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Review Article

HYDROPONIC FODDER PRODUCTION: AN ALTERNATIVE TECHNOLOGY FOR SUSTAINABLE LIVESTOCK PRODUCTION IN INDIA

Nonigopal Shit

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ABSTRACT: In India, livestock plays important role for the nutritional security particularly for the small and marginal farmers. Though, India represents as the highest livestock population and milk producing country, but only 5% of cropped land area is utilized for cultivating fodder and facing a deficit of 35.6% green fodder, 26% of dry fodder and 41% of concentrate feed ingredients. Rapid urbanization, climate change, water scarcity etc. are the momentum to search alternate system for green fodder production. Hydroponic is the best alternative which involves production of fodder without soil in a confined environment (hi-tech or low-cost device) and harvested at 7-8days period of time. It is gaining importance as it is used to guarantee a constant production of high quantity of green forage round the year for livestock. Seed for hydroponic cultivation is the major input and shares 90% of the total cost of production as compared to conventional system. Since the hydroponics fodder is more palatable, digestible and nutritious, it improves immune status of the animals and augments productive and reproductive performance of the livestock. Supplementation of 5-10kg hydroponic fodders per cow per day increases milk production by 8-13%; and meat quality based on the digestibility of the nutrients. Farmers can adopt small- or large-scale hydroponic production following low cost devices and sustain green fodder supplements round the year for profitable livestock production. Livestock farmers are to be educated and aware through capacity building programme for their keen interest towards importance of the hydroponic and green fodders for sustainable livestock production.

Key words: Livestock, Health, Production, Hydroponic Fodder, Conventional fodder, Agriculture.

INTRODUCTION

Production of the natural diet for livestock, Green Fodder, to meet the current demand has become a greatest challenge among livestock farmers. Fodder production cannot easily be increased due mainly to ever increasing human pressure on land for production of cereal grains, oil seeds and pulses. India statistically utilizes only 4.9% of gross cropped land for cultivating green fodders and facing a deficit of 35.6% green fodder, 26% of dry fodder and 41% of concentrate feed ingredients (Rachel Jemimah *et al.* 2015). They are the natural diet for animals which improves the fat percentage of milk through rumen digestion and production of volatile fatty acids (VFAs). Further, the green leaves are enriched with beta-carotene that helps in vitamin-A synthesis and plays greater impact on animal reproduction. Green fodder constitutes 13-35% of the total input cost out of total feed cost is about 70-75% of the total cost (Ramteke *et al.* 2019). Realizing the need and gap between demand and supply of the green fodder, Hydroponic fodder production technology has revolutionized the green fodder production in the 21st Century.

It is a science of growing plants in nutrient broth under controlled environment conditions without soil. It can be efficiently used to take pressure off the land to grow green feed for the livestock. This green source claims an increment of 8-13% in milk production and to be the best alternative technology for dairy animals with low cost materials in places where conventional green fodder production is limited (Prafulla *et al.* 2015). There is renewed interest in this technology due to shortage of green fodder in most of the Middle East, African and Asian countries.

Assistant Professor, Animal Science Section, Regional Research Station-Terai Zone, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar 736165, West Bengal, India.
**Corresponding author. e-mail: drnonigopal@gmail.com*

LIVESTOCK STATUS IN INDIA

In India Livestock contributes about 25% of the total agricultural GDP and plays a major role in livelihood generation of small and marginal farmers and landless labours agriculture-based economy (Ramteke *et al.* 2019). As per the 19th livestock census 2012, cattle share 37.59% of the total livestock population while buffalo, sheep and goat shows 19.89%, 13.51%, and 26.54% respectively. The growth rate has shown increasing trend in cattle (28.19%), buffaloes (142.72%), sheep (83.02%) and goat (197.76%) and the overall growth rate in livestock is 80.91% (GoI 2014). Fortunately, India stands first in total bovine population, milk and carabeef production in the world but the per head capita availability is low due to stumpy productivity. Green fodder is considered as vital inputs in livestock raising as it provides required nutrients for milk and meat production and helps to maintain the health of the animals. The National Dairy Development Board (NDDB) recommends that a cow yielding 8 to 10 litres of milk per day be fed 25-30 kg of green fodder, 4-5 kg of dry fodder and 4-4.5kg of concentrate per day during lactation (Jahagirdar and Saha 2007). The unavailability of quality green fodder adversely affects the productive and reproductive efficiency of the livestock. In view of this, hydroponic technology is an alternative to grow fodder for farm animals.

RATIONALE FOR SCARCITY OF GREEN FODDER

*Rapid urbanization caused decrease of land available for grazing and fodder cultivation.

