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Watering Intervals and Harvesting Dates Affected Fodder Yield and Nutritional Values of Maize Varieties under Hydroponic System in Wollega University

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Abstract: Three experiments were conducted to examine the effect of varieties, frequency of watering and harvesting dates on biomass yield and nutritive values of hydroponically sprouted fodder of four different maize varieties. For this study maize varieties such as BH-661, BH-140, BH-540 and BH-545 (QPM) were grown hydroponically for 17 consecutive days in lath house at 2, 3 and 4 h watering intervals. The different harvesting date treatments include 7, 9, 11, 13, 15 and 17 days after sowing on the tray. The effect of frequency of watering showed significant differences ($p<0.0001$) in all fodder yield and yield related components. Except for root weight, the four hours intervals of watering has resulted in the highest ($P<0.0001$) biomass yield and yield related components. The differences in maize varieties also significantly ($p<0.0001$) affected the biomass yield and related components. The average dry matter yields for the varieties were 40.63, 36.22, 33.99 and 35.78 t/ha for BH-661, BH-140, BH-540 and BH-545 (QPM), respectively in one production cycle. It was observed that BH-661 yielded the highest DM yield. The results showed that longer harvesting dates decreased fodder yield. The crude protein (CP) and cell wall co ntents such as neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were higher for sprouted maize varieties than its grain. The *in vitro* dry matter digestibility (IVDMD) of the maize fodder (71.88%) for all varieties was lower than the mean values for their grain (82.65%). From the above results it could be concluded that BH-661maize variety has got highest fodder yield and yield related components. The four hours watering interval was best for hydroponic fodder yield and yield related components of maize. The 17^{th} date of harvesting had resulted in highest fodder yield of BH-661 maize variety. Sprouting maize varieties had brought highest CP and cell wall contents (NDF, ADF and ADL) compared to its maize grain. The IVDMD of hydroponically grown maize fodder had lower digestibility compared to its grain counterpart.

Key words: Chemical Composition · Fodder Yield · Hydroponic · *In vitro* DM Digestibility · Maize Varieties

INTRODUCTION

Ethiopia is endowed with huge population of livestock as 59.5, 30.7, 30.2, 9.01,0.92 and 56.53 million heads of cattle, sheep, goat, equines, camels and poultry, respectively [1]. Livestock ownership is an important asset because of its multiple social, economic and cultural uses [2]. Like other developing countries, agriculture is the largest economic sector in Ethiopia accounting for about 46% of the national GDP, employment of 85% of the labor force and 90% of the poor depend on the sector for their livelihood [3]. According to MoARD [4], the livestock sector in Ethiopia accounts for 16% national GDP and 27-30% agricultural GDP and 13% of the country's export earnings.

Highland livestock production in Ethiopia supports 85% of the total human population [5, 6]. Despite its large population size, the contribution of livestock production to agriculture and the overall economy of the country is low due to different constraints. Among the various constraints limiting livestock productivity in Ethiopia, poor quality and quantity animal feed is the major one

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[7, 8]. The crop-livestock systems in Ethiopian are under stress because of high rate of population growth, land degradation and reduced pasture land due to gradually turning into crop fields [9]. This has led to reduction in grazing areas and consequently to shortage of feed to livestock. As a consequence, crop residues have become the dominant ruminant feed resources in Ethiopia accounting up to 30-80% of the diet of ruminant livestock [9]. These constraints result in low milk and meat yields, high mortality of young stock and retarded growth, longer parturition intervals and low animal weights.

Production and utilization of quality feed, is therefore, required to realize the necessary intensification of forage production such as hydroponic techniques. Hydroponics fodder production is one of technologies that could be used as an alternative fodder production year round. The plants are grown in water and mineral rich solution. This technology can be used as an alternative for livestock feeds production especially where the farmers have a limitation of land and also during the dry seasons. In hydroponics fodder production, less space is needed because the fodder is grown in trays which are arranged in shelves inside the hydroponics system [10, 11]. In such situations, cheap cereal grains which impose less competition for food between animals and human beings are useful. Maize is one of low cost cereal grain in Ethiopia and could be used for hydroponic fodder production. Thus it can be hypothesized in such a way that the sprouted maize through hydroponic system improves herbage protein and fiber content so that it can be more utilized by ruminant animals. This experiment was, therefore, conducted to evaluate fodder yield and nutritional values of different varieties of maize as affected by difference in frequencies of watering and harvesting dates under hydroponic systems in Wollega University.

