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Article

Effect of different organic nutrient solutions and day of harvest on growth, biomass yield and chemical composition of hydroponically grown sorghum

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Abstract: An experiment was carried out to investigate the effect of different organic nutrient solutions and day of harvest on growth parameters, biomass and chemical composition of hydroponically grown sorghum red fodder. The experiment was a 3 × 2 factorial design comprising of 3 nutrient solutions (cattle, poultry and rabbit) and 2 harvesting regimes (8th and 10th day). Cattle, poultry and rabbit dungs were collected fresh and processed into nutrient solutions. Sorghum red seeds were treated, planted on trays, and irrigated twice per day with organic nutrient solution according to the treatments. Growth parameters which were investigated included fodder mat thickness, seedling height, leaf length and width, number of leaves, fresh and dry matter yield; and proximate composition. The results showed that sorghum red fodder irrigated with cattle manure nutrient solution (NS) harvested at 10 days was higher in all, except one (fodder mat thickness) of the growth parameters considered. The crude protein (CP) was highest and similar ($P > 0.05$) for Poultry NS harvested at 8 and 10 days, and Cattle NS at 10 days (13.13%, 12.67%, and 12.69% respectively). The ash content also favored Cattle NS at 10 days. Cattle NS at 10 days harvest was significantly ($P < 0.05$) the highest (7.00%), but comparable ($P > 0.05$) with Rabbit NS at 10 days for NDF. Fresh and DM yields were highest for Cattle harvested at 10 and 8 days respectively. The study recommends Cattle NS as hydroponic organic NS for sorghum red as it enhances fresh and dry matter yields, and nutritive values.

Keywords: hydroponic fodder; organic nutrient solution; cattle; poultry; rabbit

1. Introduction

"No farmer, No food; No food no nation". This is a common slogan for teeming Nigerian farmers, and it indicates that food is essential for the continuity of life. Among the essential nutrients found in food is protein, which is derivable from plant and animal sources. Ruminant animals remains the main source of animal protein consumed in Nigeria. The main and cheapest feed source for ruminants are natural pastures which are negatively affected by a number of factors, and produce inadequate supply, and low quality feed for the animals, especially during the dry season. Land scarcity is a major challenge of feed scarcity, leading to decrease in land meant for grazing and fodder cultivation. There is a need for an alternative method of making feed available enough to meet ruminant animal demand. The adoption of hydroponic technology or soilless farming for fodder production presents a solution that allows for all-year-round feed production of increased availability and enhanced quality.

The use of this technology has been identified to improve the development of livestock industry Masud and Bhowmik [1]. The standard or conventional chemical-based hydroponic nutrient solutions had been in use for this purpose; however, the

cost, technical know-how, and availability to farmers limit their use, and the widespread adoption of hydroponic technology. Ojo et al. [2] reported an enhanced nutritive value for the manured forage than the unfertilized that received no organic manure in an open field. Although, there is a dearth of information, positive results had been reported in the use of organic manure as nutrient solution for fodder production Adeyemi et al. [3]. Maize is a common cereal used for hydroponic fodders, however sorghum is also known for its versatility and adaptability Gouws and Botha [4] Sorghum as hydroponic fodder presents a unique approach to livestock feed production, offering increased efficiency and reduced resource requirements Meraz-Murillo et al. [5].

A number of research had been carried out on effect of day of harvest on hydroponically produced sorghum fodders with the use of chemical based-nutrient solutions Sriagtula et al. [6], Chrisdiana [7]. However, there is paucity of information on the use of organic nutrient solutions to investigate effect of harvesting days on sorghum. This study therefore investigates effects of three organic manure nutrient solutions (cattle, poultry and rabbit) and harvesting time (8 and 10 days) on the growth, biomass and proximate composition of hydroponically produced sorghum red fodder.

2. Materials and methods

2.1. Experimental site

This experiment was conducted at the Screen house of the Department of Pasture and Range Management, Directorate of University Farms (DUFARMS), Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria.

2.2. Manure collection and nutrient solution preparation

Fresh cattle, poultry and rabbit dungs were collected from the Livestock unit of Directorate of University Farms (DUFARMS), Federal University of Agriculture, Abeokuta (FUNAAB), and air-dried for 14 days. Air-dried cattle, poultry and rabbit dungs were crushed and put inside a jute bag, which was suspended in clean water at a ratio of 1:10 (animal dung: water). The settings were left for 72 h, after which the jute bag and the residue were discarded. The solutions were used as organic nutrient solutions. Mineral composition of each of the organic nutrient solutions sources (dungs), used in this study is shown on **Table 1**.

Table 1. Mineral composition of the nutrient solution sources.