*Fragmentation of land reduces land holdings.

*The farmer prefers to cultivate commercial and food crops over green fodder.

*Water scarcity as depletion of ground water label and inadequate irrigation facilities.

*Most farmers are poor and not able to fence their land which leads to free grazing cattle and wild animals enter the fields and causes menaces in the fodder field.

*Labour shortage is an acute problem in agriculture and animal husbandry allied activities such cultivation of green fodder, cutting, chaffing and feeding the same to the cattle.

*In forest fringed and coastal belt areas non-availability of land for forage cultivation.

THE HYDROPONIC FODDER

The concepts of hydroponic fodder are date back to the 1800s (Kerr *et al.* 2014) or earlier, from the 'Hanging Gardens of Babylon' era, when European dairy farmers fed sprouted grains to their cows during winter to maintain milk production and improve fertility (Anonymous 2008). The word hydroponic is derived from two Greek words: 'hydro' meaning water and 'ponos' meaning labour *i.e.* water working. It is a viable friendly alternative technology for landless farmers for fodder production without soil. It is also called fresh fodder biscuits, sprouted fodder or sprouted grain or alfa-culture (Dung *et al.* 2010). Fodders including maize, barley, oats, sorghum, rye, alfalfa, horse gram, ragi, bajra, jowar and triticale can be produced by hydroponic technology (Rachel Jemimah *et al.* 2015). This fodder seems like a mat with probably a height of 20-30cm consisting of roots, seeds and plants with highly palatable, digestible and nutritious for animals.

PRINCIPLES OF HYDROPONIC TECHNOLOGY

Hydroponics is growing of cereal grains with necessary moisture, nutrient without solid growing medium. Germination is a response for the supplied moisture and nutrient and produce 20-30 cm long forage green shoot with interwoven roots within 7-10 days. Different cereal grains *i.e.* maize, bajra, millets, horse gram etc. can be used for fodder production with varied chemical and structural changes throughout the growing processes. Enzyme activation is found necessary for hydrolysis of nutrients to their simpler forms. Grain variety, quality, treatments like nutrient supply, pH, water quality, soaking time etc are influencing factors for the amount of sprouted and quality fodder (Sneath and McIntosh 2003).

REASONS FOR HYDROPONIC FODDER PRODUCTION

Conservation of water

Hydroponic system minimizes water wastage since it is applied directly to the roots and is often recycled and used several times. The research findings concluded that hydroponic system equates to only 2-5% of water used in traditional fodder production system (Al- Karaki and Al-Momani 2011, Naik 2014). It has been reported that only 1.5 - 2 litre of water is enough for 1 kg hydroponic fodder production compared to 73, 85, and 160 litres of water to produce 1 kg green fodder of barley, alfalfa, and Rhodes grass under conventional field conditions respectively (Rachel Jemimah *et al.* 2015, Yvonne Kamanga 2016). This is especially important in those areas suffering from chronic water shortages or where the infrastructure for irrigation does not exist.

Precise use of Space

Hydroponic systems require much less space and makes ideal for urban dwellers with limited yard space (Fig. 1 and Fig. 2). Using hydroponics technology, up to 1000 kg maize fodder can be produced daily from 45-50 m^2 area which is equivalent to conventional fodder produced in 25 acres of cultivable land (Naik and Singh 2013, Rachel Jemimah *et al.* 2015). It is also easy to start a hydroponic system indoors where number of racks with multiple tiers thereby resulting in land preservation. Practically, one square meter area can produce ample fodder for two cows per day and the milk yield was increased by 13% (Yvonne Kamanga 2016).

Reduces growth time

Hydroponic technology takes only 8days to develop from seed to fodder where it took at least 45 days for a conventional fodder to grow.

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. One kg of un-sprouted seed yields 8-10 kg green forage in 7-8 days (Sneath and McIntosh 2003, FAO 2015). The hydroponics maize fodder yield on fresh basis is 5-6 times higher (Fig. 3) than that obtained in a traditional farm production and is more nutritious (Naik *et al.* 2014).

