |              | 14.30a    | 14.40a        | 17.81  |
| Flag leaf width (cm)      |              | 0.70b     | 1.23a         | 13.18  |

Table 2. Characteristics of Benggala Riversdale cultivar productivity on acidic and non-acid soils

| Variable                  | Type of Soil | Acid Soil | Non-Acid Soil | CV (%) |
|---------------------------|--------------|-----------|---------------|--------|
| Fresh Weight (g clump\(^1\)) |              | 63.00b    | 186.00a       | 20.40  |
| Number of Tillers         |              | 11.00b    | 41.90a        | 18.32  |
| Fresh Weight 1            |              | 24.95b    | 87.28a        | 9.71   |
| Dry Weight 1              |              | 7.78b     | 35.59a        | 16.91  |
| Fresh weight 2            |              | 30.37b    | 133.73a       | 19.73  |
| Dry Weight 2              |              | 9.82b     | 36.20a        | 17.45  |
| Root Fresh Weight (g)     |              | 7.10b     | 57.97a        | 16.47  |
| Root Dry Weight (g)       |              | 2.59b     | 19.26a        | 18.56  |
| Root Length (cm)          |              | 31.80     | 34.20         | 18.67  |

The production of the Riversdale cultivar was influenced by soil type (P <0.05). Riversdale cultivar productivity in acid soils decreased by about 50% than its productivity on non-acid soils (table 2). The decline in crop productivity on acidic soils also occurred in rice [11], beans [13], maize [14] and other main crops. The decrease in productivity in the Riversdale cultivar is thought to be due to Al poisoning, which caused inhibition of plant roots growth and function [15], inhibits the growth of plant parts and decreased in plant yield [4]. Aluminum also affects plant photosynthesis [16] and hormone levels [13], thereby affecting plant tissue metabolism. Aluminum's effect on plant photosynthesis is very influential in Riversdale cultivar production because its productivity depends on the number of leaves produced.

The fresh root weight of Riversdale cultivar grown in acid soils was lower than in non-acid soils (P <0.05). Roots were the most affected part of the plant to Al poisoning. Inhibition of root growth even occurred only a few minutes or hours after the plants were exposed to Al [17]. Root inhibition could be seen in the primary and lateral root apices and the roots became thick and brown [18]. Abnormal root morphology directly inhibited nutrient uptake and water absorption. As a result, plants showed a short growth and are prone to drought [11]. The results showed that acid soils' root weight was lower (P <0.01 when compared to non-acid soils. It means that Riversdale cultivar root growth is inhibited in acid soils; as the results, the forage production is 75% lower on acid soils (table 1). Others, also reported the decline in several forages on acid soils [19]. The decrease production of Riversdale cultivar on acid soil was caused a decrease of the tiller (table 1). The number of the tiller on acid soil was lower than on non-acid soil (P <0.05). The decreasing number of tiller in acid soil was an average of 65%. This decrease was directly propotional to the reduction of production. The decreasing number of tiller in acid soil also
occurred in rice [20]. The decline in the number of tillers directly proportional to the decrease in production also occurred in Purple guinea cultivars [21].

![Booting phase, flowering phase, full flowering phase, spikelet number and length of inflorescence](image1)

**Figure 1.** Booting phase, flowering phase, full flowering phase, number of spikelet and length of inflorescence cultivar Riversdale

The booting age, flowering and full flowering of the Riversdale cultivar in acid soils were longer (P <0.05) than in non-acid soils (figure 1). Slower booting to flowering on acid soils is due to Al in acid soils affecting photosynthesis and hormone levels [13], thus inhibiting flowering time in Riversdale cultivars.

The production of Riversdale cultivar seeds in acid soils was lower (P <0.05) when compared to non-acid soils (figure 2). Due to low P content in acid soils, decreased seed production will disrupt plant growth, decrease plant height and decrease seed production [22].

![Percentage of pithy and empty seed on acid and non-acid soil](image2)

**Figure 2.** Seed production, percentage of pithy and empty seed on acidic and non-acidic soils.

![Seed weight on acid and non-acid soil](image3)

**Figure 3.** Seed weight on acid and non-acid soil and empty seed on acidic and non-acidic soils.
4. Conclusions
Benggala Riversdale cultivars grown on acid soils have decreased morphology, forage production and seed production. The Riversdale cultivar was less tolerant of acid soils. Further research is required to improve the susceptible level of the Riversdale cultivars on acid soils.

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