Nutritional composition and yield comparison between hydroponically grown and commercially available Zea mays L.fodder for a sustainable livestock production

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KeyWords: *Fodder, Hydroponic, Livestock, Maize, Nutrients.*

Abstract

Hydroponically grown green fodder may aid the soaring challenge of food scarcity throughout the world. This research is fixated on disseminating the hydroponic fodder production which involves growth of plants in a nutrient rich, soilless solution within a short time span of approximately 8 days. The nutritive value of hydroponic maize fodder in comparison to that of commercially available maize fodder (harvested in 60 days) was assessed. The nutritive content i.e. dry matter, crude protein, ether extract, crude fibre, nitrogen free extract, total ash, micro and macro nutrients were analysed. Macronutrients (Ca, Na, K, Mg) and trace elements (Fe, Zn, Mn, Cu) were analysed using atomic absorption spectroscopy. Analysis revealed a higher concentration of crude protein, ether extract, nitrogen free extract, macronutrients (Ca, Na, K, Mg) and trace elements (Mn and Cu) in hydroponically grown maize fodder. The denouement of the experiment depicted the superlative nutritional value of hydroponically grown maize fodder as compared to the commercially available fodder produced by conventional practices. This technology can ensure provision of quality fodder for sustainable livestock production.

Introduction

Livestock production is a significant subsector of agriculture around the world. About 40% of the total value of world's agricultural GDP (gross domestic production) is due to livestock products. In industrialized countries more than 50% of agricultural GDP is attributed to livestock products. More than 1.3 billion people are associated with it globally (Bruinsma, 2017; Thornton, 2010).

The livestock sector is the backbone of agriculture in Pakistan with a momentous economic value. It shares 56.3% of the agricultural GDP of the country, which accounts to about 11% of the total GDP (Ashfaq et al., 2015; Rehman et al., 2017). About 60% rural population of the country depends on the livestock production for livelihood. According to a recent survey, about 336 million people are directly or indirectly related to livestock sector (Bilal, 2004). The provision of sustainable livestock production is ensured by quality fodder and substantial nutrition supply.

Green fodder is an important part of the dairy ration. Its absence has a direct impact on the production and reproduction processes of the dairy animals. A prolific dairy farming requires that good quality green fodder should be supplemented to the animals on regular basis (Younas and Yaqoob, 2005; Naik et al., 2012). In this aspect, maize (*Zea mays* L.) is suggested as a supplementary diet in term of green fodder. Maize (*Zea mays* L.) is a multi-trait crop. It is accounted as the country's third important cereal crop followed by wheat and rice. Its nutritive value makes it a suitable constituent of cattle diet in terms of fodder (Tariq and Iqbal, 2010; Tahir and Habib, 2013). Furthermore, the soil conditions are very important to predict the presence of hazardous substances such as pesticides and other xenobiotics (Ahmad, 2018; Ahmad, 2019; Naeem et al., 2020). The issue of adding fertilizers to soils to enhance its nutrient efficiency is also significant (Iftikhar et al., 2018). Despite the suitable soil type and favourable climatic conditions of the country, per hectare yield of maize fodder in Pakistan is unsatisfactory as compared to other maize producing countries around the world. Such a scenario necessitates the use of fertilizers in the recent decades that are presented as the solitary solution to maximize the yield (Ayub et al., 2002; Oad et al., 2004).

However, this practice is not ecologically favourable. Another constrain is the insufficient availability of cultivable land, since the increasing livestock population is demanding credible amount of fodder.

To overcome the complications and issues associated with fodder production, hydroponic technology is presented as the sustainable, cost-effective and environmentally benign substitute (Naik et al., 2013; Naik et al., 2015). This technique is unique as it ensures the availability of green fodder around the year and within a small germination period. Furthermore, the fodder thus produced is rich in term of essential nutrients. Due to these characteristics hydroponic fodder production technique can be regarded as an outstanding solution for sustainable livestock production (Naimasia, 2015; Gebremedhin, 2015). The aspiration of the current study is aimed at suggesting the best alternative to the conventional fodder production practice. Maize fodder was grown in a hydroponics nutrient rich solution. This technique ensures nutritional improvement and economic feasibility of the resultant fodder.

