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Hydroponic Fodder Production in India

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Preface

India has 56.7 percent of world's buffaloes, 12.5 percent of cattle and 20.4 percent of small ruminant population. While we are the largest milk producer in the world, our average production of milk (and also of meat) per animal is much lower than the world average. One of the reasons for this is that the genetic potential of our indigenous germplasm has not been fully utilized due to poor nutrition, breeding and health management. The facts that deficiency of feed and fodder alone account for nearly 50 percent loss in livestock production and that 60-70 percent of expenditure on milk or meat production is on feeding, the livestock nutrition deserves our priority R & D attention. As of now only about 4 to 5 percent of the cultivable land is available for forage cultivation. We are not able to provide adequate and nutritious feed to our livestock and the shortage of feed and fodder continues. Needless to say that feeding of quality green fodder and forages not only result in higher milk production, the quality of milk in terms of CLA, Omega 3 and vitamin contents are also high, making it health promoting for the children and adults consuming milk.

Considering the continuing shortage of quality green fodder and constraints in diverting more land for forage production, production of hydroponic green fodder could be an option especially in hilly and arid regions. The hydroponic green fodder/sprouted feed rich in nutrients including protein, vitamins and micronutrients could be fed as supplement for enhancing both quality and quantity of the milk.

Keeping this important issue in view, a brainstorming session (BSS) on "Hydroponic Fodder Production in India" was organized on July 5, 2014 to identify the strategies, policy options, R & D issues to augment quality green fodder in peri-urban and rural areas for sustainable livestock production.

The Academy appreciates the efforts of the conveners; Dr H.S. Gupta and Prof M.P. Yadav in convening this important session, and compliments the contribution of the participants. I trust that this publication will lead the way towards developing research agenda on hydroponics in the country. The editorial support extended by Dr K.K. Vass and Dr V.K. Bhatia is appreciated.

(Panjab Singh)
President

Hydroponic Fodder Production in India

1. INTRODUCTION

The livestock population in India showed consistent increasing trend subsequent to the 1st Census conducted in 1951 and the 19th Census completed in 2012 (DAHDF, 2012). During this period, the number of cattle increased by 24%, buffaloes by 151%, sheep by 66%, goats by 186% and pigs by 134%, while there was a decline in the equine and camel population by 60% and 33%, respectively. Thus, the total livestock (LS) population increased by 75% (on an average 1.23% per year) during this period. The poultry population increased by about 892% (14.62% per year average) between 1951 and 2012. Economic viability of livestock keeping in India is dependent on their genetic potential for production, livestock husbandry practices, animal management, health protection, feeding and nutrition. About 60-70% of the total cost of livestock farming is attributed to feeding alone. Therefore, efficiency of livestock production and the prosperity of the farmer is directly related to the availability of quality feeds, fodders and forages in adequate quantity.

However, conflict of interest for land availability for production of food, feed, fodder, fiber, fuel and various developmental projects put livestock at disadvantage. Amidst this scenario, it is unlikely that more land will be available in future for feed and fodder production or for grazing and pastures. Hence, innovative technology, like hydroponic fodder production requiring less water, land and energy could be an option for producing quality green fodder/ feed, particularly when it is not possible to produce/provide green fodder and forages due to paucity of land, water, climatic conditions or other factors.

India is largest producer of milk in the world since 1998, registering a record production of 155.5 million tons in 2015-16 (DAHDF, 2016). The per capita availability of milk at 130 g/ day in 1950-51 increased to 337 g/day in 2015-16. However, the productivity per animal is low as compared to developed countries or world average for which inadequate and imbalanced nutrition including green fodder is the major limiting factor. Since there is little scope for horizontal expansion of land for fodder production, pasture development or grazing, there is need to promote hydroponic fodder production (HPFP) system. The hydroponic technique has the potential for meeting fresh green fodder requirement for livestock.

2. FODDER AND AREA UNDER PRODUCTION

Fodder crops are the plant species that are cultivated and harvested for feeding the animals in the form of forage (cut green and fed fresh), silage (preserved under anaerobic condition) and hay (green fodder dehydrated in shade). Green fodder is an integral component of nutrition for livestock and a natural diet for dairy animals. It improves both the productivity as well as quality of milk. Green fodders are known to enhance the content of poly- unsaturated fatty acids, *viz.* omega-3; vitamins, minerals and carotenoids. Ancient livestock practitioners advocated green fodders and pasture grazing for cows.

The total area under cultivated fodders in India is approximately 8.3 million ha (mha) on individual crop basis (NAAS, 2016). Sorghum amongst the *kharif* crops (2.6 mha) and Berseem (Egyptian clover) amongst the *rabi* crops (1.9 mha) occupy about 54% of the total cultivated fodder cropped area. The area under permanent pastures and grazing lands has been declining over the years and this trend is likely to continue in the future too. Presently, the land availability for fodder production and pastures is a meagre 4-5 per cent of the cultivated area. Due to overgrazing and other factors, the productivity of the pastures has been declining. The area under fodder crops has almost remained static for the last 3-4 decades (DAHDF, 2015). However, the demand for fodder has increased especially in peri-urban areas that have developed as milk sheds under intensive dairy production systems in recent years. Sizeable proportion of fodder demand is fulfilled through grasslands and rangelands (NAAS, 2016).

3. CONSTRAINTS IN FEED AND FODDER PRODUCTION

3.1 Gaps in demand and supply

Livestock production, productivity and profitability in India suffer because of the huge gap between demand and supply of fodder and feed. As per the estimates, it has been predicted that demand and supply of fodder (from 1995 to 2025) would fall short from about 60-65% for green and around 20- 25% for dry fodder (Table 1 and 2). Presently, deficiency of feed and fodder combined is about 50%, accounting for about half of the total loss in livestock production.

Table 1: Estimates of demand and supply of fodder resources in India (m.t.)

Year	Supply (m.t.)		Demand (m.t.)		Deficit of demand (%)	
	Green	Dry	Green	Dry	Green	Dry
1995	379.3	421	947	526	59.95	19.95
2000	384.5	428	988	549	61.10	21.93
2005	389.9	443	1,025	569	61.96	22.08
2010	395.2	451	1,061	589	62.76	23.46
2015	400.6	466	1,097	609	63.50	23.56
2020	405.9	473	1,134	630	64.21	24.81
2025	411.3	488	1,170	650	64.87	24.92

Source: Anon (2001) and Khanna, R.S. (2014).

