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Article

Agronomic characteristics and chemical composition of hydroponic maize fodder as influenced by animal waste solutions

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Abstract: The growing of plants hydroponically is a soilless form of growing in modern day agriculture. It helps to make feed available for animals throughout the season since it is not affected by what is faced by field grown crops. The use of animal waste, that is, their faeces, in the growth of forage was compared with commercial hydroponics solutions as a way of looking for a reduction in the cost incurred in the purchase of commercial hydroponics solutions. The study evaluated the use of organic nutrient solutions (ONS) alongside a standard/commercial nutrient solution in growing crops hydroponically on the growth, dry matter yield, water use efficiency, and chemical composition of hydroponic maize fodder. The ONS used were formulated from the dried faeces of cattle, poultry, rabbits, and swine. The prepared organic nutrient solutions with the control were used in growing the maize seeds for 10 days, and growth, yield, and chemical composition were determined. Results show the highest (196 g) dry matter yield for maize hydroponic fodder irrigated with poultry ONS. Similarly, maize irrigated with poultry ONS was significantly ($P < 0.05$) higher in CP content, while it was not significantly different from maize irrigated with cattle, swine, and commercial solutions. A lower water use efficiency value (0.19 kg DM/m^3) was recorded for maize irrigated with cattle ONS. According to the study, irrigating maize with different organic nutrient solutions produced maize fodder with a higher yield and a similar chemical composition as the commercial nutrient solution.

Keywords: dry season feeding; feed scarcity; hydroponics; maize; organic nutrient solutions

1. Introduction

Feed scarcity has been the major factor that limits the productivity of livestock in Nigeria. Indeed, available feed in the form of forage has consistently been attenuated by climate change effects, declining land hectares for fodder production, urbanization, deterioration of fertile soil, prevailing water scarcity and natural calamities (frequent drought), constant conflicts with crop farmers and herdsmen for limited land space, and a lack of modern facilities like irrigation to cope with dry season stress [1]. Given the increase in demand for animal products as a result of the rising population, the livestock production system has been greatly intensified, raising demand levels for green fodder. However, the difference created between the request and provision of feed for animals is increasing at a fast pace, and as a result, farmers and researchers are in search of alternative fodder and fodder production options that can bridge the gap created. In this sense, soil-less farming (hydroponics culture) has been identified as a possible means whereby high quality and sufficient feed can be made available throughout the year by practicing vertical farming when compared with conventional farming methods.

The hydroponics technique requires less land, water, and manpower resources [2].

Although the use of commercial hydroponic nutrient solution, which is a chemical fertilizer that is required to grow the seeds as fodder, has been reported to have a remarkably appreciable impact on growth, yield, and the chemical composition of the fodders produced [3], its use can be expensive to acquire or formulate and is not readily available, especially to poor resource farmers. Aside from that, Mohsenzadeh et al. [4] reported that the production of chemical fertilizers from inorganic formulations for plant growth could cause natural ecosystems to experience imbalance. Formulating nutrient solutions from animal manures could possibly alleviate the highlighted problem associated with the use of commercial nutrient solutions. The use of processed poultry manure as a nutrient solution has been reported to have significantly improved the seedling height of the Swan-1 maize cultivar more than the use of NPK fertilizer, and dry matter yield and crude protein contents were comparable with the results observed with NPK fertilizer [3].

This study evaluated the effects of the use of processed animal faeces as liquid fertilizers in comparison with commercial hydroponics nutrient solutions on the growth, yield, and chemical composition of hydroponically grown maize fodder.

2. Materials and methods

Experimental location:

This study was conducted at the Pasture Experimental Unit Screen House of the Federal University of Agriculture, Abeokuta Farm, Ogun State, Nigeria (7°58′ N, 3°20′ E). The minimum and maximum monthly temperature of the screen house were 23 ℃ and 34.7 ℃.

Experimental design:

The study was arranged in a completely randomized design with 5 treatments (cattle, poultry, rabbit, swine organic nutrient solutions and already prepared hydroponics nutrient solution which served as the control) replicated three times.