Materials and Methods

Production of hydroponic maize fodder

Maize (*Zea mays*) seeds were collected from the local market of Rawalpindi, Pakistan. The seeds were subjected to germination test in a petri dish to examine their viability before being utilized. Few drops of deionized water were sprinkled on seeds for the provision of moisture and placed in an incubator at a temperature of 30° for two days for examining the germination percentage of seeds. The outcomes of the germination test was 70% for maize (Fig. 1).

Seeds were sterilized by soaking in hydrogen peroxide (H_2O_2) solution for 30 minutes to prohibit the formation of molds followed by washing and soaking them in water for 48 hours. Subsequently, the water was drained and seeds were covered for 48 hours before plantation (Al Ajmi, 2009). After the incubation of 48 hours, seeds were transferred to a clean tray and spread into an even mat (Njeru, 2014). The tray with perforated end was used for the growth of fodder and the perforated end of the tray was placed on the lower side of a slope. Seeds were kept moist throughout the growth period and nutrients were supplied via spray irrigation thrice a day. Sprouting of seeds started within 24 hours and after 8 days of growth 9.5 inches high grass mat was produced with 2.5 inches of roots.

Fig. 1- Maize seed germination test (two days).

Nutrient Analysis of the hydroponically grown fodder

On 8th day of growth, maize fodder mat was removed from the tray and nutrient constitutes were analyzed in term of Ash content (AOAC, 2000), dry matter (AOAC, 1999), crude protein (AOAC, 1990), ether extract (Ahmed et al., 2013) and nitrogen free extract (Chandra and Mali, 2014). The concentration of micro-macro nutrients including Na, K, Mg, Fe, Zn, Mn, Ca and Cu were investigated by atomic absorption spectrophotometer in both fodders i.e. hydroponically grown maize

$$Ash\ content\ \% = \frac{Weight\ of\ Ash}{Weight\ of\ sample} \times 100$$

fodder in nutrient rich solution and commercially available maize fodder (Ehi-Eromosele et al., 2012). Hoagland solution recipe was employed to prepare the nutrient solution for the production of hydroponic maize fodder (Hoagland and Arnon, 1950). Statistical analysis was performed with the assistance of Microsoft excel, computer software and ANOVA (analysis of variance). At 0.05 probability level, data analysis was done by testing significance between mean.

Ash Content

Ash content is considered as an inorganic content or

$$Dry\ Matter\ \% = \frac{W2 \times 100}{W1}$$

total mineral present in the sample. Two grams of dry sample was weighed in a porcelain crucible and was placed in a furnace at a temperature of 600° for 12 hours. After drying, the crucible was transferred to a desiccator to cool down. The crucible was carefully weighed again with the ash content (AOAC, 2000).

Dry matter Content

Dry matter content was estimated by first drying the porcelain crucibles in the oven at 105° for 3 hours and later transferring them to desiccator for cooling. The weight of crucibles was determined after cooling. Three g of sample was weighed in an electronic balance. Sample was spread with the aid of a spatula in crucibles and dried in an oven for 3 hours at 105°. After drying, the sample was placed in a desiccator to cool. The crucibles were reweighed with dried sample (AOAC, 1999). The value calculated for moisture content was also used to analyze dry matter present in a fodder.

$$Crude\ fiber\ (\%) = \frac{W2 - W1}{W1} \times 100$$

Where, W1 is the weight of sample before drying and W2 is the weight of sample after drying.

