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Efficacy of Nutrient Solutions Growing Fodder in a Greenhouse Hydroponic System in The Gambia

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ABSTRACT

Background and Objective: In The Gambia, feeding of ruminant animals was becoming a challenge. The study addressed the feeding gap and demand for ruminant animals because of the shortage and nutritious fodder and the need to find an alternative method to feed these animals. **Materials and Methods:** The 3 nutrient solutions in growing maize fodder in The Gambia were carried out between July and August, of 2022. Cow manure (CM), poultry manure (PM) and tap water (TW) in a Complete Randomized Design (CRD) with four replicates where maize was used to produce fodder in a low-cost greenhouse hydroponic. The 3 cycles of the experiment were carried out. GenStat was used to analyze the data in One-way Analysis of Variance (ANOVA). **Results:** On day 12, the height of maize fodder was 11.12 cm in PM and 7.55 cm in CM, significantly higher than 6.10 cm in TW. The weight of maize fodder from PM was 4.99, 4.25 and 4.12 kg/tray, significantly higher than TW. Water and nutrient use efficiency from PM and CM were significantly lower than TW. **Conclusion:** This work suggested that ruminant animals can be fed more conveniently by cultivating maize fodder hydroponically.

KEYWORDS

Maize fodder, poultry manure, cow manure, greenhouse, hydroponic

INTRODUCTION

Bamikole *et al.*[1] studied the effect of green fodder on dairy animals and reported that a vital component of animal productivity, reproduction and production is green feed. As a result, consistent feeding of high-quality green fodder to dairy animals is essential for sustainable dairy production. Numerous obstacles face the conventional way of producing fodder, including a lack of water, land, high-quality seeds, labor costs, increased fertilizer costs, longer development periods and more. Adeoye *et al.*[2] found that in a hydroponic system, 1.5-2 L of water is required for the germination of 1 kg of grain, whereas in a typical barley production system, 1 kg of green fodder requires 73 L of water. Al-Karakiand and Al-Hashimi[3] studied the production of animal feed using hydroponics and concluded that one way to grow plants without soil is hydroponically and that a new alternative method for producing feed for farm animals is hydroponics. It is a well-known method for producing large amounts of feed with minimal water usage and year-round output. Pagani and Mallarino[4] concluded that this method could be

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particularly significant in areas with poor fodder production. In the study conducted by Sillah[5] on the fodder production using water and maintained that creation of this planting strategy has made it possible to produce new fodder from grains such as oats, barley, wheat and others throughout the year.

The agriculture sector in The Gambia has the potential to meet its long-term development objectives, particularly food security and poverty reduction. The country's highly populated settlements have limited land resources and livestock only have very small areas for grazing because farmlands are seriously threatened by the expanding housing estate industry. The variation in crop and livestock yields from year to year due to environmental stresses like drought, high wind velocities and high or low temperatures, as well as the degradation and depletion of rangeland resources, pose a serious threat to the growth of the livestock sub-sector in The Gambia. Throughout the extended dry season in Gambia, bushfires frequently occur in rural areas, affecting over 70% of the nation's grasslands and woods on an annual basis. The development of livestock in The Gambia is severely hampered by the lack of animal feed and fodder. Naik *et al*.[6] studied feeding hydroponics maize fodder and submitted that year-round lack of consistent, high-quality green fodder availability brought on by shrinking agricultural land and water resources, the hydroponic system's ability to produce green fodder is becoming more and more significant with 7,140 square kilometers of agricultural land and 4590 square kilometers of pasture, 78.4% of the population is employed in agriculture; nevertheless, the amount of agricultural land is growing at a rate of 2.3% per year. The livestock industry imported £6.4 million worth of goods with animal origins and exported £0.1 million worth. Due to the varied use of agricultural wastes, there is potential for a rise in the demand for green fodder in The Gambia. Because of the growing demand on land for the cultivation of cash crops, food grains and other products, fodder crop production is not receiving enough attention to augment the limited pasture supplies. Fazaeli *et al*.[7] researched the hydroponic cultivation of maize fodder and submitted that the best option was to produce fodder hydroponically to complement the limited pasture supplies to meet the growing demand for green fodder. This will turn the livestock industry from a traditional low-output, subsistence economy into a modern industry driven by the market with diversified production bases and efficient value chains.

