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

BY

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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

By

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A Thesis Research

Submitted to the Department of Animal Science, College of Agriculture and Veterinary Medicine in Partial Fulfillment of the Requirements for the Degree of Master of Science in Animal Production

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Chair Person, CGS	Signature	Date

DEDICATION

This thesis is dedicated to my almighty God who saved me from the horrible car accident at Ifa biyya area (the village between Hareto and Bako towns) on our ways to Nekemte at 3:45 local time on 04/05/2011 E.C where many people passed away.

STATEMENT OF AUTHOR

First I, declare that this thesis is a result of my own authentic work that all sources of materials used for writing it have been properly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for the M.Sc. degree at the Jimma University College of Agriculture and Veterinary Medicine (JUCAVM). The thesis is placed at the university's library to be made available to borrowers under the rules and regulations of the library. I solemnly declare that this thesis has not been submitted to any other institution anywhere for thk2e award of any academic degree, diploma or certificate.

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BIOGRAPHICAL SKETCH

The author Mintamir Lema Ayana was born on December 21, 1995 G.C in wombera Woreda, Metekel Zone, Benishangul Gumuz Regional State, Ethiopia. She attended her Elementary and High School Education at wombera town between 2002 to 2013. She joined Wollega University in 2014, and graduated with B.Sc. degree in Animal Science in June 2016. Soon after graduation, she was employed at Wollega University Shambu campus as graduate assistant and she served for one year. Then she joined Jimma University College of Agriculture and Veterinary Medicine in October, 2018 to pursue her M.Sc. study in Animal Production.

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ACRONYMS

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ARC	Agricultural Research Council
CC	Canopy Circumference
CP	Crude Protein
CRD	Completely Randomized Design
CV	Coefficient of Variation
DM	Dry Matter
DMY	Dry Matter Yield
FAO	Food and Agricultural Organization
GDP	Growth Domestic Product
HARC	Holeta Agricultural Research Center
HRR	Herbage Root Ratio
HSD	Honest Significant Difference
IVDMD	*In-vitro* Dry Matter Digestibility
LW	Leaves Weight
NDF	Neutral Detergent Fiber
PH	Plant Height
RW	Root Weight
SAS	Statistical Analysis System
SEM	Standard Error Mean
SW	Stem Weight
TA	Total Ash

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ABSTRACT

Three experiments were carried out to evaluate the effect of frequency of watering, harvesting dates and species difference on fodder yields and nutritional values of three selected herbaceous legumes under hydroponic systems in Wollega University. In all the three experiments, completely randomized design (CRD) with three replications was used to manage the experiments and the general linear model procedure of Statistical Analysis System (SAS) was used analyze the data and Tukey HSD was used to separate means. The legumes (Lupinus albus, Vigna unguiculata and Lablab purpureus) were grown hydroponically at 2hrs, 3hrs and 4hrs watering intervals and for 13th, 15th, 17th and 19^{th,} harvesting dates in lath house. All the fodder yield and yield related components of the legumes species were affected (p= 0.0001) by watering frequencies. The dry matter yield (DMY) (t/ha) for all the three legumes at one production cycle was highest at 2 hours interval of watering followed by 3 hours while the least was 4 hours of watering. The fodder yield and related components for L.albus and V.unguiculata consistently decreased with increasing watering intervals from 2 hours to 4 hours except for herbage to root ratio while that of L. purpureus did not revealed like others growth pattern. The fodder yield and yield related components of the legumes were all affected (p= 0.0001) by harvesting dates except the stem weight (p>005) of V.unguiculata. The dry matter yield (DMY) (t/ha) for L. albus and L. purpureus was significantly (p= 0.0001) affected by harvesting dates and showed consistently decreasing trend with increasing dates of harvesting. The DMY of V.unguiculata was not affected (p>0.05) by differences in harvesting dates. The components such as leaves weight (t/ha), roots weight (t/ha), stem weight (t/ha), plant height (cm), canopy circumference (cm) and herbage to root ratio for L. albus and L. purpureus followed similar trend of their DMY while most of the studied parameters of V.unguiculata did not show clear trend. The nutrient composition and in vitro DM digestibility of all the three legume species were significantly (p=0.0001) affected by variation in harvesting date. The ash, NDF, ADF and ADL content of the sprouted legumes was higher (P=0.0001) than that of their grain counterparts. The DM and CP composition, and in vitro DM digestibility was higher (P=0.0001) for the grain than the sprouted fodders across all the three legumes. The sprouted legumes, the DM composition of the V.unguiculata was increased with increased date of harvesting whereas that of L.albus and L. purpureus did not vary (P>0.05). The Ash, NDF, ADF and ADL contents of the sprouted fodder was significantly increased with delayed date of harvesting while the in vitro DM digestibility was in reverse trend. The study revealed that watering frequency of 2 hours interval at one production cycle had resulted in optimum hydroponic fodder yield and yield related components. Delayed date of harvesting had resulted in decreased fodder yield of all the three species of legumes. In addition all the legume species had attained different optimum harvesting dates for fodder yield and related parameters. Accordingly, L. purpureus had its maximum DM yield at 17th day of harvesting; V. unguiculata at 19th day but L.albus had a linear growth potential even at 27th day of harvesting. Delayed date of harvesting resulted in reduced CP composition, reduced in vitro DM digestibility and increased fiber contents. Thus the L. purpureus had best hydroponic characteristics while L.albus had highest fodder nutritive values.

Keyword: Chemical Composition, Fodder Yield, Herbaceous Legumes, Hydroponic System, *In Vitro* DM Digestibility.

1. 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. Livestock production contributes up to 80% of farmers income in our country and about 20% of farmer income is agriculture in Ethiopia (Negash, 2017). Even though, its contribution to the economy and smallholders livelihood, livestock productivity remains very low due to various constraints that include poor nutrition. Among these constraints, issues related to feed are the most remarkable ones (Azage *et al.*, 2008). Livestock production has mostly been subsistence oriented and characterized by very low reproductive and production performance.

Feed shortage in quantity and quality has been a critical problem in Ethiopian livestock production system (Adugna, 2009). The declining grazing land, due to expansion of cultivation for food crops production, has resulted in lower green fodder production, higher crop residue yield of poor nutritional value and low productivity of livestock. However, the major constraints in production of green fodder are decreasing land size for forage cultivation and also the high cost of fertilization (MOA, 2014).

Feed shortage and low quality of available feeds have become the major constraint for livestock production in Ethiopia. The feed shortage becomes more severe during the long dry period when green forage is rarely available. The most common types of animal feeds are predominantly high-fiber feeds, which are incomplete in nutrients necessary for microbial fermentation (Osuji *et al*., 1993). These constraints result in low milk and meat yields, high mortality of young stock and retarded growth, longer parturition intervals, and low animal weights. To cope up with this challenge majority of the smallholder farmers have resulted to feeding their dairy cattle with crop residues and grass collected from the roadside, these are poor quality feeds (Wambugu *et a*l., 2006). To sustain the dairy production, some farmers are forced to buy commercial feed and this has resulted in the rising cost of production is supported by a corresponding increase in input cost at the farm level (MOALFD, 2013). Production and utilization of quality feed is required to realize the necessary intensification of animal farming in Ethiopia. Such a process basically demands science based development in turn requires pertinent technology and information on feed industry.

Therefore, urban and per-urban dairy farming system is common in the country, there is land limitation especially in urban areas resulted in difficulty of forage production predominantly for ruminants. To overcome the problems related to the aforementioned feed shortage in the conventional method of fodder cultivation, hydroponics is an alternative technology to grow fodder for farm animals (Naik, *et al.,* 2014). Hydroponic is defined as the cultivation of plants by using water, without soil. Hydroponic fodder production is a technique for germinating seeds to sprout into a high quality, highly nutritious, disease free animal feed in a hygienic environment free of chemicals like insecticides, herbicides, fungicides, and artificial growth promoters (Jensen and Malter, 1995; Al-Hashmi, 2008). Hydroponic fodders, although used by most livestock, are mainly useful for animals such as ruminants whose basal diet is roughage or forages.

The hydroponics green fodder is produced from forage grains that are germinated and grown for short period of time inside the green house, provided with the appropriate growing conditions (Sneath, and Mclntosh, 2003). In hydroponics fodder production, less space is needed because the fodder is grown in trays which are arranged in shelves inside appropriate room (Sinsinwar, 2012). In such situations, cheap cereal grains impose less competition for food between animals and human beings are useful. Development of this planting system has enabled the production of fresh forage from oats, barley, wheat and other grains (Rodriguez-Muela *et al*., 2004). Even though barely, wheat and maize are suitable for hydroponic fodder production in tropical condition they are used for human consumption in Ethiopia. Hence the use of legume species such as *L. albus, L. purpureus and V. unguiculata* is more suitable for hydroponic fodder production because it was not further used for human intake in the country.

Hydroponic system is a technique that returns grains into forage and indirectly compensating the grazing land used for food crop production. Growing hydroponics fodder also increases fiber, protein (in cereal case) and vitamin content of grains and improve animal performance (Firehiwot *et al*., 2018; Rodriguez-Muela, *et al*., 2004 and Boue *et al*., 2003). In general, fodder produced hydroponically has a short growth period, better nutritive values and requires only a small area for production to take place (Cuddeford, 1989; Mooney, 2005). This method of producing green fodder has many advantages for the farmer and environment. These advantages are hydroponic system requires the water usage of conventional farming while still supplying high quality stock feed. Al-Karaki, (2010) reported that 1.5-2L water is necessary for germination of 1kg grain in hydroponic system as against 73L water intake for 1kg green fodder under conventional barley production. Conventional method of fodder production facing many constraints like scarcity of land, water, good quality seeds, higher labor cost, more investment on fertilizers and longer growth period. Hydroponics is now an alternative technology to grow fodder for farm animals (Naik *et al*., 2015). It is a well-known technique for high fodder yield, year round production and least water intake. This technology may be especially important in regions where forage production limited (Fazaeli *et al*., 2012).

Therefore, to reduce the shortage of feed for livestock, which is encountered with shortage of land specially in urban and per urban areas, in our country its better to produce green fodder for animals by using hydroponic system. This experiment was proposed with the following objectives:

1.1. Objectives

1.1.1. General Objective

The general objectives of the study was to determine the effect of watering frequency, harvesting dates and species on fodder yield and nutritive values of selected herbaceous legumes under hydroponic condition at Wollega University.

1.1.2. Specific Objectives

- To determine effect of watering frequency on fodder yield and yield related components of *Lupinus albus*, *Vigna unguiculata* and *Lablab purpureus* legumes under hydroponic condition at Wollega University
- To determine effect of date of harvesting on fodder yield, yield related components of *Lupinus albus*, *Vigna unguiculata* and *Lablab purpureus* legumes under hydroponic condition at Wollega University.
- To determine the effect of species and harvesting dates on chemical composition and *in vitro* DM digestibility of *Lupinus albus*, *Vigna unguiculata* and *Lablab purpureus* under hydroponic condition at Wollega University.

2. LITERATURE REVIEW

2.1. Definition of Hydroponics

Hydroponics is the science of growing plants without soil (Dan J, 2007). Hydroponic Fodder is essentially the germination of a seed and sprouted into a high quality, highly nutritious, disease free animal food. This process takes place in a very versatile and intensive hydroponic growing unit where only water are used to produce a grass and root combination that is very lush and high in nutrients. Hydroponics is produced in green houses under controlled environment within a short period (Sneath and McIntosh, 2003). This green fodder is extremely high in protein and metabolisable energy, which is highly digestible by most animals (Cader, 2002).

2.2. History of Hydroponics

The word hydroponics has been derived from two Greek words hydro means water and ponic means working. Thus, fodder produced by growing plants in water or nutrient rich solution but without using any soil is known as hydroponics fodder or sprouted grains or sprouted fodder (Dung *et al*., 2010a). Hydroponic methods have been used for a long time to grow plants, primarily vegetables, but hydroponics is now being used across many countries to take pressure off the land and grow green feed for livestock, birds and carp raised for agriculture.

The growing of fodder using soil-less growing systems is by no means a new concept to the world. These systems have been in use for over 50 years to supply a wide range of livestock types for many different purposes in varying living environments (Agrotek Greenhouse fodder systems, 2002). During the war, the Australian Army used a similar system to produce feed. South Africa, South and North America were also using similar types of systems during this era and beyond (Gatti Chris in the Daily News, 2002). As early as the 1930's crop-a-day culture, as it was known then, was being practiced throughout Great Britain. The fodder was considered then as sprouted forage, which would provide a variety of livestock and birds with a highly nutritive food with important mineral and vitamin contents.

2.3. Production of Hydroponics Fodder

Hydroponics is produced in green houses under controlled environment within a short period (Sneath and McIntosh, 2003). A green house is a framed or inflated structure covered with a transparent or translucent material in which the crops could be grown under the conditions of at least partially controlled environment. However, the structure should be large enough to permit a person to carry out cultural operations (Chandra and Gupta, 2003). The green house for the production of hydroponics fodder can be of hi-tech greenhouse type or low cost greenhouse type as per the financial status of the farmer and availability of building material.

(i) Hi-tech greenhouse type hydroponics fodder cultivation unit

The hi-tech greenhouse type unit consists of a control unit and may be used with or without air conditioner. The control unit regulates input of water and light automatically through sensors. Although all types of fodder crops can be grown in the hi-tech greenhouse but the routine operational cost is more particularly for sprouting the rabicrops (barley, oat, wheat etc.). This is because of the requirement for air conditioner in the hydroponics system to maintain cold and dry environment.

(ii) Low cost greenhouse type hydroponics fodder cultivation unit

Hydroponics fodder can also be produced in low cost greenhouses or devices (Naik *et al*., 2013c). Low cost greenhouses or shade net structures can be prepared from bamboo, wood, steel or galvanized iron steel. The cost of the shade net structures depends up on the type of fabricating material but is significantly lower than the hi-tech greenhouses. One side wall of the house can be used to construct lean-to-shade net structure which reduces the cost of fabrication. The irrigation can be made by micro-sprinklers (manually or automatic controlled) or knapsack or backpack sprayer at frequent intervals. Shade net structures, the type of cereals to sprout hydroponically depends up on the season and climatic conditions of the locality.

