Hydroponic maize fodder as a supplementary feed for livestock

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Journal of Livestock Science (ISSN online 2277-6214) 16: 378-384
Received on 5/6/24; Accepted on 11/5/25; Published on 20/5/25
doi. 10.33259/JLivestSci.2025.378-384

Abstract

In many parts of the world, the limitation of land allocation, fertilizer requirements for cultivation, lack of irrigation facilities and natural calamity, production of sufficient green fodder and grain to feed for livestock has become a big challenge. To overcome this problem, hydroponics production technology is an alternative to grow sufficient quantity and quality fodder. Hydroponic fodder production is a new method of fodder production, which fodder seeds are germinated into a high quality, highly nutritious, disease-free animal feed in a hygienic environment. It is also more palatable, digestible and can be grown in low cost devices with locally home-grown grains. Moreover, it is advantageous in terms of nutritional benefit and economic value, constant feed supply year-round, marginal land use, reduced labor requirement and natural feed for livestock. Under intensive production system, feeds account for 70-80% of the total cost of production. Inclusion of hydroponically grown cereal fodder in the livestock diet can reduce the cost on feeding in free-range production system. From 1kg of maize seed grown for 7 days without using any nutrients in the irrigated water was obtained 6 kg of hydroponic maize fodder.

Key words*:* Hydroponic maize, Livestock

Introduction

Livestock sector has been playing important role in Ethiopian economy and agriculture. Ethiopia has the huge livestock population in Africa (CSA, 2021). Despite its huge number and economic importance, the Livestock sector in Ethiopia is less productive as compared to its potential, the direct contribution to the national economy is limited (Duguma et al., 2012). Poor utilization of locally available feed resources leads to low performance of Livestock, reduces the income of farmers, and decreases the profitability of the sector (Yirdaw et al., 2017). The corn or maize is considered to be one of the most productive feed and fodder crop for the livestock in different part of world and agroecosystem (Fallah, 2019; Gatdula et al 2023; Aguilera et al., 2024). Conventional forage production practices have been constrained by many factors such as long dry period, more land requirement, scarcity of water or saline water, more labor requirement for, more growth time (approx. 60 days), non-availability of same quality green fodder round the year, requirement of fertilizer, and affected by natural calamities (Yayneshet, 2010; Naik *et al*., 2013).

Due to the above constraints faced in the conventional method of fodder cultivation is not sustainable manner. so, alternative methods of feeding advocated as a solution in order to overcome the challenges faced for climate change adaptation, the hydroponics is now emerging as an alternative technology to grow fodder for Livestock (Naik and Singh, 2014; Saidie and Omer, 2015).

Hydroponics is defined as the science of growing plants without soil provides year round supply of fresh green fodder while using minimal labor, land, water and space (Sinsinwar and Teja, 2012; Naik et al., 2013). Hydroponic fodder is palatable and germinated grain embedded in the root system is also consumed along with the shoots of the plants without any nutrition wasting (Bamikole et al., 2020). This technology is very important in tropical regions with limited forage production especially where the farmers have a limitation of land size and also during the dry seasons (Fazaeli et al., 2012). Depending on the grain selected, hydroponics looks like a mat of 11-30 cm height by end of the germination period of 7-8 days consisting of germinated grain embedded in their white roots and green shoots (Naik et al., 2014). The hydroponics fodder can be produced up to ten times higher compared to conventional fodder and less space is needed because the fodder is grown in trays, which are arranged in shelves inside the hydroponics system (Sinsinwar and Teja, 2012).

Hydroponics development

In the late 1920s and early 1930s, hydroponics to grow plants in a nutrient solution on large scale investigated by Gerke W.F. from University of California. The basic principles are derived from the work of Woodward, an English scientist who in 1699 attempted to grow plants in water collected from many sources. While in the middle of the 19th Century, Jean Boussingault, a French chemist verified the nutritional requirements of plants grown without soil, the techniques of "nutriculture" were being perfected by Sachs and Knop working independently in England.

In 1960 an American inventor, Ivan Z. Martin, developed a complete system by which "optimum temperature, humidity, aeration, light and periodic rainfall of a nutrient solution could be automatically maintained". Now, for the first time, it was possible to exercise the control necessary to produce a product of consistent quality, sprouted grain grown for 8 days, at which time they were 7 or 8 inches in height and rivaled the first bloom of a lush spring pasture.

Production of hydroponics maize fodder

Hydroponics is produced in greenhouses under control environment within a short period (Sneath and McIntosh, 2003). A greenhouse is a framed or inflated structure covered with a transparent or translucent material in which the fodder could be grown under the conditions of at least partially controlled environment. The green house for the production of hydroponics fodder can be hi-tech or low cost greenhouse type as per the financial status of the livestock producers and availability of building material (Bhat et al., 2023).

