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Hydroponics Fodder Production - An Innovative Approach for Sustainable Livestock Production under Varied Climatic Distress

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ABSTRACT

In India, livestock plays an important role in the nutritional and livelihood security of small and marginal farmers. In comparison to the 2012 livestock census, the country's livestock population has increased to 535.78 million with a growth rate of 4.63 per cent . The scarcity of fodder and land allocation for the cultivation of green fodder lead to reduction in the productivity of livestock. Also, fodder production is constrained further with the changing climate due to erratic distribution of rainfall. The failure of dual crops (food and fodder purpose) is increasing as they are becoming vulnerable to vagaries of weather and aggravating the problem of fodder crisis. These problems can be cope with a new alternative tool of producing green fodder for farm animals through hydroponics technology. The studies conducted by different researchers revealed that the optimum seed rate of hydroponically grown fodder was 2.50 to 7.6 kg m^{-2} for maize, 2.54 kg m^{-2} in cowpea, 4.66 kg m^{-2} in bajra, 4 kg m^{-2} in oat, 4 to 10 kg m^{-2} in barley and 5.5 kg m^{-2} in wheat. The fresh yield of hydroponically grown fodder increased to 2.8 to 8 folds in a period of 8 to 14 days. Application of nutrient solutions has recorded higher yield as compared to control; Urea and MOP each @ one per cent at three and 10 days after sowing, respectively in maize increased yield from 4.60 to 5.64 kg^{-1} seed and 19-19-19 water soluble fertilizer @ 0.5 per cent was recommended for maize, bajra, oat, barley and wheat. The cost of production of the hydroponic fodder was about Rs.2 to 3 per kg of fresh fodder with own seeds to Rs.3 to 3.50 per kg with purchased seeds. Farmers got Rs.25 to 50 additional net profit per animal per day by feeding hydroponic fodder. The hydroponic fodder production system helps to overcome the challenges on fodder availability due to climatic change and also helps fodder production systems in management and efficient utilization of natural resources.

Keywords : Economics, Hydroponics fodder, Livestock, Nutrition, Seed rate

LIVESTOCK sector plays a multifaceted role by providing a significant contribution to the agricultural economy. The livestock sector provides livelihood support, employment opportunities, asset creation, regular income, social and financial security to millions of households.

The total livestock population in India during 2019 census was 535.78 million showing an increase of 4.63 per cent over Livestock Census 2012. Livestock population depicted a steady increasing trend from 1956 to 1997 and 2007 with an increment of 4.77 per cent, 26.54 per cent and 82.33 per cent, respectively and a decline in trend was observed in 2012 to 76.27 per cent (Sonavale *et al.,* 2020). The total Bovine population (Cattle, Buffalo, Mithun and Yak) was 302.79 million during 2019 which showed an increase of one per cent over the previous census. In total livestock cattle, goats, buffaloes, sheep and pigs accounted for 35.94, 27.80, 20.45, 13.87 and 1.69 per cent, respectively of total livestock in the country. Among different states of the country, Uttar Pradesh has the highest number of livestock of 67.8 million (68.7 million in 2012), followed by Rajasthan 56.8 million (57.7 million), Madhya Pradesh: 40.6 million (36.3 million) and West Bengal: 37.4 million (30.3 million).

Status of Fodder in India

The growth and development of livestock's is conditioned by adequate availability of feed and fodder. The availability of feed and fodder is a major area of concern. There is a clear gap between its demand

and supply in the country. As per the estimates of the National Institute of Animal Nutrition and Physiology (NIANP), the deficit in the requirement and the availability of dry fodder, green fodder and concentrates during 2015 were to the extent of 21, 26 and 34 per cent, respectively. This is likely to increase to 23, 40 and 38 per cent, respectively by 2025. The fodder deficit in India in terms of green fodder, dry fodder and concentrates were 26 million tonnes (MT), 21 MT, and 34 MT in 2015, which is expected to reach 40 MT, 21 MT, and 38 MT by 2025, respectively (Anonymous, 2017). The demand will reach to 1012 million tonnes of green fodder and 631 million tonnes of dry forage and face 18.4 per cent deficit in green fodder and 13.2 per cent deficit in dry fodder by the year 2050 (Anonymous, 2013).