Different types of fodder crops viz. barley (Reddy *et al*., 1988), oats, wheat (Snow *et al*., 2008); sorghum, alfalfa, cowpea (AI-Karaki and AI-Hashimi, 2012) maize (Naik *et al*., 2011;

Naik *et al.,* 2012a) can be produced by hydroponics technology. However, the choice of the hydroponics fodder to be produced depends on the geographical and agro-climatic conditions and easy availability of seeds. In India, maize grain should be the choice as the grain for production of hydroponics fodder due to its easy availability; lower cost, good biomass production and quick growing habit. The grain should be clean, sound, undamaged or free from insect infestation, untreated, viable and of good quality for better biomass production.

2.4. Forage Legumes

Forage legumes can be defined as members of the Fabaceae (Leguminosae) that have plant parts other than separated grain that are used to feed ruminant livestock (Barnes *et al.*, 1995; Graham and Vance, 2003). They are generally grazed or offered as silage or hay, and can be grown as mono cultures or mixtures with other species, most commonly grasses. Fabaceae are extremely diverse and widespread, with an estimated 16,000 to 17,000 species in 750 genera (Allen, 1981). The number of these that are used worldwide as forages is not entirely known, but the online animal feed information repository produced by the Food and Agriculture System of the United Nations (Phelan *et* al., 2015) lists 153 different species of legume used for forage. This list gives some idea of the diversity, including plants ranging in size from small herbaceous to large shrubs and those with temperate, tropical and arctic distributions.

However, a much smaller number of forage legume species are widely recognized as being of global commercial importance and include the following: *Medicago sativa* (lucerne, alfalfa),*Trifoliumrepens*(white clover), *Trifoliumpratense* (red clover) *Trifolium subterraneum* (subterranean clover) and *Lotus corniculatus* (birds foot trefoil) (Thomson, 1984; Frame *et al.*, 1998; Peyraud *et al.*, 2009). The primary agronomic benefits of forage legumes are the following: (i) their contribution to the nitrogen (N) economy of agricultural land due to their association with N fixing bacteria and (ii) their ability to increase herbage production, herbage feed value and ultimately ruminant production of meat/milk, particularly in areas of low fertilizer N input (Marten *et al.*, 1989; Frame *et al.*, 1998).

2.4.1. Importance of Hydroponic System

Traditional fodder production requires a major investment for the purchase of land, in addition to investment in agricultural machinery, equipment, infrastructure required for pre- and post-harvesting, including handling, transportation and conservation of fodder. It also requires labor, fuel, lubricants, fertilizers, insecticides, pesticides, and weedicides. On the other hand, hydroponic fodder production requires only seed and water as production inputs with modest labor inputs (Jensen and Malter, 1995; Al-Hashmi, 2008). Hydroponics minimizes post-harvest losses, with no fuel required for harvesting and post harvesting processes.

Moreover, in hydroponic systems it takes only 7-8 days to develop from seed to fodder while it takes 45-60 days under traditional systems. However, the initial investment required for setting up high-tech, sophisticated, automated commercial hydroponic fodder production systems, with environmental control, plus operational costs are much higher than traditional soil-based fodder production farming. Such hydroponic systems require much more specialized equipment and technical knowledge than is required in traditional farming. Mold is highly likely and thus prevention or treatment could further involve investment. Therefore, even if there are benefits of feeding hydroponic fodder, the benefits are usually outweighed by the costs (Tranel, 2013; Reddy, 2014).

There are a number of advantages of hydroponic fodder production:

Efficiency: By providing the optimal environment the efficiency of fodder production is increased remarkably. Hydroponic systems minimize water wastage since it is applied directly to the roots and is often recycled and used several times. However, the water should be clean because bacteria and fungi proliferate during recycling during the growth cycle. It is, therefore, suggested to go for infrared filtering of the water before recycling (FAO, 2015). It has been reported that about 1.5-2 liters are needed to produce 1 kg of green fodder hydroponically in comparison with 73, 85, and 160 liters to produce 1 kg of green fodder of barley, alfalfa, and Rhodes grass under field conditions, respectively. Under hydroponic systems this equates to only 2-5% of water used in traditional fodder production (Al-Karaki and Al-Momani. 2011; Naik, 2014; Rachel Jemimah *et al.*, 2015; Yvonne Kamanga, 2016). This is especially important in areas suffering from chronic water shortages or where the infrastructure for irrigation does not exist.

Space: Hydroponic systems require much less space and time than conventional systems, which makes the former ideal for urban dwellers with limited yard space. The plant root systems of hydroponic fodder are much smaller than in a traditionally grown fodder, which means higher numbers of plants per unit of space. It is also easy to start a hydroponic system indoors, wherein numbers of racks with multiple tiers (vertical farming) are used, and minimizing land requirement thereby resulting in land preservation. Crop rotation is not necessary in hydroponics, the same fodder species can be grown throughout the year. Using hydroponics technology, about 600-1000 kg maize fodder can be produced daily in7-8 days growth cycle, in only 45-50m^2 area compared with one ha, required in traditional farming (Naik and Singh, 2013; Rachel Jemimah et al., 2015). Another study revealed that only one square meter space is required to produce fodder for two cows per day and the milk yield was increased by 13% (Yvonne Kamanga, 2016).

Use of pesticides, insecticides and herbicides: Traditional outdoor farming must rely on herbicides, fungicides and/or insecticides for optimum production. Hydroponic fodder is grown in a controlled environment without soil and, therefore, is not susceptible to soil-borne diseases, pests or fungi, thereby minimizing use of pesticides, insecticides and herbicides. An outbreak of pests or infections in hydroponically grown fodder can be quickly controlled by spraying the crops with appropriate pesticides or fungicides. Fresh and clean water should be used for irrigation as waterborne plant diseases spread quickly (Bakshi, *et al.*, 2017).

Fodder yield: Fodder production is accelerated by as much as 25% by bringing the nutrients directly to the plants, without developing large root systems to seek out food. Plants mature faster and more evenly under a hydroponic system than a conventional soil based system. One kg of un-sprouted seed yields 8- 10 kg green forage in 7-8 days (Sneath and McIntosh, 2003; Naik *et al.*, 2013; Reddy, 2014; Anonymous, 2015; FAO, 2015; Yvonne Kamanga, 2016). The hydroponics maize fodder yield on fresh basis is 5-6 times higher than that obtained in a traditional farm production, and is more nutritious (Naik *et al.*, 2014).

Fodder quality: The crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and Ca content increased, but organic matter (OM) and non-fibrous carbohydrates (NFC) content decreased (P<0.05) in the hydroponic green forage compared with the original seed on a DM basis (Abdullah, 2001; Fazaeli *et al*., 2012; Kide *et al*., 2015; Mehta and Sharma, 2016). Hydroponic fodder is a rich source of vitamin A, vitamin E, vitamin C, thiamin, riboflavin, niacin, biotin, free folic acid, anti-oxidants like β-carotene (Finney, 1982; Cuddeford, 1989; Naik *et al*., 2015) and minerals (Bhise *et al*., 1988; Chung *et al*., 1989; Fazaeli *et al*., 2012). Shipard (2005) and Naik *et al*., (2014) found that hydroponic fodder is also a rich source of bio active enzymes, with the highest activities in sprouts being mostly between germination and 7 days of age (Chavan and Kadam, 1989). The fatty acid concentration showed a significant (P<0.05) positive relationship with the growth period. The concentrations of linoleic, linolenic and stearic acids increased (P<0.05) linearly with sprouting time (Peer and Leeson, 1985). Besides, helping in the elimination of the anti-nutritional factors such as phytate in the grains, hydroponic fodders are good sources of chlorophyll and contain a grass juice factor that improves the performance of livestock (Naik *et al*., 2015). Crop is free from antibiotics, hormones, pesticides, or herbicides (Naik, 2014).

The in Sacco degradability of barley grain (BG) and hydroponic barley sprouts (HB) was comparable (Dung *et al*., 2005). These findings were confirmed when HB were supplemented to herbage-based or hay lage-based diets evaluated by a dual-flow continuous-culture fermented system. In addition the methane output and bacterial protein synthesis were also comparable with those obtained by using BG supplemented diets (Hafla *et al*., 2014: Mehta and Sharma, 2016). The availability of metabolisable energy (ME) in hydroponic barley was lower than the original barley grain (Fazaeli *et al*., 2012).

Impact on animal production: Because hydroponic fodders are highly succulent, their intake varied between 15 to 25, 0.25 to 2.0, 1.5 to 2.0 and 0.1 to 0.2 kg/animal/day in large ruminants, small ruminants, adult pigs and rabbits respectively (Naik *etal*., 2013; Rachel Jemimah, 2015), or 1.0 to 1.5% of body weight (Starova Jeton, 2016). (Saidi and Abo Omar, 2015) reported that hydroponic barley fodder (HBF) had no effect on feed intake, body weight change, milk yield, and milk composition; however, HBF had positive effects on ewe's health, mortality, conception rate and abortion. Hydroponic fodders are highly digestible, palatable and relished by the animals.

Feeding vitamin-rich hydroponic green barley fodder did not increase bio availability of nutrients for fattening calves. There was no effect of the fodder on average daily gain (ADG), but feed cost was increased by 24% (Fazaeli *et al*., 2011). Rachel Jemimah *et al*., (2015) found no adverse effects on ADG and feed conversion ratio (FCR) in goat kids and rabbit kittens. A 90-day feeding trial on 3-month-old weaned Awassi ram lambs showed that feeding hydroponic barley fodder improved ($P<0.05$) feed intake, ADG and FCR significantly compare to those fed a ration containing barley grains (Mysaa *et al*., 2016). Feeding hydroponic fodder to beef cattle resulted in leaner meat containing more omega-3-fatty acids and vitamins (Maxwell Salinger, 2013).

Reddy *et al*., (1988) observed significant increases in the digestibility of nutrients in lactating cows fed hydroponic fodder compared to those fed Napier bajra (NB-21) green fodder. Feeding of a total mixed ration (TMR) containing either hydroponic maize fodder (HMF) or Napier bajra hybrid green fodder (NBH) for 68 days to lactating dairy cows did not have any significant effect on digestibility of nutrients, except that the digestibility of CF and NFE was higher ($P<0.05$) in the HMF fed group (Naik *et al*., 2014). The daily milk yield was 8.0-14.0% higher in animals fed TMR containing hydroponic maize or barley fodder than those fed conventional green fodder (Reddy *et al*., 1988; Naik *et al*., 2014; Rachel Jemimah *et al*., 2015; Yvonne Kamanga, 2016). Naik *et al*., (2017b) further reported that feeding of hydroponic maize fodder by replacing 50% maize grains in the concentrate mixture did not have any adverse effect on nutrient utilization and performance of low yielding lactating cows. Besides increased milk yield, conception rate, herd health and longevity were also improved (Naik *et al*., 2015). Furthermore, it must follow that improved animal health stemming from higher quality hydroponic fodder will reduce veterinary costs.

Hydroponic fodder heavily infested with *Aspergillusclavatus* should not be fed to dairy/beef cattle. Animals may develop posterior ataxia, knuckling of fetlocks, dragging of hind legs, high stepping in the hind limbs, stiff gait, tremors, progressive paresis, hypersensitivity, recumbence, clonic convulsions, decreased milk yield and possibly death (McKenzie *et al*., 2014).

Consistency of feed: One of the major obstacles being faced by many beef producers is the variability/ inconsistency of plant species within their pasture, due mainly to seasonal fluctuation. By feeding hydroponic fodder, one is assured of the quality and quantity of fodder that is being consumed. This consistency of feed can lead to better-tasting end products of consistent quality, which is one of the major goals of the beef producers. Similarly consistency in feed can also increase the quality of meat and other products of swine and poultry. Hydroponic fodder production is a way to substantially improve the quality of animal products (Maxwell Salinger, 2013).

Reduced carbon footprints: Hydroponics is more environmentally friendly than traditional agriculture, because fertilizers are rarely used. This reduces greenhouse gas emissions considerably (Anonymous, 2016). In traditional farming, run-off can lead to the degradation of the surrounding environment (Naik, 2014). Hydroponic systems help in reducing the fuel consumption for transportation of product from distant agricultural farms and carbon emissions in turn.

Water usage: Producing green fodder under hydroponic conditions increases water use efficiency when compared to field production of green fodders. "The hydroponic system requires a fraction of water compared to conventional farming while still supplying high quality stock feed" (Mooney, 2002). In conventional fodder production, 80 units of water are used to produce 1 unit of fodder while in a hydroponics system 1.5 units of water are used to produce 1 unit of fodder (Bill and Pavel, 2002; Al-Karaki and Al- Hashimi, 2011). Additionally water from the hydroponics system can be collected and recycled for other farm uses. Reduced labor requirement: In conventional fodder production requires continuous intense labor for cultivation to harvesting of the grass, but in hydroponics labor required is 2-3 hours / day only. Reduction in growth time of green fodder: To obtain nutritious fodder requires just over 7 days from seed germination to fully grown plant of 25 – 30 cm height. Biomass conversion ratio is as high as 7-8 times to traditional fodder grown for 60-80 days.

Green fodder round the year: Technology is capable to make provision for the green fodder round the year, as per demand .Constant supply can be organized irrespective of rain, storm, sunshine or drought. Natural feed for animals: growing of green fodder through Hydroponics is completely by natural source. No pesticides are used in green fodder production that could contaminate milk and milk products.

Enhancement of milk production: by providing green fodder to milch animals it can compensate the concentrate feed so as to have economically viable milk producing industry.
Minimizing wastage of fodder: Green fodder produced from hydroponics will be fully utilized as there won't be loss of the fodder during feeding as compared to wastages of chopped traditional grasses during consumption by the animal.

2.5. Hydroponic Fodder vs Conventional Fodder

The hydroponic system requires a fraction of water compared to conventional farming while still supplying high quality stock feed" (Mooney, 2002). Green fodder is an essential component of dairy ration; otherwise the productive and reproductive performance of the animals is adversely affected. Therefore, for sustainable dairy farming, quality green fodder should be fed regularly to the dairy animals (Naik *et al*., 2012a). The current levels of growth in future resources, will lead to a deficit of 18.4% in green fodder and 13.2 % in dry fodder by 2050 (IGFRI, 2015).

Hydroponic fodder cultivation provides an opportunity to grow green nutritious fodder with better palatability and digestibility. Naik *et al*., (2015) reported that hydroponics fodder is highly palatable and the germinated seeds embedded in the root system are also consumed along with the shoots of the plants without any nutrient wasting. Hydroponics fodder is extremely high in protein and energy (Morsy *et al*., 2013; Dung *et al*., 2010).

