Austin Journal of Veterinary Science and Animal Husbandry

Open Access

Austin Publishing Group

Research Article

Effect of Seed Rates and Harvesting Ages on Hydroponic Maize Fodder Biomass Yield, Chemical Composition, *In-Vitro* Digestibility and Water Use Efficiency

Mulu Worana*
Department of Veterinary Science, Addis Ababa University, Ethiopia

***Corresponding author:** Mulu Worana, Department of Veterinary Science, Addis Ababa University, Ethiopia
Email: anuworana@gmail.com

Received: November 21, 2025
Accepted: December 26, 2025
Published: December 31, 2025

Abstract

Study on the effect of seeding rates and harvesting dates of hydroponic maize fodder on biomass yield, chemical composition, in-vitro dry matter digestibility and water use efficiency was carried out in Hawassa University. The treatments were comprised of three seeding rates of BH-546 maize variety and three harvesting dates. A 3 x 3 factorial experiment in a Completely Randomized Block Design was used to evaluate the effect of seeding rates (4kg/m2, 6kg/m2 and 8kg/m2) and harvesting dates (8th, 10th and 12th) of hydroponic maize fodder on growth parameters (plant height, root weight and leaf weight), biomass yield, chemical composition, invitro dry matter digestibility (IVDMD) and water use efficiency. The study was carried out in green house at the College of Agriculture using 27 translucent plastic trays measuring 37cm length, 23 cm width and 9 cm height. The bottoms of the trays were drilled uniformly to open holes to drain excess water during irrigation and placed on shelves. The effect of seeding rates, harvesting dates and their interaction was significantly (P<0.001) affected plant height, leaf weight and root weight of hydroponic maize fodder. Maize hydroponic fodder fresh biomass yield was significantly (P<0.001) varied among harvesting dates with highest value at 12th day and 8kg/m2 seeding rate. Higher (P< 0.001) DM fodder yield was observed at 8kg/m2 seeding rate. The water use efficiency was higher in fodder harvested 12th date compared to the other harvesting dates. The crude protein (CP) and cell wall contents such as neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were higher for sprouted maize seed rates and harvesting dates than its grain. The average in vitro dry matter digestibility (IVDMD) of the maize fodder (74.9%, 75.7%, 76.4%) and (74.1%, 75.8%, 77.1%) respectively for all seeding rates and harvesting dates which was better than the other fibrous feeds. From the above results it could be concluded that 8kg maize seeding rate has got highest fodder yield and yield related components. The 12th date of harvesting had resulted in highest fodder yield at 8 kg/m^2 maize seeding rate. Thus, it is recommended to produce hydroponic maize fodder of grain at 8kg/m^2 seeding rate and 12th day harvesting for higher fodder yield, optimum fodder quality and hydroponic maize fodder production improves nutrient content with less water, less space used and cost effective.

Keywords: Chemical analysis; Cost analysis; Harvesting date; Hydroponics maize fodder; *In-vitro* digestibility; Seeding rate; Water use efficiency

Introduction

Ethiopia has a large livestock population and diverse agro ecological zones suitable for livestock production and for growing diverse types of food and fodder crops (Tsegaye *et al.*, 2008). Livestock production contributes up to 80% of farmer's income in our country and about 20% of farmer income is derived from agriculture in Ethiopia. Ethiopia has the largest livestock population of any country in Africa. In Ethiopia livestock plays a major role for food security, particularly small holders and marginal farmers (Shapiro *et al.*, 2015). Livestock sector contribute 15-17% of national GDP and 35- 49% of agricultural GDP, and 37- 87% of the household incomes including monetary values and the non-marketed services (traction and manure) in the country (IGAD, 2010). Livestock also plays an important role in urban and peri-urban areas for the poor evoking a living out of it and for those involved in commercial activities (Ayele *et al.*, 2003). Hence, livestock remains as a pillar for food security, human nutrition and economic growth of the county (Shapiro *et al.*, 2015). Despite the huge numbers and multiple roles, livestock productivity remained very low in Ethiopia and unable to meet the demands for the rapidly growing population. This is often attributed to various constraints such as feed scarcity, high prevalence of diseases and parasites, low genetic potential of local breeds, inadequate veterinary services, lack of access to credit, land scarcity, and poor management practices across all livestock production systems (Dawit *et al.*, 2013;Selamawit *et al.*, 2017 and Welay *et al.*, 2018). Among these constraints, poor quality and inadequate quantity of feed supply, especially during the dry season, were identified as the major cause of the low livestock productivity (Adugna *et al.*, 2012). The major causes for feed shortage are diminishing natural pastures/grazing land, population growth,

Citation: Mulu Worana. Effect of Seed Rates and Harvesting Ages on Hydroponic Maize Fodder Biomass Yield, Chemical Composition, *In-Vitro* Digestibility and Water Use Efficiency. Austin J Vet Sci & Anim Husb. 2025; 12(5): 1181.

Figure 1: The first day that seed was placed on gunny bag before putting on tray.

expansion of cropping at the expense of grazing lands, and expansion of degradable lands, which can no longer support either annual crops and pasture (Alemayehu., 2004;Endeshaw.,2007). According to CSA (2018), improved forage production covers only 0.32% of the total feed resources of livestock in Ethiopia.

Feeding of quality green fodder to farm animals could play an important role in sustainable and economical animal production. However, various constraints are faced by the farmers for production of green fodder like small land holdings, unavailability of land for fodder cultivation, scarcity of water or saline water, non-availability of good quality fodder seeds, more labour requirement, requirement of manure and fertilizer, longer growth period of forages (45-60 days), fencing to prevent fodder crop from wild, animals and natural calamities. Furthermore, the non-availability of constant quality of fodder round the year aggravates the limitations of the sustainable farming (MOA, 2014). And also long dry period, unavailability of water for irrigation and competition for land with food crop production are some of the challenges that make the use of improved forage crops still at its low level (Yayneshet, 2010; Naik and Singh, 2013).

Due to the above constraints and the problems faced in the conventional method of fodder cultivation, hydroponics is now emerging as an alternative technology to grow fodder for farm animals (Naik *et al*., 2017). Hydroponics is an art and technology that has revolutionizing the green fodder production during 21st century. This is a concept of growing crops without soil in the presence of water and proper nutrition. This process takes place in a very versatile and intensive growing unit where only water and nutrients are used to produce a grass and root combination which is very lush green and rich in nutrients (Ningoji et al., 2020). In hydroponics fodder production, less space is needed because the fodder is grown in trays which are arranged in shelves inside the hydroponics system (Shashank and Teja, 2012). As a result, hydroponic fodder production technology has been advocated as a solution in order to overcome the challenges faced by conventional green fodder production and for climate change adaptation (Muthuramalingam *et al*., 2015; Saidi and Omar., 2015). Despite its importance in producing green feed to livestock, the compatibility of the technology to the local conditions, including its technical simplicity, cost-effectiveness, and performance of locally available seeds in hydroponic systems was not well assessed in Ethiopia. Moreover, the comparative biological and economic importance of hydroponic fodder with other forms of the same crop (i.e. the grain as it is and its malted form) are not evaluated for many crops including the popular livestock grain supplement, the maize (Getachew *et al*., 2020).

Maize is one of the cereals having diversified usage. Apart from grain consumption, it is used as fodder due to its higher fresh biomass. Maize is a better choice for production of hydroponic fodder due to its availability, lower cost of seeds, higher biomass production, higher seed to biomass ratio and quicker growing habit (Naik *et al*., 2012). However, to our knowledge, no research was conducted in the current study area on hydroponic fodder production, particularly effect of seed rate and harvesting ages of hydroponic maize fodder biomass yield, chemical composition, invitro digestibility and water use efficiency. Thus, this study was designed with the intent of evaluating the effect of seed rate and harvesting ages of hydroponic maize fodder biomass yield, chemical composition, invitro digestibility and water use efficiency with the specific objectives:

- To determine the effect of seed rates on the biomass yield, chemical composition and invitro digestibility.
- To determine the appropriate date of harvest for biomass yield, chemical composition and organic matter digestibility.
- To evaluate water, use and water use efficiency of hydroponic maize fodder.
- To estimate the cost of production of hydroponic maize fodder.

Materials and Methods

Experimental Site

The experiment was conducted in green (shade) house of Hawassa University; College of Agriculture which is located in Hawassa city. Hawassa city is located at 273 km south of Addis Ababa via Bishoftu, 130 km east of Sodo, and 75 km north of Dilla. Geographically, Hawassa city is located at latitude and longitude of 7°3′N 38°28′E and at an of elevation 1,708 meters (5,604 ft) above sea level. The city has a prolonged period of wet season (March-October with mean monthly rainfall varying from 85 to 133mm) with the June to September rainfall contributing 44% of the mean annual precipitation. The climate of Hawassa can be classified as dry to sub-humid. The annual temperature ranges from 9°C to 29°C, whereas the mean monthly temperature is 19.7°C.The annual rainfall of the area is 1124 mm (NMA, 2021).