Source of essential nutrients

Compared to the un-sprouted seed, the content (DM basis) of crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF) and Calcium increased but organic matter and non-fibrous carbohydrates (NFC) decreased in the hydroponic green forage (Kide *et al.* 2015, Mehta and Sharma 2016). Hydroponic fodder is a rich source of vitamin A, vitamin E, vitamin C, thiamin, riboflavin, niacin, biotin, free folic acid, anti-oxidants like β-carotene (Finney 1982, Cuddeford 1989, Naik *et al.* 2015) and minerals (Bhise *et al.*1988, Chung *et al.* 1989, Fazaeli *et al.* 2012). The biomass conversion ratio is as high as 6-7 times that of the conventional green fodder grown for 65-80 days. Besides, hydroponic fodder is a good source of bioactive enzymes, essential fatty acids, chlorophyll and minerals (Table 1) which directly responds fodder growth and improves the performance of livestock (Chavan and Kadam 1989, Naik *et al.* 2015).

Persistent flow of green fodder

Fodder can be produced round the year irrespective of the failure of the monsoon, land availability, natural calamities and labour shortage that leads to sustainable agriculture and livestock production. This consistency perhaps ensures promising milk production and better quality of meat and other animal produce. Hydroponic fodder production is a way to substantially improve the quality of animal products (Maxwell Salinger 2013).

Reduced carbon footprints

Hydroponic is more environment friendly compared to traditional agriculture in relation to use of inorganic chemicals. This condenses GHGs emissions and lessens considerable global warming (Anonymous 2016). Hydroponic systems help in reducing the fuel consumption for transportation of product from distant agricultural farms and carbon emissions in turn.

Limits 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 no soil borne disease resulting minimizing use of pesticides, insecticides and herbicides. The susceptibility of any infection can easily be ruled out with specific compound in hydroponically grown fodder.

Impact on animal production

Hydroponic fodders are highly digestible, palatable and relished by the animals. They are highly succulent and can intake 1-1.5% 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.* 2013, Rachel Jemimah *et al.* 2015). Saidi and Abo Omar (2015) reported that hydroponic barley fodder (HBF) had no effect on feed intake, body weight change, milk yield, and milk composition but had positive effects on ewe's health, mortality, conception rate and abortion. No adverse effect was noticed on average daily gain (ADG) and feed conversion ratio (FCR) in kids and rabbit kittens fed hydroponic horse gram or sunn hemp fodder replacing 50% of a concentrate mixture (Rachel Jemimah *et al.* 2015). Reddy *et al.* (1988) observed significant increases in the digestibility of nutrients in lactating cows fed hydroponic fodder compared to those fed Napier bajra (NB-21) green fodder. The daily milk yield was 8.0-14.0% higher in animals fed total mixed ration (TMR) containing hydroponic maize or barley fodder than those fed conventional green fodder (Rachel Jemimah *et al.* 2015, Yvonne Kamanga 2016). The hydroponic fodder tunes longer lactation period, improve fat percentage and

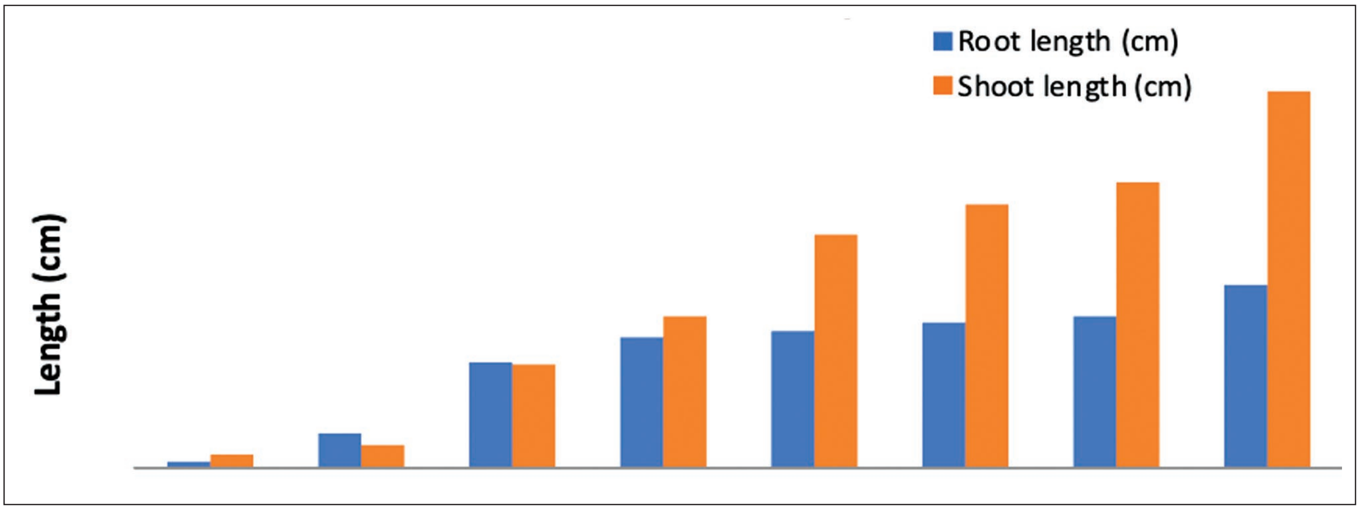

Fig. 1. Comparison of root and shoot length (cm) in fodder maize under hydroponic fodder production system (TANUVAS 2015).