Mineral composition (%)	Cattle	Poultry	Rabbit
Nitrogen	1.5	2.74	1.44
Phosphorus	1.37	1.89	2.87
Potassium	0.65	2.80	1.82
Calcium	2.08	2.95	1.65
Magnesium	1.18	1.68	1.85
Sodium	0.13	0.22	0.12

2.3. Seed sourcing and treatment

Local red sorghum seed was sourced from a reputable agro-allied store within Abeokuta metropolis. The seeds were subjected to germination test which was 95%. The seeds were properly cleaned of all impurities, weighed inside a cheesecloth and sterilized by soaking in water containing a pinch of common salt (NaCl) for 5 minutes, in order to prevent mouldiness. Seeds were later rinsed, and soaked in distilled water for 8 hours, after which they were transferred into damped jute bags until sprouting was initiated. Planting trays, cabinets, and the surrounding environment of the screen house were also cleaned and disinfected.

2.4. Experimental design

The study was laid in a 3 × 2 factorial experiment with 2 factors: Nutrient solution at 3 levels (cattle, poultry, rabbit), and day of harvest at 2 levels (8, 10 days). The 6 treatment combinations on planting plastic trays were replicated 3 times, and randomly arranged on each shelf of the cabinet.

2.5. Planting and irrigating with nutrient solution

Sprouted seeds were spread on trays, and were irrigated twice (morning and evening) daily with 50 mL per time, to make a total of 100 mL of the different organic nutrient solutions (ONS) per day. Planting trays were slightly tilted in such a way to allow draining of excess nutrient after seedling saturation. This was done two hours after each irrigation time, through the holes perforated at one side of the trays. The pH of the two organic manure nutrient solutions were above 7, but was maintained between 5.5 and 6.5 throughout the experiment by adding lime juice. Sprouted sorghum red seeds were irrigated with the respective manure nutrient solutions (cattle, poultry, and rabbit) according to the treatment. The nutrient solutions (50 mL) were applied at regular intervals in the morning and in the evening to maintain a consistent level of nutrient availability throughout the growing period.

2.6. Data collection

The data collected included fodder mat thickness, plant height, leaf length, leaf width, fresh yield, dry matter yield, crude protein, ash.

2.7. Harvesting and determination of biomass yield

Sorghum red hydroponic fodders were harvested 8th and 10th days after sowing. The complete yield was harvested fresh, subsamples were taken, oven dried and weighed to determine the dry matter % as

$$\text{Dry matter percentage (DM \%)} = \frac{\text{Weight of dry sample} \times 100}{\text{Weight of fresh sample}}$$

The dry matter yield was calculated as

$$\text{Dry matter yield (DMY)} = \text{total fresh weight} \times \text{DM\%}.$$

The fresh green matter yield and DMY were extrapolated to kg/m^2. Dry matter subsamples were weighed, oven dried at 65 ℃ until constant weight was attained. The dry fodder was milled to pass through 1 mm sieve, and used for chemical analysis.

2.8. Chemical analysis

Proximate composition of the sorghum red fodder samples were determined according to the procedure of AOAC [8], Neutral detergent fiber (NDF) was determined according to the procedure of Van Soest [9].

2.9. Statistical analysis

All data collected were subjected to two-way Analysis of Variance (ANOVA) SAS [10]. Treatment means were separated using Duncan Multiple Range, and means were declared different at $P < 0.05$.

3. Results

3.1. Effect of different nutrient solutions and day of harvest on growth parameters of hydroponic sorghum fodders

Table 2 presents a significant ($P < 0.05$) effect of different nutrient solutions and day of harvest on all growth parameters of hydroponic sorghum red fodders, except the leaf width and number of leaf ($P > 0.05$). For all the growth parameters considered, day of harvest was not significant ($P > 0.05$) for Cattle nutrient solution (NS) irrigated sorghum fodders. Fodder mat thickness differs significantly ($P < 0.05$) in the means recorded across the treatments. Fodders that received Poultry and Rabbit NSs harvested at day 10 were observed with the highest (1.70 cm) but similar ($P > 0.05$) mat thickness, with the least recorded in Cattle NS. As observed, Cattle NS had the highest and similar ($P > 0.05$) seedling heights at 8 and 10 days of harvest (17. 78 cm and 18.78 cm respectively). Poultry and rabbit NS also followed the same trend of no-significant-difference ($P > 0.05$) for the means of the seedling height at 8 and 10 days of harvest. Means of Leaf length ranged from 7.12 cm to 11.24 cm recorded for Rabbit and Cattle NSs respectively, both harvested at 10 days.

Table 2. Effect of nutrient solution and harvesting day on the growth parameters (cm) of hydroponically grown sorghum fodders.