Land availability for cultivation of green fodder crops is limited and has hardly about 3.60 per cent of the gross cropped area (Anonymous, 2013). Due to ever increasing pressure of the human population, arable land is mainly used for food and cash crops, thus there is little chance of having good quality arable land available for fodder production (Naik *et al.,* 2015). The major problem being faced by this sector is the shortage of quality fodder leading to livestock productivity. The regional scarcity of fodder and feed are more important than the national deficit since transport of fodder to longer distances is not economical. Feed and fodder account for a significant proportion in the cost of production in livestock and their products generation (Satyanarayan *et al,* 2017). With the limiting land availability, there is a need to increase available total feed and fodder for livestock production.

Climate Change and its Effect on Fodder Scarcity

Major constraints associated with the conventional method of green fodder production are the unavailability of land due to small land holding, more time and labour requirement for cultivation (sowing, earthing up, weeding, harvesting etc.), rainfall scarcity, higher manure and fertilizer requirement, uncertainty of rainfall, scarcity of water, fencing requirement to protect the fodder crops from wild animals, natural calamities etc. (Naik *et al.,* 2013b). The most visible effect of climate change will be on the primary productivity of forage crops and rangelands. Developing countries are more vulnerable to climate change than the developed countries due to predominance of agriculture in their economies and their warmer baseline climates, besides their limited resources to adapt to newer technologies.

In view of the coming years, there will be an increase in temperature, carbondioxide levels in the environment and also diminishing water availability due to erratic, uneven and ill distributed precipitation, these ultimately affect the forage production (Ziervogel *et al*., 2006). Climate change causes significant changes in composition (Polley *et al*., 2013), growth and development of pastures (Hopkins and Del Prado, 2007). Higher temperature will lead to lengthening of cropping season, which results into decrease in dry matter accumulation in forage crops (Izaurralde *et al.,* 2011). With proper adaptation measures ably supported by suitable policies by the governments, it is possible to minimize the adverse impacts of climate change and ensure livestock productivity through optimum forage availability (Giridhar Kandalam and Anandan Samireddypalle, 2015).

Reasons for the Scarcity of Green Fodder

Lack of green fodder directly affects the reproduction and productive capacity of animals. The major constraints associated with the conventional method of green fodder production are the unavailability of land for fodder cultivation due to urbanization (Naik *et al*., 2013a). shortage of feed fodder for livestock due to frequent droughts induced water crisis is evidenced. Labour shortage is another problem in agriculture, animal husbandry and allied activities such as the cultivation of green fodder, cutting, chaffing and feeding the same to the cattle. Hence, there is a need for crop rotation, change in cropping pattern, conservation tillage, the inclusion of agroforestry species in animal feed (Ghosh *et al.,* 2017). Another best alternative tool of producing green fodder for farm animals through hydroponics technology (Sneath & Mc Intosh, 2003 and Naik *et al.,* 2015). As hydroponic technology can improve water use efficiency and productivity under limited available water resources (Naik *et al.,* 2015 and Santosh Nagappa Ningoji *et al.,* 2020b).

Hydroponic Technology

The word hydroponics has been derived from the Greek word 'water working' (Hydro means 'water' and ponic means 'working') and it is a technology of sprouting grains or growing plants without soil in the presence of water and proper nutrients (Naik *et al.,* 2015). Hydroponic technology is an art and science of growing crops without soil in the presence of water and proper nutrients, which is more advantageous than the conventional method of fodder production. n 1699 an English scientist, Woodward attempted to grow plants in various sources of water. During the mid-1800s, the French chemist John Boussingault verified nutritional requirements of plants grown without soil and Sachs and Knop in 1860 perfected the techniques of 'nutriculture' in England (Hoagland and Arnon, 1938). In India attempts were made during the late 1980s for propagating hydroponics technology for forage production and research works were undertaken by several workers (Reddy *et al.,* 1988; Pandey & Pathak 1991 and Rajendra *et al.,* 1998).

Hydroponically grown fodders are rich in vitamins, minerals, enzymes and about 85 to 90 per cent digestible protein. Sprouting of grains increases the enzymatic activity, total protein and changes amino acid profile, increase in sugars, crude fibre, certain vitamins and minerals, but decrease starch and increases simple sugars (Naik *et al.,* 2016). Hydroponic fodder is grown inside a greenhouse or in a shaded net within a short period of approximately eight to ten days, even upto 14 days in case of maize to get higher production (Santosh Nagappa Ningoji *et al.,* 2020b).

