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# Hydroponic Fodder Production: An Alternative Solution for Feed Scarcity

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## Abstract

Feeds and animal nutrition presents a major sector in providing food security. However, there is a large gap between fodder supply and demand [1]. This gap can be attributed basically to climatic changes, urbanization and increase in meat demand. Nowadays, especially after the covid-19 pandemic, there is a crucial problem in supplying fresh green feed to remote and urban regions.

Hydroponic fodder is an alternative solution to provide the sustainability of quality forage for ruminant. Hydroponics can include several crops such as maize, wheat and barley, the fodder can be produced in a short duration (6-10 days) and all year around. The hydroponics fodder present various benefits for animal health. Feeding hydroponically produced fodder increases the digestibility of the nutrients in the ration, which could increase milk production [2].

Hydroponic fodder production is an economic solution particularly where the conventional production of green fodder is limited or unavailable. This technology put forward a solution to address the shortage of forage production caused by the scarcity of green feed in dry seasons and urban areas [3]. That´s why, further studies and academic efforts are needed to expand hydroponic fodder production.

The purpose of this study is to review the actual literature on hydroponic fodder production process, nutritious value and effects on livestock production and productivity.

***Keywords:*** Hydroponic, Fodder, Livestock, Production, Animal Nutrition; Sustainable Agriculture

## Introduction

Feeds and animal nutrition presents a major sector in providing food security. However, there is a large gap between feed supply and demand [1]. This gap can be attributed basically to climatic changes, urbanization and increase in meat demand. Nowadays, especially after the covid-19 pandemic, there is a crucial problem in supplying fresh green feed to remote and urban regions. The main problems of feed scarcity emanate from land scarcity; actually, rapid urbanization is the major cause behind the decrease in land meant for grazing and fodder cultivation. With Water, labor shortage and elevated cost of fertilizers the farmer leans to cultivate commercial food crops over green fodder [2].

Nevertheless, producing green fodder to meet the current demand has become a greatest challenge among livestock farmers. In fact, green fodder is very important for productive and reproductive performance of animals. Feeding green fodder can improve livestock products [3].

Livestock production in most region is limited due to poor production and pricy imported green fodder. Today, land scarcity presents an important limit towards forage production for animal especially sheep, goats and cattle. Unlike monogastric mammals, ruminant cannot solely dependent on cereal grains. That's why, alternative technologies, such hydroponics, are regarded as vital to face these issues. The use of this technology can help improve the long-term economic development of the livestock industry [4]. Hydroponic fodder can also improve the performance of the animals [5] by providing their nutrient needs [6].

Hydroponic fodder is an alternative solution to provide the sustainability of quality forage for ruminant. Hydroponics can include several crops such as maize, wheat and barley, the fodder can be produced in a short duration (6-10 days) and all year around. The hydroponics fodder present various benefits for animal health. It is rich in protein, vitamins, fiber, and minerals [5]. Feeding hydroponically produced fodder enhance the digestibility of the ration's nutrients, which help improve the milk production [7]. Hydroponic fodder production is an economic solution particularly where the conventional production of green fodder is limited or unavailable. This technology put forward a solution to address the shortage of forage production caused by the scarcity of green feed in dry seasons and urban areas [8]. It is one of the important agricultural techniques used nowadays in different

countries. Hydroponics is currently an arising alternative technology for growing fodder in farms, it is also a solution face all the limits and challenges raised by traditional fodder cultivation [2]. That´s why, further studies and academic efforts are needed to expand hydroponic fodder production. The purpose of this study is to review the actual literature on hydroponic fodder production process, nutritious value and effects on livestock production and productivity.