general herd health. Besides increased milk yield, conception rate, herd health and longevity were also improved as well as reduce the cost of veterinary aids (Naik *et al.* 2015). The fast-growing poultry industry gains some benefits on hydroponic fodder *i.e.* faster weight gain, good quality carcass, lower feed cost per kg of weight gain and improve health and production potentials (Rachel Jemimah *et al.* 2015). Nutritional composition of different hydroponic fodders and their nutrient digestibility are well evident for the better livestock use and production (Table 2 and 3).

HEALTH HAZARDS ON INFECTED HYDROPONIC FODDER

Hydroponic fodder heavily infested with *Aspergillus clavatus* should not be fed to dairy/beef cattle. Animals may develop posterior ataxia, knuckling of fetlocks, dragging of hind legs, high stepping in the hind limbs, stiff gait, tremors, progressive paresis, hypersensitivity, recumbency, clonic convulsions, decreased milk yield and possibly death (McKenzie *et al.* 2004).

LAND FOR HYDROPONIC TECHNOLOGY

Hydroponic technology is used in harsh climates such as deserts, areas with poor soil or in urban areas where high land costs have driven out traditional agriculture. It is probably best-suited to semi-arid, arid, and drought-prone regions of the world, suffering from chronic water shortages or in areas 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. Destruction of fodder by stray cattle's and wild animals, higher cost of labour for cultivation practices and poor participation of educated unemployed youths for fodder farming are the thrust area to assume hydroponic fodder production.

METHODOLOGY OF HYDROPONIC FODDER PRODUCTION

Seed storage, preparation and washing

In the hydroponic fodder production system, the seed cost contributes 85-90% of the total cost of production (Naik *et al.* 2014, Rachel Jemimah *et al.* 2015). It comprises procuring clean, sound, intact, untreated, viable seeds/grains of high quality (Sneath and McIntosh 2003, Naik *et al.* 2015). Seeds are dried directly under sun light one day prior to seed washing. Seeds are washed thoroughly for 5 minutes with tap water till all dirt and poor-quality seeds are removed. The seeds of various fodders are soaked in stimulant solution (0.1-1.5% sodium hypochlorite or 1-2% hydrogen peroxide solution for a period of 20, 12, 10, 6 and 15 hours for maize, jowar,

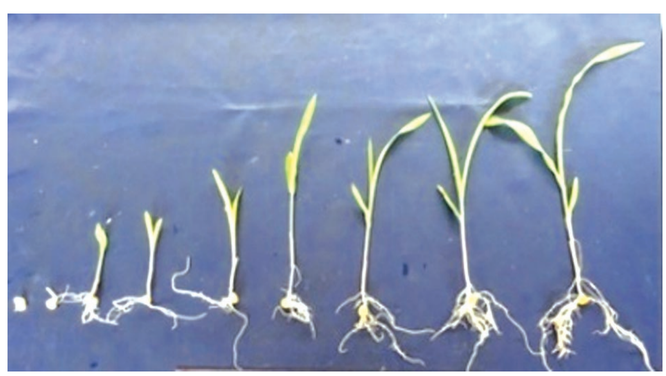

Fig. 2. Developmental stages of hydroponic fodder (Maize) from 0 to 8 days (TANUVAS 2015).