Table 2: Deficit of feed and fodder in India (2007)

S.No.	Type of fodder/feed	Demand* (m.t.)	Availability* (m.t.)	Gap (m.t.)
1.	Dry Fodder	416	253	163 (40%)
2.	Green Fodder	222	143	79 (36%)
3.	Concentrate	53	23	30 (57%)

*Source: (NABCONS-2007); (DAHDF, 2014); * Calculated on dry matter basis in million tons*

Availability of fodder, both dry and green, has not been commensurate with the requirement. Though the projected requirement of fodder has increased by more than 50%, the fodder availability is estimated to have increased by only 14.5% between 2001 and 2006 (IGFRI, 2011). The projected shortage by 2020 for green fodder and dry fodder are to the tune of more than 64% and 25%, respectively (Table 1). When converted into absolute terms, this deficit works out to 728 million tons in respect of green fodder and 157 million tons in respect of dry fodder (IGFRI, 2011). According to Ghosh and Mahanta (2014), currently there is a net deficit of 35.6% for green fodder and 10.9% of dry fodder. By 2020, the shortages for green fodder, dry fodder and concentrate feeds are expected to be 45%, 11% and 35%, respectively.

Estimates made between1985-86 and 2005-06 indicated improvement in the availability of feed resources in the country which varied from area to area. The country as a whole recorded 52% (240.7 to 365.8 mt), 76.0% (19.6 to 34.5 mt) and 1.8% (124.3 to 126.6 mt) increase in dry forages, concentrate feeds and green forages, respectively (NAAS, 2016). However, despite this increase, the gap persisted in the availability and the requirement of feed and fodder. The deficiency was worked out to be 46.2% and 44.2%, respectively in terms of digestible crude protein (DCP) and total digestible nutrients (TDN) (ICAR, 2013).

India with about 2.3% of the land area of the world, supports about 10.71% of the world's livestock population (DAHDF, 2015), which is expected to grow at the rate of around 1.23% in the coming years. By 2030 it is estimated that the demand for green fodder and dry fodder will be 1,207 and 671 million tons, respectively; thus, resulting in 66% deficit for green fodder and 25% deficit of dry fodder. To fill the gap, the green fodder production needs to grow at 3.2% (IGFRI, 2011).

3.2 Constraints of grazing land & policy

The major policy related issues for the shrinkage and degradation of common grazing lands are (i) transfer of land for developmental purposes, (ii) allocation of land to landless, (iii) need for bringing more land under irrigation and shift in crop preference, (iv) non-sustainable use/ overgrazing, and (v) lack of a National Pasture and Grazing Policy. In the absence of suitable policy on pasture and grazing lands and fodder seeds, unilateral implementation of animal husbandry policy permitting increase in the number of livestock without corresponding focus on developing fodder resources has resulted in further degradation of the pastures and fodder resources.

4. EXISTING POLICY ON FODDER DEVELOPMENT

To overcome the problems of fodder shortages, the Central and State governments have taken up special programmes for the promotion and development of fodder which includes (i) development of State Fodder Seed Farms for the production of foundation/certified seeds; (ii) establishment of silvipasture system for forage bio-mass production; (iii) development of grass lands and grass reserves; (iv) establishment of fodder banks; (v) supply of mini-kits of fodder seeds to the farmers; and (vi) enrichment of straws and cellulose waste. Under the first four programmes, the farmers are given funds for strengthening of infrastructure for growing fodder and production of fodder seed. Similarly, farmers receive assistance under the last two schemes in terms of fodder seed mini-kits, equipment and other materials.

The existing eight Regional Fodder Stations (RFS) of the DAHDF, GoI located in different agro-climatic zones of the country, have the mandate of producing foundation seed of fodder crops which are provided to the State governments to produce certified seeds to be made available to dairy farmers for fodder production, for which funds are available under National Livestock Mission (NLM). Funds are also available under RKVY and MNREGA schemes for improving availability of fodder. Support for coarse cereals is available under National Food Security Mission (NFSM) from 2014-15.

5. STRATEGIES FOR INCREASING GREEN FODDER PRODUCTION

Multipronged strategies, such as production of quality seeds of fodder crops and grasses (breeder, foundation, certified, truthfully labeled) in sufficient quantities by establishing producer companies in collaboration with private sector agencies, creation of fodder seed banks at village level; utilizing vast area of wastelands, estimated to be over 122 mha for fodder and fodder seed production, rejuvenation of common property grazing/pasture lands in rural areas; minimum support price and insurance for fodder crops, differentiated area-based approach for cultivation of green fodder, creation of authentic data-base on fodder resources with regular update, and having a national grazing-cum-fodder, pasture and range land management policy are required for enhancing the production of green fodder and forages.

Despite extensive efforts being made by the central and state agencies, fodder shortage continues to be a major constraint in dairy industry. This shortage is in green as well as dry fodder both. It is, therefore, imperative to look for alternative methods of fodder production especially green fodder. Green fodder production through hydroponic technique is one of the efficient and economic methods. In this background, the National Academy of

Agricultural Sciences on July 5, 2014 organized a BSS on this important issue under the convenership of Dr H.S. Gupta and Prof M.P. Yadav.

6. THE HYDROPONICS

Hydroponics fodder production has two aspects a) physiology and nutrition of plant-animal system and b) engineering of hydroponic technology. The term 'hydroponics' is derived from Greek word 'Hydro', which means 'water' and 'Ponic' (working). Thus, hydroponics is the science of soilless growing of plants in nutrient rich solutions at regulated temperature and humidity. With this technique, the physiological requirement of plant is met without use of soil and natural sunlight. Though the technique of hydroponics for growing plants dates back to 1930, the renewed interest, being shown by the R&D institutions in India and abroad, is because of acute shortage of land and increasing value being attached to water for cultivation of food and fodder crops. In the conventional system, seed starts germinating when it gets favourable conditions, like water/moisture, air, temperature and light. A seed utilizes maximum energy from the nutrients stored in it for developing radical (roots). However, very less amount of energy is utilized for the growth of the plumule (shoot). Therefore, in hydroponics technique, favourable conditions are provided to the seed so that the nutrients stored in the seed are directly utilized for development and growth of the plumule. The hydroponic technique differs from the aeroponic method which also involves growing plants without soil, but instead of growing plants in a growing medium (plant nutrients dissolved in water), the roots of plants are suspended/hung in dark chamber and periodically sprayed with nutrient rich solution (mist culture).