MATERIALS AND METHODS

Location of the Study Area: The Study was conducted in main campus of Wollega University, Nekemte town, East Wollega Zone of Oromia Regional State, Ethiopia. Wollega University is found at 328 km West of Addis Ababa on the outskirts of Nekemte town on 150 hectares of land and it is surrounded by ever green forest with views of mount Komto. It is located 9°, 5° North latitude and 36°, 33° East longitude and has an elevation of 2,088 meters (68050 feet) above sea level. The Lath house in which the experiments were conducted had average temperature of 22°C (16-28°C) and humidity 68% (52-80%) during the time of experiments.

Planting Materials for the Hydroponic Maize Fodder: The seeds of different varieties of maize such as BH-661, BH-540, BH-140 and BH- 545(QPM) which were from Oromia Seed Enterprise of Nekemte branch were grown hydroponically and used as experimental for this study.

Production of Hydroponics Maize Fodder: Fresh hydroponic maize fodder (HMF) was produced in lath house using tap water. Clean seeds of maize were distributed in the trays with a seed rate of 500gm per tray (5.9kg/m^2 in all experiments which is a bit lower than the reports of Naik *et al.* [12] who suggested a seeding rate of 6.4-7.6 kg/m2 for higher output in Hydroponic maize fodder production. Compared to the present experiments this seed rate was higher but we were forced to use the mentioned seed rate to prevent decomposition of seed due to high seed rate as report of Naik *et al.* [13] stated that if seed density is high, there are more chances of microbial contamination in the root mat which affects the growth of the sprouts.

Experiment One

Frequency of Watering Experiment: This was the first hydroponics experiment before beginning on maize variety biomass yield and agronomic traits and harvesting dates experiment. The first phase of frequency of watering of the seeds was done for identification of appropriate frequency of watering for BH-661, BH-540, BH-140 and BH-545 (QPM) maize varieties at 2 hours, 3 hours and 4 hours intervals of day time. Seeds of the maize varieties were sown in the planting trays which have been perforated (have uniform holes) at the bottom to allow drainage of excess water.

Experiment Two: Under this experiment, the potential of different varieties of maize were tested for fodder yield and yield related parameters such as leaf to root ratio (LRR), plant height (PH), leaf weight, root weight and total fresh fodder yield. The treatments were different maize varieties (BH-661, BH-140, BH-540 and BH-545 (QPM)) sprayed for 30 seconds at 4 hours intervals of the day.

Agronomic Data Collected

Plant Height at Harvest: At the end of the 17th day the height of the plant (cm) was taken using transparent glass ruler. For this the height of plants from four different areas of the tray were taken and the average was recorded.

Leaf Weight (g): During harvesting 200gm of the fodder was randomly taken from each tray and leaves were trimmed using razor blade, the weight of the leaves were taken and the result was converted to total yield of the tray.

Root Weight: After removal of the leaf from the 200grm which was used for leaf weight determination, the rest parts were considered as root weight and with the same procedure of leaf it was converted to total weight of the tray for total root weight.

Leaf: Root Ratio: Was calculated by dividing total leaf weight to total root weight.

Total Fodder Yield: At harvesting total weight of green fodder obtained was calculated by taking fodder and tray weight together. Total fodder weight = fodder and tray weight - tray weight.

Experiment Three

Determination of Appropriate Harvesting Date: This experiment was done a day after the frequency of watering experiment was completed. Accordingly, the fodder of hydroponically produced BH-661 maize was harvested at 7^{th}, 9^{th},11^{th},13^{th}, 15^{th} and 17^{th} days after sowing and was measured to identify the appropriate date at which maximum biomass yield of sprouted maize fodder could be harvested.

Design of the Experiments: In all the three experiments, each treatment was replicated three times and completely randomized Design (CRD) was used.

Chemical Analysis and *In vitro* DM Digestibility: From each treatment, about 300gm of samples was taken and dried at 65°C for 24 hours in forced air draft oven. The sample was grounded to pass 1 mm sieve sizes. The Nitrogen (N) content was determined by Kjeldahl method. Crude protein (CP) was calculated by multiplying Nx6.25. DM and ash contents of the samples were determined according to the procedures of A.O.A.C [14]. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) was determined according to procedures developed by VanSoest, Robertson, Ve Lewis [15]. The hydroponic maize fodder was evaluated for *in vitro* DM digestibility [16] with strained rumen liquor (SRL) collected from rumen fistulated animals maintained on green native pasture hay diet.