Crude Fiber

One g of ground sample (W1) was weighed accurately by using an electronic balance and put in a Teflon beaker. 150 m1 of sulphuric acid (H_2SO_4) (1.25%) was prepared by the addition of 6.7 ml of 98% concentrated acid to 1000 ml distilled water in a beaker with addition of 35 drops of castor oil as an antifoaming agent to prevent the sample content from adhering to the beaker. It was boiled for 30 minutes followed by filtration of the sample. The sample was washed thrice with 30 ml deionized water. After draining the last wash, 150 ml of potassium hydroxide (KOH) 1.25% (prepared by the addition of 12.5 g of KOH to 1000 ml with distilled water) and 3-5 drops of castor oil was added again. The sample was boiled for 30 minutes, filtered and washed thrice with deionized water. The beaker content was also washed thrice with 25 ml of acetone with stirring.

$$Ether\ Extract\ content\ \% = \frac{(B - A)}{C} \times 100$$

The Teflon beaker was removed from the hotplate and the dry weight of sample was determined after drying the beaker content in the oven at 105° for an hour and cooled in a desiccator. This weight (W2) represented the value of crude fiber (AOAC, 1990).

Ether Extract

Fats present in the sample were extracted using petroleum ether followed by evaluation of the ether extract content. Three grams of sample was weighed with the help of electronic balance and transferred into the extraction thimble. Extraction thimble containing sample was handled with tongs and placed in the extraction unit. Pre-weighed flask containing petroleum ether at 2/3 of total volume was connected to the extractor and boiled for 3 hours in a soxhlet apparatus. After boiling, ether was extracted by distillation and the flask was transferred to desiccator for cooling. The flask was weighed again to calculate the ether extract content (Ahmed et al., 2013).

$$Nitrogen\ sample\ (\%) = \frac{Ax\ B\ x\ 0{,}014}{C} \times 100$$

$$Crude\ protein\ \%\ \ nitrogen\ in\ sample\ x\ 6{,}25$$

Where, A is the weight of clean dry flask (g), B is the weight of flask with fat (g) and C is the weight of sample (g).

Crude Protein

One gram of oven-dried sample was placed in a kjeldahl flask containing 10 grams of potassium sulphate, 0.7 grams mercuric oxide and 20 ml of concentrated sulphuric acid. Castor oil was added as an anti-foaming agent to prevent the solution from foaming. Flask was tilted to an angle, placed in a digester and boiled for 30 minutes until the solution became clear. The solution was left to cool followed by addition of 90 ml of deionized water in the sample. 25 ml of 4% sodium sulphate solution was added and the sample was stirred. One glass bead and 80 ml of 40% sodium hydroxide (NaOH) was added in the solution flask, which was connected to distillation unit and heated to collect 50 ml of distillate containing ammonia in 50 ml of indicator solution prepared by the addition of 0.1 g of bromocresol green indicator in 40 g of boric acid and deionized water up to 1000 ml of volumetric flask. After distillation, flask containing distillate was titrated with 0.1 N of ammonium chloride (NH_4Cl) solution (Ahmed et al., 2013).

Where, A is the hydrochloric acid used in titration (ml), B is the normality of standard acid and C is the sample weight in grams.

Nitrogen free extract (NFE)

NFE is made up of vitamins, digestible carbohydrates and other non-nitrogen soluble organic compounds in feed. It was determined on dry matter basis by subtracting percentage of CP, CF, EE and ash content from 100 (Chandra and Mali, 2014).

$$\%\ NFE = 100 - (\ \%CP + \%CF\ \%EE + \%\ ash)$$

Where, CP is the crude protein, CF is the crude fiber and EE is the ether extract.

Composition of Nutrient Solution

Hoagland solution recipe was used to prepare the nutrient solution for the production of hydroponic maize fodder (Hoagland and Arnon, 1950). To avoid precipitation, chemicals were mixed separately in two groups, but in final dilution, chemicals of both groups were mixed thoroughly. Table 1 displays the chemicals used for the preparation of nutrient solution with modifications.

Table 1 - Composition of Groups A and B for the preparation of nutrient solutions.