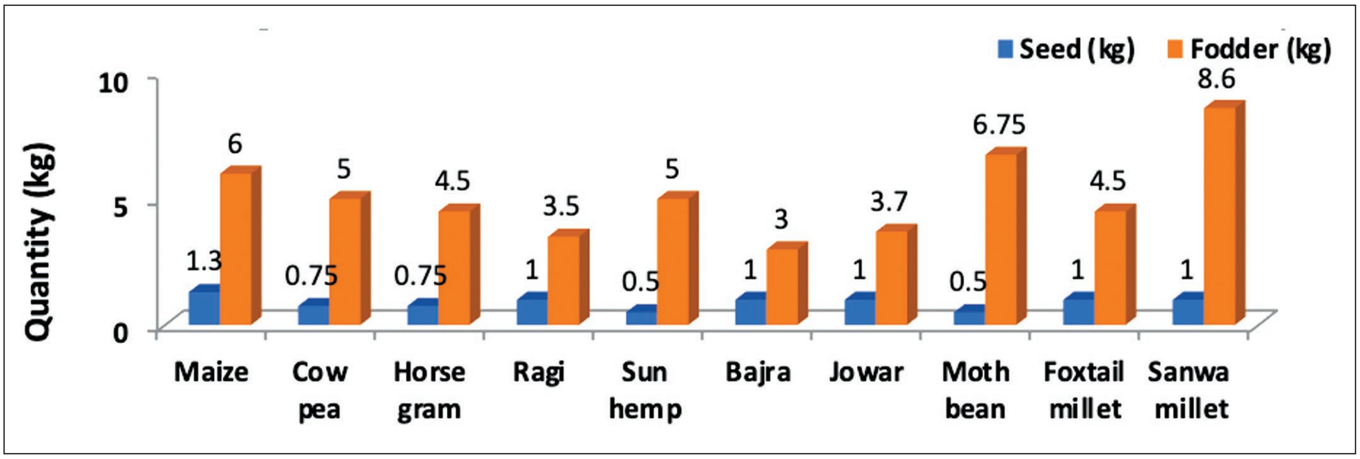

Fig. 3. Production details of different types of fodder under hydroponic fodder production system (TANUVAS 2015).

Fig. 4. Large scale (A, B, C) hydroponic fodder production (Maize) by hydroponic fodder production system for livestock use.

barley, wheat and bajra respectively (Rachel Jemimah *et al.* 2015).

Seed cleaning

The seeds should be cleaned in 0.1-1.5% bleach solution (sodium hypochlorite) or 1-2% hydrogen peroxide solution for 30-60 minutes (Rachel Jemimah *et al.* 2015, Starova Jeton 2016). 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 (Naik *et al.* 2014), 8 h (Starova Jeton 2016), 12-16 h or overnight (El-Deeba *et al.* 2009, Al-Karaki and Al-Momani 2011, Brownin 2017), 24 h (Shashank Sinsinwar *et al.* 2012, Reddy 2014) depending on the hardness of the seed coat. Temperature of the water or solution used for soaking also affects the germination rate. The optimum temperature at soaking is 23ºC (Sneath and McIntosh 2003).

Germination of seed

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 seed rate (quantity of seeds loaded per unit surface area) which varies with the type of seeds also affects the yield of the fodder. The recommended seeding rate for production of hydroponic barley, wheat or sorghum fodder is 4-6 kg/m^2 (Al-Karaki and AlMomani 2011, Starova Jeton 2016) and for maize 6.4-7.6 kg/m^2 (Naik and Singh 2013, Naik 2014, Naik *et al.* 2017).

Loading seeds in trays and racking

A specially constructed frame made of GI pipes or

Environment controlled hydroponic fodder production.

Low cost hydroponic fodder production.

Fig. 5. A comparison of environment controlled and low-cost hydroponic fodder production system.

angle bars is erected to hold plastic trays measuring 18" x 32.5" x 2" in which 1-1.25 kg of seed can be placed to produce about 5.5-7.5 kg of green fodder. Other standard size of trays such as 41" x 41" x 7", 53" x 53" x 7", 29"x 53" x 7" are also available in the market. The seed trays are clean, washed with cleaning solution & are free from any dust / dirt etc. After germination of seeds, trays are transferred and put them in the sprout section (lower section where the height between two rows is around 5 inches). Finally, trays should be distributed evenly on both sides of the alley.

Shifting trays and harvesting

The germinated seeds are irrigated with fresh tap water or nutrient enriched solution (Table 4). The trays should never be exposed to direct sunlight, strong wind and heavy rain. During the growing period, the seeds are kept moist by drip or spray irrigation but are not saturated. Shift trays to the next level daily so that it moves one step ahead in the growth cycle. Take the last tray out from every row and put it back on the front side of the same row. If left side tray shows more growth, rotate the tray to the right and vice-versa. On 9th day, the fodder mat is harvested from the tray and feeds to the livestock. The trays are washed with cleaning solution before reuse it for the next cycle.

NUTRIENT SOLUTION FOR HYDROPONIC PRODUCTION

A nutrient solution for hydroponic systems is an aqueous solution containing mainly inorganic ions which play vital physiological role to complete plant life cycle (Taiz and Zeiger 1998). Currently, 17 elements *i.e.* carbon, hydrogen, oxygen, nitrogen, phosphorus, copper, potassium, calcium, magnesium, sulphur, zinc, manganese, molybdenum, boron, chlorine and iron, nickel are considered essential for most plants (Salisbury and Ross 1992). Other elements *i.e.* sodium, silicon, vanadium, selenium, cobalt, aluminum and iodine are also considered beneficial as they stimulate the growth or can compensate the toxic effects of other elements or may replace essential nutrients in a less specific role (Trejo-Téllez *et al.* 2007).The nutrient composition determines essential pH, electrical conductivity and osmotic potential of the solution.