Nutrient solution	**Cattle**		**Poultry**		**Rabbit**		**SEM**
Harvesting day	8	10	8	10	8	10	
Mat Thickness	0.50^{d}	0.52^{d}	0.70^{c}	1.70^{a}	1.00^{b}	1.70^{a}	0.094
Seedling height	17.78^{a}	18.78^{a}	13.60^{c}	$14.56b^{c}$	14.82^{b}	16.42^{b}	0.062
Leaf Length	11.24^{a}	10.98^{a}	9.30^{ab}	8.30^{b}	7.12^{c}	8.14^{b}	0.049
Leaf Width	0.40	0.38	0.39	0.36	0.40^{a}	0.42	0.019
No of leaf	2	2	2	2	2	2.2	0.33

$^{a, b, c,}$ means along the same row with different superscripts are significantly ($P < 0.05$) different.
SEM: standard error of mean.

3.2. Effect of different nutrient solutions and day of harvest on fresh and dry matter yields of hydroponic sorghum fodders

Fresh and dry matter yield of hydroponic sorghum fodders differed significantly ($P < 0.05$) in their means (**Figure 1**). Effect of different nutrient solution and day of harvest on sorghum fodders irrigated with cattle NS harvested at 10 days was

significantly ($P > 0.05$) higher for both fresh matter yield (17.98 kg/m^2) and DMY (4.50 kg/m^2) than values of the other treatments. The least yields—8.275 kg/m^2 fresh matter and 3.26 kg/m^2 DM were harvested at day 10 from Poultry NS.

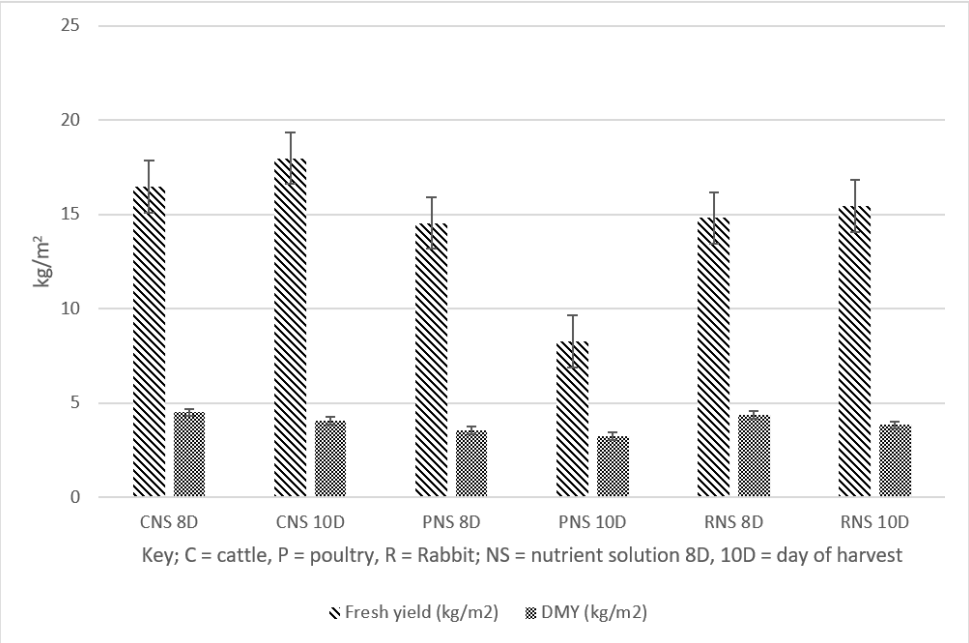

Figure 1. Effect of different nutrient solution and day of harvest on fresh and dry matter yield of hydroponic sorghum fodder.

3.3. Effect of different nutrient solutions and day of harvest on proximate composition of hydroponic sorghum fodders

Table 3. Effect of nutrient solution and harvesting day on the chemical composition (%) of hydroponically grown sorghum fodders.

	Cattle		**Poultry**		**Rabbit**		**SEM**
	8	**10**	**8**	**10**	**8**	**10**	
Dry Matter (%)	89.00^{b}	94.00^{a}	91.00^{b}	91.00^{b}	89.50^{b}	91.00^{b}	3.12
Crude Protein (%)	7.08^{c}	12.69^{a}	12.67^{a}	13.13^{a}	7.44^{c}	11.38^{b}	0.04
Ether Extract (%)	5.59	6.37	5.50	6.04	5.58	7.15	0.22
Ash (%)	5.66^{ab}	7.00^{a}	4.00^{bc}	6.67^{a}	2.67^{c}	2.66^{c}	0.48
NDF (%)	45.33^{ab}	47.33^{a}	43.00^{c}	44.00^{bc}	45.00^{abc}	46.33^{ab}	0.42

$^{a, b, c}$, means along the same column with different superscript are significantly different;
SEM = Standard Error Mean; NDF = Neutral Detergent Fiber.