6.1 Advantage of hydroponic feed/fodder

Hydroponics technique has proven useful and efficient for producing quality fodder/feed for livestock. The technique is advantageous when compared with conventional agriculture because it controls the climatic conditions as well as plant nutrition. Hence, it is possible to get increased production, stable harvests of high quality fresh green fodder all the year round, and can be produced on a commercial scale. The hydroponic fodder/feed is produced under completely controlled conditions and is thus free from undesirable materials such as weeds, insects, dust, insecticides, pesticides, germicides and carcinogens. Hydroponics culture is probably the most intensive method of crop production in today's agricultural industry. With the possibility of adjusting air and root temperature, light, water, plant nutrition and adverse climate, hydroponics can be made highly productive, conserving water and land, and protective of the environment. The HPFP technology has several advantages, such as producing highly nutritious fodder rich in vital nutrients, minerals, proteins, amino acids and having better palatability and digestibility; saving water, soil, time and labour. It can ensure round the year production of quality fodder/feed free from pathogens, residues of pesticides or chemicals, fungal or mycotoxins contamination; pest and diseases; freedom from weeds and contaminants; faster growth and higher yields in less time, and control over the growing environment. It helps in improving the health, productivity, fertility and longevity of livestock. One more reason for the need for adopting HPFP is the increasing diversified use of agricultural residues for bio-fuel production, raw material for industry etc. Some other qualities of hydroponic fodder (HPF) include: uniform quality, taste, tender, fresh and green fodder; having high acceptability by the animals, being palatable and succulent. In addition, it saves cultivable land, water, labour, post-harvest overheads along with the worries arising from uncertainties of fodder supplies due to inclement weather, drought, flood etc. It is possible to achieve better than normal fodder production through hydroponic technique in about 5% of the land and water requirement as compared to conventional production system.

6.2 Indian experience in HPFP

India imported 'Fometa' machines during 1980s to conduct test trials for production of fodders through the hydroponic technique. These machines required certain strict regimentation such as maintaining the temperature at 22 ± 2°C, installation of fluorescent tubes for photosynthesis and continuous power supply. In addition, the cost of the machines was prohibitively high and could not be promoted for rural application or for commercial production of fodder. During 2006, the Ayurvet Research Foundation (ARF) sponsored a project to a College of Engineering &Technology to develop an indigenous hydroponics machine. From the prototype so developed, the ARF, Ayurvet Ltd. developed commercially viable machines. In Ayurvet's hydroponics machine, green fodder is grown in controlled environmental conditions with a temperature range of 15-32 ºC, and a relative humidity of 80-85%. The green fodder/feed is also grown in multilayer shelves. Natural light is provided through suitably glazed windows. Specially prepared nutrient "NUTROSOL" and herbal solution "HERBOSOL" are used for the growth of plants and seed treatment, respectively. The bio-conversion ratio was found to be 6-8 times. Ayurvet's Pro Green Hydroponics machine was also found suitable to produce wheat grass, paddy and sugarcane nursery (Unpublished data; Ayurvet Research Foundation Ltd. India).

A few institutes/organizations in public/private sector, including ICAR Research Complex, Goa; Rajasthan University of Veterinary & Animal Sciences, Bikaner; Tamil Nadu Veterinary and Animal Sciences University, Chennai; IIT, Kharagpur; Ayurvet India Ltd., have taken up work on hydroponic fodder production in recent years. The Ayurvet India Ltd. Research Foundation has commissioned indigenously developed commercially viable HPFP machines in various parts of the country.

In another study, sponsored by the ICAR for development of hydroponic fodders in Goa and Satara, a low cost 'greenhouse' was developed using bamboo wood, mild steel pipes and brick masonry for production of hydroponics fodder (Khanna, 2014). The irrigation of hydroponics fodder growing chambers is operated through manual or automatically controlled micro-sprinklers. The requirement for water, light, temperature and humidity is maintained by water fogging and tube lights, and controlled automatically through the sensors in the control unit. To save water, provision for recycling of water is made inside the greenhouse with water tank and pump facility. A greenhouse with approximate area of 25 feet x 10 feet and a height of 10 feet is required to produce 600 kg/day green fodder. Trays containing soaked seeds are accommodated on racks. Just above the trays, micro-foggers are installed for water fogging. It is optional to use air conditioners in the greenhouse depending upon the fodder being grown and the existing ambient conditions. The land required for producing 240 kg of green feed per day for one year by hydroponics method is 218 sq ft as compared to the requirement of 37,673 sq ft in conventional method of fodder production, thus saving 37,455 sq ft of land (Unpublished data; Ayurvet Research Foundation Ltd. India)

6.3 Comparative hydroponics and conventional fodder cultivation & nutrition

Based on the experiments carried out in India to study the advantages of growing hydroponic fodder over the conventional system of fodder cropping, using ARF machine include, i) **Saving of water:** HPFP requires about 2-3 litres of water to produce 1 kg of green fodder as compared with 80-90 litres/kg required in the conventional system, thus saving of around 95% of water; ii) **Minimum land usage:** on an average, hydroponic system requires less than 1/15th of the space needed by conventional agriculture to grow same amount of fodder; iii) **Reduction in growth time:** growing time of hydroponic plants takes as little as 7 days from seed germination to a fully-grown plant having a height of 20-25 cm (Fig. 1). The biomass conversion ratio from the seed grains to feed was up to 6-8 times under optimum conditions.