Nutrient	Amount (grams)
Group A	
Calcium nitrate	50
Potassium nitrate	25
Potassium chloride	12.5
Group B	
Magnesium sulphate	32
Mono-potassium phosphate	12.5
Ferrous sulphate	1.00
Copper sulphate	0.1
Zinc sulphate	0.25
Manganese sulphate	0.25
Borax	0.50
Sodium molybdate	0.02

Stock solutions of Group A and Group B were prepared in 1000 ml of distilled water with the addition of different nutrients in their respective amounts as mentioned in the table. Group A and Group B ingredients were mixed separately in distilled water. After the formation of individual dilutions, the two solutions of Group A and B were mixed together to obtain the final nutrient solution.

Analysis of Micro-macro nutrients

One gram of dried powdered sample of fodder was weighed in a Teflon Beaker and 25 ml of nitric acid (HNO_3) was added. The sample was mixed thoroughly with the addition of 4 ml of per chloric acid and 1 ml of conc. Hydrogen peroxide (H_2O_2). The mixture was heated on a hot plate until white fumes appeared. After digestion, the sample was cooled followed by addition of 4 ml of distilled water. The mixture was boiled for 1 minute and filtered through Whatman No. 42 filter paper in a conical flask. The filtrate was used to find the concentrations of micro and macro nutrients Na, K, Mg, Fe, Zn, Mn, Ca and Cu in fodder by using atomic absorption spectrophotometer (Ehi-Eromosele et al., 2012).

Statistical Analysis

ANOVA (Analysis of variance) was used without replication factor with the purpose of performing a comparison between the nutrients content of hydroponic fodder with commercially available maize fodder. Data analysis was done at 0.05 probability level by testing significance, using Microsoft excel, computer software.

Results and Discussion

Maize fodder was grown under hydroponic nutrient rich solution within 8 days. The supplemented nutrients in a hydroponic system had a significant impact on fodder growth. The fodder grew to the height of 9.5 inches while the roots grew up to the length of 2.5 inches. Results of this experiment exhibited that hydroponically grown maize fodder was rich in nutrients including crude protein, ether extract, nitrogen free extract and micro-macro nutrients in comparison to the commercially available maize fodder harvested in about 60 days whereas, ash content, crude fibre, dry matter, iron content was recorded lower in hydroponic maize fodder.

Hydroponic fodder production

Maize fodder was grown in hydroponic nutrients rich solution within 8 days. The seeds sprouted within 24 hours and the process of sprouting of seeds continued until 8th day of growth. The completely grown maize fodder looked like a mat consisting of seeds, roots and plant. The hydroponically grown fodder was 9.5 inches high grass mat with 2.5 inches of roots. 250 grams of seeds were grown for fodder production and on day 8, the weight of fodder was recorded as 1.5 kg. Nutrient content on alternate days i.e. 2nd, 4th, 6th and 8th day of fodder growth was analysed (Fig 2).

Fig. 2 Temporal progression (2-8 days) hydroponic maize production in a nutrient plenteous solution.

Nutrient content assessment

The maize fodder exhibited varying nutrient content during different stages of growth period as shown in Table 2 (Fig. 3). Additionally, a considerable difference in nutrient percent content was observed between hydroponically grown and fodder produced by conventional practice as reported by Naik et al. (2012a). The results were also validated through statistical analysis.

Table 2 displays that the dry matter content of hydroponic maize fodder decreased continuously and the final value was considerably low (14.0%) compared to

Table 2 - Comparison of nutrient content of hydroponic maize fodder (grown from 2 to 8 days) with commercially available maize fodder (after 60 days of growth).

Days of Sprouting under hydroponics system					Commercially available maize fodder
Nutrients (%)	**2nd**	**4th**	**6th**	**8th**	**60th**
Dry Matter	34.74	31.7	21.5	14.01	42.03
Total Ash content	1.1	1.25	1.4	1.75	2.15
Crude protein	9.01	11.02	12.16	13.03	10.59
Crude Fiber	3.1	5.5	7.3	10.4	28.4
Ether Extract	2.52	3.13	3.4	3.55	2.28
Nitrogen free extract	84.29	79.1	75.74	71.27	56.58

commercially available fodder (42.0%). The decline in the starch content in the hydroponically grown fodder caused the depreciation of the dry matter. Naik et al. (2015) explained in an earlier research that in order to support the metabolism and energy demand of the

