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Research Article
Ability of Dwarf Elephant Grass (*Pennisetum purpureum* Cv. Mott) and *Gliricidia sepium* to Capture Ammonia (NH_3) Around Chicken Cages: An *in vitro* Evaluation

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Abstract

Background and Objective: Manure accumulation in open areas for long periods of time promotes the synthesis of ammonia (NH_3) by microbes and its emission to the atmosphere. Forage plants are used as ammonia trapsin poultry farms. This study aims to evaluate the potential of planting dwarf elephant grass and *Gliricidia sepium* around poultry farms to trap ammonia. **Methodology:** This study used a complete randomized design with a 2×3 factorial pattern with 6 replications as follows: Factor A: Two species (Dwarf elephant grass and *Gliricidia sepium*) and Factor B: The distance of the cages from the laying hen (1.5, 3 and 100 m). The parameters measured were the dry matter forage yield, plant height, protein content, ammonia concentration and *in vitro* dry matter digestibility. **Results:** The dry matter production of dwarf elephant grass was higher than that of *Gliricidia sepium* (0.5 vs 0.24 kg pot^{-1}), but for the other parameters, such as the plant height, protein content and dry matter digestibility, the values for *Gliricidia sepium* were higher than those for dwarf elephant grass. Regarding the plant's distance from the cage, a distance of 1.5 m yielded the highest levels of dry matter, forage yield, plant height, protein content and *in vitro* dry matter digestibility. The ammonia concentration at the cage of the laying hen was 7.7 ppm and at a distance of 3 m was 0.88 ppm. **Conclusion:** *Gliricidia sepium* was effective at absorbing air borne NH_3. Plants 1.5 m from the laying hen cage showed the best results.

Key words: Elephant grass dwarf, *Gliricidia sepium*, ammonia, emission, capture, protein content, digestibility

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Forage plants, especially natural grass, are not readily available in Indonesia for the development of ruminants. This is because most of the land has been used for housing, plantation and industry. Therefore, it is necessary to develop forage plants, including superior grasses and leguminous plants that can be planted on limited land with high production. Forage plants include all types of green plants that can be consumed by ruminant livestock, do not poison the animals and provide sufficient nutrients that can meet the needs of livestock. Forage feed is divided into two major groups:Grass (gramineae) and legumes (leguminosae). Both are providers of forage feed[1] and represent up to 60% of the forage consumption in cattle[2].

The production of cultivated grass is optimal with proper handling, including seed selection, land clearing and fertilizer application. The use of fertilizer on elephant grass planted in ultisol soil with 10 t ha^{-1}/year manure fertilization, 200 kg ha^{-1}/year TSP and 200 kg ha^{-1}/year urea can produce 27.3 t ha^{-1}/year of elephant grass or 4.86 t ha^{-1}/year of dry matter, whereas with the same level of fertilization on king grass yields 82.2 or 14.63 t ha^{-1}/year of dry matter[3].

Feed consumed by livestock is partially excreted in the form of manure, which consists of nitrogen (N ammonia). Up to 40% of nitrogen from laying hens travels into the air in the form of NH_3[4] and 25% originates from manure that decomposes in the form of ammonium (NH_4^+) and nitrate (NO_3^-)[5]. The accumulation of manure in open areas for long periods of time promotes the synthesis of ammonia (NH_3) by microbes. This results in atmospheric gas emissions[6], which degrade overall air quality and can cause respiratory problems in cage workers[7]. According to Bittman and Mikkelsen[8], NH_3 is a trans boundary gas because it can be transferred as far as 10-100 km from its source to contaminate areas with no potential to produce ammonia (NH_3).

Plants can absorb surrounding ammonia (NH_3) through buds, whereas NH_4^+ uptake occurs through buds and roots[9,10]. Uptake of NH_3 or NH_4^+ in the air through the leaf stomata occurs via cellular assimilation through the glutamine synthetase and glutamate synthase (GS-GOGAT) pathways[11]. NH_4^+ is converted into glutamine by GS and further converted from 2-Oxoglutarate (2-OG) to glutamate by GOGAT with the help of glutamate dehydrogenase. The N of NH_3 manure can be used as a free source of nitrogen in forage fodder, reducing the cost of purchasing N fertilizer. Legumes are able to absorb N-NH_3 released from poultry farms to the air[12]. The content of nitrogen in leguminous plant leaves increases in this environment[13,14] and can be used as high-quality ruminant livestock feed. Other forage crops that potentially capture NH_3 air include dwarf elephant grass (*Pennisetum purpureum* cv. Mott) and *Gliricidia sepium*.

Dwarf elephant grass (*Pennisetum purpureum* cv.Mott) is a plant that can grow in low-intensity sunlight (30-40%) and adapt to different types of soil, but requires a greater number of tillers and a longer harvest time. *Gliricidia sepium* is a leguminous tree with leaves that can be used as animal feed. *Gliricidia sepium* leaves work well as livestock feed because they have a high protein content and grow efficiently, even in the dry season[15].