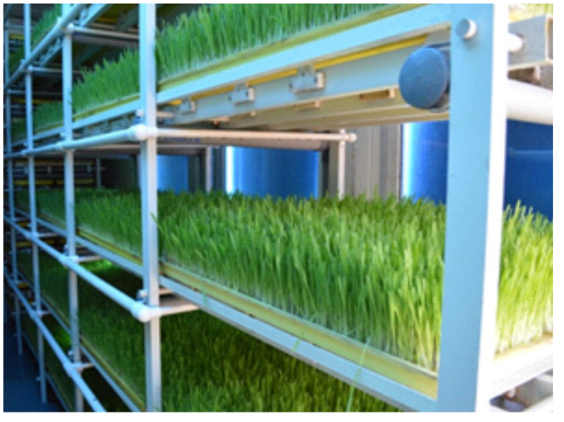

Fig.1: Hydroponic fodder grown in Ayurvet ProGreen hydroponics machine

Courtesy: Prof A.K. Gahlot, Vice Chancellor, RAJUVAS, Bikanar

Various studies conducted suggest that Hydroponic green fodder has been claimed to be highly palatable, digestible and nutritious having higher amount of protein as compared to the conventionally grown fodders. In this connection work conducted under an ICAR project in Satara district of Maharashtra revealed that feeding hydroponic fodder resulted in increase in milk yield by 0.5-2.5 litres per animal per day with higher fat and SNF content. Similarly Naik *et al*. (2014) reported 13.7% increase in the milk yield and higher net profit of Rs. 12.67 / cow / day on feeding hydroponic maize fodder (Fig 2.). Reports also indicated that hydroponics maize fodder (HMF) had higher CP (13.30 *vs* 11.14, %), EE (3.27 *vs* 2.20, %), NFE (75.32 *vs* 53.54, %) and lower CF (6.37 *vs* 22.25, %). Digestibility of CP (72.46 *vs* 68.86, %) and CF (59.21 *vs* 53.25, %) was higher ($P<0.05$) for cows fed with HMF as compared to controls fed with conventionally grown green fodder of Napier grass. The DCP content (9.65 *vs* 8.61, %) of the ration increased significantly ($P<0.05$) due to feeding of HMF; however, the increase ($P>0.05$) in the CP (13.29 *vs* 12.48, %) and TDN (68.52 *vs* 64, %) content was nonsignificant. The feed conversion ratio of DM (2.12 *vs* 2.37), CP (0.29 *vs* 0.30) and TDN (1.45 *vs* 1.52) to produce one kg milk was better in the hydroponic fodder group than the control group. The farmers also reported improvement in health and conception rate of the dairy animals, reduction in feed requirement by 25%, better taste of milk, reduction in labour cost, freshness and high palatability of fodder. While reproductive efficiency of heifers was reported to have improved by 30%, and the feeding cost per kg weight gain was reduced in the group fed with hydroponic maize fodder (Table 3). Verma *et al*. (2015) reported that feeding of male calves of Hariana breed on hydroponically grown barley feed (Fig. 2) for 90 days resulted in increased DM intake up to 3.38%, digestibility of nutrients by about 9% for OM and about 7 % for CP, higher growth rate and increase in profits. There was 33 % reduction in feeding cost per kg weight gain per calf / day where 50% of CP and energy requirements were met through hydroponic barley fodder (2.5 kg). Naik *et al*. (2014) observed higher digestibility of CP and CF for cows fed on hydroponic maize fodder. Reddy *et al*. (1988) also observed significant increase in the digestibility of DM, OM, CP, CF, EE and NFE in milch cattle fed on hydroponic fodder. On the other hand, Fazaeli *et al*. (2012) opined that hydroponic green fodder had no advantage over barley grain in feeding calves, rather increased the cost of feed.

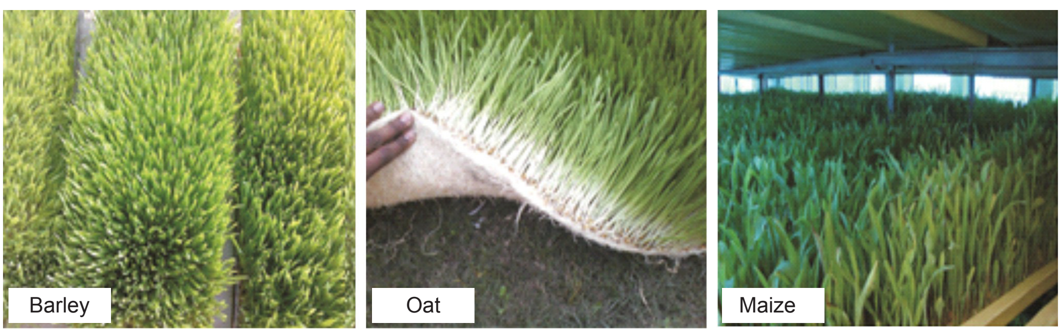

Fig. 2. Hydroponically grown green fodders

Courtesy: Dr. Anup Kalra, Ayurvet India Ltd.

Table 3: Effect of feeding hydroponic maize green feed on growth and fertility of heifers

Sl.	Particulars	Control	Hydroponic green feed
1.	Number of heifers	20.00	20.00
2.	Initial average body weight (kg)	155.00	153.00
3.	Post feeding average body weight (kg)	231.00	244.50
4.	Average weight gain/day (g)	461.00	555.00
5.	Cost of feeding for 165 days (Rs.). See table 4	11356.00	12581.00
6.	Cost of feeding/ kg weight gain (Rs.)	149.42	137.49
7.	Heifers conceived	11 (55%)	17 (85%)

Source: Ayurvet Ltd. India; Khanna (2014)

The Surat District Milk Producers' Union Limited (SUMUL) carried out experiments on heifers by feeding on hydroponics maize green feed to 20 heifers while another 20 heifers were given conventional fodder. The group fed with hydroponic fodder had 30% higher reproductive efficiencies while body weight gain was higher by 20% and the cost of feeding was lower by about 10% (Table 3 and 4). This obviously suggests that hydroponic fodders can substantially help in reducing the age at first conception and may also prove a good source in improving the fertility of cows and buffaloes, and thus reduce the inter-calving period.