Statistical Analysis: The hydroponics Fodder yield and other agronomic data, chemical analysis and *In vitro* DM digestibility data were analyzed using the general linear model procedure of statistical analysis systems, SAS [17]. When the analysis of variance (ANOVA) show significant differences among treatments means, Tukey Honestly Significant difference test (α=0.05) was used to compare means. The model used in the hydroponics experiment was:

$Y_{ijk} = \mu + \tau_i + \varepsilon_{ijk}$ where, μ = overall mean of the population; τ_i = the i^{th} treatment effect and ε_{ijk} = random error associated with yij

RESULTS AND DISCUSSION

Watering Frequency Affected Fodder Yield and Related Components of the Maize Varieties: The effect of frequency of watering on hydroponic fodder yield and yield related components (Dry fodder yield, leaf weight, root weight and plant height) of different maize varieties were given in Table 1. The results showed that there was significant differences (p<0.0001) in all fodder yield and yield related components as effect of frequency of watering. Except for root weight 4 hours intervals of watering has resulted in the highest (P<0.0001) biomass yield and yield related components. The average fresh yields were 163.43, 158.71and 186.34 ton/ha for 2hrs, 3hrs and 4hrs watering intervals respectively. The results showed that the original seeds were increased 2.8 times,2.7 times and 3.2 times on fresh yield in 2hrs, 3hrs and 4hrs watering intervals, respectively after sprouting for 17 days on fresh weight basis. This increase in fresh weight of green fodder was due to the intake of large amount of water during germination and growth of the plants since no nutrient solution was used. Reports of Naik *et al*. [18] shows that farmers producing hydroponics maize fodder under low cost devices or greenhouses revealed fresh yield of 8-10 kg from one kg locally grown maize seeds in 7-10 days which was very high compared to the present results and this might be due to environmental factors and type and quality of seed. Peer and Leeson [19] also reported as 4-8 kg out of 1kg maize from their experimental work. The conversion ratio of seed to fodder in the above reports were different from one another and also shows different results from the present study because of different factors such as type and quality of seed, sprinkling frequency [20] only since the other factors were controlled and that it was equal across all the treatments.

The average dry matter yield of hydroponically grown maize were 33.05, 36.43 and 40.48tone/ha for 2hrs, 3hrs and 4hrs watering intervals, respectively after sprouting for 17 days. As frequency of watering increases

Table 1: Effect of frequency of watering on fodder yield and yield related components of different maize varieties

Parameters	2 h	3 h	4 h	SEM	P-level
Fresh yield (t/ha)	163.4^{b}	158.71^{c}	186.34^{a}	0.995	0.0001
Dry matter yield (t/ha)	33.05^{c}	36.42^{b}	40.48^{a}	0.451	0.0001
Leaf Weight (t/ha)	13.74^{c}	16.34^{b}	18.25^{a}	0.273	0.0001
Root weight (t/ha)	24.25^{a}	21.73^{b}	19.32^{c}	0.386	0.0001
Leaf to root ratio	0.57^{c}	0.75^{b}	0.95^{a}	0.017	0.0001
Plant height (cm)	15.42^{b}	15.83^{b}	17.25^{a}	0.262	0.0002

Means followed by different superscript letters within treatments differ at p<0.05.

Table 2: Effect of maize varieties on biomass yield (t/ha) and yield related components

Parameters	BH-661	BH-140	BH-540	BH-545	SEM	P-level
Fresh yield ¥	226.3^{a}	204^{b}	108.7^{d}	138.9^{c}	1.149	0.0001
Dry matter yield¥	40.63^{a}	36.22^{b}	33.99^{c}	35.78^{c}	0.521	0.0001
Leaf Weight ¥	18.32^{a}	16.92^{b}	13.79^{d}	15.42^{c}	0.315	0.0001
Root weight¥	24.03^{a}	21.15^{b}	21.61^{b}	20.27^{b}	0.446	0.0001
Leaf to root ratio	0.77^{a}	0.82^{a}	0.67^{b}	0.77^{a}	0.02	0.0002
Plant height (cm)	18.33^{a}	16.67^{b}	14.11^{c}	15.56^{b}	0.303	0.0001

