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Hydroponic fodder production: A review

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Abstract
Livestock sector has a major role in nutritional security; however, there is a large gap in fodder supply and demand, which is attributed due to climatic changes, urbanization, and increased growth rate of the cattle. A best alternative is hydroponics fodder production, which is economical and available round the year. Hydroponics can be produced in various ranges of crops viz., maize, cowpea, barley, chickpea etc and the fodder can be made available in a short duration of 5-10 days. Fodder is highly nutritive due to the conversion of complex compounds into simpler and essential forms, and enzyme activation during the germination. Feeding the cattle with hydroponic fodder enhanced the uptake and digestibility of fodder, which in turn increased the milk production in the cattle.

Keywords: hydroponic, livestock, digestibility

Introduction
In India, livestock plays a major role for the nutritional security, particularly of the small and marginal farmers. As per 19th Livestock census, 2012 (GOI, 2014) India's livestock sector, holding upto 11.6% of worlds livestock population is the largest, including cattle, buffaloes, goats and sheep. The growth rate during last 56 years in livestock is 80.91% (Ab Rahim M. A. Saidi 2015) [1]. This increased growth rate of livestock demands an increase in the fodder production increase in the fodder production required for the sustainability of the cattle. But there is a gap between the need and produced feed, since the land allocation for green fodder production is limited to only 5% of the gross cropped area (Jamal Abo Omar, 2015) [1].
Livestock growth is adversely affected due to the non-availability of the quality green fodder. Rapid urbanization, land fragmentation, water scarcity, labour shortage, more growth time, requirement of manure and fertilizer, non-availability of land for forage cultivation (coastal belts), uncertain rainfall and natural calamities are the major constraints for green fodder production by the livestock farmers. Due to the above constraints of the conventional method of fodder cultivation, hydroponics technology is coming up as an alternative to grow fodder for farm animals. However, hydroponics requires a well-established framework (green house) with moderately controlled environment equipped with automatic sensors for regulating the temperature, light, humidity and water
The word hydroponics has its roots from Greek, "Hydro" meaning water and "ponics" meaning 'working' It is based on raising plants/crops in aseptic water or nutrients, rather than growing in soil. In fodder crops, the cereal grains (maize, malt, oats, and barley) possessing high germination and faster growth rate of generally seven days are preferred for hydroponic production. These young and tender sprouts are nutritionally rich, highly palatable, free from pests and diseases and have high metabolizable energy (El-Morsy *et al.*, 2013) [5], thus comparable with the fresh green fodder.
The enhanced nutritional value of the sprouted grains is due to conversion of the complex compounds into simpler and essential form and by minimizing the effect of anti-nutritional factors during germination (Udensi, E. (2013) [12]. Along with the increased protein quantity, quality can also be improved by increased sugars, certain minerals, vitamin, and enzyme contents (Shipard, 2005) [17]. These enzymes convert the complex compounds of proteins into albumin and globulin thus, improving the protein quality. Activation of amylase and lipase during germination increases the sugar and essential fatty acid contents of the grains. Earlier reports by Udensi, E. (2013) [12] revealed that, using sprouted barley and maize in growing goats howed improvement in the digestibility, body weight gain and feed conversion efficiency

History of hydroponic fodder production
A detailed scenario of the history of hydroponics was given in the below in the figure 1