Establishment of Hydroponic System

The hydroponic system was composed of stick frame and shelves with the rectangular shaped plastic trays were put on the shelved stick frames to sprout the fodder grains and each shelf of the system unit could carry 9 planting trays and all are 27 trays. The experiment was conducted using trays that purchased from market with dimensions approximately 37 cm (length) x 23cm (width) x 9 cm (height) and the available surface area for spreading of seeds in each tray are approximately 0.0851 m^2 (0.37 m x 0.23 m) to produce green fodder. An air conditioning was used to control temperature inside the growth room which were the experiments conducted has ranged temperature between of 18-26°C and its average was 22.5°C, and the humidity in the experimental room (lath house) ranged between 35-70% during the time of experiments.

Table 1: Effect of seeding rate, harvesting date and their interaction on plant height (pH, leaf weight (LW), root weight (RW) and leaf to root ratio (LRR) of hydroponic maize fodder.

Harvesting date	PH (cm)	LW (kg)	RW (kg)	LRR
HD8	15.4c	0.31c	0.9c	0.2
HD10	17.6b	0.33b	1.0b	0.3
HD12	22.1a	0.36a	1.07a	0.4
$LSD_{0.05}$	0.68	0.01	0.09	NS
P-value	<0.001	<0.001	0.001	0.2
Sig.	***	***	***	NS
Seeding rate				
SR4	15.2c	0.27c	0.7c	0.39a
SR6	18.2b	0.31b	0.9b	0.36b
SR8	21.8a	0.41a	1.4a	0.31c
$LSD_{0.05}$	0.683	0.014	0.0943	0.034
P-value	<0.001	<0.001	<0.001	<0.001
Sig.	***	***	***	***
HD * SR				
$LSD_{0.05}$	0.68	0.01	0.09	0.03
P- value	<0.001	0.001	0.01	0.013
Sig	***	***	**	*
CV%	3.7	4.2	9.8	9.8

[a-c] Columns with different letters differ significantly; PH=Plant height; RW=root weight; LW=leaf weight; LRR=leaf to root ratio; NS=non-significant; CV= Coefficient of Variation; HD8= Harvesting date 8th; HD10= Harvesting date 10th; HD12=Harvesting date 12th; SR4=Seed rate 4kg/m2; SR6 = Seed rate 6kg/m2; SR8= Seed rate 8kg/m2.

Planting Materials for the Hydroponic Maize Fodder

The maize grain variety BH-546 was chosen for the intended study as this variety dominantly used by the farmers in the Hawassa surrounding rural kebeles. The seed was obtained from Sidama N/R/S of Agricultural and Natural Resource Development bureau. The seeds were freed from debris and other extraneous materials before the experiment began and they undergone a germination test to determine their viability which was 87%.The planting trays were also thoroughly cleaned by tap water and hydrogen per oxide before use that.

Treatment of Seeds Before Planting: The seeds were soaked in 1-2% hydrogen peroxide solution (household bleach) for one hour separately, to control the formation of mould and was taken place without water for an hour, because this is the breathing time of the seeds and it helps in proper germination. After breathing time maize seeds were placing into gunny bag. The seeds were thoroughly washed from residues of the bleach and re-soaked overnight in tap water before sowing. Before planting, soaked grains were stored in a gunny bag in a dark room for 24 or 48 hours until a root mat emerged (Endalew *et al.*, 2019). Planting trays and other equipment's were also cleaned and disinfected with similar solution of 1% sodium hypochlorite or hydrogen per oxide (Getachew *et al.*, 2020) (Figure 1).

Seed Planting and Watering: The seeding rate used in this experiment were used 4, 6 and 8 kg/m^2. Before sowing the trays were stacked on the shelves of the hydroponic system. The maize seeds were water sprayed 1.5 lit of tap water three times a day until harvest time or harvesting date (Lamidi *et al.*, 2022). Trays were irrigated manually with tap water three times a day that mean early in the morning (1 hour), lunch time (6 hour) and late in the afternoon (12 hour) with tap water to provide enough water to keep the seeds/ seedlings moist. There were no media to grow the hydroponic fodder in the hydroponic unit except tap water (chemical free) and sprouting trays purposely designed for cultivation and growing of hydroponic fodder.

The amount of water irrigated to grow 4kg, 6kg and 8kg of hydroponic maize fodder was 1.5 liter for all growth days (Weldegerima *et al.*, 2015).

Biomass Yield Measurement

Biomass yield of hydroponic maize fodder and yield related parameters were measured. Accordingly, the fodder of hydroponically produced BH-546 maize was harvested at 8th ,10th and 12th days after sowing and were measured to identify the appropriate date at which maximum biomass yield of sprouted maize fodder could be harvested.

Morphological Data

Plant height at harvest: At the end of 8th, 10th and 12th day of sprouting, the height of the plant (cm) was taken using transparent glass ruler. For this purpose, the heights of ten plants were randomly taken from four different segments of the tray and the average was recorded.

Leaf weight: During harvesting, the weight of total fodder (sprout with a tray) was taken first (W1). Then the leaves were trimmed using razor blade, and the tray and root together was weighed again (W2). The weight of the fresh leaf was then computed as a difference (W1-W2).

Root weight: After removal of the leaf, weight of tray and root together minus tray weight was considered as root weight.

Leaf to 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.

Total Water Use and Water Use Efficiency

The daily total water added and drained out of trays throughout the course of experiments were recorded per tray to compute for total water use and water use efficiency. The total water used by plants (liters/tray) is calculated using following equation (Al-Ajmi *et al.*, 2009). Drained water out of irrigation was collected in plastic trays which was placed under each planting tray. The total added and drained water out of trays were recorded to compute for total water use (liters water used/ kg fresh fodder produced) and water use efficiency (kg fresh fodder produced/liter water was used).

The total water used by plants (liters/tray) were computed according to the equation:

Total water use = Total added water in irrigation – Total drained water out of rays.

Water use efficiency (WUE) in kg fresh weight/m^3 water was computed according to the equation: WUE = Total green fodder produced (kg/tray)

Total water used (liter/tray)

Harvesting

After 8th 10th and 12th days of plantation the samples of fodders were collected for chemical analysis and in-vitro digestibility. Finally, after 12 days hydroponic fodder were harvested and total production was calculated on DM basis.

Table 2: Effect of seeding rate, harvesting date and their interaction on fresh biomass yield (FBMY), dry matter yield (DMY) and crude protein yield (CPY) of hydroponic maize fodder.

Seeding rate	FBMY kg/m^2	DMY kg/m^2	CPY kg/m^2
SR4	6.8c	1.3c	0.2c
SR6	10.4b	2.4b	0.3b
SR8	14.7a	4.0a	0.5a
$LSD_{0.05}$	1.07	0.33	0.04
p-value	<0.001	<0.001	<0.001
Sig.	***	***	***
Harvesting date			
HD8	7.6c	1.7c	0.2c
HD10	9.6b	2.3b	0.3b
HD12	14.7a	3.7a	0.5a
$LSD_{0.05}$	1.07	0.33	0.04
p-value	<0.001	<0.001	<0.001
Sig.	***	***	***
HD*SR			
p-value	1.86	0.011	<0.001
Sig.	NS	*	***
CV%	10.2	13	13.7

[a-d]Means with different superscripts within column and under seed rate differ significantly;
NS= non-significant; FBMY= Fresh biomass yield; DMY= Dry matter yield; CPY= crude protein yield; CV= Coefficient of Variation; HD8= Harvesting date 8th; HD10= Harvesting date 10th; HD12=Harvesting date 12th;
SR4=Seed rate 4kg/m2; SR6 = Seed rate 6kg/m2; SR8= Seed rate 8kg/m2

Experimental Design

The treatments for seed rates and harvesting dates were explained under each experiment. This study was conducted in a 3 × 3 factorial experiment in a Randomized Complete Block Design (RCBD) with three replications, considering the position of a tray on a shelf as a block.

Chemical Analysis and *In vitro* DM Digestibility

Both the grain and herbage (sprouted) parts of the hydroponically grown maize fodder was analyzed in the laboratory. Chemical analysis of fresh hydroponic maize fodder samples were determined at Hawassa University laboratory. Representative fresh samples were weighed and air-dried in a well-ventilated room by spreading over a plastic sheet. After air drying, the samples for each treatment per replication were weighed, packed in a labeled polyethylene bags and taken to laboratory for chemical analysis. Partial DM of each maize fodder was determined by drying the fodder samples at 60°C in air forced oven for 48h (Fazaeli *et al*., 2012) and ground to pass through a 1mm sieve size Wiley mill for subsequent chemical analysis and determination of in vitro DM digestibility (Hande *et al*., 2014). The DM and ash contents were analyzed according to the procedures of (AOAC, 2000). The Nitrogen (N) content was analyzed by Micro Kjeldahl method and the crude protein (CP) was calculated as N×6.25. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to Van Soest *et al*.(1991). The in-vitro DM digestibility (IVDMD) was determined using the two stages Tilley and Terry (1980) procedure. Rumen fluid was collected from intact ram fed with *ad libitum* natural pasture hay, 200g concentrate and 1kg succulent natural grass per day per head at Hawassa University. Samples of 0.5g hydroponic fodder along with 50 ml of buffered rumen fluid were incubated in an in-vitro digestion tube in duplicate at 39°C and fermented for 48 hours followed by 48 hours of digestion with pepsin. At the end of digestion, the flasks were removed from the water bath and the residue was washed with hot water and acetone twice. The filtrates were dried overnight at 105°C in an oven to determine IVDMD. The hydroponic maize fodder was evaluated for in vitro DM digestibility with strained rumen liquor (SRL) collected from rumen fistulated animals maintained on green native pasture hay diet.