## Hydroponic Fodder's History

The concept of hydroponic fodder culture dates to 1800, the era of Hanging Gardens of Babylon, when dairy cows has been fed sprouted grains during winter to maintain milk production and improve fertility [2]. The word hydroponic is derived from two Greek words, hydro and ponics, which means respectively water and functioning. It is an eco-friendly alternative technology for landless farmers to produce fodder without soil. It requires only a limited amount of time for the fodder to grow and can mature under controlled environmental conditions inside greenhouse. Greenhouse provides a growing habitat with totally or partially controlled environmental conditions [9]. Hydroponic fodder culture may be based on growing forage without soil, but it definitely needs water; a nutrient-rich solutions can be used but generally tap water is sufficient. Fodders such as maize, barley, oats, sorghum, rye, alfalfa, horse gram, ragi, bajra, jowar and triticale can be produced by hydroponic technology [10]. The final product is a mat of 20-30cm height made of roots, seeds, and sprouts, it is highly palatable, digestible, and nutritious for animals. This is a great alternative technology to be used where conventional green forage production is limited especially with low-cost materials [11].

## Principle of Hydroponic Fodder Production Technology

Hydroponics is a method used to grow cereal grains providing sufficient moisture and nutrients without soil or solid medium (Fig1). Germination will end with a produce of 20-30 cm long forage green shoot and interwoven roots within 7-10 days. Fodder production can include different cereal grains that undergo various chemical and structural changes during growing process. Such as enzyme activation, which a necessary step to hydrolyze nutrients to much simpler forms. Grain variety, quality, nutrient supply, pH, water quality, soaking time etc are important factors that affect the quantity and quality of sprouted fodder [2]. Water, nutrients, and sunlight are the most needed elements for plants to flourish. Hydroponics is a direct method to provide the required nutrients for plants to grow without soil and under controlled environmental elements. This technology has been proved successful using various crops such as Maize, Sorghum, Barley, and Oats and resulted in high-quality, nutritious and palatable green fodder for dairy animals [12].

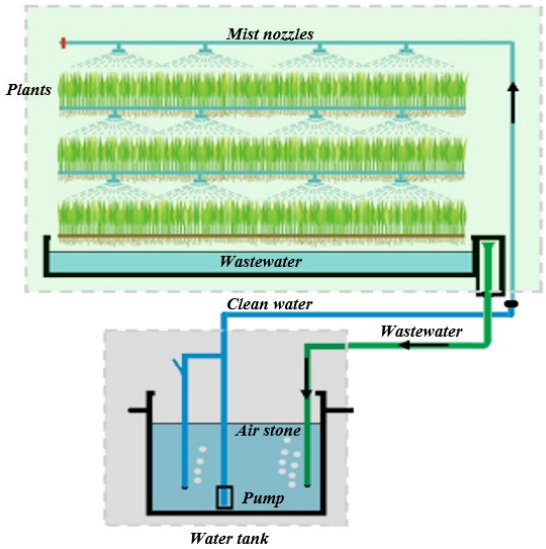


Figure 1. Scheme of Hydroponics system.[27]

## Importance of Hydroponic Fodder

### Adapted to Extreme Climate

Hydroponic technology is usually suited to difficult climates like deserts, areas with poor soil or urban areas where high land costs discouraged traditional agriculture. It is probably best used in semi-arid, arid, and drought prone regions, areas with chronic water shortages or where irrigation, fencing

and land preparation resources are limited. Green fodder production by this technology is a boon for farmers from mining and coastal belt whose soil is rocky and infertile [2].

**Minimum Land Use**

Hydroponics avoids problems presented in conventional fodder production. Hydroponics is a vertical growing system that uses small pieces of land to produce a large volume of fodder in fraction of the area needed by conventional fodder production. Different reviews indicated that around 600kg of maize fodder per day is produced in 50 square meters of area [13]. However, to produce the same amount of fodder in the conventional production method, 1ha of land is required [7].

**Minimum Water Requirement**

There is less water use when producing fodder hydroponically because water get recycled. Actually, 1 kg of hydroponic maize fodder is produced in 7 days with 1.5 liters (if water is reused) or 3 liters (if water is not reused). The non-recycled water can be exploited in irrigating the land outside the greenhouse [2].