Table 4: Comparative economics of feeding cattle with hydroponic and conventional fodder

Group Feed Components	Fed on conventional fodder			Fed on hydroponic fodder		
	Units	Rs./kg	Cost (Rs.)	Units	Rs./kg	Cost (Rs.)
Green fodder (kg)	5-8 (6.5)*	2	2145	2-4 (3)	5	2475
Dry fodder (kg)	2-4 (3)	6	2970	3-6 (4.5)	6	4455
Cattle feed (kg)	1-2 (1.5)	13	3217	1-1.5(1.25)	13	2681
Mineral mixture	30	60	2970	30	60	2970
Total cost (165 days)			11356			12581

**Figures in parentheses are average*
Source: Ayurvet Ltd. India; Khanna (2014).

In another study, the Haryana Livestock Development Board conducted experiments by feeding hydroponic fodder to the bulls kept at the semen bank. Encouraging results were obtained in terms of reproductive efficiency, body weight gain and cost of feeding. Besides an improvement in their general health status, average semen volume increased from 5.67 ml to 6.4 ml, indicating an increase by about 12%. The average sperm concentration increased from 1185 to 1199 million/ ml and the number of straws produced increased from 1310 to 1433 per ejaculation, while the cost of feeding was reduced by Rs. 21 per bull per day (Unpublished data; Ayurvet Research Foundation Ltd. India).

In view of the large variations observed by different workers with regard to the increase in the protein content of the HPF, DM intake, digestibility of the nutrients and other benefits, such as reproductive performance of bulls and heifers/cows, weight gains, reduction in the feeding cost etc., further studies are warranted to validate the findings along with scientific justification.

6.4 FAO experience with hydroponic fodder

The FAO of United Nations reported that hydroponic fodder production was a dependable alternative for the vulnerable herders in the West Bank of Gaza. This practice strengthened the resilience to drought and increased the profitability of vulnerable herders. The practice was implemented under the project “Prepare and respond to shocks affecting low resilience farmers and herders in the West Bank and Gaza Strip’’. This technology provided the herders a low-cost, high quality, sustainable source of fodder which is available year-round (Anon, 2015).

In recent years, hydroponics technology is being adapted in several parts of the world for production of green fodder, feed, vegetables, flowers and crop nursery seedlings due to its distinct advantages. Hydroponic fodder growing is the state-of-the-art technology intervention to supplement the available normal green fodder resources required by the dairy cattle. With the rising pressure on farm land to fulfil the increasing needs of food grains, providing green fodder by growing hydroponics fodder/feed is a necessity for the Indian dairy industry, especially in peri-urban areas due to paucity of land for cultivation of green fodder.

7. THE ISSUES

Some of the issues, such as justification for growing and feeding hydroponic fodder and challenges involved to accomplish it throughout the country are discussed below:

7.1 Why hydroponic feed system

With changing cropping systems, shrinking pasture and grazing lands; livestock farmers across the country are facing unpredictable high prices of dry fodder crop residues. The dairy farmers are in desperate need of a dependable and affordable feed for their livestock.

The HPFP System offers an opportunity to the farmers to take control of the regimen of his livestock feed and thus bringing the farm closer to sustainable production. With the availability of palatable hydroponic fodder or sprouted grains at their command for supplementing with dry crop residues, the farmer will be able to feed his livestock with optimum quantity and quality fodder.

The Hydroponic Technology needs to be applied with suitable modification for location specific livestock based farming system. Use of sprouted grains or hydroponic alfalfa, has several advantages, such as production of higher milk, egg, meat and pork; better animal wellbeing, skin and hide texture. In addition to dairy animals, best use of HPFP can be made in goat, sheep, rabbit, and poultry production. In the US, HPF is used in specialized animal production like pasture based chicken, egg, mutton and pork. There is realization in the corporate world for linking small farmers to produce grass fed or pasture fed products from poultry, pig, goat and rabbit farming (Fazaeli *et al*., 2012).

7.2 Hydroponics feed system as business model

The hydroponics fodder has potential as business model where it is produced by a business concern and purchased by the livestock farmers as per their need www.lishabora.com/businessmodel. This model can benefit the organic dairy, cage free poultry; grass fed piggery and goatery kept under intensive and semi intensive management. This innovative quality fodder supplement system can be linked with organized livestock industry and contract farming. These small units can be made relatively carbon free and climate resilient. This is the future of highly competitive global animal agriculture, adopted by thousands of farmers in several countries. Hydroponics is also a tool of sustainable farming system as it is an efficient water saving technology.

7.3 Challenges in adopting hydroponic fodder

The availability of quality seed grains in adequate quantity for HPFP, though most crucial for the success of the technology, it will be the most difficult task, particularly when area under coarse grains has been squeezing over the years.

7.3.1 The issues of fodder seed production

Current demand for seeds of cultivated fodder crops is estimated to be 3,50,000 tons /annum based on the area under cultivation (8.3 mha) for fodder crops. However, the availability of quality seed is only 15-20% of the requirement for various fodder crops (NAAS, 2016). Considering the fact that comparatively less importance is being given to fodder seed production by National Seed Corporation as well as by other private seed companies, alternate solutions like establishing fodder seed producer companies, linkage with private sector agencies etc. are required to address this problem. Involvement of ICAR institutions, SAUs, State agencies, Private sector along with farmers' participation is required to address this issue.

7.3.2 Promoting area/situation specific hydroponic green fodder production

In order to make hydroponic fodder production suitable for rural conditions, there is a need to make it successful in areas having inadequate electricity supply, higher ambient temperature and constraints of expertise and capital. Hence, the real challenge in producing hydroponic fodder in India lies in devising a system which is viable and adaptable throughout the year in a cost effective and energy sustainable manner. Hydroponic fodder/feed is expected to be more useful in arid and hilly regions, and in areas of high population density where there are scarcities of cultivable land and water.

Since regular supply of quality seeds of suitable grains in adequate quantity is a prerequisite for continuous production and supply of the hydroponic fodder, additional land area will be required for fodder seed production for important crops, such as maize (QPM), barley and oats. The enhanced land thus put under fodder seed cultivation can be compensated by the negligible requirement of land for HPF production, reduction in the demand for concentrate feed and better nutritional quality of the HPF. Besides the availability of more milk, meat and egg of higher quality in the food basket, it will also reduce the demand of cereals, such as rice and wheat and our overflowing granaries of wheat and rice will allow additional land for production of fodder seeds.