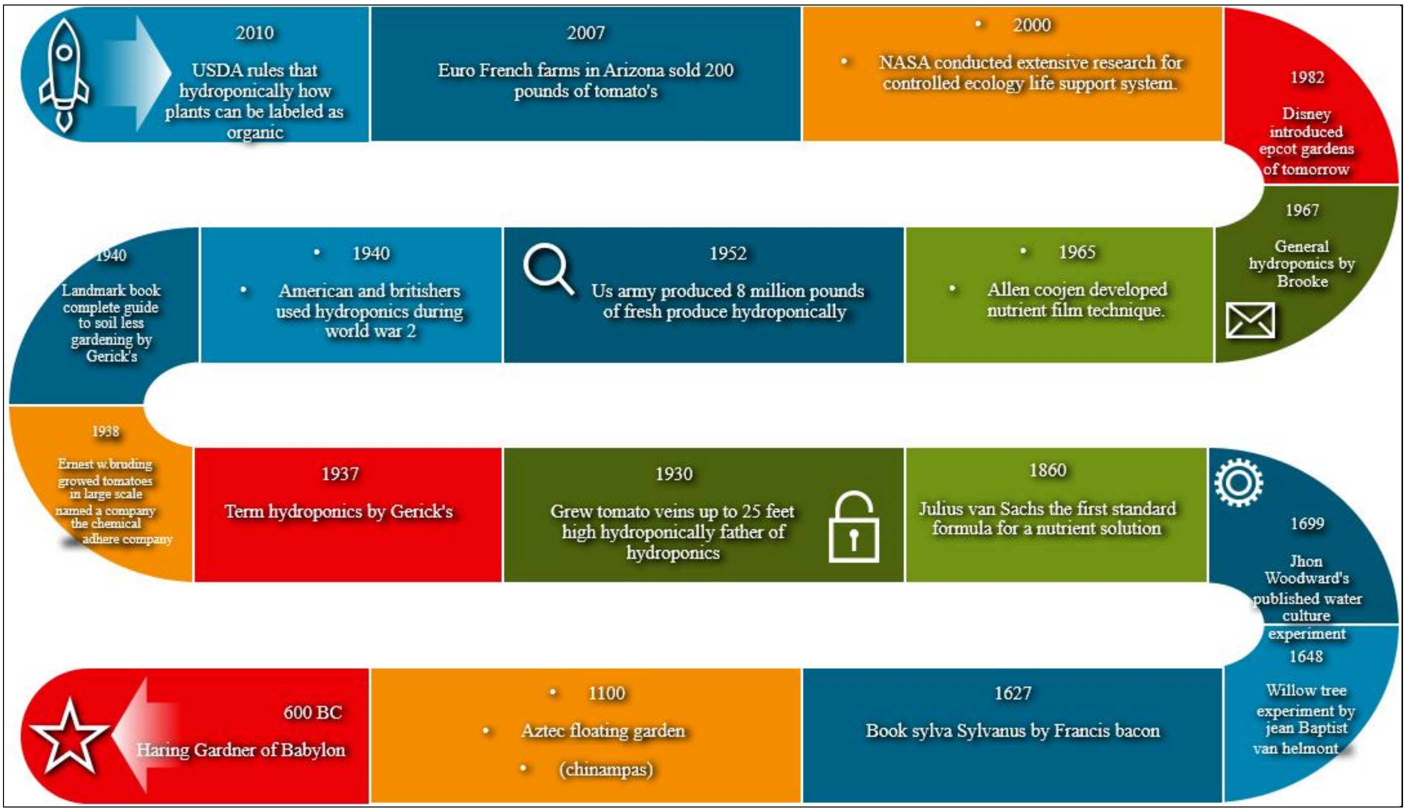


Fig 1: History of hydroponics

Fodder crops used for hydroponic fodder production
Various sorts of grain crops *viz.*, oats, ragi, bajra, wheat, sorghum, barley, Alfa- Alfa, cowpea and maize can be employed for by aqua-farming. However, the crop preference depends on the seed availability and agro –climatic conditions. In India Maize and barley was the best choice for hydroponics, owing to their high biomass production, faster growth rate, cheaper and easy availability of the seed (Naik *et al*., 2015) [11]. The grain used for aqua culture ought to be sound, perfect and flawless. Besides cereals, some leafy vegetables *viz.*, spinach and coriander can also be grown hydroponically.