**Minimum Labor**

Minimum manpower is needed to produce hydroponic fodder. It is a soilless agriculture technology so there is no soil preparation, constant weed removal, fencing, and post-harvest labor requirement [14]. Actually one person can be sufficient to produce around 600kg fodder hydroponically.

**All Year Supply**

Hydroponic technology can provide green fodder round the year. Constant supply can be provided despite of climate elements such as rain, storm, sunshine, or drought [15]. In addition, the nutritive value of hydroponic fodder can be enhanced by additional growth promoters, nutrients… which will have positive effect on milk quality for dairy animals.

**Minimum Fodder Loss**

Hydroponically produced green fodder is given to animal as a mat to be eaten wholly so there will be no feeding loses compared to wastages of chopped traditional grasses during feed intake [16].

**Higher Yield:**

Hydroponic fodder production aims to high growth with no compulsive need for nutrients. The lack of soil nutrient loss spares crop rotation [7].The hydroponic fodder has a high moisture content, minimum weeds and dust due to sterile media.

**Low Cost**

Materials used for the system can be low cost and locally provided. The operational systems like irrigation, cooling, and lighting are controlled and can be maintained at a low cost [17].

**Effect on Livestock**

This feed is highly palatable and nutritious which can make it conducive for almost all livestock. Hydroponic feed is a natural product that can be produced without hormone, growth promoter, or chemical fertilizer. It can also be free of pesticide, fungicide, dust, or any toxic contaminating livestock products. Providing green fodder to milk animals can replace if not totally but partially the concentrate feed which can help lead to an economically viable milk-producing industry [18].

## Fodder Crops for Hydroponic System

Various sorts of grain crops; oats, ragi, bajra, wheat, sorghum, barley, Alfa- Alfa, cowpea and maize can be employed for soilless farming. However, the crop preference depends on the seed availability and agroclimatic conditions. The grain used for soilless culture ought to be sound, perfect, and flawless. Maize and barley can be the best choice for hydroponics, owing to their high biomass production, faster growth rate, cheaper and easy availability of the seed [19]. According to [21], amongst all the hydroponic fodders such as oats, rye, triticale and wheat, the sprouted barley has the highest forage quality. The 6th day is harvesting day for barley seed sprouts as it presents the highest nutrient and biomass yield. Besides cereals, some leafy vegetables such as spinach and coriander can also be grown hydroponically [1].

## Nutrient Solution for Hydroponic System

A nutrient solution for hydroponic systems is an aqueous solution containing mainly inorganic ions which play vital physiological role to complete plant life cycle. Currently, 17 elements i.e., carbon, hydrogen, oxygen, nitrogen, phosphorus, copper, potassium, calcium, magnesium, sulfur, zinc, manganese, molybdenum, boron, chlorine and iron, nickel are considered essential for most plants. Other elements such sodium, silicon, vanadium, selenium, cobalt, aluminum and iodine are also considered beneficial as they can boost the growth, limit the toxic effects of other elements or replace essential nutrients [2].

## Environmental Factors for Hydroponic System

The environmental factors are important for optimization of the hydroponic fodder growth and production. The standard level of environmental cues such as temperature (19 to 22ºC), humidity (average 60%), light intensity (2000 lux), length (12-16 h) and aeration for 3 minutes at every 2 h interval should be maintained [20]. The electricity requirement to produce hydroponic fodder is much lower than for traditional fodder production.

## Hydroponic Fodder Production

### Seed Storage and Preparation

In the hydroponic fodder production system, the seed cost contributes 85-90% of the total cost of production [10][22]. It includes procuring clean, sound, intact, untreated, viable seeds/grains of high quality [19]. Seeds must be dried directly under sun light one day prior to seed washing.

### Seed Cleaning

The seeds must be washed firstly for 5 minutes thoroughly with tap water till all dirt and poor-quality seeds are removed. Next, seeds should be soaked in 0.1-1.5% bleach solution (sodium hypochlorite) or 1-2% hydrogen peroxide solution for 30-60 minutes [10][20]. Then, the cleaning solution is drained off and seeds are then washed in tap water.