Hi-tech greenhouse Hydroponics cultivation

The hi-tech greenhouse type unit consists of a control unit and may be used with or without air conditioner (Figure1). 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 green house but the routine operational cost is more particularly for sprouting the cereal crops. This is because of the requirement for air conditioner in the hydroponics system to maintain cold and dry environment.

Figure 1: - Hi-tech greenhouse type hydroponics cultivation (Nonigopal Shit, 2019)

Low-cost greenhouse Hydroponics cultivation

Low-cost greenhouse is prepared from bamboo, wood and galvanized iron steel (Naik *et al*., 2013) (Figure 2). The cost of the shade net structures depends upon the type of fabricating material but is significantly lower than the hi-tech greenhouses (Kide *et al.*, 2015). 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. In shade net structures, the type of cereals to sprout hydroponically depends upon the season and climatic conditions of the locality. The farmers revealed that the cost of the wooden shade net greenhouse with daily production potential of about 30-350 kg fresh hydroponics fodder (Naik *et al*., 2013).

Figure 2: - Low cost greenhouse type
(Photo credit: Dr. P.K. Naik, Central Avian Research Institute Regional Centre, Bhubaneswar, India

Advantages of hydroponics over conventional fodder

Global climate change

Global climate change cause negative impact on the grazing lands in the arid and semi-arid regions. The rainfall is reduced while environmental temperature is increased, so the grassland yields decrease and range and meadow deteriorated over the time in the tropics (kide et al., 2015). From 1kg of grain seeds, producing 6 to 10 kg of fresh green sprouts, independent of weather and cultivated at any time of year (Fazaeli et al., 2012).

Water use efficiency

The hydroponic green fodder has higher water use efficiency than field production of green fodders (FAO, 2015). The total water added to and drained out of the trays was recorded every day to compute the total water use and water use efficiency.

The total water used by plants (liters/tray) = Total added water in irrigation -Total drained water out of the trays (AI-Karaki and AI Hashimi, 2012).

$$\text{Water use efficiency (WUE) (kg m}^{-3}) = \frac{\text{Total green fodder produced (kg/tray)}}{\text{Total water used (liters/tray)}}$$

In conventional fodder production, 80 litter of water are used to produce 1kg of fodder while in a hydroponics system 1.5 litter of water are used to produce 1kg maize of fodder (Al-Karaki and Al- Hashimi, 2012). Additionally, water from the hydroponics system can be collected and recycled for other farm uses. The amount of water required to grow 1kg of hydroponic maize fodder was 1.65-2 liter (if water recycled) and 2-3.3 liter (if water is not recycled) per 8th-day growth period (Kide *et al*., 2015).

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 (Naik et al., 2016).

Space of Land Requirement

The technology of green fodder production is especially important in Arid and semi-arid regions where forage production is limited (Omar et al., 2012). Fodder produced hydroponically has a short growth period and requires only a small piece of land for production to take place, 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, where in number of racks with multiple tiers (vertical farming) are used, minimizing land requirement thereby resulting in land preservation (Jemimah et al., 2015). Another study revealed that 1m^2 spaces is required to produce fodder for two cows per day and the milk yield was increased by 13% (Kamanga, 2016). Naik and Singh (2013) stated that an area of 50m^2 under hydroponics fodder production, approximately 600 kg of fodder could be produced while conventional to produce the same amount of fodder required 1 ha of land.

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 8 days (Kamanga, 2016). The hydroponics maize fodder fresh basis yields are 5-6 times higher than that obtained in a traditional farm production (Naik et al., 2014).

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 et al., 2014). Hydroponic systems help in reducing the fuel consumption for transportation of product from distant agricultural farms and carbon emissions in turn. No nutrition pollution is released into the environment because of the controlled system.

The optimum temperatures

Temperature of the water or solution used for soaking also affects the germination rate. The optimum temperature for soaking the seeds is 23 ºC (Sneath and McIntosh, 2003). Dry matter (DM) losses were measured over 8 days at two growing temperatures, 21ºC. From day 3 the sprouts received balanced nutrient feed and light for 16 hours daily. They observed that the dry matter loss was gradual to day 4, after which it began to drop rapidly. DM appeared to increase after six days. Sprouts grown at 21ºC lost 18% DM by day 8 and at 27 ºC loss was 23.6% DM%. The optimum temperatures required by hydroponic crops was around 22ºC and the maximum that a crop can tolerate is 30-32ºC.