Greenhouses are highly advanced, fully automated (Moisture, light, temperature and humidity), controlled and costlier as compared to conventional hydroponic fodder production systems unaffordable to small and marginal farmers (Naik and Singh, 2014). Recycling of used water can also be done in a greenhouse using the pump, which would enhance water use efficiency. In recent years, low-cost hydroponic fodder production technologies were taken up by shade net structure constructed with bamboo or wood or MS or GI pipes, or brick masonry. Micro-sprinklers can be used for irrigation (manual or automatic) or a knapsack sprayer at frequent intervals. A start-up designed a low-cost unit called as Kambala machine which produces 25-30 kg of fodder per day which is enough for at least 4-5 cows in a week. It hardly cost around Rs.30000 and comes with solar power. The wooden shade net greenhouse with a daily production potential of about 30-350 kg fresh hydroponics fodder costs approximately around Rs.6000-50000 (Anonymous, 2012). MS shade net greenhouse with a daily production potential of about 150-750 kg fresh hydroponics fodder cost approximately Rs.25000-150000 (Naik and Singh, 2014).

Hydroponics Fodder Production Process

Hydroponics fodder production process includes Seed storage, cleaning, sterilization, soaking of seeds for better germination, sowing, racking, periodical spraying of water and harvesting. The seeds should be dried and stored in air tight containers. Best quality seeds that are unbroken and disease-free have to be used by soaking the seeds for five minutes in water and floating lightweight seeds are remove (Sneath & McIntosh, 2003 and Naik *et al.,* 2015). Seeds are sterilization by soaking them in 0.1 per cent bleach solution (sodium hypochlorite) or 1-2 per cent hydrogen peroxide solution for ond hour (Rachel Jemimah *et al.,* 2015 and Starova Jeton, 2016). Sterilized seeds shoul be soaked in the water in the 1:2 proportion (one part seeds and two parts water) in a container for 4-24 hours depending on the hardness of the seed coat (El-Deeba *et al.,* 2009; Al-Karaki and Al-Momani, 2011; Sinsinwar *et al.,* 2012; Reddy, 2014; Naik *et al*., 2014; Starova Jeton, 2016 and Brownin, 2017). Soaking the grains increases moisture content and enzymatic activity. These enzymes break down storage compounds into more simple and digestible fractions, for example, starch to sugars, proteins to amino acids and lipids to free fatty acids. There is an increase in fibre and some vitamins and a reduction in antinutritional compounds (Sneath and Mc Intosh, 2003). The days required for growth, crude protein, crude fibre, ether extract, total ash and NFE are standardized by Rachel Jemimah *et al.* (2015).

To promote better germination the soaked seeds are drained and packed in a air-tight gunny or cotton cloth, away from the direct sunlight and frequent wetting has to be taken up by sprinkle water every 2-3 hours. After 24 hours, sprouted seeds were placed uniformly in trays and were racked in a slanting position in such a way that excess water drains out easily to avoid the decay of unsprouted seed and growth of fungus. The water should be sprayed daily on a periodical basis either manually or with an automated fogging system where foggers were designed for each tray. The water spray is automated every 2-4 hours for a one-three minute time depending on the season to maintain the optimum moisture in the system (Santosh Nagappa Ningoji *et al.,* 2020a). Later green fodder on forming a mat-like structure is harvested 10-14 days after the sowing and fed to the livestock.

Hydroponic Fodder Research

In India attempts were made during the late 1980s for propagating hydroponics technology for forage production and research works were undertaken by several workers. The crops like maize (Naik *et al*., 2011; Naik *et al*., 2012 and Santosh Nagappa Ningoji, 2020b), barley (Reddy *et al*., 1988), oats, cowpea, horse gram, ragi, sun hemp, bajra, jowar, moth bean, foxtail millet, sanwa millet, kodo millet and little millet can be grown successfully under hydroponic fodder production system.