Principles for hydroponic fodder production
The basic principle is growing plants in nutrient supplemented liquid media (without soil) under controlled conditions of moisture and temperature. The seedlings would show a growth of about 20-30 cm long within a time of 7-10 days. The liquid media contains significant amount of supplements like nitrogen, potassium, phosphorus, sulfur, calcium, magnesium and etc that are required for the plant growth (El-Morsy *et al*., 2013) [5]. Several structural and chemical changes occur during the germination, where the enzymes were activated which results in hydrolysis of proteins, carbohydrates, unsaturated fats and lipids into simple compounds (Tinley NL *et al*., 1938) [19]. This hydrolysis enhances the contents of fatty acids, amino acids and soluble sugars in the grains, thus producing shoots (Micera *et al*., 2015) [9]. This growth will affect the nutrient contents by increasing fats, fibers, and proteins (Tinley *et al*., 1938) [19]. However, the measure of yield delivered and nature of the hydroponic is affected by various factors including Grain - grain quality and grain assortment, developing climate temperature, mugginess and rate of shape and the board of the framework-water quality and pH, dousing time, supplement supply, profundity and thickness of grain inbox.

Systems setup for hydroponic fodder production: There are total six types of hydroponics system setups, those are based on the flow, nutrient solutions, application of electricity, hang of transplants etc. and they are named as:

1. **Wicking:** A wicking hydroponics system is the easiest to set up because it's the only system that doesn't specifically need electricity. With this system a specific material (nylon rope, wool strip, polyethene strip etc.) acts as the wick that connects the plant roots to the nutrient solution. The wick slowly absorbs the liquid below and delivers it to the plant roots. Electricity is not necessary, but an air pump is optional.
2. **Deep water culture (DWC):** One of the most basic and easiest systems is deep water culture systems, or DWC. In the DWC system, the plant roots are suspended and hang directly down into the nutrient solution. There is basically no water being pumped or moving around because the roots always sit directly in the nutrient solution. An air pump provides the oxygen to the water which completes the system. Water culture systems are a great choice for larger plants especially because the roots can have a lot more room than other systems mentioned below. One of the most popular methods of any hydroponic system for beginners is known as the Kratky method. This is a form of deep-water culture that eliminates all electrical components.
3. **Drip system:** A drip hydroponic system involves the nutrient solution being pumped through a tube above the plants which drips the solution down onto the plant and

roots. The drip system is great for closely monitoring the drip amount to each plant. However, with more drippers, more can go wrong. These systems can be prone to clogs. Drip systems can either be circulating, where the solution returns to the basin, or non-circulating. Non-circulating means the nutrient-rich solution is single-use only and does not get recycled back into the system.

4. **Aeroponics:** Aeroponics is a system where the plant roots are suspended and sprayed with nutrient-rich water The nutrient spray effect is achieved using an aerosol or misting spray. Aeroponics uses even less water than a traditional hydroponic system. Since the roots are suspended in air, they can absorb even more oxygen. Mister nozzles can spray the nutrient water continuously or intermittently.
5. **An ebb and flow system:** Is also known as flood and drain and is another great method to consider. This system involves a flooding reservoir that your plants sit in and is positioned above the nutrient reservoir water. The top tray with the plants gets flooded with the nutrient solution and then, in a specific interval, drains back down to the lower reservoir. You can change the interval of the flooding by using a timer with your ebb and flow system. Ebb and flow hydroponics system for specific plants that flourish under these conditions of excess nutrients followed by a period of dryness. During the dry intervals, the plant roots will expand in search of more nutrients which causes faster growth overall.
6. **Nutrient Film:** Technique is a great option if you want to increase the oxygen levels and decrease the amount of water used. The key difference with NFT systems is that they rely on the plants to be suspended in a row at a slight tilt. This tilt allows for gravity to move the water through the tips of the roots. NFT brings in the most oxygen because the roots are almost entirely exposed to the air and only the tips of the roots touch the nutrient solution. Hybrid systems can be created using a combination of any of the above six methods. These are just the basic six; there are also other interesting subsets including aquaponics and fogponics that are worth exploring.