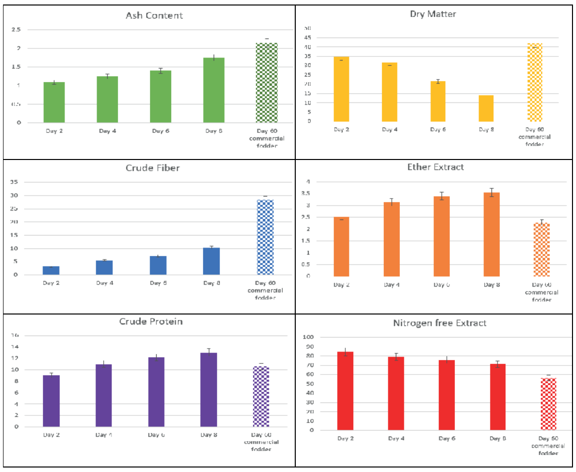

Fig. 3 Nutrient analysis (content %) of hydroponic fodder (total 8 days) as compared to commercially available maize fodder (60 days).

growing plants, specifically for cell wall synthesis and respiration, starch usually catabolizes to soluble sugar during sprouting. Therefore, any reduction in the amount of starch content leads to the decrease in dry matter content. The process of photosynthesis usually begins around day 5 of the seed sprouting, so when chloroplast activates, it does not provide sufficient time for dry matter to accumulate (Dung et al. 2010b). Additionally, nutrient solution used to produce hydroponic fodder also reduces the percentage of dry matter (Dung et al. 2010a; Dung et al. 2010b). The statistical evaluation of the dry matter content through two way ANOVA displayed a p value considerably lower than 0.05. A significant p value validated that the variation in the dry matter content of the hydroponically grown and commercially available fodder was noticeable.

Contrastingly, total ash content of hydroponic fodder showed an increasing trend and its value fluctuated from 1.1 to 1.75% ($P<0.05$). These values were found in accordance with Naik and Singh (2014). Dung et al. (2010b) reported the presence of increased ash content in fodder grown in nutrient solution rather than in water, because increased mineral uptake by roots in presence of nutrient solution accounted for high ash content. The crude protein content of the maize seed was 9.01%, which displayed increasing trend with germination time and was found highest ($P< 0.05$) on 8th day (13.03%) of growth. This resultant value is higher than that of commercially available fodder and is in consonance with that reported by Naik et al. (2012a). This tremendous increase in CP content may be associated with the loss in dry weight, predominantly the carbohydrates due to respiration and longer sprouting time, which leads to the loss of dry weight and increased crude protein content. Sneath and McIntosh (2003) stated that variation in the percentage of ash and protein contents usually occurred from day 4 due to the extension in roots, which permitted the mineral uptake. Decrease in dry weight due to longer sprouting time and breakdown of nitrogenous mixture from carbohydrates reserves due to nitrates absorption also leads to increased crude protein content (Chavan et al., 1989; Naik et al., 2012). The consequential percentage of crude fibre of hydroponic fodder (10.4%) on 8th day of sprouting was lower than CF value of commercially available fodder (28.4 %) ($P<0.05$). Naik et al (2012) attributed this lower percentage of CF content in hydroponic maize fodder with the more leafy and succulent nature of green fodder. Increase in the size and number of cell walls for structural carbohydrate synthesis might be the reason of elevated percentage of crude fibre content in commercially available fodder (Naik et al., 2014).

The percentage of ether extract content was more in hydroponic maize fodder (3.55%) on 8th day of germination ($P<0.05$) than in commercially available fodder on the 60th day of germination (2.28%). Similar increasing trend was reported by Naik et al. (2015) due to the increase in structural lipids and elevated chlorophyll content associated with fodder growth.

The percentage of Nitrogen free extract examined on the 8th day of germination was 71.27%, which was much higher than that of conventionally grown fodder (56.58%) ($P<0.05$). Naik et al. (2015) found that the higher value of nitrogen free extract in the hydroponically grown maize fodder was due to the increase in size and cell wall for structural carbohydrate synthesis.