The fresh yield and dry matter content of the crops are very important for successful hydroponics fodder production as there will be an increase in the fresh weight and a consequent decrease in the DM content due to the rapid growth of seedlings, as they deplete the food reserves present in the endosperm (Sneath and Mc Intosh, 2003). The higher seed to fodder ratio will help to increase the profitability and livelihood of farmers. The seed to fodder ratio of different crops reported is compiled in Table 1. The fresh yield of 2.8-8 folds in 6-8 days with dry matter content of 8-19.7 per cent in hydroponics barley and fresh yield of 3.5-6.0 folds in 7-8 days with dry matter content of 10.3-18.5 per cent in maize fodder have been reported (Morgan *et al.,* 1992; Sneath and Mc Intosh, 2003; AI-Ajmi *et al.,* 2009; Dung *et al.,* 2010; Fazaeli *et al.,* 2011; Naik *et al.,* 2011; Fazaeli *et al.,* 2012; Naik *et al.,* 2014; Gunasekaran *et al.,* 2018 and Santosh Nagappa Ningoji *et al*., 2020b).

Table 1

Seed: fodder production ratio (kg.) of different crops

Type of fodder	Seed: fodder production ratio (kg.)
Maize	1.3 :6.0 (Rachel Jemimah *et al.*, 2015); 1:5.07 (Naik *et al.,* 2017); 1:4.50 (Gunasekaran *et al.,* 2018); 1:4.60 (Santosh Nagappa Ningoji *et al*., 2020b)
Cowpea	0.75 :5.0 (Rachel Jemimah *et al.*, 2015)
Horse gram	0.75 :4.5 (Rachel Jemimah *et al.*, 2015)
Ragi	1.0 :3.5 (Rachel Jemimah *et al.*, 2015)
Sun hemp	0.50 :5.0 (Rachel Jemimah *et al.*, 2015)
Bajra	1.0 :3.0 (Rachel Jemimah *et al.*, 2015); 0.7: 5.55 (Mutum Lamnganbi and Surve, 2017a)
Jowar	1.0 :3.7 (Rachel Jemimah *et al.*, 2015)
Foxtail millet	1.0 :4.5 (Rachel Jemimah *et al.*, 2015)
Moth bean	0.5 :6.75 (Rachel Jemimah *et al.*, 2015)
Kodo millet	1 :5.9 (Rachel Jemimah *et al.*, 2015)
Little millet	1:5.9 (Rachel Jemimah *et al.*, 2015)
Oat	0.6:3.84 (Mutum Lamnganbi and Surve, 2017a) 1:5.50 (Hillier and Perry, 1969)
Barley 2017a)	0.6:3.60 (Mutum Lamnganbi and Surve, 1:2.76 (Al-Ajmi *et al.,*2009)1:5.30 (El-Morsy *et al.,* 2013)
Wheat	0.8:5.62 (Mutum Lamnganbi and Surve, 2017a)

Optimum seed rate is the primary aspect in the agro-techniques, as productivity, profitability and quality are associated with it. The recommended seeding rate for production of hydroponic barley, wheat or sorghum fodder is 4-6 kg m^{-2} (Al-Karaki and Al Momani, 2011; Starova Jeton, 2016) and for maize is 6.4-7.6 kg m^{-2}

(Naik & Singh, 2014; Naik, 2014 and Naik *et al.,* 2017).

Most of the commercial units recommended seeding rates of 6–8 kg m^{-2} (Morgan *et al.,* 1992), however, the total dry weight increases with the increase in seeding rate up to five kg m^{-2}, thereafter, it decreases significantly. Hence, the optimum seeding rate of 4 kg m^{-2} is the most efficient under hydroponics (Massantini and Magnani, 1980). Dung *et al.* (2010) and Fazaeli *et al.* (2011) maintained seed rate density of 6.7 kg m^{-2} and 4.5 kg m^{-2} for growing hydroponics barley fodder. Maintaining the barely seeds density to 1.5cm thickness could be the optimum for achieving appropriate barely growth and essential forage production (El-Morsy *et al.,* 2013). The optimum seed rate for hydroponic fodder production reported by different research workers is compiled in Table 2. The range of seed rate suggested by different resesrchers is wider and lack clarity of optimum seed rate in different crops. Hence, there is need to reduce ambiguity and errors in conducting experiments to obtain optimum seed rate.

