Herbage yield and nutritional composition of selected fodder crops under hydroponic

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Abstract

This study was conducted to evaluate the herbage yield and nutritional values of maize, millet, white sorghum and red sorghum grown under hydroponic system in other to ensure sustainable fodder for livestock production. The experiment was laid out in a completely randomized design with grain trays laid out into 12 groups comprising 4 treatments (maize, millet, white and red sorghum) with 3 replicates. Grains in each treatment group were grown in a nutrient solution placed under a natural illumination in a growth chamber. Seeding rate of 500g of the fodder /tray were used. Fodder were harvested 7 days after planting. The result of herbage yield showed that maize, millet and white sorghum fodders had better herbage yield (950g sprouts) each compared to red sorghum fodder. The proximate composition of the fodder was significantly different (P<0.05) across the treatment groups. Dry matter content of the red sorghum fodder was higher (88.09%) and lower (87.51%) for white sorghum fodder. The crude protein content of red sorghum fodder was higher (15.33%) while that of maize fodder (12.84%) was the least. Crude fiber value was higher in millet fodder (11.77%) than maize (9.65%), white sorghum (10.64%) and red sorghum (11.55%) fodders. However, Gross energy of the fodder ranged from 3960.00 to 4071.00 kcal/kg being higher for red sorghum and lower in maize fodder. Macro and micro mineral concentration was higher in red sorghum fodder than other fodders. In conclusion, red sorghum had superior nutritional values and which is a potential feed resource for optimal livestock production.

Keywords: Fodder yield, Hydroponics, Proximate composition

Rendement en herbage et composition nutritionnelle de cultures fourragères sélectionnées sous système hydroponique

Résumé

Cette étude a été menée pour évaluer le rendement en herbage et les valeurs nutritionnelles du maïs, du mil, du sorgho blanc et du sorgho rouge cultivés sous système hydroponique dans d'autres pour assurer un fourrage durable pour la production animale. L'expérience a été disposée selon un dispositif complètement randomisé avec des plateaux à grains disposés en 12 groupes comprenant 4 traitements (maïs, mil, sorgho blanc et rouge) avec 3 répétitions. Les grains de chaque groupe de traitement ont été cultivés dans une solution nutritive placée sous un éclairage naturel dans une chambre de croissance. Un taux de semis de 500g de fourrage/plateau a été utilisé. Le fourrage a été récolté 7 jours après la plantation. Le résultat du rendement de l'herbe a montré que les fourrages de maïs, de mil et de sorgho blanc avaient un meilleur rendement d'herbe (950 g de germes) chacun par rapport au fourrage de sorgho rouge. La composition immédiate du fourrage était significativement différente (P<0,05) entre les groupes de traitement. La teneur en matière sèche du fourrage de sorgho rouge était plus élevée (88,09%) et plus faible (87,51%) pour le fourrage de sorgho blanc. La teneur en protéines brutes du fourrage de sorgho rouge était la plus élevée (15,33%) tandis que celle du fourrage de maïs (12,84%) était la plus faible. La valeur de la fibre brute était plus élevée dans les fourrages de mil (11,77 %) que dans les fourrages de maïs (9,65 %), de sorgho blanc (10,64 %) et de sorgho rouge (11,55 %). Cependant, l'énergie brute du fourrage variait de 3960,00 à 4071,00 kcal/kg, étant plus élevée pour le sorgho rouge et plus faible pour le maïs fourrager. La concentration en macro et micro minéraux était plus élevée dans le fourrage de sorgho rouge que dans les autres *fourrages. En conclusion, le sorgho rouge a des valeurs nutritionnelles supérieures et constitue une ressource alimentaire potentielle pour une production animale optimale.*