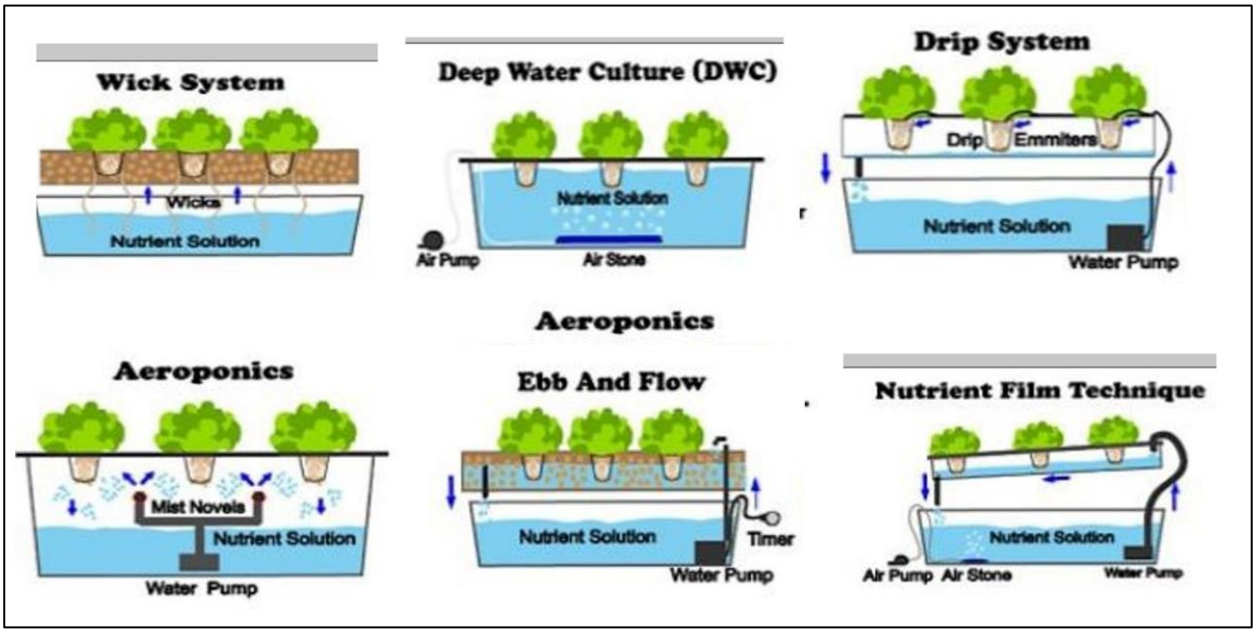


Fig 2: Different systems of hydroponics (source: www.nosoilsolutions.com)

Environmental factors for hydroponics

The natural components are significant for enhancement of the aqua farming grain development and creation. The standard degree of ecological signals like temperature (19 to 22ºC), moistness (normal 60%), light force (2000 lux), length (12-16 hrs) and air circulation for 3 minutes at each 2 hrs span ought to be maintained (Shit, N.*et al*., (2019) [18]. The last phase of collecting for grain seeds sprouts is sixth day of planting when it holds the most note worthy supplement and biomass yield. Furthermore, among all the tank-farming foods for example oats, rye, triticale and wheat has the most noteworthy fodder quality.