TABLE 2

Optimum seed rate reported by different researchers for hydroponic fodder

Type of fodder	Seed rate
Maize	6.4-7.6 kg m^{-2} (Naik and Singh, 2014; Naik, 2014; Naik *et al.,* 2017) 2.50 kg m^{-2} (Santosh Nagappa Ningoji *et al.*, 2020b); 4 kg m^{-2} (Massantini and Magnani, 1980); 250g/ sq.ft (Gunasekaran *et al.*, 2018)
Cowpea	2.54 kg m^{-2} (Naik *et al.,* 2016)
Bajra	4.66 kg m^{-2} (Mutum Lamnganbi and Surve, 2017b) 6.7 kg m^{-2} (Dung *et al.*, 2010) 4.5 kg m^{-2} (Fazaeli *et al.*, 2011)
Oat	4 kg m^{-2} (Mutum Lamnganbi and Surve, 2017b)
Barley	4.65 kg m^{-2} (Al Ajmi *et al.,*2009); 10 kg m^{-2} (El-Morsy *et al.*, 2013); 4 -6 kg m^{-2} (Al-Karaki and Al Momani, 2011)
Wheat	5.5 kg m^{-2} (Mutum Lamnganbi and Surve, 2017b)

Under the hydroponic system, nutrients are provided for the growth and development of crops in the form of a nutrient solution containing mainly inorganic ions from soluble salts of essential elements at regular intervals. Further research works carried by Patricia Merigout *et al.* (2008) resulted in higher nitrogen use efficiency and utilization efficiency with the application of Ammonium sulphate. The foliar nutrient spray also enhanced protein concentration (17.3 %) than those grown with tap water irrigation (15.9 %) Massantini and Magnani (1980) (Table 3).

TABLE 3

Optimum nutrition for the production of hydroponic fodder

Type of fodder	Nutrition
Maize	19-19-19 WSF spray @ 0.5 % at 5 DAS (Mutum Lamnganbi and Surve, 2017b) Two sprays of urea and MOP each @ 1 per cent at 3 and 10 DAS 10 per cent vermivash (Gunasekaran *et al.*, 2017)
Bajra	19-19-19 WSF spray @ 0.5 % at 5 DAS (Mutum Lamnganbi and Surve, 2017b)
Oat	19-19-19 WSF spray @ 0.5 % at 5 DAS (Mutum Lamnganbi and Surve, 2017b)
Barley	19-19-19 WSF spray @ 0.5 % at 5 DAS (Mutum Lamnganbi and Surve, 2017b)
Wheat	19-19-19 WSF spray @ 0.5 % at 5 DAS (Mutum Lamnganbi and Surve, 2017b)

The experiment conducted by Mutum Lamnganbi and Surve (2017a) revealed that hydroponically grown white maize with 0.5 per cent 19:19:19 foliar spray recorded significantly higher growth parameters, yield parameters and wateruse efficiency as compared to control (Fig. 1). The above studies have reported a positive influence of nutrient sources on hydroponically grown fodder crops. Hence balanced and periodical application of nutrients is required to enhance the quality and production of fodder under hydroponics

Water scarcity is one of the major cause for declining feed and fodder supplies in the present scenario. Achieving suitable green fodder production under the

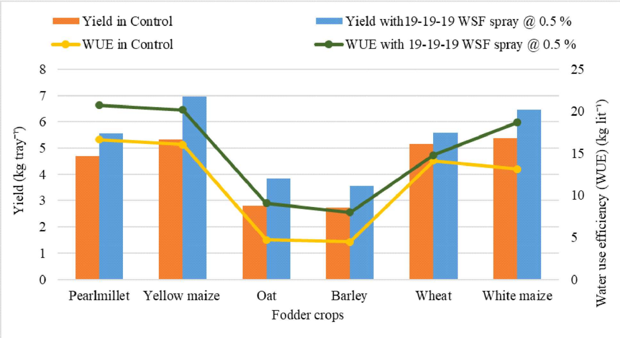

Fig. 1: Comparison of Yield and water use efficiency of hydroponically grown fodder crops with and without application of nutrients

prevailing water-scarcity conditions requires the introduction and implementation of agricultural policies and techniques which minimize water consumption and improve yield per unit of water used. Hence, the water scarcity problem can cope alternatively by producing green fodder for farm animals through hydroponics technology (Sneath & Mc Intosh, 2003 and Naik *et al.,* 2015), since it needs 2-5 per cent of water used