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 (El-Deeba *et al.* 2009, Starova Jeton 2016). The electricity requirement for the production of hydroponic fodder is much lower than for traditional fodder production. The final stage of harvesting for barley seed sprouts is 6th day of sowing when it reserves the highest nutrient and biomass yield. Besides, amongst all the hydroponic fodders *i.e.* sprouted barley, oats, rye, triticale and wheat the sprouted barley has the highest forage quality (Heins *et al.* 2015).

PRECAUTIONS FOR HYDROPONIC TECHNIQUES

*Seed treated with pesticides and fungicides should not be used for cultivation.

*The water should be replaced at every 3 days to reduce microbial contamination.

*In order to reduce contamination and fungal growth cleanliness, washing and cleaning should be performed as prescribed. Fungicides should best be avoided as any residue may adversely affect health of animals.

*White maize seed better as compared to yellow maize for hydroponic fodder production.

*The seeds should be procured from certified organization and to be used for cultivation.

*The green shed net is important for aeration and lighting to prevent yellowing of the leave because green shade net allows sufficient light and maintain favourable temperature and humidity for optimum photosynthesis which results better yield of hydroponic fodder.

NUTRITIVE VALUE OF HYDROPONIC FODDERS

Hydroponic fodder from cereal grains deviate in their nutrient content (Fazaeli *et al.* 2011). Once the starch content decreases, both organic matter and dry matter content are decreased. Sprouting catabolises starch in to soluble sugar during biochemical processing of the plants. However, ether extract of hydroponic fodder increases due to increment of structural lipids and chlorophyll as the plant grows. There is also increment in concentration with sprouting. Development of structural carbohydrates increases the concentration of crude fibre (CF), neutral detergent fibre (NDF), acid detergent fibres (ADF) and linoleic acid but decreases nitrogen free extract (NFE). Sprouting process increases total ash content associated with decrement of organic matter. Root growth which increases the mineral uptake increases the mineral content of the sprout from day four and evidently more as nutrient solution is used than water (Dung *et al.* 2010).The nutrient quality of hydroponic fodder is superior over common non-leguminous fodders in terms of crude protein (CP), organic matter, ether extract (EE) and NFE.

Table 1. Plant analysis report of hydroponic fodder (maize) on dry matter basis (Ramteke *et al.* 2019).

Nutrients	Composition	Nutrients	Composition
Moisture	89%	Nitrogen	4.6%
Calcium	0.167%	Protein	29.87%
Magnesium	0.246%	Sodium	0.117%
Potassium	2.22%	Phosphorus	0.91%
Manganese	53 mg/kg	Copper	28 mg/kg
Zinc	56 mg/kg	Iron	235 mg/kg

However, the energy uptake during respiration of the plant, the gross energy (GE), metabolisable energy (ME) and total digestible nutrient (TDN) content decreases (Al-Ajmi *et al.* 2009).

A number of studies reported that sprouting resulted 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 (Sneath and McIntosh 2003, Dung *et al.* 2005, Fazaeli *et al.* 2012, Putnam *et al.* 2013). Seed soaking activates enzymes that convert starch stored in endosperm to a simple sugar which produces energy and gives off carbon dioxide and water leading to loss of DM with a shift from starch in the seed to fibre and pectin in the roots and green shoots.

The sprouts are the most enzyme rich plants and maintain highest level from germination to seven days age. They are rich with antioxidants especially â-carotene (Sneath and Mclntosh 2003). In terms of palatability, there is no wastage of nutrients as the shoots and roots both are consumed together. Dairy animals can be fed 25 kg/day based on the physiological status with low concentrate and roughage.

HYDROPONIC FEED ON LIVESTOCK PRODUCTIVITY

Milk production

Studies on improvement of milk production through hydroponic fodder feeding shows improvement than animals fed cereal grains, hay or silage. Hydroponic fodder increase milk yield by 10.07% (Reddy *et al.* 1988), 12.5% (Anonymous 2012) and 13.73% (Naik *et al.* 2013) due to feeding of hydroponic fodders to lactating cows. 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 litres of milk after a leave off of 6.8 kg fed per day (Mooney 2005). The feedback from the farmers of the Satara district of Maharashtra revealed increase in the milk yield by 0.5 - 2.5 litres per animal per day and net profit by INR 25-50/- per animal per day due to feeding of hydroponics fodder to their dairy animals (Bakshi *et al.* 2017). The principal component analysis (PCA) revealed that dietary hydroponic supplementation increases milk fat percentage and pH with superior quality of milk (Agius *et al.* 2019). Mincera *et al.* (2009) reported an improvement in welfare and milk yield in Comisana sheep feed on hydroponically germinated oats.