Mots-clés : Rendement fourrager, Culture hydroponique, Composition immédiate

أجريت هذه الدراسة لتقييم محصول الأعشاب والقيم الغذائية للذرة والذرة البيضاء والذرة الحمراء المزروعة في إطار نظام الزراعة المائية في نظم أخرى لضمان استدامة علف الإنتاج الحيواني وتم وضع التجربة بتصميم عشوائي تمامًا مع صواني الحبوب الموضوعة في اثنتي عشرة مجموعة تتألف من أربعة علاجات الذرة (والدخن والذرة الرفيعة البيضاء والحمراء) مع ثلاث نسخ. تمت زراعة الحبوب في كل مجموعة علاجية في محلول مغذي موضوعة تحت إضاءة طبيعية في غرفة النمو, تم استخدام معدل بذر 500 جرام وتم حصاد العلف بعد سبعة أيام من الزراعة.أظهرت نتيجة إنتاج الأعشاب أن الذرة والدخن وصواني الذرة الرفيعة البيضاء كانت أفضل (950 جرام براعم) كل منها مقارنة بأعلاف الذرة الرفيعة الحمراء كان التكوين القريب للعلف مختلفة بشكل كبير (P<0.05) عبر مجموعات العلاج. كان محتوى المادة الجافة من علف الذرة الرفيعة الأحمر أعلى(88.09%) وأقل (87.51٪) للذرة الرفيعة الأبيض. كان محتوى البروتين الخام لعلف الذرة الرفيعة الأحمر أعلى (15.33%) في حين أن علف الذرة كان الأقل (12.84%) كانت قيمة الألياف الخام أعلى في علف الدخن(11.77%) أكثر من الذرة (9.65%) والذرة الأبيض (10.64%) ومع ذلك، تراوحت الطاقة الإجمالية للعلف من 3960.00 to 4071.00 kcal/kg أحيث كون أعلى للذرة الرفيعة الحمراء وأقل في علف الذرة وكان تركيز المعادن الكلية والجزئية أعلى في علف الذرة الرفيعة الأحمر من العلف الآخر. في الختام، الذرة الرفيعة الحمراء لها قيم غذائية عالية الذي هو مورد علف محتمل للإنتاج الحيواني الأمثل

Introduction

The livestock production is a vital sub-sector of agriculture in most countries of the world to offset the wide spread of social and economic consequences of poverty. The productivity of this sector has been hindered due to poor nutrition and inadequacy of good quality feed despite the contribution of indigenous pastures to livestock as feed. Although fodder production and livestock feeding are the two important aspects of the sustainability of products and productivity in animal husbandry, issues of land degradation, desertification and deforestation are major limiting factors in livestock production. In many parts of the world, especially Sub-Saharan region, production of sufficient fodder tends to be a big challenge to livestock producers, due to limited land allocation, labour requirements, fertilizer and manure requirements, inadequate irrigation facilities, prevailing water scarcity and natural disaster.

The search for alternative feed resources over the past decades rekindled research the interests in the use of tropical browse plants as sources of nutrients for ruminants as well as non-ruminants (Gboshe and Ukorebi, 2020). Many types of forages are limited in quality and quantity due to drastic effect of season, maturity, rapid urbanization and industrialization, poor nutritive value, labour requirements, fertilizer and manure availability. Hence, there has been a call for smart agriculture which hydroponic fodders had been considered as an alternative to grass and legumes. Hydroponic is a system of growing plants in a soilless culture. Hydroponic fodder systems are usually used to sprout cereal grains such as barley, wheat, oats, sorghum and legumes such as alfafa, clover or cowpea. (Al-Karaki and Al-hashimi, 2012). This system is a well-known technique for high fodder yield, year-round production and least water consumption (Nyako *et al*., 2020). Based on the foregoing, this study determined the herbage yield and nutritional composition of some selected fodder crops cultivated under hydroponic system.

Materials and methods

Experimental location

The experiment was carried out at the College of Animal Science Greenhouse of the Teaching and Research Farm of Michael Okpara University of Agriculture, Umudike, Abia State. The site is located in the tropical rainforest zone of Nigeria on latitude 5° 29′ E with an elevation of 122m above sea level, annual rainfall of about 2177mm, a monthly ambient temperature range of 22-36°C and relative humidity 50-95% depending on period of season. Laboratory studies were carried out at the Biochemistry Laboratory of the Institute of Agricultural Research and Training, Moor Plantation, Ibadan.