Means followed by different superscript letters within treatments differ at p<0.05. ¥=t/ha

dry mater yield decreases for this particular study and these can be due to leaching of nutrients because of frequent watering. It was reported that DM content of the seeds decreased during sprouting compared to original seed and this could be due to leaching and oxidation of substances from seed. During sprouting of the seeds, there is an increase in the fresh weight and a consequent decrease in the DM content which is mainly attributed to the imbibitions of water and enzymatic activities (oxidation) that depletes the food reserves of the seed endosperm without any adequate replenishment from photo-synthesis by the young plant during short growing cycle [21]. The reports of Chavan and Kadam [22] also stated that during germination DM is lost due to the increased metabolic activity of sprouting seeds in which the energy for this metabolic activity is derived by partial degradation and oxidation of starch. Leaf weight of hydroponically produced maize fodder showed high significant differences due to difference in frequency of watering (p<0.0001). The results showed that the average leaf weight of hydroponic maize fodder were 13.74, 16.34 and18.25t/ha for2hrs, 3hrs and 4hrs watering intervals, respectively after sprouting for 17 days. The average plant height of hydroponic maize fodder in cm were15.42, 15.83 and 17.25 for 2hrs, 3hrs and 4hrs watering intervals, respectively after sprouting for 17 days. Reddy [23] reported that hydroponic fodder with 20-30 cm grass mat containing roots, spent seeds and green shoots for harvesting within 6-8 days which was higher than the present study.

Effect of Maize Varieties on Biomass Yield and Yield Related Components: The effect of different maize varieties on biomass yield and yield related components were given in Table 2. The results showed that all the parameters measured were significantly affected by difference in varieties (p<0.0001).The average fresh fodder yields were 226.3, 204, 108.7 and 138.9 t/ha for BH-661, BH-140, BH-540 and BH-545 (QPM),respectively in one production cycle. From these results BH- 661 was the best variety in case of fresh yield which showed 4 times increase from the original seed after sprouted for 17 days. BH-140 was also high yielding variety next to BH- 661 which shows 3.5 times increase from the original seed after sprouted for 17days. This increase in fresh weight of forage was due to the difference in genetic makeup of the varieties during germination and growth. In the study BH- 540 was the least performing variety in case of fresh yield which shows only 1.9 times increased from the original seed after sprouted for 17days. Naik, Swain and Singh [24] reported fresh yield of 8-10kg from one kg locally grown maize in 7-10 days under low cost devises which was to high compared to the present study. Naik and Singh [25] also reported that fresh yields of 3.5-6.0 folds are common for HMF which was all most comparable to the present results. In another place [26] reported Fresh yield of 3.5-6.0 folds in 7-8 days in maize fodder.

The average dry matter yields for the varieties were 40.63, 36.22, 33.99 and35.78 t/ha for BH-661, BH-140, BH-540 and BH-545 (QPM), respectively in one production cycle which was lower than the original seed in all varieties. In this experiment BH-661 has got the highest dry matter and fresh matter yield and BH 540 has the least. The fresh matter and dry matter yields for all the varieties were in the same trend. From the above results it was observed that there were some dry matter losses from the original seed because of that during germination, DM is lost due to the increased metabolic activity of sprouting seeds. The energy for this metabolic activity is derived by partial degradation and oxidation of starch from the original seed. This means that the decrease in DM yield of varieties from original seeds was that part of the chemical energy in the seed that was lost for maintenance of the plant and the mount lost was not added to the weight of the sprout (growth). Previous reported result also indicated that, the original dry weight of the seed decreases during soaking and subsequent sprouting processes due to leaching of materials and oxidation of substances from the seed [22]. The reasons for the loss in dry matter have been considered in a number of studies. Reports of Dung, Goodwin and Nolan [27] showed that the loss is likely due to the use of carbohydrates and energy within the grain for the metabolic activities of the growing plant, without any adequate replacement from photosynthesis of the young plant.

The average leaf weight were 18.32, 16.92, 3.79 and15.42 t/ha for BH-661, BH-140, BH-540 and BH-545 (QPM) respectively in one production cycle. The result showed that varieties with high fresh yield have high leaf weight and those with low fresh yield have also low leaf weight in this experiment. This indicated that the leaf weight is in similar trend of biomass yield of the maize varieties. Similarly the average results for root weight of all maize varieties were 24.03, 21.15, 21.61 and20.27t/ha for BH-661, BH-140, BH-540 and BH-545 (QPM), respectively per one production cycle. It was observed that the root weight for BH-540 was relatively higher than all the varieties except BH-661 in contrary to their leaf weight and biomass yields indicating that some seeds were left without germination and this contributed to its root weight. This has shown that BH-540 had poor hydroponic fodder value. The leaf to root ratio was taken following the view that leaves and roots of sprouted maize varieties might have different nutrient contents particularly crude protein. Plant height was also measured during the experiment as one yield related components and the average results were 18.33cm, 16.67cm, 14.1 cm and15.66cm for BH-661, BH-140, BH-540 and BH-545 (QPM) respectively. Naik *et al.* [28] reported that depending up on the types of grains the hydroponics fodder looks like a mat of 11-30 cm height by the end of the germination period of about 8-days. Such ranges show variation in height and the variety with highest plant height, in the present study BH-661, could have the highest biomass yield.