Nutrient information

There is deviation in the nutritive values in the hydroponically produced fodder from the conventional fodder crops (Fazaeli *et al* 2011) [6]. Sprouting of the grains leads to increase in total ash content, that is associated with decrease in the organic matter. (El-Morsy *et al*., 2013) [5] reported high metabolic energy, digestibility, and crude protein in hydroponically produced green fodder than conventional green fodder. According to Chavan and Kadam, 1989, the nutritional quality is enhanced due to conversion of complex compounds to simpler essential forms. Besides, vitamins, minerals, enzymes, and certain sugars are increased (Shipard, 2005) [17] in the hydroponic fodders. This increased enzyme activity, converts the complex protein into albumins and globulins, thus enhancing the protein quality (Kadam, N. P. (2019) [13]. Several research have shown that there is no significance increase in DM and the dry matter grain or loss ranged between 10% loss to 15% gain over 8-10 sprouting cycles (Shit, N. (2019) [18]. Loss in dry matter may be attributed to the consumption of carbohydrates and energy for the metabolic activities of seed for germination (Adjlane *et al.*, 2016) [7]. In contrast, the nutritional quality of the hydroponic grains is constant, especially crude protein, which ranges from 2-4%. According to Sale, 2015, this increased protein is due to decrease in dry weight through respiration during germination. The nutrient content of different hydroponically grown crops by different researchers is given below in the table-

Nutrient content of different crops used in hydroponic fodder production

Crop	Dry matter (%)	Crude protien (%)	Crude fibre (%)	Ash (cm)	Crude fat (gm)	References
Green maize	21.39%	10.21%	35.50%	10.17cm	15.57gm	Rajesh *et al*., (2019). M.Ayub *et al*., (2002)
Hydroponic fodder maize	18.30%	13.30%	6.37%	1.75cm	12.52gm	Naik *et al*., (2014)
Barley	28.3%	13.27%	13.29%	22.5cm	14.07g	Rajesh *et al*., (2019). Morgan *et al*., (2015)
Cowpea	27.08%	27.84%	6.51%	17.2cm	14.41g	Rajesh *et al*., (2019).
Bajra	27.04%	9.22%	4.16%	2.25cm	12.40gm	Rajesh *et al*., (2019). Chrisdiana *et al*., (2018).
Horse gram	27.36%	30.26%	13.00%	12.5cm	15.60gm	Rajesh *et al*., (2019).

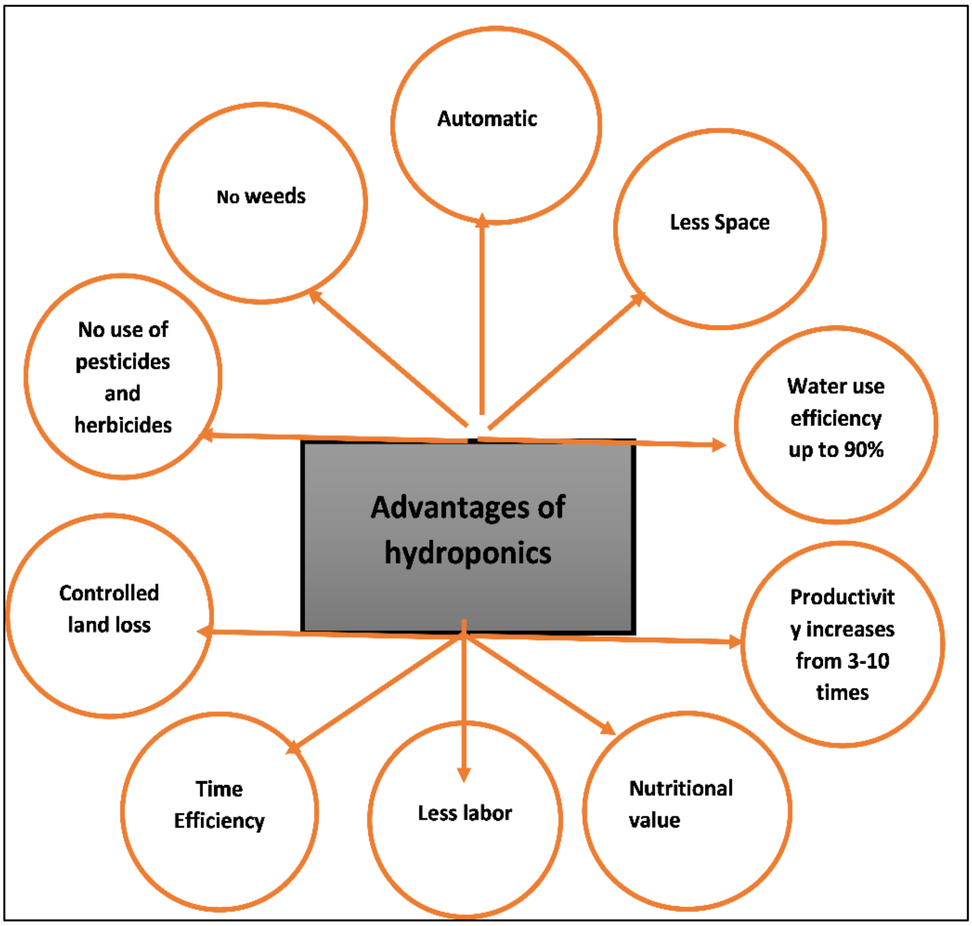
Effects of hydroponics on digestibility and Milk yield