The quality of forage ruminant feed can be determined from its digestibility value. The digestibility value is related to the quantity of food substances that can be absorbed and utilized by livestock. Digestibility is often measured by *in vitro* systems that mimic the true digestive system. *In vitro* systems are quite accurate as long as microorganisms and enzymes are sensitive to factors that affect speed and digestion[16]. The aim of this study was to test the ability of dwarf elephant grass (*Pennisetum purpureum* cv. Mott) and *Gliricidia sepium* to utilize ammonia nitrogen (N-NH_3) from chicken manure and its effect on production, protein content and digestibility *in vitro*.

MATERIALS AND METHODS

The design used was a complete randomized design with a 2×3 factorial pattern with 6 replications. Factor A represented the two species [Dwarf elephant grass (A1) and *Gliricidia sepium* (A2)] and Factor B represented the distance to the chicken cage [1.5 m (B1), 3 m (B2) and 100 m (B3)]. This study used 240 sixty-weeks-old ISA brown hens assigned to 240 individual cages (1 hen/cage). The cage size was 20 m×10 m. Individual metabolic cages were 40 cm× 40 cm×60 cm. All experimental diets were based on corn, soybean meal and palm kernel meal and formulated to be isocaloric (2,700 ME kcal kg^{-1}) and 17% crude protein. Plants were cultivated in a pot system (Fig. 1). Pots containing the experimental plants (Dwarf elephant grass and *Gliricidia sepium*) and growth medium were placed inside the socket pots. Plants were watered twice per day and given slow-release standard fertilizer once. Plants were grown for 5 months and trimmed 4 times.

The ammonia concentration (ppm) was measured using BW Technologies GAXT-A-DL Gas Alert Extreme NH_3 Single Gas Detector at the cage. The plant height (cm/plant), dry matter forage yield (kg/pot) and protein content (%) according to proximate analysis[17] and *in vitro* dry matter digestibility (IVDMD) (%) were measured among plants[18].

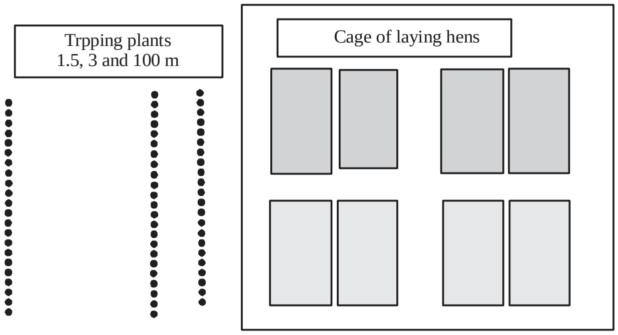

Fig. 1: Cage layout on the farm with greenery planted next to the coop

Table 1: Dry matter (DM) forage yield of dwarf elephant grass and *Gliricidia sepium* (kg/pot)

	Spacing from the cage (m)			
Treatment	1.5	3	100	Mean
Dwarf elephant grass	0.63	0.55	0.32	0.50^{a}
Gliricidia sepium	0.28	0.24	0.18	0.24^{b}
Mean	0.46^{a}	0.40^{a}	0.25^{b}	0.37

Different superscript letters in rows and columns show significantly different results ($p<0.05$)

Table 2: Height of dwarf elephant grass and *Gliricidia sepium* (cm)

	Spacing from the cage (m)			
Treatment	1.5	3	100	Mean
Dwarf elephant grass	91.33	92.50	70.67	84.83^{a}
Gliricidia sepium	251.58	200.17	136.50	196.17^{b}
Mean	171.58^{a}	146.33^{b}	103.58^{c}	140.50

Different superscript letters in rows and columns show significantly different results ($p<0.05$)

Statistical analysis: The data were analyzed by two-way analysis of variance and when significant ($p<0.05$), they were tested with the Tukey's test[19].

RESULTS AND DISCUSSION

Ammonia content at the study site: The highest concentration of ammonia was found in the laying hen coop (7.7 ppm), while at a distance of 1.5 and 3 m, the concentrations were 2.33 and 0.88 ppm, respectively. The concentration of ammonia was undetectable at a distance of 100 m. The ammonia concentration was strongly influenced by the distance from the exhaust fans[13].

Production of dry matter: Dry matter production (DM) of dwarf and gamal elephant grasses is shown in Table 1. The types and spacing of plants showed a very significant effect ($p<0.01$) on dry matter production. The result of Tukey's test ($p<0.05$) showed that the dry matter production of dwarf elephant grass (0.5 kg/pot) was higher than that of gamal (0.24 g/pot), while the spacing showed that B1 (0.46 kg/pot) was not significantly different from that of B2 (0.39 kg/pot), but was significantly different from that of B3 (0.25 kg/pot). The higher production on B1 and B2 shows that N derived from chicken manure can be utilized by mesophyll tissue in plant leaves. Dwarf elephant grass is a fast-growing plant and can be harvested at 80 days, after which it is harvested every 40 days. Each planted grass trimming can produce up to 60 tillers, increasing production. Dwarf elephant grasses grow in clumps with compact fibres and continue to produce saplings when trimmed regularly. Dense dwarf elephant grass can reach heights greater than 1 m[20]. The production of dry matter by dwarf elephant grass in this study was higher than 0.205 kg/stem[21] and approached the dry matter production of *Gliricidia sepium* (0.31-0.80 kg/stem[22]).