Effect of Harvesting Date on Biomass Yield and Yield Related Components of BH-661 Maize Variety: The effect of date of harvesting on hydroponic fodder yield and yield related components of BH-661 maize variety were given in Table 3. There were significant differences among treatments in fresh fodder yield and yield related components ($p<0.0001$). The mean fresh fodder yields at 7th, 9th, 11th, 13th, 15th and 17th days of harvesting were 93.5, 112.22, 150.18, 167.11, 211.11 and244.21 t/ha, respectively in one production cycle. It has been shown that increased date of harvesting resulted in increased fresh fodder biomass yield under this hydroponic system while the DM yield was decreased. On the 17th days the forage was fully grown and had higher fresh biomass yield which showed 4.2 times increase from the original seed after 17 days. However, this was lower than the results reported by Naik *et al.*[18] in which 7-8 times increase from original seed in7-10 days growth time for maize. In this experiment it was observed that fresh fodder yield showed the least value on the 7th day of harvesting and the highest value on the 17th days. This indicates that longer harvest time will result in higher biomass production according to this particular experiment.

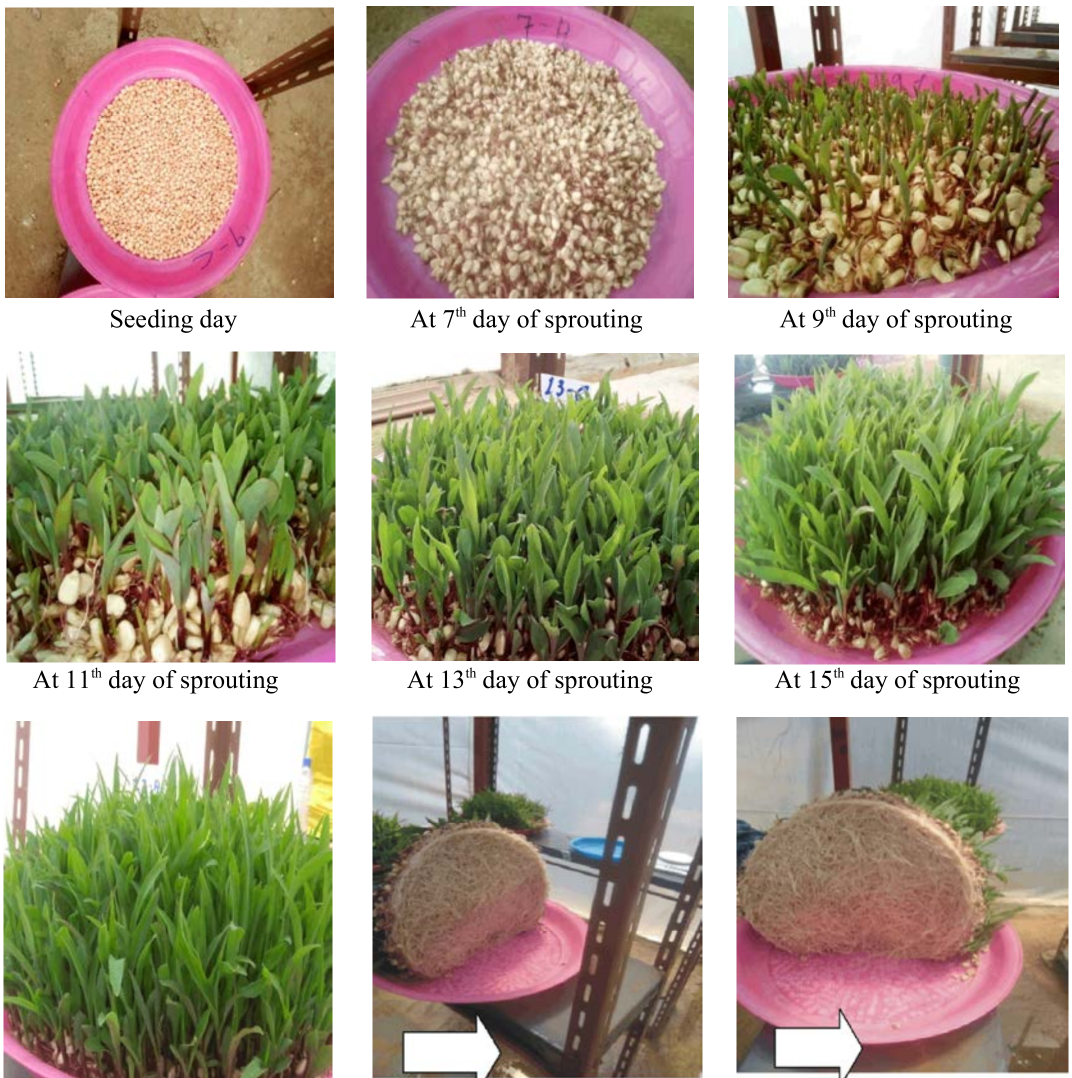
The average dry fodder yield at 7th, 9th, 11th, 13th, 15th and 17thdays of harvesting were 46.38, 45.48, 44.9, 43.38, 41.66 and 39.79 t/ha, respectively. The results show that opposite to fresh fodder yield, longer harvesting date decreased dry fodder yield. A number of studies reported that sprouting resulted in 7-47% loss in DM from the original seed after sprouting for a period of 6-7 days of growth, mainly due to respiration during the sprouting process, leaching and oxidation of nutrients from the seeds. During sprouting of the seeds, there is an increase in the fresh weight and consequent decrease in the DM content which is mainly attributed to the imbibitions of water (leaching) and enzymatic activities (oxidation) that depletes the food reserves of the seed endosperm without any adequate replenishment from photo-synthesis by the young plant during short growing cycle [21]. The average plant height at 7th, 9th, 11th, 13th, 15th and 17th days of harvesting were3.63, 5.33, 7.87 11.73[c], 16.27and 20.5 cm respectively.