### Seed Soaking

The seeds are soaked in fresh aerated water for different periods: 4 h [22], 8 h [20], 12-16 h or overnight [23], 24 h [24] depending on the hardness of the seed coat. Temperature of the water or solution used for soaking also affects the germination rate. So the optimum temperature at soaking is 23ºC.

### Germination of Seed

After soaking, the seeds are spread at up to 1 cm depth in plastic or light weighted metallic trays with holes to facilitate drainage of wastewater/nutrient solution, which can be collected in a tank and recycled. The seed rate (quantity of seeds loaded per unit surface area) changes depending on the type of seeds and can also affect the yield of the fodder. The recommended seeding rate for production of hydroponic barley, wheat or sorghum fodder is 4-6 kg/ m2 [20] and for maize 6.4-7.6 kg/m2 [22][25][26].

### Loading Seeds in Trays and Racking

A specially constructed frame made to hold plastic trays in which 1-1.25 kg of seed can be placed to produce about 5.5-7.5 kg of green fodder. The seed trays must be clean and free from any dust / dirt. After germination of seeds, trays are transferred and put in the sprouting section ( height between two rows must be around 5 inches). Finally, trays should be distributed evenly on both sides of the alley for even sun light.

### Shifting Trays and Harvesting

The irrigation of germinated seeds can be with fresh tap water or nutrient solution. Hydroponic trays should be protected from direct sunlight, strong wind, and heavy rain. During the growing process, the seeds should be kept moist by drip or spray irrigation but not saturated with water. Trays must be shifted to the next level daily so that it moves one step ahead in the growth cycle. If left side tray shows more growth, the trays must be rotated to the right and vice-versa. On 9th day, the fodder mat is harvested from the tray and can be fed to the livestock. The trays are washed with cleaning solution before reusing it for the next cycle.

## Health Hazards of Infected Hydroponic Fodder

Hydroponic fodder can be heavily infested with Aspergillus clavatus and can cause a lot of health problems in case its fed to livestock. Animals may show posterior ataxia, knuckling of fetlocks, dragging of hind legs, high stepping in the hind limbs, stiff gait, tremors, progressive paresis, hypersensitivity, recumbency, clonic convulsions, decreased milk yield and death possibilities [2].

## Nutritive Value of Hydroponic Fodder

The hydroponics fodder present various benefits for animal health. It contains high levels of protein, vitamins, fiber, and minerals [5]. The nutrient quality of hydroponic fodder is better than common non-leguminous fodders in terms of crude protein (CP), organic matter, ether extract (EE) and nitrogen free extract (NFE). Conventional fodders can be less nutritious than hydroponic fodders [5].

During sprouting there will be a nutrient enrichment, crude protein, ether extract, and nitrogen free extract content will increase but crude fiber, total ash, and insoluble ash will be decreasing. Sprouting

can also result in 7- 47**%** loss in dry matter (DM) from the original seed in the period of 6-7 days mainly due to respiration during the sprouting process [2].

Seed soaking activates enzymes that convert starch stored in endosperm to a simple sugar which produces energy leading to loss of DM with a shift from starch in the seed to fibre and pectin in the roots and green shoots. The sprouts are the most enzyme rich parts and maintain highest level from germination to seven days age. They are rich with antioxidants especially β-carotene.