The nutritional value of sprouted grains is improved due to the conversion of complex compounds into relatively simpler compounds that are nutritionally more valuable. Sprouting of grains has results in increased protein quantity and quality. Sprouting also increases the concentration of nutrients including sugars, minerals and vitamin contents (Sharif *et al*., 2013). Naik and Singh, (2013) noted that hydroponics fodder is alkaline and this improves the immune system of the livestock. It can substitute demand of land and water scarcity. It is visualized that hydroponic system will be more useful in arid and hilly regions, and in areas of high population density where cultivable land and water scarcity prevails.

Producing green fodder under hydroponic condition increased water use efficiency when compared to field production of green fodders. The hydroponic system requires a fraction of water compared to conventional farming while still supplying high quality stock feed (Mooney, 2002). In conventional fodder production, 80 units of water are used to produce 1 unit of fodder while in a hydroponics system 1.5 units of water are used to produce 1 unit of fodder (Bill and Pavel, 2002; Al-Karaki and Al- Hashimi, 2011). Additionally water from the hydroponics system can be collected and recycled for other farm uses.

2.6. Hydroponic Fodder Yield of Legumes

2.6.1. Lupine (Lupinus albus)

L. albus are highly valued as animal feed but have been underutilized as human food yet the seeds are reported to be a rich source of protein (33 - 47%) and oil (6 - 13%) (William, 2000). There are also claims that the seeds are rich in dietary fiber for human consumption and beneficial phytochemicals. *L. albus* are now receiving national and international interest as a future source of food ingredients that could be used to enhance the nutritional profile of existing food products (Feldheim , 1998). *L. albus* flour can be used in production of different products. It can be added to pasta, crisps, bread and emulsified meat products to increase nutritional value, aroma as well as modify the texture of the end products. Moreover, protein isolate produced from *L. albus* seeds can be utilized for milk and meat imitation products.

In the Middle East, *L. albus* seeds are consumed as a snack after they are soaked in water, scalded and de hulled. Additionally, in some European counties, pickle is produced from *L. albus* seeds (Dervas *et al*., 1999). *L. albus* (white *L. albus*) seeds grown in Ethiopia and locally known as '*Gibto*', is used as roasted bean '*kolo'* and to prepare local alcoholic drink '*katikala*' and other food products especially in the northwestern part of the country, after de bittering by roasting and soaking the seeds in a river/spring water for 3-7 days (Personal communication with the local people). The high-lysine, low-methionine content of *L. albus* complements that of wheat flour proteins, which are poor in lysine and relatively high in the sulphur-containing amino acids (Bloksma and Bushuk, 1988).

Little is known about the nutritional value, physico chemical and functional properties of locally grown *L. albus* in Ethiopia. This information gap does not allow intensive and extensive utilization of *L. albus* as hydroponic fodder in the country. There is little information available for farmers, processors and end-users in utilization of the of *L. albus* seeds in the Ethiopian context.

2.6.2. Lablab (L. purpureus)

L. purpureus is a summer-growing annual or occasionally short-lived perennial forage legume. It is a twining, climbing, trailing or upright herbaceous plant that can grow to a length of 3-6 m. It has a deep taproot and vigorous, glabrous or pubescent trailing stems. *L. purpureus* leaves are alternate and trifoliate. The leaflets are rhomboid in shape, 7.5-15 cm long x 8-14 cm broad, acute at the apex. The upper surface is smooth while the underside has short hairs. Inflorescences are many-flowered racemes borne on elongated peduncles. The flowers are white to blue or purple in colour, about 1.5 cm long, typically papillonaceous in shape. *L. purpureus* fruits are linear, 4-15 cm long x 1-4 cm broad, smooth and beaked pods that contain between 2 and 8 seeds. *L. purpureus* seeds (beans) are ovoid, laterally compressed with a conspicuous linear hilum. *L. purpureus* beans are variable in colour, depending on variety or cultivar, usually white to dark brown, and some are black. Wild varieties and some cultivated varieties tend to have mottled seeds (Adebisi *et al*., 2004; Cook *et al.,* 2005)

L. purpureus is a multipurpose legume. Its immature seeds and pods, and young leaves are edible and cooked as vegetables in some countries though not common in Ethiopia. Mature dry beans are edible but they require prolonged cooking with several changes of water (Adebisi *et al.,* 2004; Cook *et al*., 2005). Though valuable as a garden crop, *L. purpureus* beans have a low market value. When used for fodder, *L. purpureus* can be grazed or harvested for cut-and-carry systems, hay and silage. It can be grown with other crops such as maize to make mixed fodder. An N-fixing legume *L. purpureus* valuable green manure. *L.*

purpureus is used in ethno veterinary medicine, examples from Kenya being to treat eye problems in sheep and lung problems in sheep, cattle and goats (Adebisi *et al*., 2004).

2.6.3. Cowpea (Vigna. unguiculata)

V. unguiculata is a tropical, annual herbaceous legume; it is a di cotyledon plant classified in the family Fabaceae, subfamily Faboideae, tribe Phaseolinae, order Fabales and genus *Vigna* order Leguminosae (Singh *et al.*, 1997). *V. unguiculata* is one of the common names in English: other English *V. unguiculata* names are Bachapinbean, Black-eyed pea, Crowder pea, China pea and Cow gram. It is also known internationally as Lubia, or Frijol. Irrespective of the name they are all species *Vigna unguiculata*, which in older reference may be identified as *Vigna sinensis* (L) (Quinn, 1999; Gomez, 2004).The genus *Vigna* consists of over one hundred different species widely found in the tropical and sub-tropical regions, and has great morphological and ecological diversity (Oyewale and Bamaiyi, 2013).

V. unguiculata is primarily a short day plant or in some instances, day-neutral (Ehlers and Hall, 1997). They are two main groups of growing habits of *V. unguiculata*, they include prostrate or indeterminate type and erect or determinate type and they can be distinguished from one another by different factors such as seed size and colour, taste, yield and time to maturity (Kabululu, 2008).

Due to unavailability of green fodder, supplementation of hydroponics sprouts in the ration of dairy animals is coming up as a viable alternate technology for the livestock farmers (Naik and Singh, 2014; Naik *et al.*, 2015). During sprouting, due to neutralization of enzyme inhibitors, activities of the inactive enzymes of the grains are increased, and also help in the elimination of anti-nutritional factors of the seeds. Sprouts are good source of enzymes, antioxidants and chlorophyll, which improves the performance of the livestock (Chavan and Kadam, 1989, Sneath and Mclntosh, 2003). Cowpea (*Vigna unguiculata*) is one of the important crops, grown in different parts of India and used as pulse, vegetable and fodder. There are numerous genotypes of cowpea is one of them. However, only a few reports are available on the nutrient content of hydroponically sprouted grains (Reddy *et al*., 1988, Naik *et al*., 2015).

2.7. Nutritive Values of Herbaceous Legumes Grown under Hydroponic System

One of the modern techniques that are considered important for better use of fodder production is hydroponic culture. Usually, the seeds are allowed to germinate and grow for about one week or few weeks when a forage mat made up of the germinated seeds, their intertwined white roots, and the green shoots is obtained (Cuddeford, 1989). The whole product is then fed to the animals and the empty space in the chamber is used to germinate a new set of seeds (Mukhopad, 1994). Hydroponic green fodder has high feed quality, rich with proteins, fibers, vitamins, and minerals (Bhise *et al.,* 1988; Chung *et al.,* 1989) with curative effects on animals (Kanauchi *et al.,* 1998; Boue *et al.,* 2003). All these special features produce green fodder in hydroponic culture, in addition to others make it one of the most important agricultural techniques currently in use for green forage production in many countries. Many different types of small grains and legumes can be used in hydroponic systems. Forage legumes is an important raw material for feed industry and widely used for animal feeding as grain in livestock (whole grain, the form of cracked or pomade, particularly in the breeding season) also green fodder (Yılma, 2007).

Work by Dung *et al*., (2010) found that the energy value of the sprouts was also lower than that of the grain on a DM basis, with a gross energy loss of 2% recorded after comparing the sprouts with the original grain. In addition to this nutrient analysis, they also analyzed the digestibility of the fodder versus original grain. In line with the previously presented material, they found no significant difference in the digestibility and concluded loss of total DM without a significant improvement in digestibility, represents a considerable reduction in total digestible energy.

Protein is a critical element for animal growth and performance and is very important in analyzing the feed value of fodder. The effect of sprouting on protein content isn't clear, with some studies illustrating increases in protein, and others decreases in protein. In one of the latest hydroponic fodder studies, (Dung *et al.*, 2010) found crude protein, ash and all other minerals except potassium were higher in concentration on a DM basis in the sprouts than in the barley grain (Dung *et al.,* 2010). This illustrates an advantage to the fodder. Sneath and McIntosh, (2003) propose that this is only an apparent increase in protein though and not a true increase. Their reasons for this are that the increase in protein is due to a decrease in dry weight through respiration during germination. This is only part of it though, with (Morgan, Hunter & O'Haire, 1992) stating that the increases in protein are "due partly to the absorption of nitrogen from the nutrients solution and to the concentration of nitrogenous compounds in a reduced mass of DM.

Dung *et al*., (2010) studied the in Sacco digestibility of sprouted barley fodder visa Vis grain. They found the loss of DM and no difference in in Sacco digestibility disproved there being an advantage in sprouts rather than the original grain. They found that the initial degradation of the whole sprout was significantly higher than for cracked grain after six hours of incubation in the rumen, but from 12 – 96 hours there were no significant differences between the whole sprouts and cracked grain.

A significant difference existed in the digestibility of the shoot portion versus the root portion of the fodder. The plant shoots were easily degraded in the rumen. (Dung *et al*., 2010) report that ruminant animals prefer diets that are leafy and non-steamy and with leaves have a low to intermediate tensile strength. Some studies have shown that a forage composition that leads to degradation to 1mm particle size encourages faster passage rate out of the rumen, leading to increased voluntary intake (Dung *et al*., 2010). Processed grain (cracked) and sprouts are both highly digestible and nutritious feeds. The process of sprouting the grain turns the starch in the grain to sugars in the sprouts (Sneath and McIntosh, 2003).

2.8. Chemical Composition of Different Hydroponic Fodders

The chemical compositions of hydroponic fodder grown from various grains were reported by different research personnel working in various conditions. Thadchanamoorthy *et al*., (2012) studied hydroponic maize fodder as source of feed for six New Zealand White rabbits (4 to 5 weeks old). Maize (Zea maize L) grain of the variety Pacific A99 were per soaked and incubated for two days. Soaked grain (500g) were placed in trays and grown in a protected house. Albert's solution 2 % w/v was used as a nutrient media and harvested at 10^{th} day after planting. Moisture, ash, CP, EE, CF, NDF and ADF % in sprouted maize were higher (73.93, 3.09, 16.54, 6.42, 8.21, 29.27 and 10.16 % respectively) than the levels found in grain (10.26, 1.48, 8.21, 4.69, 2.11, 19.22 and 5.5 % respectively).

Dung *et al*., (2010 b) examined the nutrient profile of barley grain when it was sprouted hydroponically for duration of 7 days. Daily sampling of the sprouts was done to assess DM content and also to determine the nutrient concentration on day 7 in comparison to the un sprouted grain. Results showed a 21.9 % loss in DM from the original grain after sprouting for a period of 7 days. A loss of 2 % GE was recorded after comparing the sprouts with the original grain. The CP, ash and all other minerals except potassium were lower in concentration on a DM basis in the barley grain than in the sprouts. This was considered to be a reflection of a loss in DM after sprouting causing a shift in concentration of these nutrients. Further, Dung *et al*., (2010 a) used a hydroponic nutrient solution to raise barley sprouts to compare with sprouts raised using tap water irrigation (two treatments). In both treatments, the sprouts were raised in continuous light in a temperature-controlled room for a period of 7 days. There was no difference ($p>0.05$) in DM loss after 7 days of sprouting.

The DM losses after 7 days of sprouting were 16.4 vs. 13.3 % for tap water irrigation and hydroponic nutrient solution, respectively. Sprouts grown with nutrient solution had a higher protein concentration than those grown with tap water irrigation (17.3 vs 15.9 %), respectively. If these sprouts were fed to ruminants, the DM losses would have represented a loss in digestible energy which would otherwise have been available for productive purposes. On a large scale these losses could add to the cost of animal production. The samples were analyzed for the nutrients content viz. crude protein (CP), ether extract (EE), crude fiber (CF), nitrogen free extract (NFE), total ash (TA) and acid insoluble ash (AIA) and were subjected for test of significance (Snedecor and Cochran, 1994) along with the data of nutrients contents of fodder maize (Zeamaize L.) grown under conventional practices (Naik *et al*., 2011).

The crude protein had increasing trend and remained highest on 7^{th} day of growth (13.57%), which was higher ($P<0.05$) than the conventional green fodder maize (10.67%). The ether extract content of hydroponics fodder maize on 7^{th} day (3.49%) was highest ($P<0.05$). The crude fiber content of the maize grain was 2.50% and increased ($P<0.05$) up to 14.07% on 7th day of growth in hydroponics system but was lower ($P<0.05$) than the fodder maize grown under conventional practices (25.92%). The nitrogen free extract content of the maize grain decreased to its maximum level (66.72%) at 7th day of growth in hydroponics system and was higher (P<0.05) to maize fodder grown under conventional practices (51.78%).

The total ash (TA) and acid insoluble ash (AIA) contents of the hydroponics fodder maize were lower (P<0.05) than the TA (9.36%) and AIA (1.40%) contents of the conventional fodder maize. It was concluded that hydroponics fodder maize was more nutritious than the conventional fodder maize in terms of available organic matter, crude protein, ether extract and nitrogen free extract content. Fazaeli *et al*., (2012) sprouted barley grain in a still hydroponic growing chamber for 6, 7 and 8 day periods and sampled for chemical analyses and metabolizable energy (ME) determination. According to Sharif *et al*., (2013) sprouting of grain has resulted in increased protein quantity and quality. Sprouting also increased the concentration of certain nutrients including sugars, minerals and vitamin contents. However, sprouting has resulted in decreased starch content and dry matter content of grain. It also increases the plant enzyme contents. In a study by Naik *et al*., (2014) hydroponics maize fodder of 7 days growth was studied and such hydroponics maize fodder (HMF) had higher CP (13.30 vs 11.14, %), EE (3.27 vs 2.20, %), NFE (75.32 vs 53.54, %) and lower CF (6.37 vs 22.25, %), TA (1.75 vs 9.84, %) and AIA (0.57 vs 1.03, %) than Napier bajra hybrid. HMF intake was lower (0.59 kg DM/d) than NBH (1.19 kg DM/ d) by the cows.