TABLE 4

Water use efficiency of hydroponically grown fodder crops

Type of fodder	Water use efficiency
Maize	230 kg m^{-3} (Mutum Lamnganbi and Surve, 2017b) 750 kg m^{-3} (Santosh Nagappa Ningoji *et al.*, 2020a),
Cowpea	18.17 kg/lit (Sauvik Ganguly *et al.,* 2020) 633 kg m^{-3} (Al-Karaki and Al-Hashimi, 2012)
Ragi	21.07 kg/lit (Sauvik Ganguly *et al.,* 2020)
Bajra	270 kg m^{-3} (Mutum Lamnganbi and Surve, 2017b)
Little millet	20.63 kg/lit (Sauvik Ganguly *et al.,* 2020)
Oat	130 kg m^{-3} (Mutum Lamnganbi and Surve, 2017b)
Barley	122 kg m^{-3} (Mutum Lamnganbi and Surve, 2017b) 2360 kg m^{-3}(Al Ajmi *et al.,*2009) 676 kg m^{-3}(Al-Karaki and Al Momani, 2011) 794 kg m^{-3} (Al-Karaki, 2011) 645 kg m^{-3} (Al-Karaki and Al-Hashimi, 2012)
Wheat	191 kg m^{-3} (Mutum Lamnganbi and Surve, 2017b) 552 kg m^{-3} (Al-Karaki and Al-Hashimi, 2012)

in traditional fodder production system (Al- Karaki & Al-Momani 2011 and Naik, 2014). Hydroponically produced fodder was found to enhance the efficiency of water use and the research works in this line are compiled in Table 4.

Effect of Hydroponics Fodder on Animals

Hydroponically grown fodders are highly digestible, palatable and relished by the animals as sprouts are enzyme-rich food on the planet (Shipard, 2005), Pandey and Pathak (1991) reported that the digestibility of the hydroponics green fodder is comparable to that of highly digestible legumes like berseem and other clovers. Hydroponic fodder is highly succulent and animals can intake 1-1.5 per cent of body weight (Starova Jeton, 2016) or 15-25, 0.25 - 2.0, 1.5 -2.0 and 0.1 - 0.2 kg / animal/day in large ruminants, adult pigs, small ruminants and rabbits, respectively (Naik *et al.,* 2013b and Rachel Jemimah *et al.*, 2015).

The addition of sprouted grains has improved milk yield up to 8.7 per cent in ruminant animals. Reddy *et al.* (1988) observed 7.8 per cent increase in milk production when lactating cows fed hydroponic barley fodder compared to those fed Napier bajra (NB-21) green fodder. An increase in milk yield by 13.7 per cent was observed by feeding of hydroponics maize fodder, associated with higher DCP and TDN content of the ration (Naik, 2014). Farmers from Maharashtra observed an increase in the milk yield by 0.5-2.5 litres per animal per day and a net profit of Rs.25-50 per animal per day by feeding with hydroponics fodder (Naik and Singh, 2014). The increase in milk yield was mainly due to hydroponic fodder, which leads to a longer lactation period, improved fat percentage and general herd health.

Meat production trials have been conducted with beef cattle, pigs and poultry to know the effect of hydroponic fodder on meat production. Muhammad *et al.* (1991) reported eight per cent improvement in body weight in birds and other animals with hydroponic fodder. The gain in body weight of lambs was observed by feeding hydroponic fodder due to the presence of higher bioactive enzymes (Naik and Singh, 2014). Beef cattle fed with hydroponics green fodder showed an average of 200 g higher daily gain in comparison to those fed with a maize control diet (Fazaeli *et al.,* 2011). Gebremedhin (2015) reported 34.74 to 61.93 g/day increased body weight of goat. Better body weight gain was recorded in cross-bred calves (Rajkumar *et al.,* 2017), Goat (Kide *et al.*, 2015) and Awassi lambs (Atta, 2016) fed with hydroponic maize and barley fodder. Besides increased milk and meat yield, conception rate, herd health and longevity were also improved and there was also a reduction in the cost of veterinary aids.

Precautions for Hydroponic Fodder Production

Sprouts and mould grow in a warm and wet environment. Mouldy growth will reduce live weight performance and palatability of fodder. To reduce mould growth mix 20-25 g of baking soda or 20 g of Potassium bicarbonate into 3.78 liters of water and Spray onto the seeds and infested plant parts (Rachel Jemimah *et al.,* 2015).