With the decreasing of starch content, both organic matter and dry matter content also decrease. Sprouting catabolizes starch into the plant's soluble sugar [28]. However, ether extract of hydroponic fodder increases due to the increment of structural lipids and chlorophyll as the plant grows. The development of structural carbohydrates increases the concentration of crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF) and linoleic acid but decreases nitrogen free extract (NFE). Sprouting process also increases total ash content associated with the decrease of organic matter. Starting from day four of the process, the growing roots will enhance the mineral uptake which enrich the mineral content of the sprout especially if a nutritious solution was used in place of tap water [29]. However, the gross energy, metabolizable energy, and total digestible nutrient content decrease during sprouting. This is due to energy uptake during respiration of the plant. Besides, the absorption of nitrates facilitates the metabolism of nitrogenous compounds and thus increases the C.P. levels. The use of nutrient solution in place of tap water enhances the C.P. content of the hydroponics fodder and ash content of the sprouts which may be due to the absorption of nitrogenous compounds and minerals by the roots [30].

**Hydroponics Fodder Feeding Value**

Hydroponics fodder is tasty, animals will consume the seed alongside the roots and the shoots which will results in no nutrient waste. Animals sometimes can eat the green part and leave the roots, that2s why it is better if the hydroponics fodder is mixed with the other roughage components of the ration [22][33]. The improvement of indigestibility of feed is evident with when hydroponic fodder is added in dairy cows' ration. Dairy animals can be fed 25 kg/day based on the physiological status with lower amount of concentrate and roughage [11].

**Digestibility/Degradability**

The digestibility of the sprouts is higher compared to the grains, shoot and root sprouts, but shoots can also have good digestibility [22]. The increase in the digestibility of dry matter, organic matter, crude protein, and crude fibre in maize might be due to the tenderness of the fodder at early age [37]. Banakar [1] reported that the inclusion of sprouted barley with rice straw and Tamarix Mannifera improved the digestibility of DM, OM, CP, CF, NDF and ADF which may be due to the existence of bioactive catalysts that stimulates the digestion and absorption of the nutrients.

In the rumen, the sprouts had shown better digestibility than the cracked grain. However, compared to the digestibility of roots and sprouts, shoots degrade faster, that's why ruminants prefer leafy materials [29]. The digestibility of hydroponics fodder's nutrient is comparable to highly digestible legumes such as clovers. Even with the loss in the dry matter content of sprouted barley fodder, their digestibility still advantageous.

**Energy**

Both hydroponic sprouts and processed grains are regarded as nutritious and digestible feeds. Grain sprouting catabolizes the starch to sugar. On dry matter bases, sprouts show less energy value compared to the grains with gross energy loss [34].

**Protein**

Protein is a critical element that animal performance highly depends on, thus there is a major need to identify and enhance protein value in hydroponic fodder. Sprouts manifest a high concentration in crude protein, ash, and other minerals except potassium than grains. The increase in dry crude protein content is mainly due to decrease in dry matter content especially carbohydrates. In addition, nutrient absorption also enhances nitrogenous compound's metabolism which can increase crude protein content. Using nutrient solutions instead of tap water can also improve the crude protein level of the hydroponic fodder [29][26].

**Vitamins**

Hydroponic fodder is especially rich in vitamin C and E. Sprouting process can enhance the vitamin content of the grain. However, the increase in individual vitamin content is not significant enough to meet the nutritional requirements of grain-based diets. [2].

**Minerals**

In hydroponic fodder, growing roots improve mineral uptake, which increase ash and protein contents starting from day four. Absorption also facilitates nitrogenous compounds metabolism and so

increases crude protein content [5]. The nature water used to irrigate the hydroponic fodder can easily affect the mineral content of the fodder. However, chelating sprouting makes minerals more available [36].

**Anti-Nutritional Factor**

During germination enzymes can also eliminate other potentially toxic chemicals. Phytic acid is found in the seed coat and germ of plant seeds. The principal impact of phytic acid is that it has an antagonist activity with some minerals. In fact, phytate can join some minerals such as calcium and iron to compose insoluble compounds. Phytic acid levels are reduced during seed sprouting [35][5]. Sprouts have a hundred times more enzymes than fruits; the digestive enzymes in sprouts act as biological catalysts, its control the digestion of protein, fat and carbohydrates. Enzyme activity define the amount and therefore the physiological action of vitamins, minerals, and trace elements [41]. Sprouts enzyme activity is at its peak between germination and seven days. Because of the inhibitors, enzymes are still active when cereal grains are not germinated. Seed degradation is prevented for years using these inhibitors [36].