Preparation of organic nutrient solutions and sowing of maize seeds:

Different air-dried animal manures (Cattle, Poultry, Rabbit and Swine) and a commercially purchased hydroponics solutions were used in conducting the research, with the latter serving as the control. The manures were ground, sieved and each manure were soaked at 1 kg to 10 L of water to dissolve. Supernatant from each manure solutions were filtered with two layers of cheesecloth to serve as organic nutrient solutions after 72 h of soaking in water. Commercial nutrient solution was prepared by dissolving 5 g of Sample A and 2.5 g of Sample B in 10 L of water. Nutrient element content of the hydroponic control solution used includes N (232 ppm), P (53 ppm) and (184 ppm). After the preparation of the nutrient solutions, the pH ranged from 7.2–8.1. Adjustment in pH was done with the addition of lime juice, thus, the pH was maintained between 6.0 and 7.0 throughout the period of the experiment.

The mineral composition of each of the animal faeces nutrient solutions used are shown on **Table 1**.

Table 1. Mineral composition of the nutrient solution sources.

Mineral composition (%)	Cattle	Poultry	Rabbit	Swine
Nitrogen	1.50	2.74	1.44	1.60
Phosphorus	1.37	1.89	2.87	1.71
Potassium	0.65	2.80	1.82	2.00
Calcium	2.08	2.95	1.65	3.00
Magnesium	1.18	1.68	1.85	1.90
Sodium	0.13	0.22	0.12	0.24

Premier Oba Super 2 maize seed was purchased from Farmers' agro-allied store in Abeokuta town. The seed viability test was carried out in the laboratory. Both the screen house surrounding as well as the planting trays were washed thoroughly and disinfected. Maize seeds were cleaned and later sterilized by soaking in sodium hypochlorite (20%) solution according to the procedure of Al-Karaki GN and Al-Momani [5] for 30 min to prevent mould growth. Afterwards, the seeds were removed and rinsed with clean water and was later soaked in water for about 8 h. The water was drained from the seeds and then incubated by covering with jute bags to initiate growth until there was about 70% and above sprouting. The seeds were spread in individual trays according to treatment in the screen house. Perforated trays containing the sprouted seeds were arranged on shelves in the screen house and tilted a bit to one side of the tray to allow the excess water to drain into a container in order to determine the water use efficiency. Maize seeds were sown at a rate of 100 g/tray. The seeds in the trays received different nutrient solutions two times per day (in the morning and in the evening). Each treatment was replicated 3 times. The system used was hydroponic fodder technique which is similar to deep water culture.

Determination of growth and dry matter yield of maize fodder:

The seedling length (plant height), leaf length and breadth parameters were taken with a measuring ruler from five plants per tray while the leaves per stand were counted in order to determine agronomy parameters of the fodders. Thereafter, the whole plants with the roots from the tray were harvested 10 days after sowing and the total herbage was weighed (g). Afterwards, the fodders were dried in a drying cabinet at 65 °C until constant weight was reached. The dry matter percentage was determined by dividing dried weight of the sample over fresh of the sample multiply by 100.

Dry matter yield (g/tray) was calculated by multiplying dry matter percentage by total weight of the fresh sample.

The total water uses efficiency of the maize fodders depending on different nutrient solutions was determined according to the procedure of Adeyemi et al. [3].

Chemical analysis:

The dried samples were milled and allowed to pass through a 1mm sieve screen following which the proximate composition was determined according to the procedure of AOAC [6].

Proximate analysis:

Procedure such as crude protein, ash contents and ether extract in the samples were determined by the Association of Official Analytical Chemists methods [6].

Crude protein:

The crude protein content of the samples was estimated by macro-Kjeldahl method, in which the sample was digested with a known quantity of acid. The digested material was distilled after the addition of alkali. The released ammonia was collected in 4% boric acid. Boric acid along with ammonia was titrated against 0.1 NH_4Cl and by multiplying with 6.25 percentages of nitrogen was converted into protein.

Crude fat or ether extract:

The crude fat or ether extract (EE) of the samples were performed by drying, milling and extracting with an organic solvent for 4 h and the remaining residue was dried and weighed. Ether extract was calculated as the difference between the original sample and the ether extract residue.