However, the DMI (2.05 and 2.17 %) was similar in both the groups. Digestibility of CP (72.46 vs 68.86, %) and CF (59.21 vs 53.25, %) was higher (P<0.05) for cows fed HMF. The DCP content (9.65 vs 8.61, %) of the ration increased significantly (P<0.05) due to feeding of HMF; however, the increase (P>0.05) in the CP (13.29 vs 12.48, %) and TDN (68.52 vs 64, %) content was non -significant.

2.9. Anti-Nutritional Factors and Hydroponics Feed

Pythic acid occurs primarily in the seed coats and germ of plant seeds. It forms insoluble or nearly insoluble compounds with minerals including Calcium, Iron, Magnesium and Zinc, such that they cannot be effectively absorbed into the blood. Diets high in Pythic acid and poor in these minerals produce mineral deficiency symptoms in experimental animals (Chavan and Kadam, 1989). The latter authors state that the sprouting of cereals has been reported to decrease levels of Pythic Acid. Sprouts can be a rich source of antioxidants, in the form of Beta-Carotene (a precursor of Vitamin-A), Vitamin-E, Vitamin-C and related trace minerals such as Selenium and Zinc.

Antioxidants play an important role in assisting to protect the body from damage by free radicals. Free radicals are highly unstable oxygen molecules that are increasingly generated under conditions of high physical exertion and also under conditions of poor nutrition. As physiologically toxic agents, they have the potential to lead to pain and disease. Free radicals travel throughout the body in search of an ability to alter the structure of the vital biological entities DNA and RNA, which are required for the reproduction of cells. Antioxidant vitamins have an ability to neutralize free-radicals, by either taking away or donating electrons, thereby eliminating the unpaired electron, (Shipard, 2005). The highest sources of antioxidant vitamins and minerals are undoubtedly legume seeds such as :fenugreek, alfalfa, mung beans, chick peas and sunflower seeds medicinal herbs, highly esteemed by both east and west, and has been regarded as a treatment for just about every ailment known to man, (Shipard, 2005).

2.10. Economic Benefit of Hydroponic Feeds

Traditional fodder production requires a major investment for the purchase of land, in addition to investment in agricultural machinery, equipment, infrastructure required for per- and post-harvesting, including handling, transportation and conservation of fodder. It also requires labor, fuel, lubricants, fertilizers, insecticides, pesticides, and weedicides. On the other hand, hydroponic fodder production requires only seed and water as production inputs with modest labor inputs (Bakshi, *et al.*, 2017).

Hydroponics minimizes post-harvest losses, with no fuel required for harvesting and post harvesting processes. Moreover, in hydroponic systems it takes only 7-8 days to develop from seed to fodder while it takes 45-60 days under traditional systems. However, the initial investment required for setting up hi-tech, sophisticated, automated commercial hydroponic fodder production systems, with environmental control, plus operational costs are much higher than traditional soil-based fodder production farming. Such hydroponic systems require much more specialized equipment and technical knowledge than is required in traditional farming. Mold is highly likely and thus prevention or treatment could further involve investment. Therefore, even if there are benefits of feeding hydroponic fodder, the benefits are usually outweighed by the costs (Tranel, 2013; Reddy, 2014).

The feed cost/kg milk was higher when animals were fed maize fodder produced from a hi-tech hydroponic system, mostly due to higher cost of hydroponic fodder production than green fodder produced by traditional farming (Reddy *et al*., 1988; Naik *et al*., 2014). However, farmers of the Satara district of Maharashtra found that the cost of milk production of hydroponic fodder was reduced remarkably (Naik *et al*., 2013) in a low cost shade net system with home-grown or locally purchased seeds. Accordingly when fodder was produced in low cost hydroponic system, the feed cost/kg milk was reduced remarkably (25 to 30%) and net profitability was improved considerably (Boue *et al*., 2003; Naik *et al*., 2013; FAO, 2015; Rachel Jemimah *et al*., 2015).

The metabolic activity of resting seeds increases as soon as they are hydrated during soaking. Complex biochemical changes occur during hydration and subsequent sprouting. The reserve chemical Constituents such as protein, starch and lipids are breakdown by enzymes into simple compounds that are used to make new compounds. Sprouting grains causes increased hydrolytic enzymatic activity, improvements in the contents of total proteins, fats and certain essential amino acids, total sugars, B-groups vitamins, and a decrease in dry matter, starch and anti-nutrients. The increased contents in protein, fats, total ash and fiber are only apparent and attributable to the disappearance of the starch. However, improvement in amino acid composition, B-group vitamins, starch digestibility, proteins and sugars, and decrease in phytates and protease inhibitors are the metabolic effects of the sprouting process (Chavan & Kadam, 1989). Sprouting is a tremendous source of plant digestive enzymes. Enzymes act as biological catalysts needed for the complete digestion of protein, carbohydrate and fats. The physiology of vitamins, minerals and trace elements is also dependent upon enzyme activity.

The period of greatest enzyme activity in sprouts is generally between germination and 7 days of age. Grains and legumes seeds of all plants contain abundant enzymes. However, while grains and seeds are dry, enzymes are largely inactive, due to enzyme inhibitors, until given moisture to activate germination. It is these inhibitors that enable many seeds to last for years in soil without deteriorating, whilst waiting for moisture. Enzyme inhibitors in some grains and legume seeds (for example trypsin inhibitors in raw soybeans and certain other beans and peas) need to be inactivated by heating or other processes, before they can be safely fed. However, heating, cooking and grinding processes can also inactivate certain digestive enzymes within grains and seeds. Fortunately, during germination and sprouting of grains and seeds, many enzyme inhibitors are effectively neutralized, whilst at the same time the activity of beneficial plant digestive enzymes is greatly enhanced (Shipard, 2005).The absorption of nitrates facilitates the metabolism of nitrogenous compounds from carbohydrate reserves, thus increasing crude protein levels, (Morgan *et al*., 1992). Very complex qualitative changes are reported to occur during soaking and sprouting of seeds. The conversion of storage proteins of cereal grains into albumins and globulins during sprouting may improve the quality of cereal proteins.

3. MATERIALS AND METHODS

3.1. Description of Study Area

The experiment was conducted from February to March, 2019 in Wollega University, Oromia regional state, Western Ethiopia. The University is located 328 km west of Addis Ababa, the capital city of Ethiopia and 245km North West of Jimma zone. Its geographical coordinates are 10° 0' 0'' N latitude and 37° 30' 0'' E longitude and has an elevation of 2,088 meters (68050 fts) above sea level. The town has annual average rainfall that ranges from 1500-2200 mm and the average air temperature ranges from 14–26°C (Nekemte municipality) (Zemadim, *et al*., 2011).

3.2. Establishment of Hydroponic System

The hydroponic system was composed of metal frame and shelves with the circular shaped plastic trays were put on the shelved metallic frames to sprout the fodder grains. And each shelf of the system unit could carry 3 planting trays. Plastic trays with a length of 18 cm, a width of 16.5 cm, and a depth of 3 cm were used for growing seeds to produce green fodder. These trays were obtained from the local market of Nekemte. An air conditioning was used to control temperature inside the growth room which was 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.

3.3. Collection of Plant Materials for the Experiment

Three legumes grains (*L. purpureus*, *V. unguiculata*, and *L. albus)* were collected from different sources for the intended purpose. Seeds of *L. albus* were obtained from the local market of Wombera, whereas *L. purpureus* and *V. unguiculata* seeds were obtained from Bako Agricultural Research Centers, respectively.

3.4. Treatment of Seeds Before Planting

Seeds of selected crops were cleaned from debris and other foreign materials. Then the cleaned seeds were washed well from residues of bleach and re-soaked in tap water for about

4 hours before planting (Sneath and McIntosh, 2003; Naik *et al*,. 2014; Naik *et al*., 2015; Naik *et al.*, 2016). Planting trays were also cleaned and washed and then the seeds were distributed in the lath house trays (Sneath and McIntosh, 2003). The seeds of different legume species (*L. albus*, *V. unguiculata* and *L. purpureus)* were grown under hydroponic system and used as experimental materials during the study. Fresh hydroponic legume fodders were produced in lath house by using tap water. Clean seeds of these legumes were washed and soaked in tap water for 4 hrs and then distributed in the trays with equal seed rates of 7.6 kg/m2 (Naik, 2013; Naik *et al.*,2016a). Inside the lath house, the plants were allowed to sprout for 17 days based on the result obtained after experiment on harvesting dates (second experiment) of the current research.

3.5. Treatments and Experimental Design

The treatments for watering frequency, harvesting dates and species effects were explained under each experiment. For all the three experiments, the experimental design of the study was Completely Randomized Design (CRD); and each treatment was replicated three times. Since the lath house allowed equal distribution of light on the trays in all directions; Water spraying was the same for all treatments and the seeds were grown on the clean trays.

3.6. Experimental Procedures for the First Experiment

3.6.1. Frequency of Watering

This was the first experiment which was used to identify appropriate watering frequency interval hours for the different legume species. Seeds of the three species, *L. albus*, *L. Purpureus* and *V. unguiculata* were sown in the planting trays with holes at the bottom to allow drainage of excess water from irrigation. Seeds of the selected legumes species were sown in the planting trays which have holes at the bottom to allow drainage of excess water from irrigation. Since there was no frequency of watering experiment conducted on legumes species, watering frequency between 2hrs and 4hrs intervals conducted on different varieties of oats was adopted in the current experiment (Firehiwot *et al*., 2018). Then the watering frequency for this experiment were indicated accordingly, at 2hrs, 3hrs and 4hrs intervals with equal drops of tape water for 1minute during day time. Frequency of watering was drained in plastic containers which were placed under each planting tray to avoid water logging (Badran *et al*., 2017). Trays were irrigated manually with tap water as indicated in the treatments below.

Table 1: Frequencies of watering at different hours of interval

Treatment1: watering frequency			
No	Species	Minutes	Hours of watering frequency interval per day
1	*L. albus*	1min	2hours
2	*L. albus*	1min	3hours
3	*L. albus*	1min	4hours
4	*V. unguiculata*	1min	2hours
5	*V. unguiculata*	1min	3hours
6	*V. unguiculata*	1min	4hours
7	*L. purpureus*	1min	2hours
8	*L. purpureus*	1min	3hours
9	*L. purpureus*	1min	4hours

3.7. Experimental Procedures for the Second Experiment

3.7.1. Determination of Appropriate Harvesting Date

This was the second experiment conducted after frequency of watering experiment. A selected species of legumes (BH-660) were grown hydroponically to identify the appropriate date at which maximum biomass yield of sprouted legumes fodder was harvested. Two hour watering frequency interval, which was selected for best performance during the first experiment, was used across all treatments in the second experiment. Accordingly, the fodder was harvested at 13th, 15th, 17th and 19th days after sowing and was measured to identify the appropriate date at which maximum biomass yield of sprouted selected legumes species fodder was harvested. Chrisdiana, (2018) reported that harvested at 8th, 12th and 16th days in different varieties of sorghum. There were also other reports harvested at 10th, 12th and 14th days in different varieties of oats (Firehiwot *et al*., 2018) then the treatments were indicated below:

Table 2: Identifying the appropriate harvesting date

Treatment 2: Harvesting Date			
No	Species	Hours of watering frequency interval per day	Harvesting date
1	*L. albus*	2hours	13th days
2	*L. albus*	2hours	15th days
3	*L. albus*	2hours	17th days
4	*L. albus*	2hours	19th days
5	*V. unguiculata*	2hours	13th days
6	*V. unguiculata*	2hours	15th days
7	*V. unguiculata*	2hours	17th days
8	*V. unguiculata*	2hours	19th days
9	*L. purpureus*	2hours	13th days
10	*L. purpureus*	2hours	15th days

11	*L. purpureus*	2hours	17th days
12	*L. purpureus*	2hours	19th days

3.8. Experimental Procedures for the Third Experiment

3.8.1. Identifying the Effect of Species Difference

Under this experiment, the potential of the selected legumes species was tested at the same harvesting date 17th days by using same (2 hours) watering frequencies for fodder yield and yield related parameters such as herbage to root ratio (HRR), plant height (PH), leaves weight, root weight and nutritive values. At harvesting time, the following data was recorded per tray: total fresh and dry matter yield of fodder, and ratio of produced green fodder to the initial planted seeds weight were computed. A representative fresh plant samples (about 300 grams) from every tray were taken at harvest for Dry Matter yield and laboratory analysis.

3.9. Seed Planting and Watering

The seeding rate used in this experiment was about 450 g/tray (equivalent to about 4.0 kg/m2) (Al-Hashmi, 2008). The seeding rates were based on seeds size and weight. Then, the trays were stacked on the shelves of the hydroponic system. Trays were irrigated manually with tap water twice a day (early in the morning and late in the afternoon) with tap water to provide enough water to keep the seeds/ seedlings moist.

3.10. Data Collection

3.10.1. Plant Height

At the time of herbage harvest for dry matter yield determination, the plant height for each species was determined by measuring the height of five randomly selected plants from bottom of the dish to the tip of the main stem (Tarawali *et al.*, 1995), then finally the average of five plants were taken for each trays and height of the plant was measured by centimetre(cm).

3.10.2.Fodder Yield

The experiment was terminated after 13th, 15th, 17th and 19th days from seeding where the produced green fodder biomass yield was ready for harvesting and green plants by their root mats in the trays. A sub sample of 300gm freshly harvested biomass was taken and manually chopped into small pieces using sickle and dried at 105^{o}C for 48 hours in an oven for herbage Dry Matter Yield (DMY) determination.

DMY (t/ha) = (10 x TFW x SSDW) / (HA x SSFW) (James, 2008).

Where: 10 = constant for conversion of yields in kg/m2 to tone/ ha;

TFW = total fresh weight from harvesting area (kg);

SSDW = sub-sample dry weight (g);

HA = harvest area (m^2), and SSFW = sub-sample fresh weight (g).