The plant height at 17thdate of harvesting had highest value because of that the herbages of BH-661maize was not well grown at 7th days of harvesting. Longer harvest time will help the plant use nutrient in the seed and hence the plant continued to increase in height. In another experiments the average plant height 28 cm achieved on 8th-day was in line with the results reported by Naik *et al.*

Table 3: Effect of harvesting date on Biomass yield (t/ha) and yield related components of BH-661 maize variety

	Days to harvesting							
Parameters	7^{th}	9^{th}	11^{th}	13^{th}	15^{th}	17^{th}	SEM	P-level
Fresh yield$^{¥}$	93.5^{d}	112.2^{d}	150.2^{c}	167.1^{c}	211.1^{b}	244.21^{a}	4.124	0.0001
DMY$^{¥}$	46.38^{a}	45.48^{a}	44.9^{a}	43.38^{b}	41.66^{c}	39.79^{d}	0.596	0.0001
Leaf Weight$^{¥}$	4.04^{c}	7.15^{b}	10.97^{a}	12.19^{a}	12.73^{a}	14.13^{a}	0.861	0.0001
Root weight$^{¥}$	41.38^{a}	35.68^{b}	34.4^{b}	31.5^{c}	29.94^{d}	27.44^{e}	0.806	0.0001
LRR	0.097^{c}	0.2^{b}	0.33^{a}	0.41^{a}	0.43^{a}	0.48^{a}	0.034	0.0001
PH (cm)	3.63^{f}	5.33^{e}	7.87^{d}	11.73^{c}	16.27^{b}	20.5^{a}	0.182	0.0001

Means followed by different superscript letters within treatments differ at $p<0.05$; DMY= dry matter yield; LRR= leaf to root ratio; PH= plant height; $^{¥}$= t/ha



Seeding day | At 7^{th} day of sprouting | At 9^{th} day of sprouting

At 11^{th} day of sprouting | At 13^{th} day of sprouting | At 15^{th} day of sprouting

At 17^{th} day of sprouting | Root parts the fodder | At 17^{th} day of harvest

Pic. 2: Hydroponically grown maize fodder of variety BH-661 at different harvesting date

[12] in maize hydroponic fodder as 20-30cm.The height of plants in the above reports were higher than the present study results and this might be due to difference in environmental factors which affects growth of hydroponic fodder [29].

The average leaf dry weight at 7^{th}, 9^{th}, 11^{th}, 13^{th}, 15^{th} and 17^{th} days of harvesting were 4.04, 7.15, 10.97, 12.19, 12.73and 14.13.t/ha in one production cycle respectively As time of harvesting increased photosynthesis continues until nutrient in the seed lost.