Production Cost of Maize Hydroponic Fodder

The costs considered for hydroponic fodder production was seed, water, chemical and material (i.e. depreciation of materials for hydroponic fodder unit and other materials like perforating needle, plastic tray and saw blade). Labor was included in cost analysis. The total cost was computed for sources of costs, cost per seed rates, and harvesting dates. Where MRR% is marginal rate of return, NR change in net return and TVC change in total variable cost.

Statistical Analysis

The hydroponics fodder yield, water use efficiency, chemical composition and In vitro DM digestibility data was analyzed using the general linear model procedure of statistical analysis systems (SAS, 2008). When the analysis of variance (ANOVA) showed significant differences among treatments, Tukey test were employed detect differences between treatment means.

The statistical model used for the date analysis was:

Yijk= μ +Bi+Sj+Hk+ (SH)jk +εijk;

Where: Yijk = an observation in in Block i, seeding rates j, Harvesting dates k

μ = the overall mean;

Bi= Block effect

Sj=is the jth level effect of seed rate;

Hk= the kth level of harvesting date

(SH) ij = interaction effects with seed rate and harvesting date

εijk = the residual error

Results and Discussion

Morphological Parameters of Hydroponic Maize Fodder

Seeding rate, harvesting date and their interaction on plant height, root weight, leaf weight and leaf to root ratio of hydroponic maize fodder is presented in Table 1.Seeding rate, harvesting date and their interaction were significantly (P<0.001) affected plant height, leaf weight and root weight of hydroponic maize fodder. Leaf to root ratio was significantly (P<0.001) varied among seeding rates.

Plant Height: The hydroponic maize fodder height was significantly (P<0.001) varied as of seeding rates and harvesting dates and their interaction was also significant (P-value). The highest plant height of hydroponic fodder maize was 21.8cm while the shortest plant height was 15.2cm which were recorded at the 8 kg seeding rate and 4 kg and 22.1cm and 15.4 at late harvesting date of 12th day and early harvesting date of 8th day of planting, respectively (Table 1). This may be due to the spatial competition between seedlings in the tray plot of highest seeding rate. The plant height increment from early to late harvesting may be due to the physiological response of the hydroponic maize i.e., the continual growth and development of the

Table 3: Total water use and water use efficiency of seed rates and harvesting dates under hydroponic conditions of maize production.

Parameters	Total water use	Water use efficiency	
	Liters/m2	Fresh fodder (kg/lit)	DM fodder (kg/lit)
SR4	$8.8^{c}\pm0.56$	$0.11^{c}\pm0.01$	$0.02^{c}\pm0.0001$
SR6	$9.7^{b}\pm0.61$	$0.13^{b}\pm0.01$	$0.03^{b}\pm0.001$
SR8	$12.1^{a}\pm1.02$	$0.20^{a}\pm0.01$	$0.05^{a}\pm0.001$
SEM	0.35	0.0001	2.46E-06
P- value	<0.0001	<0.0001	<0.001
HD8	$7.8^{c}\pm0.3$	$0.17^{a}\pm0.02$	$0.02^{c}\pm0.003$
HD10	$10.2^{b}\pm0.5$	$0.14^{b}\pm0.02$	$0.04^{b}\pm0.003$
HD12	$12.8^{a}\pm0.8$	$0.13^{b}\pm0.01$	$0.05^{a}\pm0.004$
SEM	0.35	0.0001	2.46E-06
P- value	<0.001	<0.001	<0.001
SR	***	***	***
HD	***	NS	***
SR *HD	*	NS	***

$^{a-c}$Means with different superscripts within column differ significantly; *P<0.05;***P<0.0001; NS=Non-significant; HD8= Harvesting date 8th; HD10= Harvesting date 10th; HD12=Harvesting date 12th; SR4=Seed rate 4kg/m2; SR6 = Seed rate 6kg/m2; SR8= Seed rate 8kg/m2.

crop for agronomic managements. Longer harvesting time will help the plant use nutrient in the seed and hence the plant continued to increase in height. The highest plant height of the present study was closely related to 28 cm of previous report (Atumo et al., 2022). Reddy (2014) also 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. The mean value of plant height for current study is in the range of values reported by Dung *et al.(* 2010*)* and Naik *et al.* (2014) who have indicated that depending upon the landraces of grains, the hydroponic fodder looks like a mat of 11-30 cm height by the end of the germination period of about 8th day. It takes 12 days duration to develop from maize seed to grow fodder measuring approximately 30 cm tall. It required high seed germination percentage to provide maximum biomass production (Rabten *et al.*, 2016). Based on Bekele *et al.* (2020) the plant height at 17th date of harvesting had highest value because of that the herbages of BH-661 maize was not well grown at 7 days of harvesting. In another experiments the average plant height 28 cm achieved on 8th day was in line with the results reported by Naik *et al.* (2013) in maize hydroponic fodder as 20-30cm. The height of plants in the above reports were higher than the present as photosynthesis continue, growth of plant increase and plant leaf also increases. This means longer harvest time could bring higher plant leaf production. On this study on 8th days the plant height becomes 15.4 cm this could depend on the breed type, seed quality, temperature of green house and humidity (moisture content). Ndaru *et al.* (2020) reported the height of the hydroponic maize fodder on the 8th day and the 20th day the plant height reached 18.67 cm and 37.33 cm respectively. The same author reported that 20th day harvesting time is the peak of the plant height, then the 24th day the plant begins to wither and does not grow significantly.

Leaf Weight: The leaf weight presented in Table 1 showed significant (P<0.001) variation for the seeding rate, harvesting date and their interaction. The highest leaf weight 0.41 kg/m^2 was recorded at the highest seeding rate of 8 kg/m^2 and 12th date of harvesting. The lowest leaf weight 0.27 kg/m^2 was recorded at 4 kg/m^2 seeding rate and 8th day of harvesting. The trend of leaf weight showed increasing with increasing harvesting date and seeding rate. The current study result showed that staying for some long period for 12 days with highest seeding rate of 8 kg/m2 in hydroponic maize production improved the leaf weight by more than 10.5%. Bekele *et al.* (2020) results showed that varieties with high fresh yield had high leaf weight at 17th days of harvesting which were 46.38, 45.48, 44.9 t/ha and those varieties with low fresh yield have also low leaf weight at 15th day of harvesting which were 43.38, 41.66 and 39.79 t/ha, respectively. The results shows that the longer harvest time could bring higher plant leaf production as the photosynthesis in plants continues which increase the plant growth and leaf weight.

Root Weight: Seeding rate, harvesting date and the interaction on root weight is presented in Table 1. There was significant (P<0.001) difference among seed rates and harvesting dates on root weight. The interaction effect of seeding rate and harvesting date was also significant (P<0.001) for root weight of hydroponic maize fodder. The highest root weight of 1.66 kg/m2 was recorded at 12th day of harvesting and 8 kg seeding rate. The lowest root weight of 0.62 kg/m2 was recorded at 4 kg/m2 seeding rate when harvested as early as 8th day of harvesting. The result showed lower seeding rate at early harvesting responded lower root weight while higher seeding rates at late harvesting had significantly (P<0.001) higher root weight. Increasing the seeding rate from 4 kg to 8 kg and harvesting date from 8th day to 12th day of harvesting was showed 172.1% root weight improvement. Moreover, increased seed rate will lead to more microbial growth in root mat which effect the growth of individual plants. A number of studies reported that sprouting resulted in loss from the original seed after sprouting mainly due to respiration during the sprouting process, leaching and oxidation of nutrients from the seeds. Another author reported that the fresh yield of the roots along with the germinated seeds increased with the increase in the seed rate (Naik *et al.*, 2016). The results of Mesfin *et al.* (2020) 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 mean value 14.16% of the during sprouting.

Leaf to Root Ratio (LRR): Leaf to root ratio was significantly varied for harvesting date (P<0.001) and the interaction effect of harvesting date and seeding rate was found significant (P<0.05) (Table 1). The highest leaf to root ratio was recorded at 4 kg/ m^2 seeding rate and 12th day of harvesting. The lowest LRR was recorded at 8 kg/m^2 seeding rate and 12th day of harvesting. The current finding is supported by other related findings , as harvesting time increase the leaf weight shows high increment than root weight and the fodder had lower LRR at early harvest and higher LRR at late harvest (Bekele *et al.*, 2020).

Green Fodder Biomass, Dry Matter and Crude Protein Yield of Hydroponic Maize Fodder as Affected by Seeding Rates and Harvesting Dates

Fresh Biomass Yield: Maize hydroponic fodder fresh biomass yield was significantly (P<0.001) varied among harvesting dates and seeding rates while not varied significantly (P>0.05) among the interaction of seeding rates and harvesting dates (Table 2). The fresh biomass yield was ranging from 14.68 kg/m^2 for late harvesting in 12th day to 7.60 kg/m^2 for earlier harvesting in 8th day after planting.