The Crude Protein Yield (CPY, t/ha) and Neutral Detergent Fiber (NDFY, t/ha) was determined by multiplying DMY by CP content (Starks *et al*., 2006). Finally quantities of the sub-samples was dried in oven at 65^{0}C for 48 hours and stored in airtight bags to be used for chemical analysis.

3.10.3. Agronomic Data

The agronomic data collected were illustrated as below, which was supported procedure of (Akililu and Alemayehu (2007); Firehiwot *et al*., (2018);Tarawali *et al.*, (1995)).

Seeding date: the date at which all of the selected seed species was prepared for seedling. The seeding date for the first experiment was 13/02/2019.

Seed weight: From each legume, equal numbers of seeds (100 seeds) were taken and weighed using sensitive balance and recorded.

Germination rate: for all the three legumes used in the experiment, the date at which initial emergence of shoot appeared (1st germination) and the date at which almost all seeds (except dead seeds) germinated (2nd germination date) was recorded starting from planting date.

Plant height at harvest: At the end of the 19th day, the height of the plant (cm) was taken using transparent glass ruler. To do this, five plants per tray was randomly taken for measurement and the average was recorded.

Herbage weight (leaf and stem) (grams): During harvesting, three hundred gram (300g**)** of plants weight were taken per tray and leaves along with stems (herbage) were cut from the root using razor blade, and weighed using a digital weighing balance and the data were recorded. Then the total weight of herbage (converted ton) per tray (converted ha) was recorded by separating from its root part.

Root weight: after removing stem and leaf parts, the weight of root was recorded in similar procedure as in leaf and stem weight measured.

Herbage: root ratio: was calculated by dividing total herbage (leaf + stem) 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 (Firehiwot *et al*., 2018).

Biomass above root (Leaves + stem) weight: was calculated as total fodder yield minus root weight.

Treatments

1. *L.albus* grains was sprouted at 2hours of watering interval harvested at 17th day
2. *L. purpureus* grains was sprouted at 2hours of watering interval harvested at 17th day
3. *V.unguiculata* was sprouted at 2hours of watering interval harvested at 17th day

3.11. Chemical Analysis

A representative fresh plant samples from trays planted hydroponically with the local cultivar and green forage samples from *L. albus*, *V. unguiculata* and *L. purpureus* legumes plants grown under hydroponic technique was collected, oven-dried at 65°C for 48 hours, weighed, and ground to pass through a 1mm sieve and kept in paper bag until chemical analysis. The chemical analysis of all samples of feeds collected was analyzed at Holeta Agricultural Research Center (HARC) Animal Nutrition Laboratory. Dry mater, ash, crude protein (through kjeldhal technique) and total ash was determined according to AOAC (2000). The neutral detergent fibers, acid detergent fiber and acid detergent lignin were determined according to Van Soest and Robertson (1991).

3.12. In vitro DM Digestibility

In vitro DM digestibility of hydroponic selected legumes species was determined according to two-stage Tilley and Tkerry, 1963 technique as modified by Van Soest *et al*., 1991.Where a second stage (Rumen liquor-pepsin digestion) was substituted by neutral detergent extraction to simulate true digestibility was done at Holeta Agricultural Research Center (HARC).

3.13. Statistical Analysis

All data obtained from fodder yield and yield related components, chemical composition and *in vitro* DM digestibility were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of Statistical Analysis System (SAS) software, version 9.2 (SAS, 2008). Where the ANOVA declare variation between means, Tukey HSD was used to separate the means at α=0.05.

The model used for the experiment was:

$$Yijk = \mu + \alpha i + \beta j + (\alpha\beta)ij + eijk$$

Where;

Y_{ijk} = the response variable,

μ = overall mean,

αi = is the i th level of species of the legumes

βj = the j th level of watering frequency and harvesting date

$(\alpha\beta)ij$ = interaction effects species with watering frequency and harvesting date

ε_{ijk} = the residual error

4. RESULTS AND DISCUSSION

4.1. Effect of species on the seeding weight and germination rate of the legumes

Both the seed weight and germination rates (first germination and last germination dates) of the legumes were significantly affected (P<.0001) by species difference (Table 3). The heaviest seed weight was recorded for *L.albus* (33.83 gm) followed by *L. purpureus* (33.33 gm) and the lowest seeding weight was for *V. unguiculata* (32.13 gm). The germination dates (1^{st} germination and last germination dates) was fastest for both *V. unguiculata* and *L. purpureus* and, happened to be at the same date but, *L.albus* was germinated later than the two legumes. Heavier seeds are believed to contribute to higher herbage biomass after sprouting. This might be due to relatively higher food storage compared to lighter seeds. The earlier the seed germination date the faster the date of harvesting. This was what was observed at Figure one.

Table 3: Effect of variation in species on agronomic characteristics of the legumes

	Parameters			
Species	Swt (gm)	1^{st} germination date	Last germination date	Germination %
L.albus	33.83[a]	3.00[a]	7.00[a]	91.00[b]
V. unguiculata	32.13[c]	2.00[b]	5.00[b]	81.00[c]
L. purpureus	33.33[b]	2.00[b]	5.00[b]	93.00[a]
Mean	33.100	2.333	5.67	88.3
CV	0.4615	0	0	1.1320
P-value	<.0001	<.0001	<.0001	<.0001

CV= coefficient of variation, [a, b, c] means with different superscripts within the same column are significantly different (p<0.05), Swt= seed weight, gm= gram .

4.2. Effect of watering Frequency on Fodder Yield and Related agronomic components of the legumes

Effect of watering frequency on fodder yield and yield related components of selected species of legumes was shown in Table 4. All the fodder yield and yield related components of the legumes species were significantly affected (p= 0.0001) by watering frequencies.

The dry matter yield (DMY) (t/ha) for all the three legumes at one production cycle was highest at 2 hours interval of watering frequency followed by 3 hours while the least was for 4 hours of watering frequency intervals. The fodder yield and related components for *L.albus* and *V.unguiculata* consistently decreased with increasing watering intervals from 2 hours to 4 hours interval except for herbage to root ratio while that of *L. purpureus* did not revealed like others growth pattern which is because of the water stress that affects plants vegetative growth (Pejić *et al*., 2009; Seyed *et al*., 2012). Fathi and Tari (2016) also reported that, with increasing moisture shortage, cell wall wizened and loosed with a decrease in cell volume, pressure decreases and the potential for the development of the cell decreases and growth is reduced.

The leaf weight (LW) of the legumes species were significantly differed (p=0.0001) by the treatments. The results showed that the highest LW was recorded for 2 hours interval watering frequency for *L. purpureus*(7.506t/ha) the next highest LW was recorded for *V.unguiculata* (5.05t/ha) while the least was for *L. albus* (4.77t/ha). In similar manner, the result of root weight (RW) also revealed that, there is a significant difference (p=0.0001) that show a decreasing tendency as the watering frequency interval elongated from 2 hour to 4 hours of watering frequency. Correspondingly, the results for stem weight, plant height and canopy circumference for all the species showed that there is a significant difference (p=0.0001) by the frequencies of watering interval like that of DM and LW. However, the herbage to root ratio did not show consistent growth pattern for *L. albus* as compared to the other two legumes species.

Table 4: Effect of watering frequency on fodder yield and yield related components of selected species of legumes

	Watering Frequencies				
a). *L. albus*	2 hours	3 hours	4 hours	SEM	SL
Dry matter yield (t/ha)	20.3[a]	17.9[b]	14.03[c]	0.019	***
Leaves weight (t/ha)	4.77[a]	4.05[b]	2.73[c]	0.006	***
Root weight (t/ha)	3.38[a]	2.57[b]	2.26[c]	0.004	***
Stem weight (t/ha)	12.2[a]	11.3[b]	9.04[c]	0.049	***
Plant Height (cm)	12.4[a]	10.6[b]	6.43[c]	0.045	***
Canopy Circumference(cm)	45.5[a]	40.5[b]	37.0[c]	0.334	***
Herbage to root ratio	5.02[c]	6.00[a]	5.21[b]	0.007	***
b). *V. unguiculata* species					
Dry matter yield (t/ha)	20.4[a]	16.8[b]	13.4[c]	0.019	***
Leaves weight (t/ha)	5.05[a]	4.94[b]	4.67[c]	0.002	***
Root weight (t/ha)	8.17[a]	5.25[b]	2.74[c]	0.020	***
Stem weight (t/ha)	7.21[a]	6.64[b]	5.93[c]	0.008	***
Plant Height (cm)	12.7[a]	11.6[b]	10.5[c]	0.016	***
Canopy Circumference (cm)	49.5[a]	43.7[b]	38.0[c]	0.202	***
Herbage to root ratio	1.50[c]	2.21[b]	3.88[a]	0.018	***
c). *L. purpureus* species					
Dry matter yield (t/ha)	19.23[a]	17.00[b]	14.00[c]	0.019	***
Leaves weight (t/ha)	7.506[a]	7.070[b]	4.993[c]	0.006	***
Root weight (t/ha)	5.646[a]	5.200[b]	3.410[c]	0.002	***
Stem weight (t/ha)	6.093[a]	4.693[c]	5.600[b]	0.005	***
Plant Height (cm)	17.30[a]	15.14[b]	13.94[c]	0.136	***
Canopy Circumference (cm)	56.50[a]	53.1[b]	50.04[c]	0.035	***
Herbage to root ratio	2.41[b]	2.26[c]	3.11[a]	0.015	***

Cm= cent meter, t/ha= ton / hectare, SEM= standard error of the mean, [a, b, c] within the same row, means with different superscripts are significantly different ($p<0.05$). SL= significance level

4.3. The Combinations effects of watering frequency and legume species on fodder yield and yield related component

The interaction effect of watering frequency intervals with species on hydroponic fodder yield and yield related components of the legumes were given in Table 5. For all fodder yield and yield related components there was significant interaction effects ($p<.0001$) for the interaction of watering frequency interval with legume species.

The highest Dry Matter Yield (DMY) t/ha combination effect was recorded for two hours watering frequencies interval on *V. unguiculata* (20.43 t/ha) *legume* followed by *L.albus* (20.26 t/ha) and the least was for *L. purpureus* (19.23t/ha). The next highest (DMY) was recorded for three hours interval watering frequency by *L.albus* (17.96t/ha) followed by *L. purpureus* (17.00t/ha) and the least was for *V. unguiculata* (16.83t/ha). The last least (DMY) was recorded for four hours interval watering frequency by *L.albus* (14.03t/ha) followed by *L. purpureus*(14.00t/ha) and *V. unguiculata* (13.36t/ha).

As frequency of watering interval increased, sprouting increased but dry mater yield was decreased for this particular study and these may be due to utilization of nutrients for maintenance (respiration) of the plants. Other researchers (Fazaeli *et al.,* 2012) also reported that DM content of the seeds decreased during the sprouting compared to the original seeds and this gradual decrease in DM during sprouting process 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 inhibition 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).

The leaf weight (LW) of the legumes species was highest when 2 hours interval of watering frequency interacted with *L. purpureus* (7.50t/ha) followed by *V. unguiculata* (5.05t/ha) and the last was for *L.albus* (4.77t/ha). The highest root weight was recorded for 2 hours watering frequencies interval for *V. unguiculata* (8.170t/ha) followed by *L. purpureus* while the last was recorded for *L.albus* (3.380t/ha). The highest plant height was recorded for 2 hours interval watering frequency for *L. purpureus* (17.30cm) followed by *V. unguiculata* (12.70cm) and the last was for *L.albus* (12.40cm) at the same date of harvesting. Reddy (2014) 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 highest canopy circumference was obtained for 2 hours intervals of watering frequency interaction with species showed similar trend with plant height. The highest herbage to root ratio (HRR) was recorded for 3 hours intervals of watering frequency for *L.albus* (6.00) followed by 4 hours interval watering frequency of the same species *L.albus* (5.206).

Table 5: Effects of Watering frequency with Species interactions on fodder yield and yield related component

Factors	Parameter						
Watering frequency* Species	DMY (t/ha)	LW (t/ha)	RW (t/ha)	SW (t/ha)	PH (cm)	CaCi(cm)	HRR
2hr**L.albus*	20.26^{a}	4.77^{de}	3.380^{d}	12.17^{a}	12.40^{c}	45.50^{c}	5.020^{c}
3hr* *L.albus*	17.96^{c}	4.05^{f}	2.566^{f}	11.34^{b}	10.60^{e}	40.50^{d}	6.00^{a}
4hr* *L.albus*	14.03^{e}	2.73^{g}	2.263^{g}	9.040^{c}	6.433^{f}	37.00^{e}	5.206^{b}
2hr* *V. unguiculata*	20.43^{a}	5.05^{c}	8.170^{a}	7.213^{d}	12.70^{c}	49.50^{b}	1.500^{h}
3hr* *V. unguiculata*	16.83^{d}	4.94^{dc}	5.246^{c}	6.640^{e}	11.58^{d}	43.75^{c}	2.210^{g}
4hr* *V. unguiculata*	13.36^{f}	4.67^{e}	2.740^{e}	5.933^{f}	10.46^{e}	38.00^{e}	3.880^{d}
2hr* *L. purpureus*	19.23^{b}	7.50^{a}	5.646^{b}	6.093^{f}	17.30^{a}	56.50^{a}	2.406^{f}
3hr* *L. purpureus*	17.00^{d}	7.07^{b}	5.200^{c}	4.693^{h}	17.00^{a}	56.00^{a}	2.260^{g}
4hr* *L. purpureus*	14.00^{e}	4.99^{dc}	3.410^{d}	5.600^{g}	13.50^{b}	50.00^{b}	3.113^{e}
Mean	17.014	5.0877	4.2914	7.6366	12.442	46.305	3.5107
CV	1.24418	2.7034	3.7225	1.5368	3.7225	2.2221	2.0888
SL	***	***	***	***	***	***	***

DMY=dry matter yield, LW= leaves weight, RW=root weight, SW=stem weight, PH=plant height, CaCi= canopy circumference, HRR=herbage to root ratio, Cm= cent meter, t/ha= ton / hectare, CV= coefficient of variation, $^{a, b, c, d, e, f, g, h}$ within the same column, means with different superscripts are significantly different ($p<0.05$). SL= significance level

4.4. Effect of Harvesting Dates on Fodder Yield and Yield Related Components of Selected Legumes Species

Effect of harvesting dates on fodder yield and yield related components of selected species of legumes was presented in Table 6. The fodder yield and yield related components of the legumes were all significantly affected (p=0.0001) by harvesting dates except the stem weight (p>005) of *V.unguiculata.*

The dry matter yield (DMY) (t/ha) for *L. albus* and *L. purpureus* was significantly (p= 0.0001) affected by harvesting dates and was systematically decreasing with increasing dates of harvesting. The DMY of *V.unguiculata* was not affected (p>0.05) by differences in harvesting dates. The components such as leaves weight (t/ha), roots weight (t/ha), stem weight (t/ha), plant height (cm), canopy circumference (cm) and herbage to root ratio for *L. albus* and *L. purpureus* followed similar trend of their DMY while most of the studied parameters of *V.unguiculata* did not show like others species.