Plant height: The crop type and spacing of the chicken coop showed very significant differences ($p<0.01$) relative to plant height (Table 2). Further results from Tukey's test ($p<0.05$) on plant type showed that treatments A1 and A2 were significantly different between high-grade dwarf elephant grass (84.83 cm) and gamal (196.17 cm). The difference was caused by the characteristics of each plant. According to Muslihat[23], the difference in the height of each treatment is determined by the growth and growth of the cell, where the faster the cell divides and extends or grows, the faster the plant increases in height. Yasin *et al.*[24] stated that the average height of dwarf elephant grass is 117.2 cm and the average height of *Gliricidia sepium* is 196.17 cm, which is higher than the value reported by Winata *et al.*[25] (170.08 cm). Plant height significantly contributes to forage production.

Further Tukey's test ($p<0.05$) of plant spacing from the cage showed that the plant height at B1 (171.58 cm) was significantly different from those at B2 (146.33 cm) and B3 (103.58 cm) and that the plant height at B2 was significantly different from that at B3. The height of the plants decreased in line with an increase in the distance of the plant from the cage because the availability of N-ammonia decreases at a distance of 100 m from the cage, resulting in a decrease in the rate of photosynthesis. The rate of development of plant height after reaching the peak point will decrease with increasing age as the plant gradually decreases the rate of photosynthesis. The photosynthesis products are transported to the growing tissue. The fewer photosynthetic products are transported, the slower the growth. Eventually, the plant will stop growing[26].

Table 3: Protein content of dwarf elephant Grass and *Gliricidia sepium* (%)

	Spacing from the cage (m)			
Treatment	1.5	3	100	Mean
Dwarf elephant grass	16.82	14.82	10.70	14.15^a
Gliricidia sepium	23.70	21.58	20.04	21.77^b
Mean	20.26^a	18.25^a	15.37^b	17.96

Different superscript letters in rows and columns show significantly different results ($p<0.05$)

Table 4: *In vitro* dry matter digestibility (%)

	Spacing from the cage (m)			
Treatment	B1	B2	B3	Mean
Dwarf elephant grass	58.91	56.17	55.78	56.95^a
Gliricidia sepium	64.58	63.73	62.10	63.47^b
Mean	61.74	59.65	58.94	60.21

Different superscript letters in rows and columns show significantly different results ($p<0.05$)

Protein content: The mean protein contents of dwarf and gamal elephant grass are shown in Table 3. Variety analysis of plant species and plant spacing showed that the protein content of both plants differed significantly ($p<0.01$) from the crude protein content and that there was no interaction between the two factors. Further tests showed a higher crude protein content in *Gliricidia sepium* ($p<0.05$) than dwarf elephant grass. The leguminous plant protein content was higher than that of grass because legumes are included in the protein source feed, while the dwarf elephant grass is included in the fibre source feed. The content of dwarf elephant grass protein in this study (14.25%) was higher than that reported by Yasin *et al.*[24] (11.50%), while the protein content of *Gliricidia sepium* (21.77%) was higher than those of Aderinola and Binuomote[27](17.79%).

Further Tukey's test ($p<0.05$) showed that the plant protein content in B1 was significantly different from B2 and B3. The decrease in protein content with the increase in distance from the chicken coop was in accordance with a previous study conducted by Adrizal *et al.*[13], who stated that the N content of leaves is higher in plants that grow close to the ammonia gas drain than those that grow further away.

Dry matter digestibility *in vitro*: The results of plant variety analyses showed significantly different ($p<0.01$) levels of dry matter digestibility. Further BNJ assay results showed increased digestibility of *Gliricidia sepium* than dwarf elephant grass because the dwarf elephant grass has higher crude fibre content than *Gliricidia sepium*. A high content of crude fibre can cause a decrease in feed digestibility. The digestibility of *Gliricidia sepium* in this study was higher than that of Sukanten *et al.*[28] (52.37%), but lower than that of Ahn *et al.*[29] (79.1%). The *in vitro* digestibility of elephant grass dry matter in this research was 63.47% (Table 4), close to the value reported by Budiman *et al.*[30] (66.63%). Zailan *et al.*[31] reported that the dry matter digestibilities at 8 and 12 weeks of age were 66.63 and 60.53%, respectively. Yasin *et al.*[24] stated that the digestibility of dry matter leaves *in vitro* ranged from 71.08-72.93%.

N ammonia from manure has the potential to increase the production and quality of forage feed. Utilization of N ammonia from manure for plants can reduce contamination to the environment. Charles and Hariono[32] argued that ammonia gas can pollute the environment and decrease the appearance of livestock, increase the sensitivity of cattle to disease and decrease the work efficiency of the cage workers. Therefore, planting forage around the cage can reduce environmental pollution from ammonia.

CONCLUSION

Gliricidia sepium is effective at absorbing N-NH_3 from grass plants. The best distance is 1.5 m from the chicken coop.

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