7.3.3 Control of mould growth/mycotoxins

Contamination with fungi is a major problem in HPFP as it reduces the yields of the animals and may even sicken the stock. Moulds' spores are common in most seeds, and the damp environments of sprouting rooms are suitable for promoting their growth. Sprouting requires very clean seed that is virtually free of chaff and weed seeds. Sprouting rooms should be kept at nearly constant temperatures (around 70° F), and humidity must be kept constant, but not too high. Seed treatment with small amount of air movement is helpful.

7.3.4 Developing area specific models of HPFP

The HPFP technology should be location specific and relevant. Identification of areas for undertaking researches on various aspects of hydroponic fodder production, particularly cheaper version of the technology suitable to farmers in rural and peri- urban areas who cannot afford to set up and operate the conventional units due to inadequate electricity availability and higher basic and operational costs. For developing suitable models utilizing local materials and designs, which can be operated in the absence of electricity or by solar power, could also be considered. Besides barley and oats, other grains like wheat, *bajra*, sorghum, maize, *ragi*, etc. may also be experimented for producing hydroponic green fodder. Suitable varieties of these crops need to be developed for hydroponic fodder production. Use of locally available materials such as bamboo for making racks need to be tried for hydroponic cultivation.

Suitable organic devices also need to be developed for environment control in the chamber, besides innovations in reducing the cost of nutrient media used for the growth of grains and running costs of the hydroponic units by utilizing glass partitions and natural light for maintaining the temperature as well as photosynthesis and cheaper disinfectants to ensure freedom from fungi and mycotoxins. The real challenge in producing hydroponic fodder in India is to devise a system which is viable and adaptable throughout the year in a cost effective and energy efficient sustainable manner. Promotion of the HPFP technology R&D in the country by ensuring adequate funding and policy instrument in PPPP (Public-Private-Panchayat Partnership) mode is another challenge.

Other issues requiring redressal for promoting HPFP include credit and subsidy, linkages with non-conventional energy and rural development ministries; assured investments, piloting the machines by the government, determining the scale of operation for economizing the operation and developing suitable models.

8. DOES HPFP STAND TO STRICT SCRUTINY

The hydroponic concept may be highly appealing at first look, but HPFP may not be desirable/suitable in all situations, particularly if sufficient land is available for cultivation of fodder, and quality fodder seeds and irrigation are not constraints. However, hydroponic fodder/feed has tremendous scope as a business model to take benefit of the enhanced nutritional, nutraceutical and medicinal quality of milk, eggs and meat produced. Hydroponics technology for fruits, vegetables and flowers has only one equation to decipher-the quality, the taste and the look. But when it is applied for feeds and fodder, both qualitative and quantitative gains need to be considered. One main objection for using HPF is that there is a net loss in terms of dry matter (DM) yield (24% to 30%) after 6 to 7 days of sprout growth. The DM yields of hydroponic systems are actually negative, compared with the initial seed input. Additionally, there is likely to be a loss in feeding value of sprouted grain compared with raw grain on a dry weight basis. However, since the hydroponic feed is recommended as a supplement for providing a quick and reliable source of nutritious fodder in the areas where it is not possible to grow green fodder either due to non-availability of land or under extreme climatic conditions of severe cold or lack of water for irrigation (Arid, semi-arid, hilly and mountainous areas), the impact of DM loss in the total diet will be compensated through much better utilization of roughages due to supplementation of HPF.

9. WHERE HYDROPONIC FODDER MAY FIT

Although the economics and the quality of hydroponic sprouted grain forage may not be favourable, the concept has a great appeal to those who wish to be more self-sufficient in green fodder/feed. It may fit for those producers who do not have local sources for forage. HPF may offer a ready source of palatable feed for small animal producers (poultry, piggery, goat. rabbits). Hydroponic sprouted grains may also be an appealing feed for a change in the diet of animals fed only on dry fodder, hay and grains. Situations conducive to HPFP adoption are briefly explained below:

9.1 Landless farms and land scarcity

Peri-urban small farms, landless animal farms and steep hill farms having no agricultural land but possess small pig, poultry and/or cow units can benefit from either of the two or combining the hydroponic fodder-cum-sprouted grain technologies. This can be used as supplement green feed / fodder being rich in protein, micronutrients vitamins and antioxidants (Chavan and Kadam, 1989).

9.2 Availability of biogas and solar energy

To make hydroponic fodder cultivation suitable for rural areas lacking in adequate electricity power supply, infrastructure and capital, there is a need to make it successful under the ambient temperature without the need for continuous electricity supply. Use of solar and wind power could be considered for running hydroponic units. A combination of biogas and solar energy technologies can also be helpful in this regard. To accomplish these goals, it requires investment in R&D for hydroponic fodder production and developing suitable models utilizing local materials and designs which can be operated in the absence of electricity.

10. ENGINEERING ASPECTS OF HYDROPONIC TECHNOLOGY

Research in the following areas of engineering and machinery development will help in making the system more acceptable to the farmers.

Growing Chamber: The growing chamber (or tray) is the part of the hydroponic system where the plants' roots grow as well as where the roots access the nutrient solution. It is important to keep the root zone cool and light proof as prolonged light may damage the roots, and high temperature in the root zone will cause heat stress to the plants.

The size and shape of the growing chamber will depend on the type of hydroponic system being contemplated, as well as the type of plants intended to be grown in it. Bigger plants have bigger root systems, and need more space to hold them in. Though several types of material can be used for the growing chamber, except those made of metal, as the latter could corrode or react with the nutrients.

Reservoir Engineering and Nutrient Solutions: The reservoir is the part of the hydroponic system that holds the nutrient solution. Depending on the type of hydroponic system, the nutrient solution can be pumped from the reservoir up to the growing chamber (root zone) in cycles using a timer, as well as continually without a timer. Reservoir can be made out of materials including the plastic that can hold water. Nutrient solutions can be developed separately for hydroponic fodder crop and sprouted grain crop.