Table 4: Effect of variety on chemical composition of maize under hydroponic systems

Parameters	Grain	BH-661	BH-140	BH-540	QPM	SEM	P-value
DM (%)	92.43^{a}	91.47^{c}	91.97^{b}	91.4^{d}	91.75^{b}	0.056	0.0001
Ash (%)	1.52^{b}	2.97^{a}	2.55^{a}	2.57^{a}	2.44^{a}	0.112	0.0003
CP (%)	11.17^{b}	13.97^{a}	13.9^{a}	13.73^{a}	15.03^{a}	0.372	0.0009
NDF (%)	18.02^{b}	37.04^{a}	33.99^{a}	37.35^{a}	35.05^{a}	0.741	0.0001
ADF (%)	2.85^{c}	12.5^{a}	8.74^{b}	12.77^{a}	10.82^{a}	0.501	0.0001
ADL (%)	1.07^{c}	2.75^{b}	3.56^{a}	2.73^{b}	2.82^{b}	0.096	0.0001
IVDMD (%)	82.65^{a}	69.83^{c}	74.14^{b}	70.61^{c}	72.95^{b}	0.339	0.0001
Hemic	15.17^{b}	24.54^{a}	25.25^{a}	24.58^{a}	24.23^{a}	0.435	0.0001
Cellulose	1.78^{c}	9.75^{a}	5.19^{b}	10.04^{a}	7.99^{a}	0.543	0.0001

DM = Dry matter; NDF = Neutral detergent fibers; ADF = Acid detergent fiber; CP = crude protein; ADL = Acid detergent lignin; IVDMD= In-vitro dry matter digestibility; Hemic=Hemicellulose; SE = Standard error; a b c Means followed by different superscript letters within treatments differ at p<0.05.

As photosynthesis continue growth of plant increase and plant leaf also increases. This means longer harvest time could bring higher plant leaf production. The average root dry weight at 7th, 9th, 11th, 13th, 15th and 17th days of harvesting were 41.38,35.68, 34.4, 31.5, 29.94and 27.44 t/ha. in one production cycle, respectively. The results showed that as date of harvesting increased dry root yield decreased which was opposite to leaf dry yield mainly because of high moisture content of the root than leaf during sprouting. LRR is the ratio of plant leaf to plant root, as harvesting time increase the leaf weight shows high increment than root weight and the fodder had lower LRR at 7th day of harvest and higher LRR at 17th day of harvest. In all the above three experiments the results of frequency and variety interaction showed non-significant differences in dry matter yields (p>0.05) and for this reason we didn't include the results of interaction in our discussion.

Effects of Varieties on Chemical Composition of Different Hydroponically Grown Maize Varieties and Maize Grain: In addition to evaluation of yields and yield related parameters, chemical composition of fodder of hydroponically grown maize varieties and maize grain were evaluated and the results were given in Table 4. The results showed that all the parameters measured were significantly differed between maize grain and maize varieties (p<0.001). The average crude protein (CP) values were 11.17%, 13.97%, 13.93%, 13.73% and15.03% for maize grain and hydroponically grown fodder of BH-661, BH-140, BH-540 and BH-545 (QPM), respectively in one production cycle. The results clearly indicated that growing maize hydroponically improves the CP content of the fodder. Such techniques were proved important to avoid the need for protein concentrate diets supplementation especially for fully grown and non-lactating cows. The CP content of hydroponically grown maize fodder reported by Naik *et al*. [12], 13.3%-13.6% and [30], 13.57% was almost comparable with the results of the present study. Thadchanamoorthy [31] also reported the CP values of hydroponic maize fodder as 16.54% which was higher than the above reports and also higher than the present experimental results and such maize may be of different variety. The reports by Morsy, Abul and Emam [32] shows that the CP contents of hydroponic maize fodder was 14.56% which was slightly superior as compared to the mean value 14.16% of the present study. The reports stated above showed that hydroponic maize fodder has higher CP values compared to its maize grain because sprouting alters the amino acid profile of maize seeds and increases the CP content [32]. Dung, Godwin and Nolan [33] also reported that the increase in CP content may be attributed to the loss in DM, particularly carbohydrates, through respiration during germination and thus longer sprouting time is responsible for greater losses in DM and increase in protein content.