No empirical research on the potential and difficulties of hydroponic fodder production has been done in The Gambia yet. However, because of the unfavorable effects of climate change, the scarcity of land, the high cost and the use of rangelands, hydroponics could free up more space to produce other crops, enhancing the sustainability and economy of the land. Additionally, this technique removes extra strain from already overused areas. Thus, the goal of this research is to provide green fodder for several ruminant animals in The Gambia by growing hydroponically using various locally available and most-suited cereal maize under a low-cost screen house production system.

MATERIALS AND METHODS

Study site: The study was conducted at farm's teaching and research center in Nemakunku, Gambia, between July and August, 2022 which is situated one off the main highway in the Kombo Central West Coast Region of Brikama at Longitudes 13.39570.

Experimental unit: The hydroponic system consists of a metal frame with solar holes that were created and put together using materials found locally. Its dimensions are 2/2 m in width and 3 m in height and it uses corrugated sheets, cloths and binding wires. Clothes and corrugated sheets entirely enclose the improvised greenhouse.

Fertigation system: Using a watering can, nutrients were sprayed into trays. Water that was flowing from boreholes was used for irrigation. The crop in the hydroponics system receives the fertilizer solution after water and nutrients are combined in the watering container.

Experimental design: Completely Randomized Design (CRD) with four replications was used to treat the 3 nutritional solutions treatments:

- T1 = Control (tap water)
- T2 = 10% diluted cow manure
- T3 = 10% diluted chicken manure

Preparation of manure solution: Mahmoud[8] studied the manure solutions for a hydroponic experiment and submitted that the manure from the chickens and cows was placed in separate sacks made of porous cloth, which served as a strainer to separate the solid from the liquid. The manure was then placed in the water in a 20 L drum that had been cut to fit the barrel, with 1/3 of the manure filled and left for seven days to ferment and dissolve the nutrients. The beer was diluted ten times to give it a weak color.

Plant material: The 3 kg of maize grain was purchased from nearby farms and markets. After being cleared 3 times of debris and other extraneous elements, the viability of the seeds was assessed by a germination test. Before being distributed in half-cut 5 L gallons, clean seeds were cleaned, sterilized in a bleach solution of 10 mL and placed in plastic buckets designated for the germinating chamber. The seeds were steeped in tap water for 60 hrs.

Seed cultivation: After the seeds were soaked in water for 60 hrs to break their dormancy, 5 L of half-cut seed were utilized to sow seeds with a 2 cm seed thickness. To create a drainage port, holes were drilled in 5 half-cut litter gallons. Trays containing seeds were arranged shortly after germination. Throughout the experiment, the room's environmental parameters were regulated and consistently distributed throughout. Grow bins were checked every day during this period to monitor development and replenish any water lost through evapotranspiration with the source water stock solution that had been prepared for 14 days. The seedling achieves a specific height (over 10 cm) after this phase. Its dense white roots and dark green colour give it a carpet-like appearance[9].

Fodder yield: The total yields of green and dead fodder: Each tray's representative 300 g green fodder subsample was divided into green and dead/yellow (if any) fodder. Weighed and documented individually, each unit was packaged in suitably labeled envelopes. The total biomass production per tray/treatment was the result of adding the two sub-units[7].

Total water use and its efficiency: To calculate total water usage and water use efficiency, the total amount of water added and drained out of trays was recorded daily for each tray during the experiment. The following equation was used to calculate the total amount of water utilized by plants (litres/tray):

- Following calculation was used to calculate the total amount of water required by plants (cm^3/tray)[10]
- Total water use is equal to the sum of the water added to irrigation and the water drained from trays
- Water use efficiency (WUE) was calculated using the following equation expressed in kg fresh weight/m^3 of water
- Water and Nutrient Use Efficiency (WNUE) is calculated as follows: Total water utilized (liter/tray)/Total green fodder produced (kg/tray)[10]

Statistical analysis: The statistical analysis and experimental design. Four replicates of the fully randomized design were used. GenStat was used to statistically evaluate the data. The means of the treatments were compared using LSD ($p \leq 0.05$) and probabilities of significance among the treatments (crops).

RESULTS AND DISCUSSION

Paired t-test value of the proximate analysis of cattle manure and chicken manure: Table 1 displays the findings from the analysis of the dry chicken and cattle manure utilized in the experiment. The proportion of organic content in cow dung was substantially higher than in chicken dung, at 82.5 and 70.0%, respectively. The pH of the soil did not significantly differ between cow and chicken dung. In contrast to cattle manure, which had an N content of 3.90%, chicken manure had a much higher value of 5.40%. The 2 organic manures did not differ significantly ($p<0.05$) in terms of their K content. There was no statistically significant difference in the phosphorus values between cattle and chicken dung.