Table 2. Nutritional composition of different hydroponic fodders on dry matter basis for livestock use (TANUVAS 2015).

Sl No	Hydroponic fodder	Moisture (%)	CP	CF	EE	TA	NFE
1	Maize	76.75	10.55	5.51	4.62	1.80	77.52
2	Cow pea	77.93	27.84	6.51	1.93	4.88	58.84
3	Horse gram	90.18	30.26	13.00	2.06	5.43	49.25
4	Ragi	87.86	10.62	8.80	2.52	2.95	75.11
5	Sun hemp	77.07	38.73	13.11	4.64	4.48	39.04
6	Bajra	74.80	9.22	4.16	4.57	1.49	80.56
7	Jowar	90.06	13.27	13.39	4.99	2.98	65.37
8	Moth bean	94.37	38.83	18.91	2.63	6.61	33.02
9	Foxtail millet	75.08	14.69	12.11	5.38	3.59	64.23
10	Sanwa millet	86.40	10.70	19.61	4.39	11.60	53.70

Meat production

Hydroponic fodder improves the body weight gain of lambs which may be realized due to presence of high bioactive enzymes and ingredients that improve livestock performances (Naik and Singh 2013). Moreover, the increase in body eight also reflects microbial activity in rumen and enhanced nutrient digestibility. In beef cattle, average increase of 200 g is achieved through feeding of hydroponic fodder than maize. Similarly, 8% improvement in body weight gain is reported in birds and other animals (Muhammad *et al.* 2013). Better body weight gain was recorded in cross breed calves (Rajkumar *et al.* 2017), Awassi lambs (Atta 2016) and goat (Kide *et al.* 2015a) fed hydroponic maize and barley fodder respectively.

Overall performance

Hydroponics fodder has more potential health benefits. Sprouts are the most enzyme rich food on the planet and the period of peak enzyme activity lies between germination and 7-8 days of age. They are rich source of natural anti-oxidants *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 (Fig. 4). Besides this, helping in the elimination of the anti-nutritional factors such as phytic acid, oxalic acid and other toxicants of the fodder (Chavan and Kadam 1989, Sneath and McIntosh 2003, Shipard 2015).

INDIAN STATUS OF HYDROPONIC FODDER TECHNOLOGY

Hydroponic technology is a highly sophisticated, fully automated fodder production system where the pre-requisite factors *i.e.* water, temperature, light intensity, humidity and aeration are fully controlled by sensors. The provision of water recycling has made the technology more precise and useful. In India, Government established 11 hi-tech hydroponic units under Rashtriya Krishi Vikas Yozna (RKVY) at the ICAR-Research Complex, and Dairy Co-operatives of Goa State. Likewise, the Kerala Dairy Development Department (KDDD) has introduced a scheme to produce hydroponic green fodder and distributed 24 hydroponic fodder units to selected dairy farmers. The Directorate of Centre for Animal Production Studies and Research farm under TANUVAS have started commercial hydroponic production.

ECONOMICS OF HYDROPONICS

Traditional fodder production requires a major investment for the purchase of land in addition to the investment of agricultural machinery, equipment, infrastructure for harvesting including handling, transportation and conservation of fodder. It also requires labour, fuel, lubricants, fertilizers, insecticides, pesticides and weedicides. On the other hand, hydroponic fodder production requires only seed and water as production inputs with modest labour inputs. Further, it minimizes post-harvest losses without requirement of fuel. Likewise, this novel technology takes only 7-8 days to converts seeds into fodder compared to fodder production by traditional system. Obviously, the initial investment for this hi-tech sophisticated technology is much higher and is highly vulnerable to mold growth which needs further investment to control this unwanted growth. According

Table 3. Effect of supplementation of hydroponics maize fodder on digestibility of nutrients and milk yield of dairy cows (Naik 2013).