Ash:

Two grams of sample was put into crucible, the weight recorded and placed in muffle oven at 550 ℃ for 8 h.

Fibre fractions concentrations were determined according to Van Soest et al. [7].

Statistical analysis:

Data obtained from this experiment were analyzed using one-way analysis of variance option of the SPSS (IBM SPSS Statistics 23) software. Treatment means were statistically compared using Duncan's Multiple Range Test.

3. Results

Mean values recorded for seedling height, leaf length, leaf width, and number of leaves were not affected ($p > 0.05$) by different nutrient solutions (**Table 2**). The highest green fodder yield and DMY were recorded for maize hydroponic fodder irrigated with poultry organic nutrient solution (ONS).

Table 2. Growth and dry matter yield of hydroponic maize fodders grown with different nutrient solutions.

	Nutrient solutions						
Parameters	**Cattle**	**Poultry**	**Rabbit**	**Swine**	**Commercial**	**SEM**	***P*-value**
Seedling height (cm)	21.74	23.88	23.68	23.64	20.54	0.50	0.120
Leaf length (cm)	14.12	16.08	51.36	16.12	14.78	7.87	0.530
Leaf width (cm)	1.06	0.90	1.12	0.98	1.22	0.05	0.240
Number of leaf	2.60	2.80	2.80	2.80	2.40	0.11	0.760
Root mat thickness (cm)	1.00^{b}	1.00^{b}	2.00^{a}	0.80^{c}	1.00^{b}	0.09	0.0001
Green fodder yield (g/tray)	453.30^{c}	486.00^{a}	480.70^{b}	376.00^{e}	451.30^{d}	12.03	0.0001
Green fodder: Initial seed ratio	4.53^{c}	4.86^{a}	4.81^{b}	3.76^{d}	4.51^{c}	0.10	0.000
Dry fodder yield (g/tray)	108.00^{d}	196.00^{a}	188.00^{b}	102.00^{d}	186.00^{c}	1.70	0.0001

$^{a–e}$ means on the same row with different superscript are significantly ($P < 0.05$) different; SEM = standard error of mean.

No significant ($p > 0.05$) differences were recorded in the total water used of the maize fodders irrigated with different nutrient solutions. However, there was significant difference ($P < 0.05$) in the dry matter yield of the maize fodder for the total water use efficiency for all the organic nutrient solutions (ONS) having higher significant difference when compared with that of control (**Table 3**).

Table 3. Water use efficiency of hydroponic maize fodders grown with different nutrient solutions.

	Nutrient solutions						
Parameters	**Cattle**	**Poultry**	**Rabbit**	**Swine**	**Commercial**	**SEM**	***P*-value**
Water use (Litres/tray)	0.57	0.55	0.61	0.53	0.56	0.06	0.619
Total water use (Litres/kg fresh matter)	1.25	1.26	1.13	1.41	1.25	0.04	0.402
Water use efficiency (kg fresh matter/m^3)	0.80	0.89	0.79	0.75	0.80	0.03	0.568
Water use efficiency (kg dry matter/m^3)	0.19^b	0.36^a	0.31^a	0.40^a	0.33^a	0.02	0.001

^{a,b} means on the same row with different superscript are significantly ($P < 0.05$) different.

The crude protein and fibre fractions of maize were significantly ($P < 0.05$) affected by the different organic nutrient solutions (**Table 4**). Maize irrigated with the rabbits ONS had the significant least value of CP than maize irrigated with poultry ONS while other treatments had higher ($P < 0.05$) values for maize above the ones that are irrigated with rabbits. Similar ($p > 0.05$) values of crude protein contents were recorded for maize irrigated with other nutrient solutions.

Table 4. Chemical composition of maize grown hydroponically using different organic nutrient solutions.