Table 4: Effect of seeding rates and harvesting dates on chemical composition (DM %) of maize under hydroponic systems.

Parameter	DM	Ash	CP	NDF	ADF	ADL	IVDMD
Seeding Rate							
SR4	18.0ᵃ±0.2	2.6ᶜ±0.08	11.6ᵇ±0.22	35.2ᵇ±0.25	10.6ᵇ±0.30	5.0ᵇ±0.23	74.9ᶜ±0.59
SR6	15.0ᵇ±0.1	2.7ᵇ±0.08	11.9ᵇ±0.24	35.6ᵃ±0.20	10.9ᵃ±0.30	5.1ᵇ±0.18	75.7ᵇ±0.37
SR8	14.0ᶜ±0.2	2.8ᵃ±0.08	12.0ᵃ±0.25	35.9ᵃ±0.27	11.0ᵃ±0.31	5.9ᵃ±0.29	76.4ᵃ±0.34
P-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Harvesting Date							
HD8	16.2ᵃ±0.6	2.5ᶜ±0.03	12.6ᵃ±0.04	34.7ᶜ±0.1	9.8ᶜ±0.05	4.6ᶜ±0.08	74.1ᶜ±0.4
HD10	15.8ᵃ±0.5	2.7ᵇ±0.05	11.7ᵇ±0.1	35.8ᵇ±0.08	10.7ᵇ±0.09	5.1ᵇ±0.19	75.8ᵇ±0.21
HD12	15.0ᵇ±0.5	3.0ᵃ±0.03	11.2ᶜ±0.07	36.3ᵃ±0.1	11.9ᵃ±0.06	6.2ᵃ±1.17	77.1ᵃ±0.1
P-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
SR	***	***	***	***	***	***	***
HD	***	***	***	***	***	***	***
SR*HD	NS	NS	NS	NS	NS	NS	NS

DM = Dry matter; NDF = Neutral detergent fibers; ADF = Acid detergent fiber; CP = crude protein; ADL = Acid detergent lignin; IVDMD= In-vitro dry matter digestibility; NS = Non-Significant; a b c Means followed by different superscript letters within treatments differ at p<0.05; CV= Coefficient of Variation; HD8= Harvesting date 8th; HD10=Harvesting date 10th; HD12=Harvesting date 12th ; SR4=Seed rate 4kg/m2; SR6 = Seed rate 6kg/m2; SR8= Seed rate 8 kg/m2.

This result indicates higher fresh biomass yield in late harvesting than earlier in hydroponic maize fodder production. The fresh biomass yield improvement for late harvesting than earlier harvesting in the present experiment was 48.9%. The fresh biomass yield variation of hydroponic maize due to different seeding rates was ranging from 6.84 kg/m^2 for 4 kg seed to 14.68 kg/m^2 for 8 kg/m^2 seeding rate. Linear increment of fresh biomass yield was recorded for seeding rates from 4 to 8 kg/m^2. The improvement may be due to a process of embryo growth and seed components through the higher action of gibberellin hormone in long period than shorter growing time that promotes the formation and growth of roots and leaves this was reported by (Ndaru *et al*., 2020). Other report also presented higher biomass yield at higher seed rate than lower seed rates on hydroponic fodder production (Getachew *et al*., 2020).Other authors also reported the importance of viability and quality of selected crop seed for yielding optimum biomass. According to Baral *et al*. (2021) the germination of soaked maize seed which started on second and third day of sowing and the roots were clearly visible from third and fourth day onwards in hydroponics systems gave higher biomass yield when grow up more than 10 days. The cultivation of hydroponic fodder is a production technology that stands out by offering a yield in a short cycle of harvesting time, continuous production out of season, and high productivity (Ndaru *et al*., 2020). Hydroponic green fodder growing systems produce a greater yield over a shorter period in a smaller unit than traditionally grown crops there is no post-harvest loss of fodder as seen in the conventional practices of hay and silage making will be fully utilized as there is no loss of the fodder during feeding as compared to wastages of chopped traditional grasses (Mijena *et al.,* 2021). Naik *et al*., (2017) also reported the fresh yield of the maize grown hydroponically will increase with increase in seed rate up to some extent thereafter it will reduce drastically. Reports of Naik *et al*., (2013) shows that farmers producing hydroponics maize fodder under low cost devices or green houses 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 ,type and quality of seed.

Dry Matter Yield: Dry matter yield of hydroponically produced maize was significantly (P<0.001) varied for the effect of seeding rate, harvesting date and the interaction of seeding rates and harvestings dates in the present study (Table 2). The result indicated higher dry matter yield of 4.0 kg/m^2 at the seeding rate of 8 kg/m^2 and later harvesting date at 12th day after sowing. While the lower dry matter yield of 1.3 kg/m^2 was recorded at lower seeding rate of 4 kg/m^2 and at early harvesting of 8th day after sowing. Getachew *et al*., (2020) reported that the dry matter yield was increased with increasing seeding rate which is similar to present study result. The dry matter yield recorded in this study is in agreement with findings of Fazaeli *et al*. (2012) who have reported dry matter content of the fodder was decreased due to the sprouting when compared to the original seeds. Similarly, Sneath and McIntosh (2003) reported 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 imbibition of water (leaching) and enzymatic activities (oxidation) that depletes the food reserves of the seed endosperm without any adequate replenishment from photosynthesis by the young plant during short growing cycle and under dark conditions, there is increase in the DM loss which slows down after day 4 in lighted conditions when photosynthesis begins (O'Sullivan, 1982). According to Ningoji *et al*. (2020) the increased seed density might further increased temperature of the microclimate owing to higher plant respiration and leading to lower accumulation of dry matter.

Crude Protein Yield: Crude protein yield was significantly (P<0.001) varied for harvesting date, seeding rate and the interaction effect of harvesting date and seeding rate of hydroponic fodder maize production (Table 2). Crude protein yield was ranged from 0.2 to 0.5 kg/m2 for the present study. Higher crude protein yield of 0.5 kg/m^2 was recorded at higher seeding rate of 8 kg/m^2 and at 12th day of harvesting date. The lower crude protein yield of 0.2 kg/m^2 was observed at the lower seeding rate of 4 kg/m^2 and harvested at 8th day after sowing. At higher seeding rate and harvesting date the crude protein yield was higher while at lower rate of seeding and early harvesting stage the value of crude protein yield was lower. If the value of dry matter yield is higher, the value of crude protein yield is higher in the experiment and with lower dry matter yields the values declines accordingly. According to Islam *et al.* (2016) Crude protein Yield percentage of maize seeding rate and harvesting date in different days(8th ,9th and 10th day) are presented that data in the table shown that there were no significant variation in crude protein yield of plant and root of maize forage among the different days (8th ,9th and 10th day). In agreement with (Flynn and O'Kiely, 1986) as cited by Morgan *et al.* (1992), the CP content increases progressively with age, reaching a maximum of 48% on day 8. However, protein content may be influenced as a result of the nitrogen supplementation and other nutrients changes in sprouting grains (Islam *et al*., 2016)

Water Use and Water Use Efficiency of Hydroponic Maize Fodder as Affected by Seeding Rates and Harvesting Dates

Total Water Use: Seeding rates and harvesting dates significantly (P<0.001) affected the amount of water used in the present experiment while no significant (P>0.05) was observed for their interaction (Table 3). The total amount of water use was ranged from 8.8 to 12.1 liter per m^2 for the seeding rates and 7.8 to 12.8 liter per m^2 for harvesting dates variation. The higher water consumption was observed for the higher seeding rate and late harvesting. At lower seeding rate and early harvesting the water consumption was the minimum. Depend on Suma *et al.* (2020) to produce one kg of hydroponic fodder 1.62-2 liter of water is needed if water is recycled and 2.5-3.3 liter of water is needed if water is not recycled.

Water Use Efficiency: The water use efficiency were significantly (P<0.001) varied for harvesting dates and seeding rates of hydroponic fodder maize production while not significantly (P>0.05) varied for the interaction of seeding rate and harvesting date (Table 3). The water use efficiency of seed rates of hydroponic fodder ranged from 0.11 to 0.2 kg fresh fodder yield per liter. The highest fresh fodder yield of 0.2 kg per liter was observed at highest seeding rate (8 kg/m^2) in the experiment. Water use efficiency of fresh matter fodder was lower in the seed rate 4kg/m2 (0.11 kg/lit) compared to the other seed rates that had different values between 6 and 8 kg. The current result concurs with other authors in similar work (Ningoji *et al*., 2020) the seed rate with 2.75 kg/m² recorded significantly higher water use efficiency (612.22 kg/m³) as compared to 1.50 kg/m² (379.01 kg/m³) and it was on par with 2.50 kg/m² (599.63 kg/m³) and also the higher water use efficiency under seed rate of 2.50 kg /m^2 is mainly associated with higher fodder yield per unit area with same rate of water application . According to Al-Karaki and Al-Hashimi, (2012) this is a tremendous improvement in WUE and indicated that hydroponic system could play a significant role in saving water to produce green fodder in high amounts. Copeland and Mcdonald (2001) reported that delaying the harvesting date of hydroponic fodder maize was decreased the water use efficiency as observed in the present study. Bradley and Marulanda (2001) reported that hydroponic green fodder production technique requires only about 10–20% of the water needed to produce the same amount of fodder in soil culture. Other authors also stated that only 3–5% of water is needed to produce the same amount of fodder in comparison to that produced under field conditions (Al-Karaki and Al-Momani, 2011). This is a tremendous improvement in WUE and indicated that hydroponic system could play a significant role in improving water use efficiency in countries that suffer from scarcity of water. Also there is no/little wastage of water as the available water is also recycled and utilized (Rachel *et al*., 2015). According to Getachew *et al.* (2020) the medium and high seed rates had higher (P< 0.05) water use efficiency of DM fodder yield than the lower seed rates. In water use efficiency of experiments the results of harvesting date and seed rates and harvesting dates interaction showed non-significant differences in fresh fodder (kg/lit) (P>0.05) and for this reason didn't include the results of interaction in our discussion.