Sl. No	Parameters	Hydroponics fodder
Digestibility (%)		
1	Dry matter (DM)	61.15
2	Organic matter (OM)	64.20
3	Crude protein (CP)	68.86
4	Ether extract (EE)	82.05
5	Crude fibre (CF)	53.25
6	Nitrogen free extract (NFE)	67.37
Nutritive value (%)		
1	Crude protein (CP)	12.48
2	Digestible crude protein (DCP)	8.61
3	Total digestible nutrients (TDN)	64.00
4	Milk yield (kg / day)	4.084

Table 4. Concentration ranges of essential mineral elements for nutrient solutions (Windsor and Schwarz 1990).

Nutrient (mg L^{-1})	Hewitt (1966)	Cooper (1979)	Steiner (1984)
Nitrogen	168	200-236	168
Phosphorus	41	60	31
Potassium	156	300	273
Calcium	160	170-185	180
Magnesium	36	50	48
Sulphur	48	68	336
Iron	28	12	2-4
Copper	0.064	0.1	0.02
Zinc	0.065	0.1	0.11
Manganese	0.54	2.0	0.62
Boron	0.54	0.3	0.44
Molybdenum	0.04	0.2	Not considered

to Reddy *et al.* (1988) and Naik *et al.* (2014), the feed cost/kg milk was higher when animals were fed maize fodder produced from a hi-tech hydroponic system mostly due to higher cost of hi-tech hydroponic fodder production (Rs 4.0 - 4.50/kg). However, farmers of the Satara district of Maharashtra found that the cost of milk production of hydroponic fodder was reduced remarkably to Rs. 2.0 - 3.50 per kg (Naik *et al.* 2013) in a low-cost shade net system with home grown or locally purchased seeds. Accordingly, when fodder was produced in low cost hydroponic system, the feed cost/kg milk was reduced by 25-30% and net profit was improved (Boue *et al.* 2003, FAO 2015, Rachel Jemimah *et al.* 2015).

LOW COST SHED-NET SYSTEM

Hydroponic fodder production is one of the low-cost technologies to increase green fodder production by vertical farming which requires less land, water as well as manpower. A low-cost hydroponic fodder unit may be designed in an area of 100 ft^2 with metal sheet as roofing material with shade net on all the sides to produce hydroponic fodder. The unit consists of a four-tier system with iron angles for holding 48 plastic trays, each of dimension 60×40×8 cm and holding capacity of 1.25 kg maize seed. Fodders were cultivated in plastic trays for 9–10 days and irrigated manually with tap water six times a day (Fig. 5).

According to Gunasekaran *et al.* (2019),

*Though better biomass is obtained in hydroponic fodder maize with base materials, the growth of hydroponic fodder maize resulted in entangled root portion with base materials which resulted in wastage of fodder for feeding the livestock.

*Among the above treatments, 70% shade net as roof yielded the maximum biomass of 3.50 kg of hydroponic fodder /kg of maize seed compared to concrete, thatched or asbestos roof.

*The recorded biomass yield at the dilution of 2.5% biogas slurry as nutrient was statistically higher (4.48 kg) compared to other treatments *i.e.* 5%, 7.5%. In contrast to this study, Nugroho *et al.* (2015) produced hydroponic fodder maize with higher level of biogas slurry (25%) as nutrient solution for feeding dairy cows.

*The biomass yield recorded after nine days was found to be higher (4.16 kg) in 300 g/ft^2 compared to other seed rate.

RESEARCH SCOPE OF HYDROPONIC TECHNOLOGY

Standardization of low-cost hydroponic technology using locally available resources.

Estimation of germination rate based on seed soaking time and other factors.

Evaluation of nutrient contents, digestibility of

hydroponics green fodder sowing to increase milk and meat production.

Evaluation of production cost for different hydroponic fodders in livestock production.

Assessment of fertility performance, growth performance and immune status in young animals upon feeding of different hydroponic fodders.

Start-up of organic milk production.

CONCLUSION

One of the agro-technology which could be developed locally with low cost materials and is more nutritious, palatable and digestible fodder for livestock is hydroponics. In developed countries, where there is no dearth of quality feed and fodder, the technology is less competitive than traditional fodder production on per kg dry matter basis. It stands a smart alternative technology against scarcity of land and impeding climate changes in different agro-climatic regions in India. 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. High initial investment on fully automated commercial hydroponic systems and high labour and energy costs in maintaining the desired environment in the system added substantially to the net cost of hydroponic fodder production. Conversely, low cost hydroponic systems have been developed by utilizing locally available infrastructure where there is an acute shortage of fodder and water, transportation and fuel costs are high and seasonal variations of fodder prices are extreme. Under such situations the cost structure is often shifted in favour of hydroponic fodder production, and it becomes the best alternative for sustainable livestock production.

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