In cattle, the digestibility of the sprouts is higher when compared to the cracked grain and comparing the digestibility of shoot and root sprouts, shoots have good digestibility. Reddy *et al.* (1988) observed significant increase in the digestibility of dry matter, organic matter, crude protein and crude fibre in maize and deduced that it might be due to the tenderness of the fodder at early age. Naik *et al.*, (2014), also reported significant increase in the digestibility of crude protein and crude fibre upon feeding of hydroponics maize fodder to cows. As per Shipard (2005) [17], the early sprouts at the age of 7 days of germination are enzyme rich, which increase the rate of digestibility. In contrast, (Udensi, E. (2013) [12] observed a clashing proof regarding the digestibility, whether it is increased or decreased on feeding hydroponic fodder. Likewise, working with barley Banakar, P. S. (2018) identified that the inclusion of sprouted barley with rice straw and *Tamarix Mannifera* enhanced the digestibility of DM, OM, CP, CF, NDF and ADF and he concluded that this might be due to the existence of bioactive catalysts which increases the digestion and absorption of the nutrients.

Hydroponics can aid in the improvement in the quality and amount of milk. Several studies have shown that milk yield was improved and Heins and Paulson, 2016 observed 3.9% increase in milk yield when fed with fodder maize, while (Naik *et al.*, (2014) observed 13.7% increase in the milk yield. Reddy *et al*., 1988, supplemented the cows with hydroponic barley and reported an increase in 7.8% milk yield and concluded that the increased yield was due to high protein content in the fodder containing HMF (Salo, S. (2019) [16]. while (Adjlane *et al.* (2016) [7] experimented on dairy cows and reported that the milk yield was increased significantly @13.49 litre/day. Also (Abd Rahim *et al.* (2015) [1] observed a slight improvement in milk protein and milk fat in dairy goat but were not significant in sheep.

Advantages of hydroponics

- It can be grown in lesser space as compared to conventional method
- High water use efficiency
- No usage of pesticides and herbicides
- Faster growth (40-50 times faster than conventional method).
- It has got essential nutrient supply
- It can be grown in door and healthier
- High Fodder quality



Disadvantages of hydroponic fodder production

- Requires high initial investment.
- More chances of getting water borne diseases.
- Loss in dry matter
- Frequent and consistent monitoring

Conclusion

Nutritious green fodder is essential for high milk yield and availability of green fodder all round the year may not be possible due to land scarcity and impeding climate changes. The best alternative is hydroponic fodder production, which is a low cost agro-technology. Nutrient rich fodder with good digestibility and palatability are being produced in several crops like maize, cowpea, barley, chickpea etc. This fodder has high nutritive value because of the conversion of complex compounds into simpler and essential form, and enzyme activation during the germination. Several studies have shown that feeding the cattle with hydroponic fodder enhanced the uptake and digestibility of fodder, which in turn increased the milk production in the cattle. Therefore, hydroponics is an alternative efficient technology for producing quality fodder and year-round supply to the cattle.

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