Plant height (shoot length): The findings for maize plant height (Table 2) showed that at various times during the observation period (days 4, 8 and 12), there were substantially greater shoot lengths (1.00, 5.92 and 11.09 cm) in poultry manure. At various points during the study period (days 4, 8 and 12), cow manure (0.644, 3.85 and 7.54 cm) was observed after it. Regarding the poultry manure tea (treatment 2), white sprouts with a noticeable root and quickly opening leaves are observed. Leaf/Root mass is densely formed into several leaves, a well-formed root mass, a dark red stem and a well-developed, dark green shoot mass.

On the 4, 8 and 12 days of observation, respectively, a noticeably shorter shoot length (0.46, 2.71 and 5.54 cm) was noted in tap water. In the second and third cycles of maize fodder production, the same observation was made.

Yield of hydroponic fodder (kg): The yield of maize fodder treated with tap water (TW), cow dung (CM) and poultry manure (PW) at the 4, 8 and 12 days of harvest is displayed in Table 3. The yield of maize fodder differed significantly depending on whether tap water (TW), cow dung (CM) or poultry manure (PM). On the 4th day, the values for tap water, cow dung and poultry manure ranged from

Table 1: Proximate analysis of cattle manure and chicken manure (%)

Properties	Cattle (dairy) manure (%)	Chicken (layer) manure	Mean difference	t-value
Dry matter (%)	12.70	25.20	-12.87	0.00*
Organic matter (%)	82.50	70.00	12.20	0.00*
pH	7.40	7.50	-0.40	0.10^{ns}
Total nitrogen (%)	3.90	5.40	-1.63	0.07*
Total potassium (%)	2.60	2.30	0.18	0.188^{ns}
Total phosphorus (%)	0.70	2.10	-1.80	0.13^{ns}

*Significant at $p<0.05$, ns: Not significant and 1 g/kg: 0.1%

Table 2: Effect of TW, CM and PM on plant height (cm)

	1st cycle			2nd cycle			3rd cycle		
TRT	Day 4	Day 8	Day 12	Day 4	Day 8	Day 12	Day 4	Day 8	Day 12
TW	0.46^{b}	2.71^{c}	5.54^{c}	0.56^{b}	2.73^{c}	6.00^{c}	0.50^{b}	2.74^{c}	6.10^{c}
CM	0.64^{b}	3.85^{b}	7.54^{b}	0.65^{b}	3.90^{b}	7.57^{b}	0.65^{b}	3.90^{b}	7.55^{b}
PM	1.00^{a}	5.92^{a}	11.09^{a}	1.10^{a}	6.00^{a}	11.23^{a}	1.20^{a}	5.90^{a}	11.12^{a}

Means on the same column followed by the same letter are not significantly different at $p<0.05$, TRT: Treatment, TW: Tap water, CM: Cow manure and PW: Poultry manure

Table 3: Effect of TW, CM and PM on weight measured in kg/tray

	1st cycle			2nd cycle			3rd cycle		
TRT	Day 4	Day 8	Day 12	Day 4	Day 8	Day 12	Day 4	Day 8	Day 12
TW	3.82^{b}	4.02^{c}	4.11^{b}	3.86^{b}	4.05^{c}	4.22^{b}	3.85^{b}	4.06^{b}	4.12^{b}
CM	3.90^{b}	4.43^{b}	4.57^{a}	3.94^{b}	4.47^{b}	4.48^{a}	3.91^{b}	4.44^{a}	4.25^{a}
PM	4.23^{a}	4.93^{a}	4.96^{a}	4.97^{a}	4.91^{a}	4.98^{a}	3.93^{a}	4.80^{a}	4.99^{a}

Means on the same column followed by the same letter are not significantly different at $p<0.05$, TRT: Treatment, TW: Tap water, CM: Cow manure and PW: Poultry manure

Table 4: Effect of TW, CM and PM on water and nutrient solution use m^3/tray

	1st cycle			2nd cycle			3rd cycle		
TRT	Day 4	Day 8	Day 12	Day 4	Day 8	Day 12	Day 4	Day 8	Day 12
TW	2.75^{ab}	1.52^{b}	0.52^{c}	2.62^{ab}	1.92^{b}	0.62^{b}	2.72^{b}	1.42^{b}	0.82^{b}
CM	2.82^{ab}	2.05^{a}	1.07^{b}	2.92^{a}	2.15^{a}	1.17^{b}	2.82^{b}	2.04^{a}	1.67^{a}
PM	2.90^{a}	2.02^{a}	1.45^{a}	2.95^{a}	2.22^{a}	1.65^{a}	2.94^{a}	2.02^{a}	1.65^{a}