Advantages of Hydroponic Fodder Production

Hydroponic fodder is grown in a controlled environment without soil and therefore there will be no incidences of soil-borne disease resulting in a reduced need for pesticides, insecticides and herbicides. It needs less water than the conventional method and the water can be recycled. The hydroponic system needs 2-5 per cent of water when compared to the traditional fodder production system (Al-Karaki & Al-Momani 2011 and Naik, 2014). Only 1.5-2 litre of water is enough for one kg hydroponic fodder production compared to 73, 85 and 160 litres of water to produce one kg green fodder of barley, alfalfa, and rhodes grass under conventional field condition, respectively (Rachel Jemimah *et al.,* 2015 and Yvonne, 2016).

The hydroponic technology takes only 8-12 days duration to develop from seed to fodder, whereas conventional fodder takes 45 days to grow and also requires less cost of production *i.e.,* Rs. 2.5/kg of fodder. This technology promotes marginal land usage, daily 1000 kg green fodder can be produced from 45 m^2 area and it is equivalent to conventional fodder (CO_4) produced in 25 acres of cultivable land. Hence, it takes 99 per cent less land than the conventional production method (Naik & Singh, 2014 and Rachel Jemimah *et al.,* 2015). Here even one square meter area can produce sufficient fodder to feed two cows per day and can expect higher milk yield by 13 per cent (Yvonne, 2016).

Fodder can be produced year-round even under natural calamities, land constraints, labour shortage along with an enhanced nutritive value having higher crude protein content and rich source of vitamin A, vitamin E, vitamin C, thiamin, riboflavin, niacin, biotin, free folic acid, anti-oxidants like β-carotene (Naik *et al*., 2015), minerals (Fazaeli *et al.,* 2012) and also a good source of bioactive enzymes, minerals and essential fatty acids (Chavan & Kadam, 1989 and Naik *et al.,* 2015).

Economics of Hydroponics

Hydroponic fodder production requires only seed, water and minimum labour inputs. It takes only 8-10 days to convert seeds into fodder compared to 45 days in the traditional system. The initial investment for this hi-tech technology is much higher, but low-cost hydroponic production systems are also available which would reduce the fixed cost of production and enhance net profit. The cost of production of the hydroponic fodder with its own seeds was about Rs. 2-3 per kg fresh fodder and Rs 3-3.50 per kg fresh fodder with purchased seeds (Naik *et al*., 2013a). Cost of production of one kg of hydroponic maize fodder (Rs.3 per kg fodder), horse gram fodder (Rs.5.6 per kg), sun hemp (Rs.4.10 per kg), bajra fodder (Rs.7.43 per kg), ragi fodder (Rs.8.32 per kg), foxtail millet fodder (Rs.9.32 per kg), jowar fodder (Rs. .90 per kg), moth bean (Rs.2.75 per kg) and little millet (Rs.5.10 per kg) as reported by Rachel Jemimah *et al.* (2015). Naik *et al*. (2014) revealed feeding of hydroponic fodders to milch cows led to an increase in milk yield by 0.5-2.5 litres per animal per day and net profit of by Rs. 25-50 per day. Verma *et al.* (2015) reported that feeding hydroponics barley fodder in twelve Hariana male calves was more economical than conventional feeding. Hence, hydroponic fodder is a boon to the farmer, which will enhance the profitability and living standards of the farmers.

Hydroponic fodder production is one of the alternative technique for higher fodder yield, year round production under waters scarce situation to address fodder constraint. It is an alternative technology against the scarcity of land and impeding climate changes in different agro-climatic regions in India. Hydroponic fodder has a profitable application in intensive, small-scale livestock situations with higher value outputs, where land and alternative feed costs are higher. The higher nutritive value of hydroponic fodder enhances milk, meat and overall development of livestock. The low cost hydroponic production unit will help Indian farmers to alleviate the fodder scarcity problem faced due to lack of land, labour and water resources. Hence, hydroponic fodder production is a viable, profitable and resource efficient technology.

Research Gaps in Hydroponic Fodder Production

a. Standerdizing low-cost hydroponic fodder unit with locally available resoucres

b. Need to evaluate nutrient content of hydroponic fodder from sowing to milking of animals to know benefit over conventional fodder crops

c. Need to evaluate production cost of different hydroponic fodder crops in different livestock systems

d. Quantification of per cent of water that can be recycled in the hydroponic fodder production to enhance water use efficiency

e. The concept of organic milk can be achieved by hydroponic fodder production

f. Standardization of ratio of cereal and legume crops in fodder production will help to attain balanced nutrition for livestock

g. Need to evaluate the feasibility of hydroponic system in growing conventional fodder grasses

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