Micro-Macro nutrients analysis

The analysis of micro and macronutrients exhibited that hydroponically grown maize fodder was more nutritious as compared to the fodder grown under conventional practices (Fig. 4).

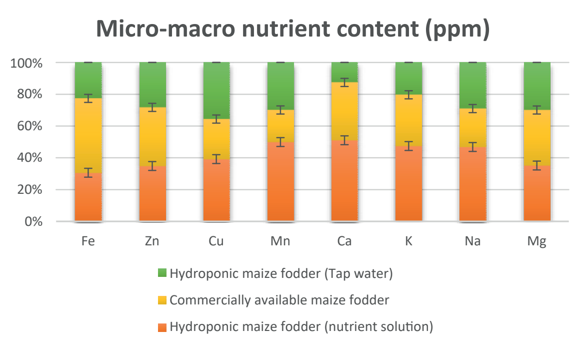

Fig. 4 Micro-macro nutrients content in hydroponic maize fodder (grown in tap water and nutrient solution) and commercially available maize fodder.

Macro-micro nutrient analysis displayed that iron was present within the permissible limit set by WHO (20 ppm) (Shah et al., 2013). It was observed to be 1.3847 mg/L in hydroponic maize fodder grown in a nutrient solution, whereas, commercially available maize contained more amount of Fe (2.1192 mg/kg) (Fig. 4). The possible factor affecting the presence of this nutrient is pH. Soil having pH ≥7.2 generally contain higher iron content. Statistical analysis applied on the Fe content values in all the fodder types exhibited a variance of 0.312 with standard deviation 0.558.

The zinc content found by Sneath and McIntosh (2003) in barley grass was recorded 21 ppm while in this study zinc content in hydroponic maize fodder was recorded 0.9956 mg/L, which was below the permissible limit given by WHO i.e. 50 ppm (Shah et al., 2013). Bloodnick (2016a) stated that the availability of zinc for plant uptakes depended on low pH in growing medium. Hence, the fodder grown under hydroponics nutrient solution possessed more zinc content than the other type of fodder (0.9811 mg/kg) (Figure 4). The variance

Table 3 - Two way ANOVA between various nutrient components of hydroponically grown and commercially available fodder.

Source of variation	SS	df	MS	F	P-value	F crit
			Ash content			
Rows	0.240938	3	0.080312	1	0.05	9.276628
Columns	0.812813	1	0.812813	10.12062	0.050044	10.12796
Error	0.240938	3	0.080313			
Crude fiber content						
Rows	166.31	3	55.43667	1	0.04	9.276628
Columns	237.62	1	237.62	4.286333	0.130199	10.12796
Error	166.31	3	55.43667			
			Ether extract content			
Rows	0.4827	3	0.1609	1	0.043	9.276628
Columns	0.0162	1	0.0162	0.100684	0.771812	10.12796
Error	0.4827	3	0.1609			
			Crude protein content			
Rows	1.8375	3	0.6125	1	0.021	9.276628
Columns	118.58	1	118.58	193.6	0.000804	10.12796
Error	1.8375	3	0.6125			
			Dry matter content			
Rows	223.4745	3	74.4915	1	0.038	9.276628
Columns	996.3648	1	996.3648	13.37555	0.035313	10.12796
Error	223.4745	3	74.4915			
			Nitrogen free extract			
Rows	147.8289	3	49.27631	1	0.042	9.276628
Columns	8365.065	1	8365.065	169.7583	0.000976	10.12796
Error	147.8289	3	49.27631			

obtained among the values of Zn in all the samples of fodder was 0.0144 with 0.119 standard deviation. The assessment also displayed that 0.7162 mg/L copper was present in hydroponically grown maize fodder and 0.4609 mg/kg of copper was recorded in a maize fodder grown under conventional practices. Both values of copper were recorded within the permissible limit (Fig. 4) given by WHO i.e. 10 ppm (Hassan et al. 2012). Analysis of variance in Cu content displayed variance of 0.0176 with standard deviation 0.132. Bloodnick (2016b) stated that like other micronutrients copper availability to plant uptake is usually possible when the pH of growing medium is low. Therefore, hydroponic maize fodder grown in nutrient rich solution having pH of 5.6 had more copper content than other type of fodder.