Ash contents of hydroponically grown maize and maize grain were analyzed and the average results were 1.52%, 2.97%,2.55%, 2.57% and 2.44% for maize grain and hydroponically grown fodder of BH-661, BH-140, BH-540 and BH-545 (QPM), respectively which showed differences among the grain and its sprouted varieties (P<0.05). The value of total ash for hydroponic maize fodder reported by Naik *et al.* [28] was within the range of 1.75-3.80% which was almost comparable with the present results. In the present results ash contents of hydroponic maize fodder showed higher values compared to maize grain and Dung,Godwin and Nolan [34] also reported that during the sprouting process, the total ash content increases due to the absorption of minerals by the root. Another reports by Thadchanamoorthy [31] showed that ash contents of hydroponic maize fodder was 3.09% and that of maize grain was 1.48% which confirms the idea that the ash content of hydroponic maize fodder was higher than that of maize grain. Similarly, Naik [35] also reported that the ash contents of hydroponic maize fodder was in the range of 1.56%-3.84% which was almost similar to the present results.

The cell wall contents (NDF and ADF) and ADL of the fodder produced from sprouting of different maize varieties and maize grain has shown significant differences among sprouted maize varieties and its grain ($p<0.05$). The average values of NDF were18.02%, 37.04%, 33.99%, 37.35% and 35.05% for maize grain and hydroponically grown fodder of BH-661, BH-140, BH-540 and BH-545 (QPM), respectively in one production cycle. This clearly demonstrated that sprouting maize grains could increase fiber content of the fodder so that ruminant animals can enjoy unlike the sole grain maize diet which they cannot consume without mixing with roughages. Thadchanamoorthy [31] reported that NDF contents of hydroponic maize fodder was 29.27% and that of maize grain was 19.22% which shows lower value than the present study in hydroponic maize fodder but almost comparable in case of maize grain. According to Singh and Oosting [36] feeds containing NDF values of less than 45% are classified as high, those with values ranging from 45% to 65% as medium and those with values higher than 65% as having low quality. The results of present study showed that NDF content of hydroponic maize fodder of all maize varieties were lower than 45% which fulfills high quality forage criteria and it confirms that the hydroponic maize fodder produced in the present study was expected to result in high animal intake.

The mean for ADL were 1.07%,2.75%,3.56%,2.73% and 2.82% for maize grain and hydroponically grown fodder of BH-661, BH-140, BH-540 and BH-545 (QPM), respectively which were significantly different among the sprouted varieties and the maize grain ($P<0.05$). The ADF contents were also analyzed and the average values were 2.85%,12.5%,8.74%,12.77% and10.82% for maize grain and hydroponically grown fodder of BH-661, BH-140, BH-540 and BH-545 (QPM), respectively and were in status which do not impair digestibility in all varieties. In his study, Thadchanamoorthy [31] reported that ADF contents of hydroponic maize fodder was 10.16% and that of maize grain was 5.5% which indicated that hydroponic maize fodder contains higher ADF than maize grain and it was also true in the present results.

The *in vitro* dry matter digestibility (IVDMD) of different hydroponically grown maize fodder and grain were tested and the average values for the grain (82.65%) was significantly higher ($P<0.001$) than the mean values (71.88%) for the sprouted varieties. In his study of IVDMD for hydroponic maize fodder and maize grain, Thadchanamoorthy [31] reported that IVDMD of hydroponic maize fodder harvested at 10th day was 79.87% and that of maize grain was 68.75%. In contrary to this, Karunathilaka, Jayawardena and Premalal [37] reported the IVDMD of hydroponic maize fodder harvested between 7 to 10 days had lower IVDMD % as compared to maize grain, which could be attributed to the increasing fiber fraction content as stage of growth advanced. This is also true in case of the present results in which IVDMD had higher value in grain than in hydroponic maize fodder because the hydroponic maize fodder was sprouted for about 17 days and in these days the soluble component in the grain was lost for maintaining the plant.

CONCLUSION

From the varieties of maize studied, BH-661 was identified as best in terms of fodder yield under hydroponic production technique. The four hours frequency of watering resulted in highest hydroponic fodder yield of the maize varieties. The 17th date of harvesting was the optimum time for highest fodder yield of BH-661 maize variety according to this particular study. Sprouting maize varieties had brought higher CP and fiber (NDF and ADF) contents than its maize grain that ruminant animals could directly consume and could be supplemented to other poor quality roughage diets. Generally hydroponically grown maize can improve fiber content and crude protein content compared to its original grain. The IVDMD of hydroponically grown maize varieties' fodder had lower digestibility compared to their grains.

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