## Effect Of Hydroponic Feed on Livestock Productivity

**Milk Production**

The milk yield significantly increases when hydroponics fodder is fed, maybe because of enhanced nutritional digestibility [22]. Hydroponics can aid in the improvement in the quality and amount of milk. Several studies have shown an increase in milk yield and concluded that the increased yield was due to high protein content in the fodder. Studies on improvement of milk production through hydroponic fodder feeding shows improvement than animals fed cereal grains, hay or silage. Hydroponic fodder increases milk yield by 3.9% [21], 7.8% [37],10.07% [37], 12.5% and 13.73% [25] due to feeding of hydroponic fodders to lactating cows. Also [42] observed a slight improvement in milk protein and milk fat in dairy goat but were not significant in sheep. Canadian dairy farmers reported that feeding of hydroponic fodder increases feed intake of their cows and improve milk yield by 3.6 kg per day over the lactation period. Moreover, farmers from South Africa reported a drop of 3.6 liters of milk after decreasing 6.8 kg of the daily fed hydroponic amount [2]. The feedback from the farmers of the Satara district of Maharashtra revealed increase in the milk yield by 0.5 - 2.5 liters per animal per day and net profit of 0.5 dollar per animal per day due to feeding of hydroponics fodder to their dairy animals [38].

**Meat Production**

Hydroponic fodder enhances the body weight gain of lambs which may be due to the high content of bioactive enzymes and ingredients that boost livestock performances [16]. Also, increasing body weight can indicates a good ruminal microbial activity and improved nutrient digestibility. beef cattle fed maize hydroponic fodder, can reach an average increase of 200 g in body weight. Similarly, 8% improvement in body weight gain is reported in birds and other animals. Better body weight gain was recorded in cross breed calves, Awassi lambs and goat fed hydroponic maize and barley fodder respectively [2][7].

**Overall Performance**

Hydroponics fodder has more potential health benefits. Sprouts are the most enzyme rich food and the period of peak enzyme activity lies between germination and 7-8 days of age. They are rich source of natural antioxidants i.e. â-carotene, vitamin - C, E and related trace minerals like selenium and Zn. Feeding of the sprouted grains improve the animals' productivity by developing a stronger immune system due to neutralization of the acidic condition by supplementation of alkaline digestive enzymes through sprouted grains. Sprouted grains are good sources of pigments containing chlorophyll, xanthophylls, grass juice and protein sparing factors which improves the production and reproductive performance of the livestock. Besides this, helping in the elimination of the anti-nutritional factors such as phytic acid, oxalic acid and other toxicants of the fodder [2].

## Conclusion

Hydroponic technology is an agro-technology that can be put to practice locally with low-cost materials to provide nutritious, palatable, and digestible fodder for livestock.

Certainly, this technology is less competitive than traditional fodder production in areas that doesn't lack quality green fodder, but it always stays as a smart alternative technology against land scarcity and hindering climate changes in different agro-climatic regions in the world. Now a day's several countries are practicing it for their sustainable livestock production. Because of greater palatability and

digestibility, hydroponic fodders become more lucrative and useful over conventional feeding of cereal grains and concentrate mixture.

Fully automated commercial hydroponic systems can demand high initial investment, qualified labor and high energy cost to maintain the desired environmental condition inside the green house which can add enormously to the net cost of hydroponic fodder production.

Conversely, in case of an acute shortage of fodder and water, a major increase in fuel costs or an extreme seasonal variations of fodder prices, low-cost hydroponic systems have been achieved using locally available infrastructure. Under such situations the employment cost of the hydroponic system will be an advantage and it would become the best alternative for sustainable livestock production.

This can pave the way to much needed studies explaining different hydroponic fodder production techniques to help the standardization of low-cost hydroponic technology using locally available resources.

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