Means on the same column followed by the same letter are not significantly different at $p<0.05$, TRT: Treatment, TW: Tap water, CM: Cow manure and PW: Poultry manure

Table 5: Water and nutrient solution use efficiency kg/m^3

	1st cycle			2nd cycle			3rd cycle		
TRT	Day 4	Day 8	Day 12	Day 4	Day 8	Day 12	Day 4	Day 8	Day 12
TW	1.39^{a}	2.65^{a}	7.90^{a}	1.47^{a}	2.31^{a}	6.81^{a}	1.42^{a}	2.86^{a}	5.02^{a}
CM	1.39^{a}	2.56^{a}	4.57^{b}	1.45^{a}	2.21^{a}	3.83^{b}	1.39^{a}	2.38^{b}	2.94^{b}
PM	1.38^{a}	2.44^{b}	3.43^{c}	1.38^{b}	2.11^{a}	3.02^{c}	1.37^{a}	2.39^{b}	3.02^{c}

Means on the same column followed by the same letter are not significantly different at $p<0.05$, TRT: Treatment, TW: Tap water, CM: Cow manure and PW: Poultry manure

3.82, 3.9 and 4.23 kg, respectively. In contrast, there was no significant difference between the 3 types of manure. On the 4th day, the amount of PM from the chicken manure was much higher than that of the cow manure and tap water. In a similar vein, the tendency continued on the eighth day of harvest, with higher tap water, cow manure and poultry manure values of 4.02, 4.43 and 4.93 kg, respectively. On the twelfth day of harvest, there was no significant difference in the yield reported from tap water and cow manure, but there were statistically higher values between chicken manure, cow manure and tap water. In the second and third cycles, similar patterns were noted, occasionally with slightly higher levels.

Water and nutrient solution use: Table 4 presents the water and nutrient use efficiency. On the fourth day, the treatments did not significantly differ in the amount of tap water used compared to the other treatments; the values for tap water, cow dung and poultry manure, respectively, range from 2.75 to 2.82 and 2.90 m^3. On the eighth day, the values for TW, CM and PM ranged from 1.52, 2.05 and 2.02 m^3, respectively. This indicates that, although there was a significant difference in the amount of water and nutrients used between PM, CW and TP, there was no significant difference between TW and CM. The amount of water and nutrients used at the 12 day mark varied significantly between the treatments; values ranged from 0.52 to 1.07 to 1.45 for TW, CM and PM, respectively. However, when it came to the amount of water and nutrients used, there was no discernible difference between TW and CM. With slightly higher values at the second cycle, the pattern was comparable to the third and second cycles.

Water and nutrient solution use efficiency (WNUE) kg/m^3: There are no appreciable differences in water and nutrient utilization efficiency across the different treatments. However, because of the higher yield and increased usage of water and nutrients, the efficiency of water and nutrient use rose with the number of days. On the eighth day, the WNUE values for PM, CM and PM range from 2.44, 2.56 and 2.65, respectively. The values for PM and other categories are statistically different, while the values for Tw and CM stay the same. By the twelfth day, there was a significant variation in the WNUE across all treatments, with TW recording the highest values (7.90), followed by CM (4.57) and PM (3.43). In the second and third cycles of cultivation, the tendencies were consistent, but significantly higher values were noted.

DISCUSSION

Both cow manure (CM) and poultry manure (PM) have good organic matter values that support soil fertility, crop growth and yield; however, the CM sample had a significantly higher organic carbon value than the PM sample, suggesting that the CM sample may be a better source of organic carbon than the PM sample. Furthermore, a high nitrogen (N) fraction indicated that PM might be a better source of N.

This result was consistent with the findings of Adeoye *et al.*[2], who thought that poultry manure has a significantly higher percentage of nitrogen. The pH values of cow dung (CM) and poultry manure (PM) indicate that if both types of manure were utilized in hydroponic maize fodder growing, the nutrients would be more soluble and accessible. This was consistent with the study conducted by Pagani and Mallarino[4] findings. They believed that between pH 6.5 and 7.5, more nutrients, including N, P, K, S, Ca and Mg, are accessible. Additionally, Bamikole *et al.*[1] thought that although wheat had a greater nutrient composition than borehole water and fish hatchery water (FHW), using nutrient solution (NS) to produce fodder was not optimal ($p<0.05$) for maize.