The significantly (p=0.0001) decreasing trend in DMY of *L. albus* and *L. purpureus*, and only numerically (p=0.1390) decrease in that of *V.unguiculata* was similar with fodder yields reported by other researchers (Firehiwot *et al.*, 2018) where DMY of oats decreased with increase in date of harvesting from 10^{th} to 14^{th} day. (Bakshi *et al*., 2017; Putnam *et al*., 2013; Sneath and Fazaeli, *et al*., 2012; Dung *et al*., 2005 and McIntosh, 2003). Reported in their review of a number of studies (different crops) 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.

Table 6: Effect of harvesting date on Fodder Yield and Yield Related components of selected species of legumes

	Harvesting Dates					
a). *L. albus* species	13^{th} day	15^{th} day	17^{th} day	19^{th} day	SEM	P-value
Dry matter yield (t/ha)	21.56^{a}	21.14^{b}	20.63^{c}	20.12^{d}	0.078	0.0001
Leaves weight (t/ha)	3.110^{d}	3.463^{c}	3.830^{b}	4.820^{a}	0.035	0.0001
Root weight (t/ha)	6.020^{b}	3.563^{c}	3.923^{c}	7.726^{a}	0.089	0.0001
Stem weight (t/ha)	12.43^{a}	10.31^{b}	9.79^{a}	8.537^{c}	0.147	0.0001
Plant Height (cm)	8.30^{d}	10.30^{c}	11.40^{b}	14.43^{a}	0.067	0.0001
Canopy Circumference(cm)	40.77^{d}	41.27^{c}	42.77^{b}	45.50^{a}	0.072	0.0001
Herbage to root ratio	2.590^{c}	3.870^{a}	3.200^{b}	1.730^{d}	0.041	0.0001
b). *V. unguiculata* species						
Dry matter yield (t/ha)	9.897	9.413	9.28	8.867	0.258	0.1390
Leaves weight (t/ha)	0.330^{b}	0.897^{ba}	0.93^{c}	1.420^{a}	0.166	0.014 1
Root weight (t/ha)	8.9067^{a}	6.367^{b}	4.35^{b}	5.280^{b}	0.471	0.0023
Stem weight (t/ha)	0.653	2.237	1.62	2.170	0.382	0.0494
Plant Height (cm)	6.900^{b}	10.20^{ab}	10.53^{b}	16.40^{a}	1.345	0.0104
Canopy Circumference(cm)	35.27^{b}	39.77^{b}	39.42^{b}	44.50^{a}	1.381	0.0147
Herbage to root ratio	0.110	0.550	0.403	0.683	0.121	0.0595
c). *L. purpureus* species						
Dry matter yield (t/ha)	19.20^{a}	18.85^{a}	16.99^{b}	15.54^{b}	0.262	0.0001
Leaves weight (t/ha)	6.267^{a}	4.830^{cb}	5.14^{b}	5.14^{b}	0.147	0.0006
Root weight (t/ha)	4.727^{b}	5.510^{a}	5.63^{a}	5.673^{a}	0.147	0.0120
Stem weight (t/ha)	8.210^{a}	7.110^{b}	7.11^{a}	4.643^{c}	0.219	0.0001
Plant Height (cm)	19.30^{b}	21.90^{a}	22.00^{a}	21.30^{a}	0.329	0.0038
Canopy Circumference(cm)	53.50^{b}	57.77^{a}	58.27^{a}	58.20^{a}	0.549	0.0023
Herbage to root ratio	3.067^{a}	2.173^{b}	1.760^{c}	1.723^{c}	0.067	0.0001

Cm= cent meter, t/ha= ton / hectare, SEM= standard error of the mean, $^{a, b, c, d}$ within the same row, means with different superscripts are significantly different ($p<0.05$).

Upon observation of the sprouting process of the legumes, all of them were not fully grown at 15th day of harvesting while *L. purpureus* had fully grown at 17th day but the rest were not (Fig. 1). The full growth of *L. purpureus* was reflected by reduced plant height from 22cm to 21.30 cm; basal circumference from 58.27cm to 58.20cm; and none increment on its leaves weight (5.14t/ha) as one moves from 17th day to 19th date of harvesting. Despite the poor germination rate of *V. unguiculata* (observation) it had continued herbage growth for three to four days even after 19th date of harvesting while the *L. albus* continued its growth linearly until 27th day (Fig. 1). From this, one can generalize that *L. albus* and *V. unguiculata* could take long time for harvesting compared to *L. Purpureus* and the former contribute low harvesting cycle per year and their productivity might be lower. Thus, *L. purpureus* had resulted in better sprouting quality and could contribute more to hydroponic fodder due to its relatively short days to harvesting. On the other hand, lack of differences in DMY of *V. unguiculata* was mainly due to less sprouting performance of the legume that could have differentiated the seeds with better DM weight into the leaves of less DM weight.

4.5.Effect of the Legume species on dry matter yield and related components

The effect of selected legume species on fodder yield and yield related components at same watering frequency (2 hours) and same harvesting date (17th day) was indicated in Table 7. All the studied parameters such as dry matter yield (DMY), leaves weight (LW), roots weight (RW), stem weight (SW), plant height (PH), canopy circumference (CaCi) and herbage to root ratio (HRR) were significantly affected ($p<0.012$) by species difference.

The highest DMY was recorded for *L.albus* (20.63t/ha) followed by *L. purpureus* (15.54t/ha) but that *V. unguiculata* (9.28t/ha) was the least. *L. purpureus* attained highest values in most parameters such as leaves weight (5.14t/ha), root weight (5.63t/ha), stem weight (7.11t/ha) plant height (21.3cm) and canopy circumference (58.3tcm) indicating its best hydroponic characteristics. *L.albus* species has attained highest stem weight (9.79t/ha) and herbage to root ratio (3.2) compared to other legumes. Even if *L. purpureus* attained highest values in most parameters studied (except DMY) including leaves weight (5.14 t/ha) its HRR was lower than *L. albus* mainly due to its highest root weight (5.63t/ha). As opposed to this, *L. albus* attained highest HRR which is solely due to lowest root weight (3.56t/ha). The HRR in this study was determined to evaluate quality aspects of the hydroponic legume fodder in similar way to the leaf to stem ratio of the conventional forage plants. Thus on the basis of HRR result, the *L. albus* qualifies to the best and this was amended by its highest IVDMD indicated in Table 10.

Table 7: Effect of selected legume species on fodder yield and yield related components at 17th date of harvesting using the same watering interval (2 hours).

Parameters	*L. albus*	*V. unguiculata*	*L. purpureus*	SEM	P-value
Dry matter yield (t/ha)	20.63[a]	9.28[c]	16.99[b]	0.417	0.0001
leaves weight (t/ha)	3.83[b]	0.93[c]	5.14[a]	0.134	0.0006
Root weight (t/ha)	3.56[c]	4.35[b]	5.63[a]	0.064	0.0120
Stem weight (t/ha)	9.79[a]	1.62[b]	7.11[a]	0.604	0.0001
Plant Height (cm)	11.40[b]	10.53[b]	22.11[a]	0.759	0.0038
Canopy Circumference(cm)	42.75[b]	39.42[b]	58.27[a]	1.005	0.0023
Herbage to root ratio (HRR)	3.20[a]	0.403[c]	1.760[b]	0.135	0.0001

Cm= cent meter, t/ha= ton / hectare, SEM= standard error of the mean, [a, b, c] within the same row, means with different superscripts are significantly different ($p<0.05$).

The biomass (fresh yield) of the selected legume species at extended harvesting dates was graphically presented below (Figure 1). The graph indicates that the optimum harvesting date for *L. purpureus* was 17th day, for *V. uniguiculata* was 19th day and that of *L.albus* was not determined in this study because it was still linearly continued growth even at 27th date of harvesting. The average biomass yield increased about 9.78, 3.8 and 1.2 times higher than the original grain for *L. albus, L. purpureus and V.unguiculata* respectively. Such superior growth performance of *L. albus* was may be due to densest food reserve in its cotyledon which was strongly attached to its stem (Figure 2) and continuously supplying nutrients for supporting linear type of herbage growth.

Ghazi and Al-Hashimi (2011) reported that fresh weight of green fodder increased about 4.5 times its original seed weight, after sprouting grain for 6 days by spraying seeds of barley. Peer and Leeson (1985), reported that fresh weight increased 5.7 times the original seed weight, after sprouting for 7th days which were higher than the present result of hydroponics fodders of selected herbaceous legumes after 15th days at 2 hours, 3hours and 4hours interval of a day.

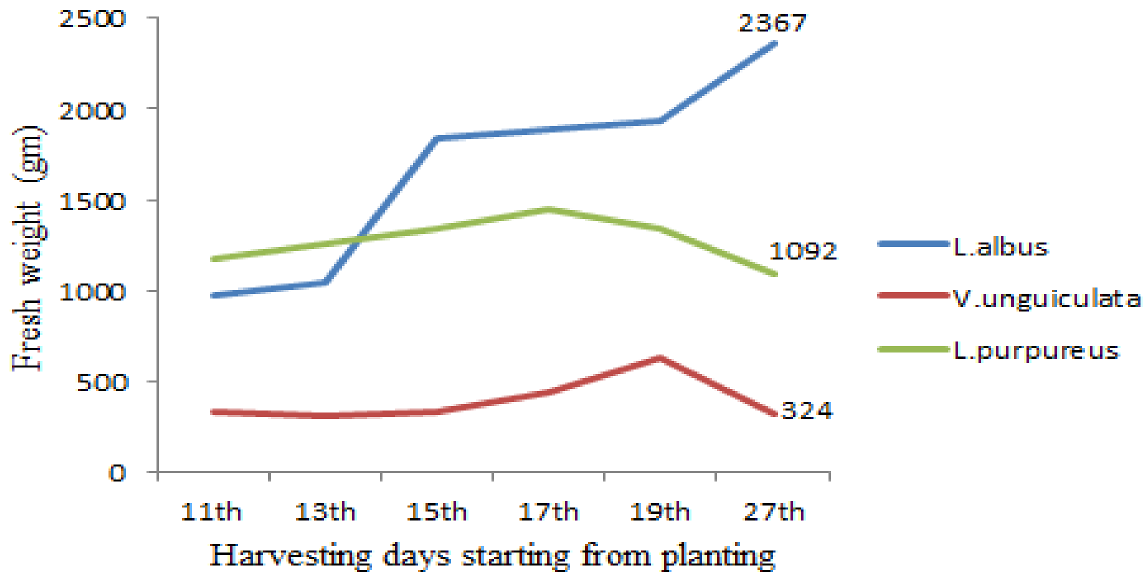

Figure 1: Biomass yield of *L. albus, V. unguiculata and L. purpureus under* extended harvesting dates

Figure 2: strong cotyledon of *L. albus*

4.6. The Combinations effect of harvesting date and legume species on fodder yield and yield related component

The interaction effect of harvesting date with species on hydroponic fodder yield and yield related components of the legumes were presented in Table 6. For all fodder yield and yield related components there was significant interaction effects ($p<.0001$) of harvesting date and legume species

The dry matter yield (DMY) of hydroponically grown selected legumes species were significant ($p<.0001$) among the treatments. The highest DMY was recorded for 13th date of harvesting by *L.albus* (21.56t/ha) followed by *L. purpureus* (19.203t/ha) and the last was for *V. unguiculata* (9.897t/ha). The next highest DMY was recorded for 15th date of harvesting followed by 17th and the last was for19th date of harvesting by species interaction that showed similar trends of 13th dates of harvesting.

L.albus at 13th day of harvesting had highest DMY followed by 15th days of harvesting while the least was for 19th days of harvesting. This is due to the fact that *L.albus* had germinated slowly at early stage of harvesting. However, germination of *L.albus* had been very fast at latter until 19th days of harvesting. Similarly, *V. unguiculata and L. purpureus* at 13th day of harvesting had also the highest DMY followed by 15th days of harvesting while the least was recorded for 19th days of harvesting.

As harvesting date increased, sprouting would increase but dry mater yield was decreased with longer harvesting time for this particular study and these may be due to utilization of nutrients for maintenance (respiration) of the plants. This gradual decrease in DMY during sprouting process might be due to leaching and oxidation of nutrients from the seeds (Firehiwot*., et al* 2018; Chrisdiana, 2018).

In hydroponic plant fodder, seeds soaking increases the activity of enzymes that breaks down the seeds in to simple fractions such as starch in to sugars, proteins in to amino acids and fat into fatty free acids, while dry matter yield and total energy decrease (Sneath and McIntosh, 2003). In barely hydroponic experiment, germination of barely fodder plants had 18% loss in dry mater yield.

There were significance ($p<.0001$) differences among treatments in leaf weight as affected by date of harvesting with species interaction. The results showed that the highest leaf weight (LW) was recorded for 19th dates of harvesting by *L. purpureus* (6.266t/ha) followed by

L.albus (4.820t/ha) and the least was for *V. unguiculata* (1.420t/ha). While time of harvesting increases, photosynthesis continues until nutrient in the seed lost. As photosynthesis continue growth of plant increases and plant leaf also increases. This means longer harvest time could bring higher plant leaf production (Firehiwot., *et al* 2018)

The root weight (RW) of hydroponically grown selected legumes species were significant differences ($p<.0001$) among the treatments. The highest root weight was recorded for 13^{th} date of harvesting by *V. unguiculata* (8.906t/ha) followed by 19^{th} date of harvesting by *L.albus* (7.726t/ha). The least was recorded for 19^{th} date of harvesting by *L. purpureus* (5.673t/ha). There were significance ($p<.0001$) differences among treatments in stem weight as affected by date of harvesting with species interaction. The highest stem weight (SW) was recorded for 13^{th} date of harvesting by *L.albus* (12.43t/ha) while the least was for 19^{th} date by *L.albus* (8.536t/ha), followed by 13^{th} date of harvesting by *L. purpureus* at (8.210t/ha) and the least was recorded for 19^{th} date of harvesting by *L. purpureus* (4.643t/ha). The interaction effect between *V. unguiculata* and 13^{th} date of harvesting had the lowest (SW) (0.653t/ha).