Source of materials and hydroponic fodder production

Yellow maize, millet, white sorghum and red sorghum grains were purchased from an open market, (Ubani market) in Umuahia Abia State. They were thoroughly examined before purchase to determine quality grains. The nutrient solution, (D.I.-grow® growth booster and hydrogen peroxide) were purchased from a reputable Agro-chemical store within Umuahia Metropolis. Other materials including perforated trays and buckets were purchased from an open market in Umuahia. The grains were cleaned from debris and other foreign materials and thereafter subjected to germination test to check for the viability of the grains. Clean grains were washed and soaked seperately in hydrogen peroxide solution with about a liter of water for 20 minutes. The grains were later washed separately, then soaked with water for 24 hours. The water was drained and the seeds were incubated in top-perforated buckets for 24 hours before distribution in perforated trays. The trays were laid out into twelve (12) groups, which includes four (4) treatments comprising yellow maize, millet, white and red sorghum with 3replicates. Each group were grown in a nutrient solution under natural illumination in a growth chamber. The growing stage lasted for seven (7) days. Below is the arrangement of the experiment;

Table 1*: Tray Arrangement*

T1 (maize)	T2 (millet)	T3 (white sorghum)	T4 (red sorghum)
Tray1	Tray1	Tray1	Tray1
Tray2	Tray2	Tray2	Tray2
Tray3	Tray3	Tray3	Tray3

Grains of the fodder crops were sown in the perforated planting trays. A seeding rate of 500g of the fodder crops/tray were used. Trays were irrigated manually with organic hydroponic nutrient solution twice a day (7:30 am and 5:30 pm) at a fixed rate of 250mL/tray/day using a spray gun for about 30 seconds. The trays were kept in a cool and well-illuminated environment for a period of 7 days.

Experimental design and data collection

The experimental design of the study is Completely Randomized Design (CRD) using four treatments with three replicates. The linear model of the design is:

$Y_{ij} = \mu + T_i + E_{ij}$. Where; Y_{ij} is the individual observation, μ is the overall mean effect, T_{ij} is the treatment effect and E_{ij} is experimental error effect.

The following data were collected during the experiment:

Herbage yield

The seeds planted were weighed at the commencement of the experiment while incubated grains were also weighed at the end of incubation. At the 7th day of the experiment, the yield of fodder in each tray was weighed using weighing balance and recorded accordingly.

Proximate and mineral composition analyses

Proximate analysis of hydroponic fodders (sprouts) were determined according to the method of AOAC (2003). The gross energy of fodder sprouts was determined using Gallenkamp Ballististic Bomb Calorimeter according to the method of AOAC (2003). Calcium, potassium, sodium and phosphorus were determined using spectrophotometric method while manganese, magnesium, chromium, copper, iron and zinc were determined using Atomic Absorption Spectroscopy (AOAC, 2003).

Data analysis

All data obtained were subjected to analysis of variance (ANOVA). Treatment means where significant were separated using Duncan Multiple Range Test (Duncan, 1955) at 5% level of significance.

Results

Herbage yield of hydroponic fodders

Table 2 shows the herbage yield of the fodders. The weights of grains, incubated seeds and sprout yield showed no significant (P>0.05) difference across the treatment groups.

Table 2: ***Herbage yield of hydroponic fodders***

Parameters (g/tray)	Maize fodder	Millet fodder	White sorghum fodder	Red sorghum fodder	SEM
Grain weight	500.00	500.00	500.00	500.00	0.00
Incubated grains	860.00	766.00	833.00	700.00	23.47
Sprout weight	1450.00	1450.00	1450.00	1400.00	53.25
Sprout/herbage yield	950.00	950.00	950.00	900.00	53.24

Means without superscripts within rows are not significantly different (P>0.05)
SEM; Standard Error of Mean.

Proximate analysis of hydroponic fodders

Table 3 presents the proximate analysis of hydroponic fodders. The dry matter and ether extract showed the same level of significances where there was significant (P<0.05) differences across the treatment groups with values of red sorghum showing a higher significance followed by millet, maize and white sorghum respectively. The results of crude protein and gross energy showed that there was significant (P<0.05) differences across the treatment groups where values of red sorghum were significantly (P<0.05) higher than millet followed by white sorghum and maize fodders respectively. The result of crude fibre showed that the values of millet was significantly (P<0.05) higher than red sorghum followed by white sorghum and maize fodder respectively, while the result of the nitrogen free extract showed that maize fodder was significantly (P<0.05) higher than the remaining treatment groups followed by white sorghum, red sorghum and millet respectively. The result of ash showed that white sorghum fodder was significantly (P<0.05) higher than millet followed by red sorghum and maize fodder respectively.