The calcium content in maize fodder grown under hydroponics nutrient solution and by conventional practice was 1.0397 mg/L and 0.6230 mg/kg, respectively (Fig. 4). The higher content of calcium in hydroponic fodder was justified by Mesić et al. (2007), who reported that moist climatic conditions cause significant losses of calcium by leaching but there was no chance of leaching in maize fodder grown under hydroponics system. High variance was observed in the Ca content in hydroponic and commercial fodder i.e. 8.56 with standard deviation 2.93.

It was assessed that maize fodder grown under hydroponics nutrient solution and by conventional practice contained 1.0397 mg/L and 0.6230 mg/kg manganese content, respectively (Fig. 4). While Glowacka (2012) recorded 10.9 ppm of manganese in a maize fodder. The variation in manganese content in plant is probably due to the high acidity and humic content of the natural soils. Due to these two factors the commercially available maize fodder grown in 60 days possessed less manganese content compared to hydroponically grown fodder. Variance among samples was recorded as 0.09 with standard deviation 0.315. The potassium content was recorded to be 0.36% in hydroponically grown barley fodder on 8th day of growth (Fazaeli et al., 2012). According to Bloodnick (2016c), potassium content in plant depends on higher potassium availability in a growing medium, hence the results of the analysis indicated the high presence of potassium content in hydroponically grown maize fodder (Fig.

4). The K content varied largely among samples exhibiting a variance of 2172 with standard deviation 46.6.

According to Sneath and McIntosh (2003), 0.21% of sodium was observed in hydroponically grown barley fodder, whereas the sodium content of hydroponic maize fodder in current research was recorded as 29 ppm. According to Bloodnick (2016d), sodium content in plant depends upon higher sodium availability in a growing medium and the sodium content of hydroponically grown maize fodder was found to be high as compared to the other fodder. Magnesium concentration was also assessed for both types of fodder. It was evaluated to be 15.4 mg/L in a hydroponic maize fodder and 15.3 mg/kg in commercially available maize fodder. Variance of Na content among samples was 54.3 with standard deviation 7.3. Fazaeli et al. (2012) analysed the magnesium content in barley fodder and recorded 0.23% of Mg on 8th day of barley growth. It was found to be less as compared to that found for this current study because Mg content in hydroponically grown maize fodder is not dependent on soil permeability and total precipitation. Statistical analysis displayed a variance of 1.68 with standard deviation of 1.29.

Statistical evaluation

Two way ANOVA, without replication factor was done to compare the nutrient contents of hydroponic fodder with commercially available maize fodder. Table 3 displays the ANOVA analysis between the following nutrient components of hydroponically grown and commercial fodder; ash content, crude fiber, ether extract, crude protein, dry matter content and nitrogen free extract. Following characteristics were evaluated in the two way ANOVA, the sum of squares (SS), mean square (MS), F statistics (F), P value and F critical values (F crit) were compared. It was evaluated that the F crit value was higher than the F statistics. Hence, signifying, that the values do not lie in the rejection zone. P value obtained was lower than 0.05 displaying the significance of the experimental results.

Conclusion

The study shows that hydroponically grown maize fodder was more nutritious than commercially available maize fodder in terms of manganese, zinc, copper, magnesium, sodium, potassium, calcium, ether extract, crude protein and nitrogen free extract content. This technology can enable farmers to produce fodder for animals in a nutrients rich solution or in a tap water within 8 days, in situations when fodder cannot be grown in natural soil. The added nutrients in a hydroponic system had a significant impact on growth. The fodder reached the height of 9.5 inches while the roots grew up to length of 2.5 inches. Current study can prove to be a landmark in further investigation relating the validity of this sustainable technique.

The authors declare that they have no conflict of interest.

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