There were significance ($p<.0001$) differences among treatments in plant height as effected by date of harvesting with species interaction. The highest plant height (PH) was recorded for 19^{th} date of harvesting by *L. purpureus* (22.00cm) followed by 13^{th} date of harvesting by *L. purpureus* (19.30cm). While at 19^{th} date of harvesting, the highest plant height was recorded for *V. unguiculata* (16.40cm) followed by *L. albus* (14.30cm) but 13^{th} date of harvesting was the least for *V. unguiculata* (6.90cm) and the last least (PH) was for 13^{th} date of harvesting L. *albus* (8.50cm).

The plant height at 19^{th} date of harvesting had highest value because the fodder of the selected legumes species was not well grown at 13^{th} days of harvesting. Longer harvest time will help the plant to use nutrient in the seed and hence the plant continues to increase in height. Firehiwot *et al.,* (2018) reported that the average plant height of 7.5-11 cm at 10^{th}, 12^{th} and 14^{th} days of harvesting in hydroponic oat verities and this results were lower than the present study. The average plant height reported by Naik *et al.*,(2013) and El-Deeba *et al.,* (2009) in maize hydroponic fodder were 28 cm and 20-30cm, respectively and those results were higher than the present study which might be due to difference in environmental factors affected the growth of hydroponic fodder.

Table 8:: Effects of Harvesting date with Species interactions on fodder yield and yield related component

Factors	Parameter						
Harvesting date with Species	DMY (t/ha)	LW (t/ha)	RW (t/ha)	SW (t/ha)	PH (cm)	CaCi (cm)	HRR
13th**L.albus*	21.56[a]	3.110[e]	6.020[cd]	12.43[a]	8.50[gf]	40.76[ef]	3.870[a]
15th* *L.albus*	21.14[ab]	3.463[de]	3.563[g]	10.31[b]	10.30[ef]	41.26[ef]	2.590[c]
17th* *L.albus*	20.63[cb]	3.830[d]	3.923[gf]	8.716[c]	11.40[e]	42.76[ed]	3.200[b]
19th* *L.albus*	20.117[c]	4.820[b]	7.726[b]	8.536[c]	14.30[d]	45.50[c]	1.730[e]
13th * *V. unguiculata*	9.897[g]	0.330[h]	8.906[a]	0.653[g]	6.90[g]	35.26[g]	0.110[h]
15th * *V. unguiculata*	9.413[gh]	0.896[g]	6.366[c]	2.236[f]	10.20[ef]	39.76[f]	0.550[fg]
17th * *V. unguiculata*	9.280[gh]	0.493[h]	4.346[gf]	0.876[g]	8.40[gf]	37.26[g]	0.316[hg]
19th * *V. unguiculata*	8.866[h]	1.420[f]	5.280[ed]	2.170[f]	16.40[c]	44.50[cd]	0.683[f]
13th* *L. purpureus*	19.203[d]	5.140[b]	4.726[ef]	8.210[c]	19.30[b]	53.50[b]	3.066[b]
15th* *L. purpureus*	18.853[d]	4.830[b]	5.510[ed]	7.110[d]	21.90[a]	57.76[a]	2.173[d]
17th* *L. purpureus*	16.996[e]	4.410[c]	5.630[cd]	5.520[e]	21.00[ab]	58.26[a]	1.760[e]
19th* *L. purpureus*	14.986[f]	6.266[a]	5.673[cd]	4.643[e]	22.00[a]	58.20[a]	1.723[e]
Mean	15.9127	3.25083	5.6394	5.9516	14.216	46.236	1.8144
CV	2.45814	7.11475	8.6549	9.6248	8.6602	2.9215	10.147
P-value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

DMY=dry matter yield, LW= leaves weight, RW=root weight, SW=stem weight, PH=plant height, CaCi= canopy circumference, HRR=herbage to root ratio, Cm= cent meter, t/ha= ton / hectare, CV= coefficient of variation, [a, b, c, d, e, f, g, h] within the same column, means with different superscripts are significantly different ($p<0.05$)

There were significance ($p<.0001$) differences among treatments in canopy circumference as effected by harvesting date with species interaction. The highest canopy circumference (CaCi) was recorded for 17th date of harvesting while the least was for 13th date of harvesting by the species interaction which revealed similar trend with plant height. There were significance (p<.0001) differences among treatments in herbage to root ratio as effected by harvesting date with species interaction. In the current experiment, as HRR is defined as the ratio of plant leaf and stem to plant root, it was revealed that, as harvesting time increased the leaf weight was also increased consequently decreasing the root weight.

4.7. Effects of different harvesting date on chemical composition and in vitro DM digestibility of hydroponically grown legumes species

In addition to quantitative (yield) evaluation, examination of the nutritive potential of fodder crops is highly important as it shows the content of nutrient and their digestibility. With this consent, Table 9 shows chemical composition and *in vitro* DM digestibility of hydroponically produced *L. albus, V. unguiculata and L. purpureus* at different date of harvesting. The nutrient composition and *in vitro* DM digestibility of all the three legume species were significantly (p=0.0001) affected by variation in harvesting date.

The ash, NDF, ADF and ADL content of the sprouted legumes was higher (P=0.0001) than that of their grain counterparts. The DM and CP composition, and *in vitro* DM digestibility was higher (P=0.0001) for the grain than the sprouted fodders across all the three legumes. When come to the sprouted legumes the DM composition of the *V. unguiculata* was increased with increased date of harvesting whereas that of *L. albus* and *L. purpureus* did not vary (P>0.05). The Ash, NDF, ADF and ADL contents of the sprouted fodder was significantly increased with delayed date of harvesting while the *in vitro* DM digestibility was in reverse trend.

The highest value of DM for the grain part of the legumes compared to the sprouted fodder was mainly due to the loss in DM, particularly carbohydrates, for life maintenance through such as respiration during germination and growth of hydroponic fodders (Dung *et al.*, 2010a). Researchers such as (Bakshi *et al.*, 2017) had disclosed from their review works that seed soaking activates enzymes that convert starch stored in endosperm to a simple sugar, which produces energy and gives off carbon dioxide and water, leading to loss of DM with a shift from starch in the seed to fiber and pectin in the roots and green shoots.

The highest ash content in the sprouted fodders was due to decrease in organic matter content while growing attributed to losses through respiration (Naik *et al*., 2015). On the other hand there might be gain of minerals from tap water irrigated all over its growth periods compared to the grains (Fageria and Moreira, 2011) even though it was low in nutrient content compared to the use of nutrient solutions (Dung *et al.*, 2010b).

The decrease in CP percentage of the sprouted legumes compared to its grain part might be due to the partitioning of the nutrient for growth of the cell wall contents such as NDF, ADF and the anti-nutritional component ADL (Megat *et al.,* 2011). The uniform decrease in CP content with increased date of harvesting might be due to the decreasing level of its grain protein while sprouting into the herbage.

There were significance (p=0.0001) differences among treatments and IVDMD was affected by variation in harvesting dates. The highest IVDMD was recorded for *L. albus* (77.2) the next highest IVDMD was recorded for *L. purpureus* (73.5) while the least was for *V. anguiculata* (72.8) in 2 hours watering frequencies intervals in one production cycle after sprouting for 13^{th} dates and the highest IVDMD of the grain was recorded for *V. anguiculata* (85.2) the next highest was recorded for *L. albus* (85.1) and the least was recorded for *L. purpureus* (74.6). The steadily decrease in *in vitro* DM digestibility with increased date of harvesting for all the legumes was an attribute of the increase in ADF and ADL components while the plants were growing. This is from the fact that higher ADF and ADL contents decrease digestibility of forage crops (Mayuddin, 2008).

Table 9: Chemical composition and *in vitro* DM digestibility of selected legume species at different date of harvesting

	Dates of Harvesting						
	a). *L. albus* species						
Nutrients	13th day	15th day	17th day	19th day	Grain	SEM	SL
DM	90.6[b]	91.2[b]	90.9[b]	91.2[b]	92.6[a]	0.2842	***
Ash	8.02[c]	9.17[b]	9.37[ba]	9.78[a]	3.39[d]	0.0904	***
CP	16.800[b]	15.8[bc]	15.1[cd]	14.6[d]	32.2[a]	0.2240	***
NDF	57.2[d]	61.8[c]	64.1[b]	68.2[a]	19.1[e]	0.3146	***
ADF	20.1[c]	20.1[c]	22.2[b]	23.2[a]	17.1[d]	0.1284	***
ADL	3.72[c]	5.43[b]	6.18[a]	6.63[a]	2.79[d]	0.1335	***
IVDMD	77.2[b]	74.9[c]	73.7[c]	71.6[d]	85.1[a]	0.2888	***
	b). *V. anguiculata* species						
Nutrients	13th day	15th day	17th day	19th day	Grain average	SEM	SL
DM	88.2[c]	88.4[c]	89.9[b]	89.5[b]	92.9[a]	0.1484	***
Ash	3.51[c]	4.75[b]	5.20[bb]	6.20[a]	2.09[d]	0.1766	***
CP	18.4[b]	17.2[cc]	16.8[c]	15.2[d]	23.9[a]	0.1042	***
NDF	25.7[d]	28.3[c]	32.8[b]	36.5[a]	20.4[e]	0.3369	***
ADF	14.5[c]	15.8[bb]	16.9[ba]	17.9[aa]	11.5[d]	0.2442	***
ADL	2.82[d]	3.11[c]	4.57[b]	5.41[a]	2.19[e]	0.0587	***
IVDMD	72.8[bb]	71.9[cbb]	71.5[ccb]	71.01[cc]	85.2[a]	0.3154	***
	c). *L. purpureus* species						
Nutrients	13th day	15th day	17th day	19th day	Grain	SEM	SL
DM	92.1[b]	92.3[b]	92.4[b]	92.6[b]	93.4[a]	0.1078	***
Ash	4.02[c]	5.31[b]	6.13[a]	6.49[aa]	3.41[d]	0.1118	***
CP	17.5[b]	16.3[c]	14.3[d]	13.3[e]	25.8[a]	0.1485	***
NDF	36.4[c]	41.8[b]	47.6[a]	48.9[a]	31.1[d]	0.9626	***
ADF	20.4[d]	25.3[c]	28.5[b]	31.9[a]	17.7[e]	0.4156	***
ADL	3.66[c]	4.57[b]	5.45[a]	5.10[a]	3.68[c]	0.0852	***
IVDMD	73.5[b]	69.3[c]	68.4[cd]	68.1[cd]	74.6[a]	0.9979	***

DM = Dry matter; CP = crude protein; NDF = Neutral detergent fibers; ADF = Acid detergent fiber; ADL = Acid detergent lignin; IVDMD = *In-vitro* dry matter digestibility; SEM =

Standard error mean; SL= significant level[a, b, c, d, e] Means followed by different superscript letters within treatments differ at p<0.05

Thad chanamoorthy *et al.,* (2012) reported that the *in vitro* dry matter digestibility (IVDMD**)** of hydroponic maize fodder harvested at 10th day after planting and the grain of the variety Pacific were 79.87 % and 68.75 %, respectively. In the present study, the reverse trend was achieved. The (IVDMD)of selected legume species of sprouted fodder harvested at 13^{th}, 15^{th}, 17^{th} and 19^{th} days after germination showed that there was the lowest value at 19^{th} dates of harvesting (IVDMD), indicating that (IVDMD) decreased as harvesting date increased.

Karunathilaka *et al.,* (2012) carried out an experiment in which the *in vitro* digestibility of hydroponic maize fodder harvested at 7^{th} , 10^{th} , 14^{th} days after germination. It was reported that hydroponically grown maize fodder at 14^{th} days of harvest had lower IVDMD values than those at 7^{th} and 10^{th} days of harvesting.

4.8.Effect of species on chemical composition and in vitro DM digestibility of selected legume species

The effects of species on chemical composition and in vitro dry matter digestibility (IVDMD) of selected legume species is presented in Table 10. All the nutrients analyzed were affected (P=0.0001) by variation in species of the legumes. Except for DM and crude protein (CP) content, *L. albus* attained highest values for all the nutrients including IVDMD.

The dry matter (DM) of selected legumes species were significant differences (p=0.0001) by variation in species. The highest DM composition was recorded for *L. purpureus* (92.38) followed by *L.albus* (90.95) while the last was recorded for *V. anguiculata* (89.93) whereas the highest CP value was for *V. anguiculata* (16.76) followed by *L.albus* (15.14) while the last was for *L. purpureus* (14.33). Such significant variations among the species in nutrient compositions provide an opportunity to select the best from the rest.

The variation in DM and other nutrients among the legumes was only the effect of their genetic makeup since other factors such as watering intervals and harvesting dates were the same for all of them (controlled) in this experiment. Mark, (2018) unlike their grain counterparts (Table 9), none of the legumes' Crud Protein content could be considered as proteins supplement (McDonald *et al.,* 2002).The reason for the highest IVDMD in *L. albus* despite its highest ADF and ADL concentration.

Table 10: Effects of species on chemical composition and IVDMD of selected legumes

	Legumes Species				
Nutrients	*L.albus*	*V. anguiculata*	*L. purpureus*	SEM	P-value
DM	90.95[b]	89.93[c]	92.38[a]	0.0625	0.0001
Ash	9.367[a]	5.197[c]	6.130[b]	0.1676	0.0001
CP	15.14[b]	16.76[a]	14.33[c]	0.1252	0.0001
NDF	64.12[a]	32.83[c]	47.56[b]	0.4210	0.0001
ADF	28.20[a]	16.88[c]	20.05[b]	0.3476	0.0001
ADL	6.180[a]	4.567[b]	4.567[b]	0.0551	0.0001
IVDMD	73.72[a]	71.52[b]	68.40[c]	0.2050	0.0001

DM = Dry matter; CP = crude protein; NDF = Neutral detergent fibers; ADF = Acid detergent fiber; ADL = Acid detergent lignin; IVDMD = *In-vitro* dry matter digestibility; SEM = Standard error of mean; [a, b, c] Means followed by different superscript letters within treatments differ at $p<0.05$

5. CONCLUSION AND RECOMMENDATION

In the first experiment, the results of this experiments shows highly significant differences (p=0.0001) in all fodder yield and yield related components as effected by watering frequency among all treatments and high average fodder yields was observed at 2hrs interval of watering frequency. The study revealed that watering frequency with two-hour interval at one production cycle had resulted the best hydroponic fodder yield and yield related components.