	Nutrient solutions						
Parameters	**Cattle**	**Poultry**	**Rabbit**	**Swine**	**Commercial**	**SEM**	***P*-value**
Proximate composition (g/kg DM)							
Dry matter	980.00^a	948.50^b	955.00^b	945.00^b	95.00^b	3.70	0.001
Crude protein	149.40^{ab}	175.40^a	140.00^b	149.00^{ab}	145.40^{ab}	4.90	0.162
Ether extract	50.80	69.30	78.60	80.90	76.50	5.20	0.399
Ash	55.00	61.50	65.00	55.00	55.00	2.20	0.498
Non fibre carbohydrate	291.40	318.80	316.30	309.30	312.30	6.70	0.783
Fibre fractions (g/kg DM)							
Neutral detergent fibre	453.30^a	375.00^b	400.00^{ab}	405.80^{ab}	410.80^{ab}	9.10	0.065
Acid detergent fibre	160.00^{ab}	180.10^a	153.30^b	151.00^b	167.50^{ab}	3.90	0.087
Acid detergent lignin	40.00^c	47.00^b	42.70^{bc}	58.50^a	45.00^{ab}	1.80	0.000
Hemicellulose	293.3^a	194.90^c	246.70^b	254.80^b	243.30^a	0.95	0.002
Cellulose	120.00^a	133.10^a	110.70^{ab}	92.50^b	122.50^a	0.47	0.038

^{ab} means on the same column with different superscript differ significantly ($P < 0.05$); SEM: Standard error of mean.

4. Discussion

Although, all animal manures provide basic nutrient needs of nitrogen, phosphorus and potassium to increase plant growth, however plant-consuming animals seem to produce a carbon-rich manure for the release of organic matter manures [8]. The result in this study is in consonance with the report of Wolfe [8] who alluded to the fact that poultry manure supplies more nitrogen for plant use.

All the organic nutrient solutions performed relatively well in enhancing the fodder yield of the maize together with the control treatment. This showed that a level of saturation of the nutrients could have been attained despite the different mineral contents in them. This observation was not in line with the findings by Adeyemi et al. [3], who reported no difference in the dry matter yield of maize fodder grown hydroponically. The yield recorded in the maize fodders revealed the ability of the rooting system to uptake nutrients that have been dissolved in the organic solutions for their maximum usage. This revealed the potential of organic solutions to be produced at relatively lower economic cost than the control.

The higher water uses efficiency (WUE) recorded for maize fodder irrigated with ONS translated into higher fodder dry matter yield. The range of WUE values reported in this study was around 0.23–0.26 kg/m^3 reported by Adeyemi et al. [3] for maize fodder irrigated with organic and chemical fertilizer solutions. It can be seen that there was better nutrient usage in this study when compared with what can be realized from irrigating maize grown on the field. The water use efficiency values for the dry matter yield of fodder maize in this study was reduced in the volume when compared with maize cultivated (0.44–8.47 kg/m^3) on the soil according to Nilahyane et al. [9] that yielded the same quantity of maize yield when compared with hydroponically maize fodders. Growing of fodders hydroponically will go a long way to grow fodders successfully in areas prone to drought because of limited quantity of water used by the method.

However, the CP values in the maize irrigated with different ONS were all above recommended requirements for animals [10]. In their study, Ergon et al. [11] reported that N content obtained from any source of fertilizer, has the potential to change the chemical composition of plants, which is evident in our study with high CP content of maize fodder. The CP content of maize in this study fall within the values of 13.53%–17.34% reported by Lamidi et al. [12] for hydroponic maize fodder and higher than 8.88% recorded by Adeyemi et al. [3] for Maize irrigated with organo-mineral NS. The differences in the results could be as the results of different solutions used to irrigate and different varieties of maize used.

The NDF content of maize irrigated with cattle ONS was higher than the one irrigated with poultry ONS. However, the NDF contents of the maize irrigated with all ONS where all below the threshold of 65 g/kg and as such animals fed with the hydroponics maize will not have impaired intake and digestibility [13].

5. Conclusion

Irrigating maize with different organic nutrient solutions produced maize fodder with a higher yield and quality than the commercial nutrient solution. The use of organic nutrient solutions may go a long way toward reducing the cost incurred by hydroponics farmers.

Author contributions: Conceptualization: VO; methodology: TA; supervision: VO, SA and OA; investigation: EBT, VH and MO; data curation: DO; project administration: VO and SA; writing—original draft preparation: VO; writing—review and editing: VO, SA and OA; All authors have read and agreed to the published version of the manuscript.

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