Effects of Seeding Rates and Harvesting Dates on Chemical Composition of Hydroponically Grown Maize Fodder

Chemical composition of maize grain fodder of hydroponically produced at different seeding rates and harvesting dates were analyzed and the results are presented in Table 4.

Dry Matter: The dry matter content of hydroponic maize fodder at different seed rates and harvesting days are presented in Table 4. There were significant (P<0.05) variation in dry matter content of hydroponic maize fodder produced the different seeding rates (4,6 and 8kg/m^2) and harvesting days (8th ,10th and 12th day).The highest DM content was observed in 4 kg/m^2 seeding rate 18.0% and 8th day highest harvesting date 16.2% respectively. There was variation among the seeding rates (4, 6 and 8 kg/m^2) on the dry matter percentage. Getachew *et al*. (2020) reported among seeding rates, the high seeding rate has lower DM content than the other seeding rates. On this study also the high seeding rate has lower DM content than the other seeding rates that had lower and medium DM content. According to Murugkar and Jha. (2009) the DM content of the seeds decreased during sprouting compared to original seed and this could be due to leaching and oxidation of substances. The study of seed that tell the original seed DM content was 95.32% and the sprouted seed average was during sprouting of the seeds it become decrease 18.0% on 4 kg/m2 seeding rate and 16.2% on 8th date of harvesting. 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 imbibition 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 (Sneath and Mcintosh, 2003). Previously reported results 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 (Chavan and Kadam, 1989). The reasons for the loss in dry matter have been considered in a number of studies. Reports of Dung *et al*., (2010) 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 reports of Chavan and Kadam. (1989) 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. According to Naik *et al*. (2015) the DM (89.7 (maize grain) vs. 13.4% (fodder)) and OM (96.60-97.19 (maize grain) Vs. 96.35% (fodder)) content is decreased which may be due to the decrease in the starch content. During sprouting, starch is catabolized to soluble sugars for supporting the metabolism and 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 and OM.

Ash: The effect of hydroponic maize seeding rate, harvesting date and their interaction on Ash is presented in Table 4. Seeding rates and harvesting dates had significant (*P*<0.001) effect on the ash content of hydroponic maize fodder. The data in Table 4 shown that there were significant (p<0.001) variation in ash content of plant and root of maize forage among the different days of harvesting and seeding rates. The higher ash content was observed at 12th day harvesting and

Table 5: Partial budget analysis of maize hydroponic fodder production.

Description	Treatments								
	SR4HD8	SR4HD10	SR4HD12	SR6HD8	SR6HD10	SR6HD12	SR8HD8	SR8HD10	SR8HD12
Fixed costs									
Fencing	100	100	100	100	100	100	100	100	100
Material purchase (tray)	100	100	100	100	100	100	100	100	100
Total Fixed Costs (TFC)	200	200	200	200	200	200	200	200	200
Variable cost									
Seed in kg	4	4	4	6	6	6	8	8	8
Seed cost in ETB per Kg (1kg=45 ETB)	180	180	180	270	270	270	360	360	360
Water amount litre/m2	7.8	10.2	12.8	7.8	10.2	12.8	7.8	10.2	12.8
Water cost (1litre=0.5ETB)	3.9	5.1	6.4	3.9	5.1	6.4	3.9	5.1	6.4
Labor cost	50	100	150	50	100	150	50	100	150
Total Variable cost (TVC)	233.9	285.1	336.4	323.9	375.1	426.4	413.9	465.1	516.4
Fresh Matter yield kg/m2	4.97	7.08	10.75	5.51	9.1	14.24	10.04	14.92	19.07
Total revenue (TR) (1kg fresh matter=40 ETB	198.8	283.2	430	220.4	364	569.6	401.6	596.8	762.8
NR=TR-TVC	-35.1	-1.9	93.6	-104	-11.1	143.2	-12.3	131.7	246.4
Δ NR		-16.3	95.5		-114	154.3		144	114.7
Δ TVC			51.3			51.3		51.2	51.3
MRR%		D	186		D	300.7		281.3	223.6

HD8= Harvesting date 8th; HD10=Harvesting date 10th; HD12=Harvesting date 12th; SR4=Seed rate 4 kg/m2; SR6 = Seed rate 6 kg/m2; SR8= Seed rate 8kg/m2.

at 8kg/m^2 seeding rate. Morgan *et al*., 1992 as cited by Sneath and Mcintosh (2003), changes in ash and protein contents occur rapidly from day 4 corresponding with the extension of the radicles (roots), which allows the mineral uptake. Morgan *et al*., (1992) reported that the ash content changed from 2.1% in original seed to 3.1 and 5.3% at day 6th and 8th respectively.

In the present results ash contents original maize grain and hydroponically grown maize fodder showed higher values compared to maize grain that 1.8% and hydroponically produced, was 2.8 % for 8kg/m2 and 3.0 % for 12th date respectively. The results clearly indicated during the sprouting process, the total ash content that growing maize hydroponically improves the ash increase due to the absorption of minerals by the root content of the fodder (Thadchanamoorthy *et al*., 2012). Such techniques were proved another reports by Similarly to current result Naik (2012) reported that the ash contents of hydroponic maize fodder in the range of 1.56%-3.84% which was almost similar to the present results.

Crude Protein: The CP content was significantly (P<0.001) varied for the effect of seeding rates and harvesting dates while not significant (P>0.05) variation recorded for the interaction of seeding rates with harvesting dates effect. The CP content of the original maize grain was 9.45%, which was lower than the fodder produced of it at different seeding rates and harvesting dates grown in hydroponics system (Table 4). Correspondingly, Islam et al. (2016) noted the CP content of the sprouted maize showed an increasing trend with germination time and remained highest (P<0.05) on 7th day (13.57%) of growth. Apparent increase in protein content may be attributed to the loss in dry weight, particularly carbohydrates, through respiration during germination and thus longer sprouting (Uppal and Bains., 2012). Higher sprouting temperature and longer sprouting time would mean greater loss in dry weight and more increase in crude protein content. There is reawakening of protein synthesis upon imbibition (Nonogaki *et al*., 2010), which leads to increase in protein content in sprouted seeds. The absorption of nitrates facilitates the metabolism of nitrogenous compounds from carbohydrates reserves, thus increasing levels of CP. Additionally, the sprouting has been reported to alter the amino acid profile of maize seeds and increases the crude protein content of hydroponic fodder (Naik *et al*., 2011). Thadchanamoorthy *et al*. (2012) 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. (McDonald *et al*., 2018) suggested threshold of about 7 to 8% CP to guarantee sufficient utilization of feed and depend on Bekele *et al*. (2020) the average crude protein (CP) values were 11.17%, 13.97%, 13.93%, 13.73% and 15.03% for maize grain and hydroponically grown fodder of varieties respectively. 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 and also Hydroponic maize fodder for present study possess >10% CP which is intermediate CP quality for grass hay and determining the composition and digestible nutrients of forages harvested in a way to simulate grazing by cattle (Atumo et al., 2021b).

Neutral Detergent Fiber, Acid Detergent Fiber and Acid Detergent Lignin Contents of Hydroponically Produced Maize Fodder

The effect of seeding rates and harvesting dates were significant (P<0.001) and on NDF, ADF and ADL contents of hydroponic maize fodder, while the interaction effect of seeding rates with harvesting dates were not significant (P>0.05). The NDF, ADF and ADL content of the original maize grain was 30.5, 8.7 and 2.7%, respectively. Compared to original maize grain, sprouted and grown seeds fibers contents were higher at each seeding rates and harvesting dates (Table 4) which could be attributed to the increasing fiber fraction as stage of growth advanced. Similarly, (Thadchanamoorthy *et al*., 2012) reported that NDF contents of hydroponic maize fodder was 29.27% and that of original 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 *et al.*(2011) the NDF content of hydroponic maize fodder of the current study had lower than 45% of NDF and (ADF) contents that fulfills high quality forage criteria and it confirms that the ruminant animals could directly consume and could be supplemented to other poor quality roughage diets. The ADF and ADL contents were also in acceptable level which do not impair digestibility in all seed rates and harvesting dates. In their study, (Thadchanamoorthy *et al*., 2012) 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 the original maize grain and it was also true in the present results. Among seed rates and harvesting dates the large seed rate has significantly higher ADF content than low seed rate.