Means for the DM content differed significantly ($P < 0.05$), with comparable ($P > 0.05$) lower values (89.00%–91.00%) recorded for all, except the sorghum fodders with cattle NS at day 10, which was higher (94.00%) than the rest (**Table 3**). Values of the crude protein (CP) were significantly ($P < 0.05$) different across the treatments, with similar ($P > 0.05$) values recorded for Cattle NS harvested at day 10 12.69%, and Poultry NS day 8 and 10 harvest (12.69% and 13.13% respectively). The same trend of similarity ($P > 0.05$) was observed with Cattle (7.08%) and Rabbit (7.44%) harvested at the 8th day. Ether extract was not influenced ($P > 0.05$) by the organic

nutrient solution and day at harvest. The ash contents ranged from (4. 00%–7.00%). The highest was observed from Cattle NS harvested at 10 days. Neutral detergent fiber (NDF) ranged between 43.0% recorded for Poultry NS sorghum fodders harvested at 8 days to 47.33% contents in Cattle NS fodders harvested at 10 days.

4. Discussion

Seedling height appears to be the most accessible growth parameter Ayoola and Adeniyan [11], an important indicator of the growth and biomass yield of a plant. The metabolism of the hydroponic fodders might have been more improved by cattle nutrient solution as reflected in its highest and similar ($P > 0.05$) seedling heights at 8 and 10 days of harvest. Seedlings of Poultry and rabbit NSs which were not affected ($P > 0.05$) by day of harvest is in line with Adeyemi et al. [3] who also reported comparable ($P > 0.05$) seedling height for hydroponically grown maize from different nutrient solutions. The values of the seedling height in this study are higher than those reported by Zalalem and Kassahun [12] sorghum grown hydroponically. The difference may be attributed to location and environmental factors; as plant height also measures effects imposed by environmental factors. A consistent increase in seedling height from 8th to 10th day of harvest across the NS may be attributed to age at harvest as seedling height increases with increasing age of plant. Leaves are important plant part, known to be positively correlated with, and determines the nutritive value of a forage plant, as they are more digestible than the stem.

Differences in the fresh and dry matter yield (DMY) may be as a result of different DM% of each treatment. The ability of each nutrient solution to hold and conserve nutrient rich moisture also differs. The DMY values in this study differ from those reported by Adeyemi et al. [3] who also used organic nutrient solutions to irrigate hydroponically produced swan-1 maize, and Lamidi et al. [13] who grew Oba 98 hybrid maize hydroponically. The difference may be due to the different cereals used. The biomass yield in this study increased from 8 to 10 harvesting day, except for the Rabbit NS, which is in line with the report of Chrisdiana [7], that longer harvesting time produced higher biomass yield.

Comparable DM contents observed in this study for hydroponic cereal fodders had been observed in the past studies Adeyemi et al. [3], Lamidi et al. [13]. Crude protein (CP) is a germane index of forage nutritive value as it is positively correlated with feed intake and digestibility. The range 7.08%–13.13% of the CP contents in this report is in line with Zalalem and Kassahun [12] for hydroponically grown sorghum varieties. All the values of CP reported in this research are above the threshold for ruminant animals NRC [14]. The contents of ash and NDF recorded for the sorghum hydroponic fodders are in tandem with the values reported in existing studies Adeyemi et al. [3], Zalalem and Kassahun [12], Lamidi et al. [13].

5. Conclusion

This study showed the possibility and positivity of the use of organic manure nutrient solution for hydroponically grown cereals. The 3 organic NS used in this study enhanced a relatively encouraging growth parameters, appreciable biomass yield and CP contents, above the threshold. Poultry and Rabbit nutrient solutions were higher

for fodder mat thickness, however, Sorghum fodders irrigated with Cattle NS harvested at 10 days had outstanding results in terms of seedling height, leaf length, fresh and DMY, ash and NDF contents. Irrigating red sorghum with cattle nutrient solution and harvesting on day 10 is hereby recommended.

Author contributions: Conceptualization, SA and VO; methodology, SA, TA and VO; software, TA and SA; validation, SA, AA (Adebayo Adetona) and OO; formal analysis, SA; investigation, AA (Amisu Ahmed) and MO; resources, SA and MO; data curation, TA, SA and OI; writing—original draft preparation, SA; writing—review and editing, SA, OI and AA (Adebayo Adetona); supervision, SA and VO; project administration, SA, VO, OO, AA (Amisu Ahmed) and AA (Adebayo Adetona). All authors have read and agreed to the published version of the manuscript.

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