Delivery System: The delivery of the hydroponic system's nutrient solution/water can be customized as per local needs.

Submersible Pump: Most hydroponic systems use a submersible pump to pump water/nutrient solution from the reservoir up to the growing chamber/root zone of the plants.

Air Pump: Other than in water culture systems, air pumps are optional in hydroponic systems. However, using them has benefits. It helps to increase dissolved oxygen levels in the water up and keep the water oxygenated. This helps in keeping the nutrients evenly mixed all the time.

The Timer: Depending on the type of hydroponic system and the place of operation, one or two simple timers may be required to control the on/off times for the lighting system.

Grow Lights: Grow lights are optional part of hydroponic systems. One can choose to either use natural sunlight, or artificial light to grow the plants depending on the place of operation of the hydroponic system. These are generally used in commercial hydroponic systems for growing fruits, vegetables and flowers (Arun Varma; Personal communication).

11. SUGGESTED APPROACH

Livestock is mainly kept by weaker sections of people in rural and peri-urban India for their livelihood, it is pro-poor domain and therefore need hand holding and policy support, and preparation of comprehensive plan to identify priority areas for providing maximum mileage by judicious use of available resources. The hydroponic fodder system will be more useful for drought prone, water deficit areas including arid, semi-arid and hilly regions. Other priority issues to be addressed for the development of the technology include assured investments and piloting the machines by the government.

The fodder availability among various states varies considerably, there is a need for preparing a green fodder deficit map for entire India using well defined protocols to access the problem for finding plausible solutions.

Regional deficits of fodder production are more important than the national deficit as it is not economical to transfer fodder over long distances, a differentiated approach need to be followed for different States / agri-ecological / climatic zones on the principle of malady-remedy combination. Out of 55 micro-regions of the country, only 12 regions have surplus fodder, while the remaining 43 have deficiencies of one or other kind of feed material (IGFRI, 2011).

12. RECOMMENDATIONS/WAY FORWARD

Action Plan for Development and Utilization of Hydroponic Fodder / Feed:

12.1 Policy options

- To prepare fodder deficit maps for entire India from district to State level to access the problem for finding plausible solutions *(Action: ICAR-NIANP; ICAR-IGFRI; DAC Min Agri & FW, GoI)*.
- The leads so far obtained in HPF, R&D should be scaled up and scaled out, following a differentiated approach for different states/agri-ecological / climatic zones *(Action: ICAR-NIANP; ICAR-IGFRI; Extn Division, ICAR & GoI).*
- For promoting the HPFP technology, provision for providing subsidy for large scale production / commercialization may be considered. HPFP has scope for adoption in dryland agriculture if suitable models are developed for small holder farmers *(Action: DAHDF Min. Agri & FW, GoI; ICAR).*
- Provision of credit for livestock farmers and developing small HPFP models for demonstration to the farmers, linkages with non-conventional energy and rural development ministries, assured investments and piloting the machines *(Action: DAHDF, GoI; ICAR, Min. Rural Development, Min. New and Renewable Energy).*
- The technique of hydroponic fodder production saves precious natural resources, particularly soil and water, and also reduces pollution, it needs to be encouraged by the government by providing incentives on par with micro irrigation (drip and sprinkler irrigation/fertigation) on various inputs, including electricity, seed grains and nutrient media for growing hydroponic fodder *(Action: DAC, Min. Agri & FW, GoI; State governments).*
- The requirement of land for providing loans for establishment of hydroponic fodder production should be dispensed with. Similarly, these loans should also be exempted from any stamp duty, and the interest rate should be not more than 4% and income from commercial hydroponic production should be exempted from income tax *(Action: DAC, Min. Agri & FW; GoI; State Depts. of Agri, Animal Husbandry & Dairying).*
- Convergence of all concerned institutions to achieve the objectives for sustainable hydroponic fodder/ nursery production *(Action: DAC, Min. Agri & FW; GoI; ICAR; DAHDF Min. Agri & FW, GoI; NABARD).*

- Dairy farmers / livestock keepers should be provided training in hydroponic fodder production at KVKs; HPFP Units; SAUs, SVUs, ICAR-IVRI; ICAR-NDRI; ICAR-NIANP; NDDB etc. *(Action by concerned Institutes / organizations).*

- The hydroponic fodder should be a component of the "Sub-Mission on Fodder Development under the National Livestock Mission (NLM) of DAHDF, GoI. The guidelines of the NLM are available on the Departments website: www.dadf.gov.in and www.dahd.nic.in *(Action: DAHDF, GoI)*.

- The data on feed and fodder resources should be updated on regular basis in the country for proper assessment of the requirements, availability, deficits and surpluses on national and regional / State level for efficient planning of needed quantities of quality seed grains for production of adequate quality of green fodder / forages, dry fodders and feeds by involving the relevant agencies *(Action: ICAR-NIANP, ICAR-IGFRI, ICAR-NDRI, NDDB, ICAR-IVRI, ICAR-IASRI, DAHDF Min. Agri & FW, GoI; Director Fodder (NLM), NSSD, CLFMA, Director AH of the States).*

- Data need to be generated crop-wise, district-wise and State-wise in regard to fodder production and seed requirement. The NSSO should include fodder crop data in their standard proforma for agricultural crops *(Action: DAHDF, Min. Agri. & FW; GoI; NSSO, State Agriculture & AH Departments).*

- The fodder seed multiplication chain should be strengthened to ensure the availability of adequate breeder, foundation / certified fodder seeds through national / state seed producing agencies *(Action: DAHDF, Min. Agri & FW GoI; ICAR & DAC (Seed Division); NDDB; ICAR; NSC; SSC; Dairy Coops. SAUs; RFS; Private agencies).*

- An apex body, namely "National Fodder Seed Corporation" be setup to spear head entire spectrum of fodder seed, e.g. seed requirement, production, quality testing, certification, storage, fodder banks, fodder transport, pricing and marketing for ensuring timely availability to the farmers *(Action: DAHDF, Min. Agri & FW, GoI; DAC, Min. Agri & FW GoI; ICAR).*