Table 3: ***Proximate analysis of hydroponic fodders***

Parameters %	Maize fodder	Millet fodder	White sorghum fodder	Red sorghum fodder	SEM
Dry matter	87.63^{c}	87.88^{b}	87.51^{d}	88.09^{a}	0.09
Crude protein	12.84^{d}	14.84^{b}	13.73^{c}	15.33^{a}	0.37
Ether extract	3.14^{c}	3.27^{b}	2.90^{d}	3.36^{a}	0.07
Crude fibre	9.65^{d}	11.77^{a}	10.64^{c}	11.55^{b}	0.32
Nitrogen free extract	57.35^{a}	52.92^{d}	54.88^{b}	53.05^{c}	0.68
Ash	4.67^{d}	5.10^{b}	5.38^{a}	4.81^{c}	0.10

Gross energy kcal/kg	3960.00^{d}	3990.50^{b}	3975.00^{c}	4071.00^{a}	16.23

^{a,b,c}=Means across rows with different superscripts differ significantly (P<0.05)
SEM; Standard Error of Mean

Macro mineral content of hydroponic fodders

Presented in Table 4 is the macro mineral content of hydroponic fodders. Sodium, potassium and phosphorous content showed the same level of significances where there was significant (P<0.05) differences across the treatment groups with values of red sorghum fodder significantly (P<0.05) higher than millet followed by maize and white sorghum respectively. The result of calcium showed that value of red sorghum fodder was significantly (P<0.05) higher than the remaining treatment groups but millet and maize fodder were not significantly (P>0.05) different from each other. The result of magnesium showed that red sorghum was significantly (P<0.05) higher that the remaining treatment groups but maize fodder and white sorghum were not significantly (P>0.05) different from each other.

Table 4: ***Macro minerals of hydroponic fodders***

Parameters %	Maize fodder	Millet fodder	White sorghum fodder	Red sorghum fodder	SEM
Sodium	0.23^{c}	0.24^{b}	0.22^{d}	0.25^{a}	0.004
Potassium	0.61^{c}	0.62^{b}	0.59^{d}	0.64^{a}	0.006
Calcium	0.18^{bc}	0.19^{b}	0.18^{c}	0.20^{a}	0.002
Phosphorous	0.31^{c}	0.32^{b}	0.31^{d}	0.34^{a}	0.005
Magnesium	0.25^{c}	0.27^{b}	0.25^{c}	0.29^{a}	0.006

^{a,b,c}= Means across rows with different superscripts differ significantly (P<0.05)
SEM: Standard Error of Mean

Micro minerals of hydroponic fodders

The micro minerals of hydroponic fodders is presented in Table 5. The result of iron, zinc, manganese and copper showed that they had the same level of significances where red sorghum fodders were significantly (P<0.05) higher than millet followed by maize and white sorghum respectively.

Table 5: Micro minerals of hydroponic fodders

Parameters mg/kg	Maize fodder	Millet fodder	White sorghum fodder	Red sorghum fodder	SEM
Iron	151.64^{c}	158.81^{b}	147.60^{d}	166.86^{a}	2.77
Zinc	45.14^{c}	46.80^{b}	43.86^{d}	49.13^{a}	0.75
Manganese	26.20^{c}	28.12^{b}	25.91^{d}	32.48^{a}	0.99
Copper	4.70^{c}	5.95^{b}	4.05^{d}	6.50^{a}	0.37

^{a,b,c}= Means across rows with different superscripts differ significantly (P<0.05)
SEM= Standard Error of Mean

Discussion

Herbage yield of hydroponic fodders

Although there are few available published materials on the herbage yield of hydroponic fodders but. The result of the sprout yield revealed about 200% increase from the weight of seeds. This implies that hydroponics has the ability to sustain livestock production due to its fast growth despite the little space requirement and the time of development. Naik *et al*. (2013) and Adekeye *et al*. (2020) reported a fresh fodder weight of 3.94-4.66kg/tray when 2kg of maize and wheat seeds were sown. The authors (Naik *et al*., 2017) observed increased leaf development as compared to less root development which discouraged mould growth