The In Vitro Dry Matter Digestibility (IVDMD)

Effect of seeding rates, harvesting dates and their interaction on in vitro dry matter digestibility (IVDMD) is presented in Table 4. Seeding rates and harvesting dates significantly ($P<0.001$) affected IVDMD while their interaction on IVDMD was not significant ($P>0.05$).The IVDMD of the original maize grain was 83.3%, while the fodder produced hydroponically at different seeding rates and harvesting dates lower to that of the maize grain (Table 4).Correspondingly, Karunathilaka *et al*. (2012) reported the IVDMD of hydroponic maize fodder harvested between 7 to 10 days had lower IVDMD % as compared to the maize grain, which could be attributed to the increasing fiber fraction as stage of growth advances. 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 12th days and in these days the soluble component in the grain was lost for maintaining the plant. However, in contrast (Thadchanamoorthy *et al*., 2012) reported that IVDMD of hydroponic maize fodder harvested at 10th day was 79.87% and that of maize grain was 68.75%.

Partial Budget Analysis of Maize Hydroponic Fodder Production

The partial budget analysis was conducted as cost of variable entities was calculated based on cost of seed used in different rates of application. However, the cost of management like watering, fencing, tray purchase, wage of watering, harvesting, transporting, labor and different activities disposed for hydroponic fodder maize production was included in calculation of variable costs. The price of 1 kg fresh grass in the local area was 40 ETB. Dry matter yield was increasing from lower seeding rate to different higher seeding rate and each kilogram increment in yield influencing the income driving from the production.

Net revenue 246.4 ETB is higher in higher seeding rate (8 kg/m2) at later dates of harvesting (12th day after sowing) followed by 6 kg seed at 12th day and sowing 8 kg seed and harvesting at 10th day of sowing. In hydroponics fodder production, less production space is required because the fodder is grown in trays which are arranged in shelves inside the hydroponics system (Getachew *et al*., 2020). Also in the same line with the CIMMYT (1988) that any treatment that has net benefits that are less than or equal to those of a treatment with lower costs that vary is dominated (D) and the recommendation is not necessarily the treatment with the highest net benefit, nor the treatment with the highest yield but identification of a recommendation requires a careful marginal analysis using an appropriate minimum rate of return (MRR) (50-100%). Where MRR% is marginal rate of return, NR change in net return and TVC change in total variable cost.

Conclusion and Recommendations

The study was conducted to examine the effect of seeding rates and harvesting dates on biomass yield, dry matter yield and crude protein yield and nutritive values of hydroponically sprouted fodder of maize BH-546 varieties. The current study showed that seeding rates tested at 8kg/m^2 is better for hydroponic fodder production due to higher plant height, leaf weight and root weight with relatively low cost of production. The 12th harvesting dates per m^2 produced higher plant height, leaf weight and low in root weight of hydroponic fodder to grain cost ratio. Changing maize grain to hydroponic fodder reduced the DM weight of the initial grain and increased the cost of feed per kg DM. However, quality advantage together with, water use efficiency and the need for green fodder under the scenarios of climate change and land scarcity for many farmers need to be considered to use hydroponic fodder production. Based on the result of the current study, it is recommended to produce hydroponics maize fodder production for farmers at seeding rate of 8 kg/m^2 and harvesting dates of 12th for optimal green fodder yield and good quality of maize fodder.

References

1. Adebiyi, O. A., Adeola, A. T., Osinowo, O. A., Brown, D., & Ng'Ambi, J. W. (2018). Effects of feeding hydroponics maize fodder on performance and nutrient digestibility of weaned pigs. Applied Ecology and Environmental Research, 16(3), 2415–2422. https://doi.org/10.15666/aeer/1603_24152422
2. Adugna, T., Alemu, Y., Alemayehu, M., Dawit, A., Diriba, G., Getnet, A., Gizachew, L., Bediye, S., & Woldesemaya, Y. (2012). Livestock Feed Resources in Ethiopia: Challenges, Opportunities and the Need for Transformation. In Ethiopian Animal Feeds Industry Association.
3. Al-Karaki, G. N., & Al-Hashimi, M. (2012). Green fodderproduction and water use efficiency of some foragecrops under hydroponic condition. Internl. Schol. Res.Network. DOI: 10.5402/2012/924672.
4. Akbağ, H. I., Türkmen, O. S., Baytekin, H., & Yurtman, İ. Y. (2014). Effects of harvesting time on the nutritional value of hydroponic barley production. Turkish Journal of Agricultural and Natural Sciences, 7(7), 1761–1765.
5. Al-Ajmi, A., Salih, A., Kadhim, I., & Othman, Y. (2009). Yield and water use efficiency of barley fodder produced under hydroponic system in GCC countries using tertiary treated sewage effluents. Journal of Phytology, 1(5), 342–348.
6. Al-Karaki, G. N. (2011). Utlization of treated sewage waste water for green forage production in a hydroponic system. Emirates Journal of Food and Agriculture, 23(1), 80–94.
7. Al-Karaki, G. N., & Al-Hashimi, M. (2012). Green Fodder Production and Water Use Efficiency of Some Forage Crops under Hydroponic Conditions. Internl. Schol. Res. Network., 924672, 1–5.
8. Al-Karaki, G. N., & Al-Momani, N. (2011). Evaluation of Some Barley Cultivars for Green Fodder Production and Water Use Efficiency under Hydroponic Conditions. Jordan Journal of Agricultural Sciences, 7(3), 448–457.
9. Al-Saadi, M. J. (2016). Productive effects and economical feasibility of substitution barley by 10 and 30% of sprouted barley in diet of Awassi male lambs. Asian Journal of Animal and Veterinary Advances, 11(9), 563–569. https://doi.org/10.3923/ajava.2016.563.569
10. Alemayehu, M. (2004). Feed Resources Base of Ethiopia: Status, Limitations and Opportunities for Integrated Development.
11. Anonymous. (2008). Grass fodder by hydroponics in 8 days. Http:// Grassfodder.Com /Hydrop Onics.Php.
12. Anonymous. (2016). Smart Farming: (Living Lab) Mobile Kilimo, Hydroponic Fodder, Aquaponic, Azolla and Cage Culture. Economic and Social Research Foundation, Tanzania. Www.Esrftz.Org/Docs/SmartFarmingTZ.Pdf.

13. AOAC. (2000). Official Methods of Analysis 17th Ed. Association of Official Analytical Chemists, Gaithersburg, MD.

14. Asadullah, A. A., Ahmed, A. S., Kadim, I., & Othman, Y. (2009). Yield and water use efficiency of Barley fodder produced under hydroponic system in GCC countries using tertiary treated sewage effluents.

15. Atumo, T., Mengesha, G., Heliso, M., & Kalsa, G. (2021). Yield dynamics and nutrient composition of Napier grass (Pennisetum purpureum) varieties under consecutive harvests. Ethiopian Journal of Sciences and Sustainable Development, 9(1 SE-Articles). https://doi.org/10.20372/ejssdastu:v9.i1.2022.379

16. Atumo, T. T., Heliso, M. F., & Hibebo, D. K. (2022). Productivity and profitability of different crops under the fertigated hydroponic condition. International Journal of Science and Research Archive, 6(1), 015–019. https://doi.org/10.30574/ijsra.2022.6.1.0102

17. Ayele, S., Workalemah, A., Jabbar, M., Ahmed, M., & Hurissa, B. (2003). Livestock marketing in Ethiopia: A review of structure, performance and development initiatives. Socio-Economics and Policy Research Working Paper 52, 44–51.

18. Bakshi, M. P. S., Wadhwa, M., Harinder, P., & Makkar, S. (2017). Hydroponic fodder production:A critical assessment. Broadening Horizons, 48(2), 1–10.

19. Baral, B. R., Khanal, B., Pandeya, Y. R., Bhusal, K., & Malla, S. (2021). Effect of seed rate on production performance of hydroponics maize fodder.

20. Bekele, M., Diba, D., & Yusuf, H. (2020). Watering Intervals and Harvesting Dates Affected Fodder Yieldand Nutritional Values of Maize Varieties under Hydroponic Systemin Wollega University. American-Eurasian J. Agric. & Environ. Sci, 20(2), 89–98.

21. Bradley, P., & Marulanda, C. (2001). Simplified Hydroponics to Reduce Global Hunger. Institute of Simplified Hydroponics Corvallis, Oregon USA and UN FAO and UNDP Armenia, Colombia, 22, 289–295.

22. Cader, B. (2002). Simple Shed Company, Morayfield, Queensland, Australia.

23. Chandra, P., & Gupta, M. . (2003). Cultivation in hi-tech greenhouses for enhanced productivity of natural resources to achieve the objective of precision farming. In: Singh, H.P., Singh, Gorakh, Samuel, J.C., Pathak, R.K. (Eds), (2003). Precision Farming in Horticulture, NCPAH, DAC, MOA, .

24. Chavan, J. K., & Kadam, S. S. (1989). Nutritional improvement of cereals by fermentation. Critical Reviews in Food Science and Nutrition, 28(5), 401–437.

25. Chung, T., Nwokolo, E. ., & Sim, J. . (1989). Compositional and digestibility changes in sprouted barley and canola seeds. Plant Foods for Human Nutrition, 39, 267–278.