The treatment solution including cow dung (CM) and poultry manure (PM) instead of tap water (TW) may have a greater concentration of macro and micronutrients, which could account for the noticeably larger length and weight yield seen in the solution. Chicken dung is the most favoured organic fertilizer because of its high amount of organic matter, availability and concentration of plant macro- and micronutrients that are easy for plants to absorb. If enough chicken dung is spread, it can meet the plant's nutritional needs. Olojugba and Cinedu[9] studied the combined use of dry cocoa bean test ash (*Theobroma cacao* L.) and Poultry Dropping for the Improvement of Soil Fertility and Maize (*Zea mays* L.) Growth and Yield on a Humid Alfisol Southwestern, Nigeria and submitted that using chicken manure tea as a balanced source of nutrients in an accessible form in the rhizosphere, growth stimulants and disease suppressors is becoming a standard agricultural technique in organic farming's sustainable crop production. Gross *et al.*[10] also researched the nutrient solution and reported that chicken manure contains the highest levels of nitrogen, phosphorous and potassium among organic fertilizers. It's interesting to note that, according to Al-Karaki and Al-Hashimi[3], hydroponic fodder production uses just 3-5% of the water required to produce the equivalent amount of forage produced in the field. Naik *et al.*[11] studied water efficiency in the production of fodder and submitted that approximately 1.50 L of water (if recycled) to 3.0 L of water (if not recycled and drained off) are needed to produce one kilogram of maize fodder.

Water and nutrient solution use efficiency (WNUE) kg/m^3: Water is the only factor needed for seed germination and growth at that point, according to Naik *et al.*[11], who maintained that water is one of the fundamental requirements for seed germination and seedling growth because it is necessary for enzyme activation, reserve storage breakdown, translocation and use in seed germination and seedling growth. This could explain the non-significance of water use and water use efficiency in Table 4-5 in the treatments applied. According to the maize fodder yield Table 3-5, the efficient use of water and manure solutions from cows and poultry on days 8 and 12 resulted in a higher yield of maize fodder, as supported by studies conducted by Fazaeli *et al.*[7] and Naik *et al.*[11], these studies submitted that a comparison of hydroponic maize grown with tap water versus nutrient solution revealed that sprouts grown with the former had higher crude protein and ash contents than those grown with tap water. The barley fodder made with nutrient solution had greater amounts of Ca, K, P, Mg, Na, Fe, Cu and Zn. Their study concluded that using nutritional solutions raises the cost of producing fodder.

Poultry manure (PM) was found to have used water efficiently on the 8 and 12th days, followed by cow manure (CM) as described in Table 4-5. This may be due to the high organic matter, which acts as a water storage facility because it contains humus and fair amounts of potassium (K) and nitrogen (N), 2 nutrient elements that have a high affinity for water and thus improve water use in crop production. In the study carried out by Naik *et al.*[11], where they compared field production with hydroponic green fodder production, they submitted that more water-efficient method of generating green fodder. They went further to submit that water requirements for field crops are relatively high, requiring 30 L of water per kilogram of green fodder. In contrast, green fodder cultivated hydroponically requires as little as 1.5-3 L of water per kilogram of green fodder.

In the present study, for any success in ruminant production in The Gambia, hydroponic cultivation of fodder with the application of homemade manure from animal sources was of great benefit. This implies timely and consistent availability of water as well as organic matter from animal sources to serve as a growth stimulator and again, water must be available as and when needed.

CONCLUSION

In the present-day study, it was observed that maize fodder yield was increased by the addition of poultry and cow manure solution over tap water. In the same vein, poultry nutrient solution uses less water to produce more fodder and the length of the maize fodder also increased with the use of poultry nutrient solution. Also, cow manure increased maize fodder yield more and above the use of tap water. For hydroponic farming, the 12th day of harvest was set aside for the best yield and harvest.
More studies are recommended for testing cereal crops.

SIGNIFICANCE STATEMENT

This study focused on creating affordable maize fodder for ruminant animals using a low-cost hydroponic method. The goal was to address the feeding gap for ruminant animals in The Gambia by using high-yielding and fast-growing cereals. The 3 nutrient solutions were used: Cow manure (CM), poultry manure (PM) and tap water (TW). The results showed that poultry manure significantly increased fodder weight and water use efficiency. Proper management of this method could provide a better alternative for feeding ruminant animals with highly nutritious cereal fodder and reduce feeding costs.

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