Proximate analysis of hydroponic fodders

There were significant differences in the nutrient content of the maize grains and hydroponics fodder. According to NIAS (2020), average dry matter content of maize seed was 95.08%, millet 88.0%, sorghum 89.0%. However, the hydroponic maize fodder was 87.63%; millet 87.88%; white sorghum 87.51% and red sorghum 88.09% based on dry matter composition. The decrease observed in the DM may be due to the decrease in the starch content of the hydroponics fodder. During sprouting, starch is catabolized to soluble sugars for supporting the metabolism of energy requirement of the growing plants for respiration and cell wall synthesis, so any decrease in the amount of starch causes a corresponding decrease in DM (Naik *et al*., 2015). The crude protein content in the present study showed that hydroponic maize fodder contained 12.84% CP; millet with 14.84%; white sorghum with 13.73% and red sorghum 15.33% as compared to 7% in maize seed; millet 10%, sorghum 12% (NIAS, 2020). According to Dung *et al*. (2010a), the use of nutrient solution enhances the CP content of hydroponics fodder than tap water, due to the uptake of nitrogenous compounds. Additionally, sprouting has been reported to alter the amino acid profile of seeds and increases the crude protein content of hydroponic fodder (Morsy *et al*., 2013).

In the present study, ether extract (EE) content of the maize, millet, white sorghum and red sorghum fodders were 3.14%, 3.27%, 2.9% and 3.36%, respectively. The ether extract values obtained in the current study was slightly lower than the range of 3.27 to 3.49% obtained by Singh (2011) and Naik *et al*. (2015). The presence of in the EE in hydroponics fodders may be due to the increase in the structural lipids and production of chlorophyll associated with the plant growth (Naik *et al*., 2015).

The Crude fibre (CF) content for maize fodder (9.65%), millet (11.77%), white sorghum (10.64%) and red sorghum (11.55%), were lower than 14.77% CF reported by Adebiyi *et al*. (2018), though fell within the range of 7.35-21.20% reported by Naik *et al*. (2015). The presence of CF of hydroponics fodder may be attributed to the build-up of cellulose, hemicelluloses and lignin (Cuddeford, 1989). The NFE content (52.92%-57.35%) observed was higher than 1.56-3.64% reported for hydroponically sprouted grains - (Naik *et al*., 2015), while the values of total ash was within 4.67% - 5.67% which is higher than what was reported by Adebiyi *et al*., (2018) and Naik *et al*. (2014) where they observed that ash content of maize fodder was within the range of 1.75-3.80%. During the sprouting process, the total ash content increases due to the absorption of minerals by the root (Dung *et al*., 2010b). The values for gross energy (3960.00-4071.00kcal/kg) was higher than maize (3150.00kcal/kg), millet (2560.00kcal/kg) and sorghum (3100.00kcal/kg) seeds as reported by NIAS, (2020).

Macro minerals and Micro minerals of hydroponic fodders

The changes in the mineral content of the hydroponics fodder are mainly influenced by the type of irrigation water (Al-Ajmi *et al*., 2009; Dung *et al*., 2010a; Dung *et al*., 2010b; Fazaeli *et al*., 2012). However, sprouting of cereals makes the minerals more available by chelating or merging with the protein (Shipard, 2005).

Bloodnick (2016a, 2016b) stated that the availability of zinc for plant uptakes depended on low pH in growing medium. Hence, the fodder grown under hydroponics nutrient for red sorghum possessed more zinc content than the other type of fodder. Also, stated that like other micronutrients copper availability to plant uptake is usually possible when the pH of growing medium is low. Therefore, hydroponic red sorghum fodder grown in nutrient rich solution having pH of 6.50mg/kg had more copper content than other type of fodder.

Conclusion and recommendation

The study showed that maize, millet and white sorghum fodder had superior herbage yield compared to red sorghum. Also, red sorghum fodder showed better improvements of nutrients compared to other fodder plants. Therefore, hydroponic fodder production should be considered, to improve fodder availability and for nutritional purposes which will help in optimal productivity of livestock animals.

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