26. CIMMYT. (1988). From Agronomic Data to Farmer Recommendations. An Economics Training Manual. Completely Revised Edition. Mexico. D.F, 18(6), 968-61 27.

27. Copeland, L. O., & McDonald, M. B. (2001). Seed science 4th Edition principles of seed science. 1–12.

28. CSA. (2018). Livestock and Livestock Characteristics (Private Peasant Holdings). Agricultural Sample Survey.

29. Dan, J. (2007). Hydroponics plants triumph in unlikely places. Http://Ezinearticles.Com/? Hydroponics Plants-Triumph-in-Unlikely Places&id=607720,14/08/07.

30. Dawit, A., Ajebu, N., & Banerjee, S. (2013). Assessment of feed resource availability and livestock production constraints in selected Kebeles of Adami Tullu Jiddo Kombolcha District, Ethiopia.

31. Domin, M., Kluza, F., Góral, D., Nazarewicz, S., Kozłowicz, K., Ślaska-Grzywna, & Szmigielski, M. B. (2020). Germination Energy and Capacity of Maize Seeds Following Low-Temperature Short Storage. Sustainability, 12(46), 10.

32. Dung, D., Godwin, I., & Nolan, J. (2010a). Nutrient content and in sacco degradation of hydroponic barley sprouts using nutrient solution or tap water. In J Anim Vety Adv (Vol. 9, Issue 18).

33. Dung, D., Godwin, I., & Nolan, J. (2010b). Nutrient content and in Sacco digestibility of barley grain and sprouted barley. Journal of Animal and Veterinary Advances, 9(19), 2485–2492.

34. Emam M. S. A. (2016). The Sprout Production and Water use Efficiency of some Barley Cultivars under Intensive Hydroponic System. Middle East Journal of Agriculture Research, 05(02), 161–171.

35. Endalew, M., Yeshambel, M., Firew, T., & Bimrew, A. (2019). Evaluation of fodder biomass yield of hydroponically-grown barley and oats and the effects on intake, digestibility and weight gain of Washera sheep when fed as a supplement to a basal diet of natural pasture hay in Ethiopia.

36. Endeshaw, A. (2007). Assessment of Production and Marketing System of Goats In Dale District, Sidama Zone.

37. FAO. (2015). Alternativefodder production forvulnerable herders in the West Bank. Resilience Promising Practice.

38. Fazaeli, H., Golmohammadi, H. A., Tabatabayee, S. N., & Asghari-Tabrizi, M. (2012). Productivity and Nutritive Value of Barley Green Fodder Yield in Hydroponic System. World Applied Sciences Journal, 16(4), 531–539.

39. Flynn, V., & O'Kiely, P. (1986). Input/output data for the ACRON germination unit.

40. Gebremedhin, W. K. (2015). Nutritional benefit and economic value of feeding hydroponically grown maize and barley fodder for Konkan Kanyal goats. IOSR Journal of Agriculture and Veterinary Science Ver. II, 8(7), 2319–2372. https://doi.org/10.9790/2380-08722430

41. Gebremedhin, W. K., Deasi, B. G., & Mayekar, A. J. (2015). Nutritional Evaluation of Hydroponically Grown Barley Fodder. Journal of Agricultural Engineering and Food Technology, 2(2), 86–89.

42. Getachew, A., Mengistu, U., Getachew, A., & Getnet, A. (2020). Effect of variety and seed rate on hydroponic maize fodder biomass yield, chemical compostion, and water use efficiency. In Biotechnology in Animal Husbandry (Vol. 36, Issue 1).

43. Hande, I., Onur, S., Harun, B., & Ismail, Y. (2014). Effects of Harvesting Time on Nutritional Value of Hydroponic Barley Production. Turkish Journal of Agricultural and Natural Sciences Special, 2, 1761–1765.

44. Hegab, K. K. (2017). Successive management programes for the deficit water resources in hydroponics and soilless green fodder production. Biological Engineering, 34(4–1), 1869–1896.

45. IGAD. (2010). The Contribution of Livestock to the Economies of IGAD Member States. IGAD Livestock Policy Initiative, 02–11, 1–45.

46. Islam, R., Jalal, N., & Akbar, M. al. (2016). Effect of seed rate and water level on production and chemical analysis of hydroponic fodder. European Academic Research, 4(8), 6724–6753.

47. Karunathilaka, J. M. ., Jayawardena, G. M. P., & Premalal, G. G. C. (2012). In vitro digestibility of Hybrid Sorghum, Millet, Hydroponically grown Maize and the Influence of Probiotic Yeast(Saccharomycescervisiae) culture on digestion of Forages. Proceedings Th of 22 Annual Students Research Session, Department of Animal Sciences, University of Peradeniya, Sri Lanka.

48. Kerr, S., Conway, L., & Conway, A. (2014). Fodder for forage: fact, folly, fable or fabulous? Http:Smallfarms.Oregonstate.Edu/ Sfn/W14fodder.

49. Kumar, S., Singh, M., K.K.Yadav, & Singh, P. K. (2021). Opportunities and constraints in hydroponic crop production systems: A review. Environment Conservation Journal, 22(3), 401–408.

50. Lamidi, A. A., Ingweye, J. N., & Mene, L. (2022). Influence of seed varieties and harvesting regimes on growth indices, yields and nutritional values of hydroponics maize fodder. In Nigerian J. Anim. Sci (Vol. 24, Issue 2).

51. Louf, J. F., Zheng, Y., Kumar, A., Bohr, T., Gundlach, C., Harholt, J., Poulsen, H. F., & Jensen, K. H. (2018). Imbibition in plant seeds. Physical Review E, 98(4). https://doi.org/10.1103/PhysRevE.98.042403

52. McDonald, P., Edwards, R. A., Greenhalgh, J. F. D., Morgan, C. A., Sinclair, L. A., & Wilkinson, R. G. (2018). Animal nutrition. Animal Nutrition. EIBS Longman, London and New York, 524. https://doi.org/10.5962/bhl.title.155283

53. Mesfin, B., Diriba, D., & Hasan, Y. (2020). Watering Intervals and Harvesting Dates Affected Fodder Yield and Nutritional Values of Maize Varieties under Hydroponic System in Wollega University. American-Eurasian J. Agric. & Environ. Sci., 20(2), 89–98.

54. Mijena, D., Getiso, A., & Ijara, F. (2021). Role of Hydroponics Technology in Green Fodder Production as Livestock Feed Resource. Research Journal of Animal Sciences, 15(4).

55. Mintamir, L. (2019). Effect of watering frequency and harvesting date on fodder yield and nutritive value of selected herbaceous legumes under hydroponic systems at Wollega University, Western Ethiopia.

56. MOA, (Ministry of Agriculture). (2014). state report of the agricultural sector in Jordan. Amman.

57. Morgan, J., Hunter, R. R., & O'Haire, R. (1992). Limiting factors inhydroponic barley grass production. Proceedings of the 8thInternational Congress on Soilless Culture., 241–261.

58. Murugkar, D. A., & Jha, K. (2009). Effect of sprouting on nutritional and functional characteristics of soybean. J Food Sci Technol, 46(3), 240–243.

59. Muthuramalingam, T., Pothiappan, P., Gnanaraj, P. T., Sundaram, S. M., & Pugazhenthi, T. R. (2015). Studies on Growth Performance of the Goats Fed Hydroponic Maize Fodder. Indian Veterinary Journal, 92(4), 94–96.

60. Naik, P. ., Gaikwad, S. P., Gupta, M. J., Dhuri, R. B., Dhumal, G. M., & Singh, N. P. (2013). Low cost devices for hydroponics fodder production. Indian Dairyman, 65, 68–72.

61. Naik, P. ., Swain, B. ., & Singh, N. . (2015a). Hydroponics :its feasibility as an alternative to cultivated forages. In: Proc. 9 Th Biennial Animal Nutrition Association Conference on 'Ecoresponsive Feeding and Nutrition: Linking Livestock and Livelihood' Guwahati, India, 74–87.

62. Naik, P. ., Swain, B. ., & Singh, N. P. (2015b). Production and Utilisation of Hydroponics Fodder. Indian Journal of Animal Nutrition, 32(1), 1–9.

63. Naik, P. K. (2012). Hydroponics technology for green fodder production. ICAR, 18(3), 70–75. https://www.cabdirect.org/cabdirect/abstract/20133131908

64. Naik, P. K. (2013). Yield and dry matter content ofhydroponics maize sprouts (Un-published).

65. Naik, P. K., Dhawaskar, B. D., Fatarpekar, D. D., Karunakaran, M., Dhuri, R. B., Swain, B. K., Chakurkar, E. B., & Singh, N. P. (2017). Effect of feeding hydroponics maize fodder replacing maize of concentrate mixture partially on digestibility of nutrients and milk production in lactating cows. Indian Journal of Animal Sciences, 87(4), 452–455.

66. Naik, P. K., Dhuri, R. B., Karunakaran, M., Swain, B. K., & Singh, N. P. (2014). Effect of feeding hydroponics maize fodder on digestibility of nutrientsand milk production in lactating cows. Indian Journal of Animal Sciences, 84(8), 880–883.

67. Naik, P. K., Dhuri, R. B., & Singh, N. P. (2011). Technologyfor production and feeding of hydroponics greenfodder. Extension Folder No. 45/ 2011, ICAR ResearchComplex for Goa, Goa.