The result of the second experiment showed that there was significant differences among treatments in fodder yield and yield related components (p=0.0001) as affected by harvesting date. Delayed date of harvesting had resulted in decreased fodder yield of all the three species of legumes. In addition all the legume species had attained different optimum harvesting dates for fodder yield and related parameters. Accordingly *L. purpureus* had its optimum date of harvesting was at 17th day, *V. unguiculata* at 19th day but *L.albus* had a linear growth potential even at 27th day of harvesting.

In the third experiment, the result of the experiment showed that there was significant difference ($p<0.012$) as affected by species difference. From the above three experiments, it could be concluded that the average fodder yields and yields related components of hydroponic fodder of *L. purpureus* species sprouted for 17 days at 2 hours interval of watering frequency was higher compared to *L.albus* and *V. unguiculata*.

Concerning the nutritive value, significant differences (P=0.0001) was obtained on DM and CP between the grain and sprouted fodder as affected by species of selected legumes. The grain of DM and CP contents was increased compared to hydroponically sprouted fodder production. And also Delayed date of harvesting resulted in reduced CP composition, reduced *in vitro* DM digestibility and increased fiber contents. Ash contents of hydroponically grown were significantly different among treatments (P=0.0001). In this study, ash contents of hydroponically grown fodder legumes were higher than ash contents of the grain which might be due to the absorption of minerals by the root during sprouting process.

The IVDMD analysis of the present study showed that hydroponically grown legumes fodder species had lower digestibility compared to grain and this might be due longer sprouting days which resulted in increasing fiber content as stage of growth advanced.

Therefore, hydroponically produced fodder is an alternative technology providing highest biomass forage yield and land saving with a short time planting and continuous production.

Based on the current work, the following recommendations are mentioned:

- Improvement of livestock productivity could be achieved by using intensive hydroponic system fodder production with in a short period (13^{th} to 17^{th} days) in more than 20 times producing cycle per year.
- At the same time intensive hydroponic fodder production system can offer an effective management not only for land shortage but also reduces land degradation due to over stocking and over grazing problems.
- More extension work should be done on hydroponic fodder production and utilization system of herbaceous legumes species to reduce the feed shortage in urban and per-urban dairy farming systems of Ethiopia.
- Further study on economical feasibility and cost benefit analysis of hydroponic fodder production system should be done.
- The legume *L. albus* should be further evaluated for its anti-nutritional factors after sprouting.

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7. APPENDICE

Appendix 1: Analysis of Variance for mean interaction of irrigation*species hydroponically grown legumes.

FMY= (fresh matter yield)

FMY= (fresh matter yield)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	42.74963	21.37481	0.86	0.4407
Irrigation	**2**	18430.35185	9215.17593	371.98	<.0001
Species	2	23082.58074	11541.29037	465.87	<.0001
Irrigation*species	4	3693.50370	923.37593	37.27	<.0001

DMY= (dry matter yield)

DMY= (dry matter yield)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.7607407	0.3803704	132.52	0.0001
Irrigation	**2**	172.5985185	86.2992593	30065.5	<.0001
Species	2	2.3207407	1.1603704	404.26	<.0001
Irrigation*species	4	3.3081481	0.8270370	288.13	<.0001

Lwt= (leaf weight)

Lwt= (leaf weight)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.10735556	0.05367778	3.68	0.0483
Irrigation	**2**	13.12046667	6.56023333	450.14	<.0001
Species	2	32.66748889	16.33374444	1120.78	<.0001
Irrigation*species	4	4.35217778	1.08804444	74.66	<.0001

Rwt= (root weight)

Rwt= (root weight)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.08820741	0.04410370	31.70	0.0001
Irrigation	**2**	38.60240741	19.30120370	13873.7	<.0001
Species	2	34.44056296	17.22028148	12378.0	<.0001
Irrigation*species	4	16.11850370	4.02962593	2896.50	<.0001

Swt= (stem weight)

Swt= (stem weight)

Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.0611556	0.0305778	2.62	0.1037
Irrigation	**2**	12.1380667	6.0690333	519.89	<.0001
Species	2	145.3672667	72.6836333	6226.32	<.0001
Irrigation*species	4	9.1825333	2.2956333	196.65	<.0001

PH= (Plant height)

PH= (Plant height)

Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	3.6540519	1.8270259	140.85	0.0001
Irrigation	**2**	77.1646296	38.5823148	2974.33	<.0001
Species	2	178.6346296	89.3173148	6885.52	<.0001
Irrigation*species	4	13.2992593	3.3248148	256.31	<.0001

CaCi= (canopy circumference)

CaCi= (canopy circumference)

Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	15.6054222	7.8027111	36.16	0.0001
Irrigation	**2**	353.7916667	176.8958333	819.87	<.0001
Species	2	868.2916667	434.1458333	2012.16	<.0001
Irrigation*species	4	32.5833333	8.1458333	37.75	<.0001

HRR= (herbage root ratio)

HRR= (herbage root ratio)

Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.03298519	0.01649259	4.14	0.0357
Irrigation	**2**	5.36316296	2.68158148	672.34	<.0001
Species	2	48.6580963	24.32904815	6099.9	<.0001
Irrigation*species	4	6.46792593	1.61698148	405.42	<.0001

Appendix 2:Analysis of Variance for mean interaction of date*species hydroponically grown legumes

FMY= (fresh matter yield)

FMY= (fresh matter yield)

Source of variation	Degree of freedom	Sum square	Mean square	F value	P value

Replication	**2**	67.03871	33.51935	0.62	0.5481
Date	**3**	2442.55090	814.18363	15.01	<.0001
Species	2	72604.22291	36302.11145	669.45	<.0001
Date*species	6	743.80078	123.96680	2.29	<.0001

DMY= (dry matter yield)

DMY= (dry matter yield)

Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.1442889	0.0721444	0.45	0.6434
Date	**3**	16.6556556	5.5518852	34.62	<.0001
Species	2	839.420138	419.7100694	2617.36	<.0001
Date*species	6	22.4103944	3.7350657	23.29	<.0001

Lwt= (leaf weight)

Lwt= (leaf weight)

Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.1653167	0.0826583	1.63	0.2195
Date	**3**	4.0059639	1.3353213	26.26	<.0001
Species	2	120.4757167	60.2378583	1184.78	<.0001
Date*species	6	8.6987278	1.4497880	28.51	<.0001

Rwt= (root weight)

Rwt= (root weight)

Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.65140556	0.32570278	1.41	0.2643
Date	**3**	21.87950000	7.29316667	31.67	<.0001
Species	2	6.20702222	3.10351111	13.48	<.0001
Date*species	6	48.74893333	8.12482222	35.28	<.0001

Swt= (stem weight)

Swt= (stem weight)

Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	1.3490167	0.6745083	2.27	0.1266
Date	**3**	28.8948556	9.6316185	32.47	<.0001
Species	2	438.2791167	219.1395583	738.69	<.0001
Date*species	6	29.7269944	4.9544991	16.70	<.0001

PH= (Plant height)

PH= (Plant height)

Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	1.8150000	0.9075000	0.58	0.5695
Date	**3**	167.6900000	55.8966667	35.58	<.0001
Species	2	843.0350000	421.5175000	268.29	<.0001
Date*species	6	56.3650000	9.3941667	5.98	<.0001

CaCi= (canopy circumference)

CaCi= (canopy circumference)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.470556	0.235278	0.12	0.8880
Date	**3**	174.447500	58.149167	29.53	<.0001
Species	2	2128.093889	1064.046944	540.34	<.0001
Date*species	6	56.728333	9.454722	4.80	<.0001

HRR= (herbage root ratio)

HRR= (herbage root ratio)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.16833889	0.08416944	2.87	0.0781
Date	**3**	3.16220000	1.05406667	35.94	<.0001
Species	2	37.91867222	18.95933611	646.48	<.0001
Date*species	6	8.38468333	1.39744722	47.65	<.0001

Appendix 3: Analysis of Variance for chemical composition of *L. albus* at different date of harvesting.

DM (Dry matter)

DM(Dry matter)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.23809333	0.11904667	0.49	0.6293
Date	**4**	7.07816000	1.76954000	7.30	0.0089

Ash

Ash					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.06752000	0.07841111	2.75	0.1230
Date	**4**	82.88976000	20.72244000	845.12	0.0001

CP (Crud Protein)

CP (Crud Protein)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.2291733	0.1145867	0.76	0.4983
Date	**4**	665.287840	166.3219600	1104.25	0.0001

NDF (Neutral detergent fiber)

NDF (Neutral detergent fiber)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.393173	0.196587	0.66	0.5421
Date	**4**	4792.514467	1198.128617	4032.93	0.0001

ADF (acid detergent fiber)

ADL (acid detergent fiber)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.34225333	0.17112667	3.46	0.0827
Date	**4**	65.25096000	16.31274000	329.65	0.0001

ADL (acid detergent lignin)

ADL (acid detergent lignin)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.01764000	0.00882000	0.16	0.8508
Date	**4**	32.1374000	8.03435000	150.19	0.0001

IVDMD (In vitro Dry Matter Digestibility)

IVDMD (In vitro Dry Matter Digestibility)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.0676933	0.00882000	0.14	0.8754
Date	**4**	327.5671600	8.03435000	327.27	0.0001

Appendix 4:: Analysis of Variance for chemical composition of *V. anguiculata* at different date of harvesting**.**

DM (Dry matter)

DM(Dry matter)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.15765333	0.07882667	1.20	0.3504
Date	**4**	42.01102667	10.50275667	159.73	0.0001

Ash

Ash					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.31137333	0.15568667	1.66	0.2489
Date	**4**	30.38284000	7.59571000	81.13	0.0001

CP (Crud Protein)

CP (Crud Protein)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.2220400	0.1110200	3.41	0.0851
Date	**4**	134.8796667	33.7199167	1034.78	0.0001

NDF (Neutral detergent fiber)

NDF (Neutral detergent fiber)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	2.6668133	1.3334067	3.91	0.0652
Date	**4**	469.2728400	117.3182100	344.43	0.0001

ADF (acid detergent fiber)

ADL (acid detergent fiber)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.13756000	0.06878000	0.38	0.6928
Date	**4**	74.24524000	18.56131000	103.72	0.0001

ADL (acid detergent lignin)

ADL (acid detergent lignin)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.01941333	0.00970667	0.95	0.4277
Date	**4**	21.13882667	5.28470667	515.25	0.0001

IVDMD (In vitro Dry Matter Digestibility)

IVDMD (In vitro Dry Matter Digestibility)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.0656533	0.0328267	0.11	0.8970
Date	**4**	437.3391600	109.3347900	367.13	0.0001

Appendix 5::Analysis of Variance for chemical composition of *L. purpureus* at different date of harvesting**.**

DM (Dry matter)

DM(Dry matter)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	2	0.09669333	0.04834667	1.39	0.3042
Date	4	2.89936000	0.72484000	20.78	0.0003

Ash

Ash					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.02676000	0.01338000	0.36	0.7107
Date	**4**	21.25457333	5.3136433	141.55	0.0001

CP (Crud Protein)

CP (Crud Protein)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.2443333	0.1221667	1.85	0.2192
Date	**4**	296.4759067	74.1189767	1119.76	0.0001

NDF (Neutral detergent fiber)

NDF (Neutral detergent fiber)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	4.5526533	2.2763267	0.82	0.4748
Date	**4**	675.7852267	168.9463067	60.77	0.0001

ADL (acid detergent fiber)

ADL (acid detergent fiber)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.5670933	0.2835467	0.55	0.5988
Date	**4**	402.3051600	100.5762900	194.06	0.0001

ADL (acid detergent lignin)

ADL (acid detergent lignin)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value

Replication	**2**	0.01617333	0.00808667	0.37	0.7013
Date	**4**	7.91456000	1.97864000	90.78	0.0001

IVDMD (In vitro Dry Matter Digestibility)

IVDMD (In vitro Dry Matter Digestibility)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	28.7364933	14.3682467	0.75	0.5031
Date	**4**	112.3734267	28.0933567	1.47	0.2986

Appendix 6:: Analysis of Variance of species on chemical composition of selected legumes

DM (Dry matter)

DM(Dry matter)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.01448889	0.00724444	0.62	0.5841
Date	**2**	9.11095556	4.55547778	387.88	0.0001

Ash

Ash					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.06175556	0.03087778	0.37	0.7144
Date	**2**	28.7360222	14.36801111	170.45	0.0001

CP (Crud Protein)

CP (Crud Protein)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.13760000	0.06880000	1.46	0.3336
Date	**2**	9.20166667	4.60083333	97.82	0.0004

NDF (Neutral detergent fiber)

NDF (Neutral detergent fiber)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.146467	0.073233	0.14	0.8753
Date	**2**	1470.270600	735.135300	1382.27	0.0001

ADL (acid detergent fiber)

ADL (acid detergent fiber)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	2.0553556	1.0276778	2.83	0.1711
Date	**2**	216.44062	108.2203111	298.50	0.0001

ADL (acid detergent lignin)

ADL (acid detergent lignin)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.04748889	0.02374444	2.61	0.1885
Date	**2**	5.20568889	2.60284444	285.68	0.0001

IVDMD (In vitro Dry Matter Digestibility)

IVDMD (In vitro Dry Matter Digestibility)					
Source of variation	Degree of freedom	Sum square	Mean square	F value	P value
Replication	**2**	0.19246667	0.09623333	0.76	0.5240
Date	**2**	42.87680000	21.43840000	169.97	0.0001

Figure 3: Hydroponically grown selected herbaceous legumes species at different harvesting date

At seeding day

At 3rd day of seeding

At 5th day of seeding

At 7th day of seeding

At 9th day of seeding

At 11th day of seeding

At 13th day of harvesting

At 15th day of harvesting

At 17th day of harvesting

At 19th day of harvesting

=>Root parts of hydroponic legumes at harvesting time

***L. albus* at 27th day of planting**