Some of the other benefits

When cereal crops are sprouted it releases many vitamins and minerals as well as converting hard to digest starches in easily digestible proteins. Therefore, some of the benefits include: reduction in overall daily feed costs, significant reduction in feed waste the entire root mass is consumed with the grass, increased nutritional value in the feed, high digestibility and vitamins and mineral saturation (Sneath and Mcintosh, 2003). Fodder grown hydroponically is also free of dust and any other agriculturally related contaminants and toxins (Ahamed et al., 2023).

The procedure for production of hydroponic

The procedure for production of hydroponic fodder comprises procuring clean, sound, intact, untreated, viable seeds/grains of high quality (Bhat et al., 2023). The seeds should be soaked in 0.1-1.5% sodium hypochlorite solution for ½ to 1hr and thereafter washed in tap water (Jemimah et al., 2015). The seeds are then soaked in fresh aerated water for different periods depending on the hardness of the seed coat: 4 h (Naik et al., 2014), 8 h (Bhat et al., 2023), 12-16 h or overnight (Brownin, 2017), 6-20 h (Jemimah et al., 2015). After soaking, the seeds are spread at up to one cm depth in plastic or light weight metallic trays with holes to facilitate drainage of the waste water/nutrient solution, which can be collected in a tank and recycled.

The trays are placed in hydroponic racks, and seeds are irrigated with fresh tap water or nutrient enriched solution. The trays should never be exposed to direct sunlight, strong wind and heavy rain (Figure 3). During the growing period, the seeds are kept moist by drip or spray irrigation but are not saturated.

Figure 3: The seed soaking under shade (Naik et al., 2013)

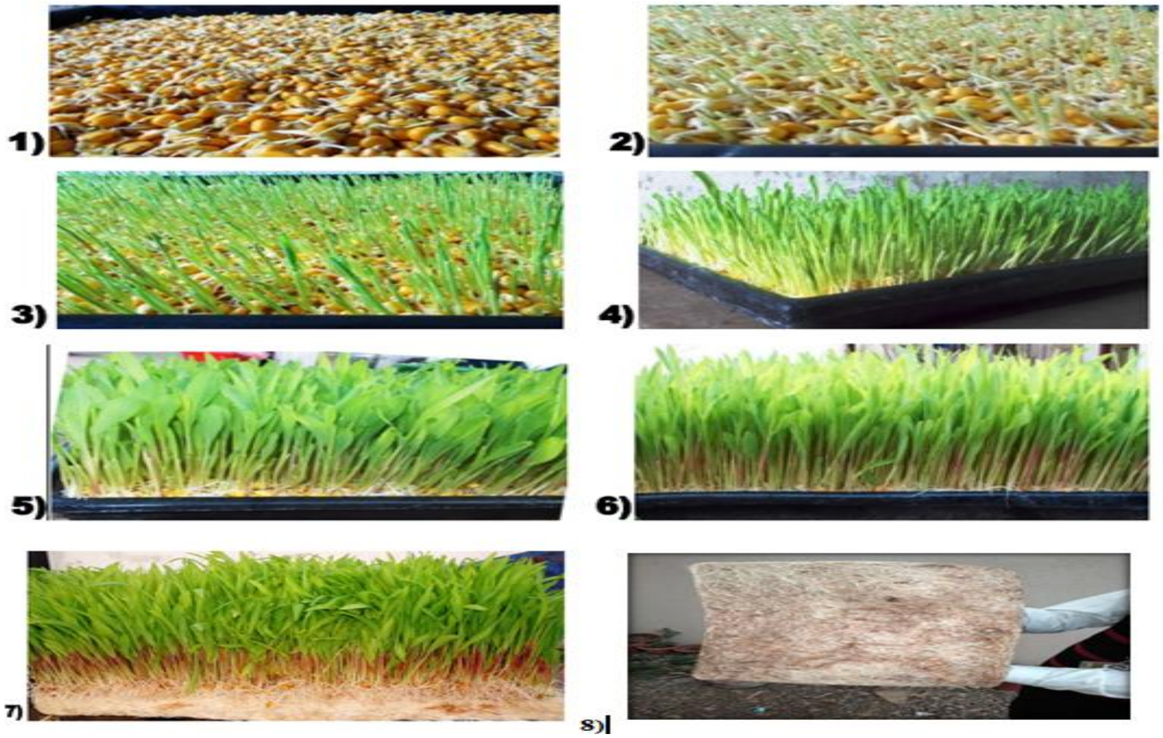

Figure 4: Growth of hydroponic maize from day 1 to 8th (Indira D et al., 2020)

Nutritive values of hydroponic maize

In a 8-day sprout, photosynthesis commences around day-5 when the chloroplasts are activated and this does not provide enough time for any significant DM accumulation (Dung et al., 2010). The DM % of green fodder was significantly reduced by increasing the growing periods from 6 to 8 days (Naik et al., 2016) (Figure 4).