68. Naik, P. K., Dhuri, R. B., Swain, B. K., Karunakaran, M., Chakurkar, E. B., & Singh, N. . (2013). Analysis of existing dairy farming in Goa. Indian Journal of Animal Sciences, 83(3), 299–303.

69. Naik, P. K., Dhuri, R. B., Swain, B. K., & Singh, N. P. (2012a). Nutrient changes with the growth of hydroponics fodder maize. Indian Journal of Animal Nutrition, 29, 161–163.

70. Naik, P. K., Dhuri, R. B., Swain, B. K., & Singh, N. P. (2012b). Water management for green fodder production aslivestock feed in Goa. 126–127.

71. Naik, P. K., & Singh, N. P. (2013). Hydroponics Fodder Production: An Alternative Technology for Sustainable Livestock Production against Impeding Climate Change. MTC on Management Strategies for Sustainable Livestock Production against Impending Climate Changes, 70–75.

72. Naik, P. K., & Singh, N. P. (2014). Production and feeding of hydroponics green fodder. Indian Farming, 64(6), 42–44.

73. Naik, P., Swain, B., Cakurkar, E., & Singh, N. (2017). Effect of seed rate on yield and proximate constituents of different parts of hydroponics maize fodder. Indian Journal of Animal Sciences, 87(1), 109–112.

74. Ndaru, P. H., Huda, A. N., Marjuki, Prasetyo, R. D., Shofiatun, U., Nuningtyas, Y. F., Ndaru, R. K., & Kusmartono. (2020). Providing High Quality Forages with Hydroponic Fodder System. IOP Conference Series: Earth and Environmental Science, 478(1). https://doi.org/10.1088/1755-1315/478/1/012054

75. Ningoji, S. N., Thimmegowda, M. N., Boraiah, B., Anand, M. R., Murthy, R. K., & Asha, N. N. (2020). Effect of Seed Rate and Nutrition on Water Use Efficiency and Yield of Hydroponics Maize Fodder. International Journal of Current Microbiology and Applied Sciences, 9(1), 71–79. https://doi.org/10.20546/ijcmas.2020.901.008

76. NMA. (2021). Revised Meteological Station Network Master Plan. Addis Ababa, Ethiopia.

77. Nonogaki, H., Bassel, G. W., & Bewley, J. D. (2010). Germination—Still a mystery. Plant Sci, 179(6), 574–581.

78. O'Sullivan, J. (1982). Possible effects in the culture of barley seedlings compared tobarley seeds as fodder. Department of Horticulture, University CollegeDublin.

79. Rabten, T., DLO, & Gatshel, P. (2016). Hydroponics Maize Fodder.

80. Rachel Jemimah, E., Gnanaraj , PT Muthuramalingam, T., Devi, T., Babu, M., & Sundharesan, A. (2015). Hydroponic green fodder production-TANUVAS experience. Http:// Rkvy.Nic.in/ (S(Dj5ug3cfjygd1hmikvs3bm25)/ 2016023524 Hydrophonic _Final. Pdf.

81. Reddy, G. V. N., Reddy, M. R., & Reddy, K. K. (2012). Nutrient Utilisation by Milch Cattle Fed on Rations Containing Artificially Grown Fodder. Indian J Anim Nutri, 5(1), 19–22.

82. Reddy, Y. . (2014). Hydroponic fodder production. http://www.authorstream.com/ P Presentation/ kiranreddy 526438-2376257 hydroponic fodder production/ Fresh HM. Hydroponic Food Production: A Definitive Guidebook for the Advanced Home Gardener and the Commercial Hydroponic Gr. Seventh Edition. CRC Press, 199-292.

83. Saidi, A. R., & Omar, J. A. (2015a). The Biological and Economical Feasibility of Feeding Barley Green Fodder to Lactating Awassi Ewes. Open Journal of Animal Sciences, 5, 99–105.

84. Saidi, A. R., & Omar, J. A. (2015b). The Biological and Economical Feasibility of Feeding Barley Green Fodder to Lactating Awassi Ewes. Open Journal of Animal Sciences, 99–105.

85. Salinger, M. (2013). Grass fed beef. Http:/Fodderking.Blogspot.in/2013/07/ Grass-Fed-Beef.Html.

86. SAS. (2008). The Little SAS® Book: A Primer, Fourth Edition, version 9.1.3. Statistical Analysis System Institute Inc., NC. USA. Http:// Dx.Doi.Org 10.5402/2012/924672.

87. Selamawit, D., Asmare, B., & Mekuriaw, Y. (2017). Assessment of livestock production system and feed balance in watersheds of North Achefer district, Ethiopia.

88. Shaban, M. (2013). Effect of water and temperature on seed germination and emergence as a seed hydrothermal time model. International Journal of Advanced Biological and Biomedical Research, 1(12), 1686–1691. http://www.ijabbr.com

89. Shapiro, B. I., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset, G. and, & Mechal, H. (2015). Ethiopia livestock master plan. Ethiopia Livestock Master Plan. ILRI Project Report. Nairobi, Kenya: International Livestock Research Institute (ILRI), 10.

90. Sharma, S., Shadloo, M. S., & Hadjadj, A. (2018). Effect of thermo-mechanical non-equilibrium on the onsetof transition in supersonic boundary layers. Heat and Mass Transfer.

91. Shashank, S., & C Teja, K. (2012). Development of a cost effective, energy sustainable hydroponic fodder production device.

92. Shit, N. (2019). Hydroponic Fodder Production: An Alternative Technology for Sustainable Livestock Production in India. Exploratory Animal and Medical Research, 9(2), 108–119.

93. Sneath, R., & Mcintosh, F. (2003). On-farm review of hydroponic fodder production for beef cattle. Meat and Livestock Australia Limited, 1–54.

94. Sneath, R., & McIntosh, F. (2003). Review of Hydroponic Fodder Production for Beef Cattle. Queensland Government, Department of Primary Industries,Dalby, Queensland.

95. Snow, A. M., Ghaly, A. E., & Snow, A. (2008). A comparativeassessment of hydroponically grown cereal crops forthe purification of aquaculture waste water and theproduction of fish feed. Am. J. Agric. Biol. Sci, 3(1), 364–378.

96. Starova, J. (2016). Hydroponic fodder production. 'Feed the Future Programme' of US Government Global Hunger and Food Security Initiative in Ethiopia Sponsored by USAID. Https:/ /Www.Primeethiopia.Org/Wp-Content/ Uploads/2016/06/Fast%20 Fodder %20manual%20portrait-Fnl.Pdf.

97. Suma, T., Vivek, R. K., Sangeetha, T., & Malla, R. (2020). Review on hydroponics green fodder production: Enhancement of nutrient and water use efficiency. International Journal of Chemical Studies, 8(2), 2096–2102.

98. Thadchanamoorthy, S., V Jayawardena, & Pramalal. (2012). Evaluation of Hydroponically Grown Maize as a Feed Source for Rabbits. Proceedings of 22nd Annual Students Research Session, Department of Animal Science, University of Peradeniya, Sri Lanka.

99. Tilley, J. M. A., & Terry, R. A. (1980). A two-stage technique for the in vitro digestion of forage crops. Journal of the British Grassland Society, 18, 104–111.

100. Tsegaye, B., Tolera, A. and, & Berg, T. (2008). Livestock production and feed resource constraints in Akaki and Lume districts, central Ethiopia. 37(1), 15–21.

101. Uppal, V., & Bains, K. (2012). Effect of germination periods and hydrothermal treatments on in vitro protein and starch digestibility of germinated legumes. Journal of Food Science and Technology, 49(2), 184–191. https://doi.org/10.1007/s13197-011-0273-8

102. Van Soest, P., Robertson, J., & Lewis, B. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science, 74(10), 3583–3597.

103. Welay, G. M., Tedla, D. G., Gebru, T., Kahsay, W. S., Belay, S. M., Hadush, K. H., Berhe, B. G., & Abraha, T. H. (2018). A preliminary survey of major diseases of ruminants and management practices in Western Tigray province, northern Ethiopia.

104. WELDEGERIMA, BALKRISHNA, K., & DESAISHALU, K. (2015). NUTRITIONAL IMPROVEMENT AND ECONOMIC VALUE OF HYDROPONICALLY SPROUTED MAIZE FODDER. Life Sciences International Research Journal, 2(2), 76–79.

105. Weldegerima, K., Balkrishna, D., & Shalu, K. (2015). Nutritional improvement and economic value of hydroponically sprouted maize fodder. Life Sciences International Research Journal, 2(2), 76–79.

106. Yayneshet, T. (2010). Feed Resources Availability in Tigray Region, North Ethiopia, for Producing Export Quality Meat and Livestock. Ethiopia Sanitary and Phytosanitary Standards and Livestock and meat Marketing Program (SPS-LMM). USAID, Ethiopia.

107. Yvonne Kamanga. (2016). Hydroponic fodder: increasing milk production and income. YAP- Youth Agripreneur Project. Https://Blog.Gfar.Net /2016/ 03/09/Yapproposal-242-Hydroponic-Fodder-Increasing-Milk-Productionandincome-Yvonn- Kamanga- Malawi.