The DM content of the hydroponics fodder are mainly influenced by the type of crops, days of harvesting, degree of drainage of free water prior to weighing, type and quality of seed, seed rate, seed treatment, water quality, irrigation frequencies, nutrient solution used, light, growing period, temperature, humidity, clean and hygienic condition of the seed (Dung et al., 2010; Fazaeli et al., 2011). Fazaeli et al. (2012), states that due to the large uptake of water during germination of the seeds resulted in a sharply reducing of DM % in green fodder. The ash content of the sprouts increase more it nutrient solution is used rather than water, which may be due to the absorption of minerals by the roots (Dung et al., 2010). The nutrient contents of hydroponics forages are superior to certain common non-leguminous fodders, but comparable to leguminous fodders in terms of available OM, CP, EE and NFE content (Naik et al., 2012). According to Sharif et al. (2013), sprouting of maize grain has resulted in increased protein quantity and quality. During sprouting of cereal grains, the vitamins content; particularly B-group vitamins are increased and besides, sprouting provide a good supply of vitamin A, E, C and B-complex. The sprouted grains have more protein value of gains by converting the protein polymers into amino acids and small peptides.

Fresh yield of 3.5-6.0 folds in 7-8 days with DM content of 10.3-18.5% in maize fodder (Fazaeli et al., 2012; Naik et al., 2014).The results indicate that the nutritive value of HMF was found more nutritious than maize grain. The sprouting of maize grown up to 8 days resulted in increase of crude protein, ether extract, crude fiber and total ash content but decrease in carbohydrate was observed. The decrease in NFE content may be due to utilization for germination process (Naik et al., 2015).

Supplementation of hydroponic Maize fodder for livestock

Hydroponic fodder should be used as feed supplement. The recommended amounts of fodder that can be fed daily to a single animal depending of body weight using the rule that an animal can eat up to 1 - 1.5% of its weight of hydroponic fodder daily: Cattle live weight of 300 - 400 kg eat approximately 3 - 5 kg/day, Shoats live weight of 25 - 35 kg eat approximately 0.3 - 0.5 kg/day and Chicken live weight of 1 - 1.5 kg eat approximately 0.15 - 0.2 kg/day. Sometimes, animals take the leafy parts of the hydroponics fodder and the roots portions are not consumed which can be avoided by mixing the hydroponics fodder with the other roughage components of the ration (Naik et al., 2014). Sprouting 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 poultry.

The Poultry industry increase in demand for cereals, the cost of poultry feed is high resulting low net returns from broiler production. The germination process improves lysine content and activated enzymes and vitamins. Hydroponically grown maize fodder is found as nutrient rich feed source of livestock. Inclusion of 23% of hydroponic barley fodder in Kuroiler diet increased the growth rate (Alinaitwe et al., 2019). The consistency in feed can be increase the quality of meat. Higher body weight at six weeks age and growth rate was observed in basal feed. This indicated that inclusion of 25% hydroponic maize in basal feed reduced the feed intake and thereby low feed conversion efficiency value, which reflected on saving of feed cost of Rs.10.36 per bird.

Economic value of feeding hydroponic fodder over conventional feed

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 and pesticides. On the other hand, hydroponic fodder production requires only seed and water as production inputs with modest labor inputs. 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 conventional systems. The cost of hydroponics forages is mainly influenced by the seed cost as it contributes about 90-98% of the total cost of production (Naik et al., 2012).

Conclusions

Hydroponics is the fastest growing sector of agriculture, and it could very well dominate food production in the future. As population increases and arable land declines due to poor land management, people will turn to new technologies like hydroponics to create additional channels of crop production. The nutritive value of gains can be improved though sprouting. The protein value in the maize grains increase up to 7 days and can be supplemented as feed to livestock. Supplementation of 50 g of HMF per bird along with the basal feed did not affect the growth rate in broiler chicken. It also reduces the cumulative feed intake and feed conversion ratio. Inclusion of HMF decreases the cost of feeding in livestock production. Therefore, governmental and nongovernmental organization should give emphasis for effective utilization and advancement of hydroponics fodder technology, and formal training should be given for the livestock producers to increase widely used of this technology.

Funding: The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Conflict of interest: There is no conflict of interest.

Authors' contributions: Mekuanint Tadilo for writing and Netsanet Beyero for editing the manuscript.

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