- Post of Joint Director (Feed and Fodder) should be created in all the States under the Department of Animal Husbandry and Dairying/Animal Resources for development programmes planning and implementation *(Action: Minister (s) of Animal Husbandry and Dairying of the States).*

- To ensure the availability of quality protein maize grains for hydroponic feed production as its biological value is almost double than the normal maize varieties owing to its higher contents of tryptophan and lysine essential amino acids *(Action: ICAR-IGFRI; DAHDF, Min. Agri & FW, GoI; SVUs; SAUs; M/s Ayurvet India Ltd).*

12.2 Researchable areas

- State Agricultural/Veterinary Universities and ICAR Institutes like NDRI, NIANP, IVRI, CIRB and M/s Ayurvet India Ltd. may work together to validate cost effective HPFP technology developed by the later *(Action: ICAR, ICAR-NDRI, ICAR-NIANP, ICAR-IVRI, ICAR-CIRB; M/s Ayurvet Ltd.).*

- The HPFP technology should be made farmer friendly and affordable to small and marginal farmers keeping less than 10 dairy animals. The multitier system should be experimented to reduce requirement of space and ensuring 24x7 supply of electricity, solar or biogas energy *(Action: ICAR; DAHDF, Min. Agri & FW, GoI; M/s Ayurvet India Ltd.; ICAR-IGFRI; SAUs; SVUs).*

- There is urgent need to address the problem of availability of quality grains/certified seed and their germination quality. Optimum conditions/ treatment of seeds for their germination need to be standardized for various fodder seeds *(Action: ICAR-NIANP; ICAR-IGFRI; ICAR-IVRI; ICAR-NDRI).*

- To develop technology for HPFP which suits to location specific requirements of farmers *(Action: ICAR-IGFRI; ICAR-NIANP; DAHDF, Min. Agri & FW, GoI; SVUs; SAUs; M/s Ayurvet India Ltd.).*

- Biogas, solar or wind energy should be experimented for its use as alternative to electricity *(Action: ICAR-IGFRI; DAHDF, Min. Agri & FW, GoI; ICAR-NIANP; SVUs; SAUs; M/s Ayurvet India Ltd.).*

- In order to make hydroponic fodder cultivation suitable for rural conditions, there is a need to make it successful in rural areas not having adequate electricity supply, having higher or low ambient temperature, such as arid, semi-arid and hilly regions. Community based system at Panchayat level also need to be experimented and worked out *(Action: ICAR-IGFRI; ICAR-NIANP; DAHDF, Min. Agri & FW, GoI; SVUs; SAUs; M/s Ayurvet India Ltd.).*

- Besides barley and oats, other grains like wheat, pearl millet, sorghum, maize, *raggi*, etc. should also be experimented and suitable varieties be developed for hydroponic fodder production *(Action: ICAR-IGFRI; ICAR-NIANP; DAHDF, Min. Agri & FW, GoI; SVUs; SAUs; M/s Ayurvet India Ltd.).*

- Suitable organic devices should be developed for environment control in the chamber, besides innovations in reducing the cost of nutrient media used for the growth of grains and running costs of the hydroponic units, cheaper disinfectants, and safety of the fodder for freedom from fungi and mycotoxins *(Action: ICAR-NDRI; ICAR-NIANP; ICAR-IGFRI).*

- Cost effectiveness and improvement in the milk quality and quantity, weight gain in calves, and effect on semen quality need to be worked out in planned studies in cattle, buffalo, sheep, goats and pigs to document the advantage of feeding with hydroponic green feed. Similar studies should be conducted to study the effect of HPF on egg quality, fertility, immunity etc. *(Action: ICAR-IGFRI; ICAR-NIANP; DAHDF, Min. Agri & FW, GoI; SVUs; SAUs; M/s Ayurvet India Ltd.).*

- Comparative nutritional analyses and health benefits of feeding on hydroponic and conventionally grown fodder, be taken with regard to reduction in usage of concentrate mixture; contents of fatty acids, micronutrients, CLA, vitamins, omega, metabolizable net energy etc. *(Action: ICAR-IVRI; ICAR-NIANP; ICAR-IGFRI; DAHDF, Min. Agri & FW, GOI; SVUs; SAUs, M/s Ayurvet India Ltd.).*
- Development of suitable model of small seeded capacity machines with faster growth of seedlings for landless and small holder livestock farmers *(Action: ICAR; ICAR-CIAE, Bhopal).*
- Use of hydroponic technology for preparing nursery for paddy, onion, sugarcane and other crops need to be researched for benefitting agriculture farming as a whole. *(Action: ICAR-IARI; ICAR-IRRI; ICAR-DWR).*
- For commercial exploitation of hydroponic fodder production technology, studies should be undertaken on low temperature preservation of the green feed and its transportation to other areas *(Action: ICAR-NIANP; ICAR-IGFRI, NABARD).*
- Hydroponic fodder-cum-sprouted seed technology for dairy production system, grass fed pork production & poultry production system for developing business models for respective systems. *(Action: ICAR-NDRI, Karnal; ICAR-NRC Pig and ICAR-CARI Izatnagar).*
- Growing hydroponic feed and fodder is considered to be environment friendly as it saves water, energy and other inputs. However, there is need to have comparative studies on the carbon foot print (CFP) of the hydroponic system and the conventional system (www.hydroponics.com.au/calculating-the-cost-of-carbon) *(Action: ICAR-IGFRI-NDRI).*

13. CONCLUDING REMARKS

The Hydroponic fodder/feed technology is gaining importance in the farming model of ruminant and non-ruminant systems for small, medium and land less farmers. However, it will require education, training and linkages with animal health and public health Institutes for innovations and monitoring of microbial and mycotic diseases/infections of animals and plants from animal and public health angles. For raising animals for production of milk, egg, pork, chicken and other meat the two approaches, namely hydroponic fodder and sprouted grains can be used together in complimentary manner. The existing knowledge level is insufficient so it would still need adequate research.

The challenges of Hydroponic fodder-cum-sprouted grain technology are enormous in producing quality green feed and fodder, and using it for value addition of products, such as milk rich in CLA, Omega-3, vitamins and micro minerals; cage-free poultry products, grass-fed meat and meat products. Better outcome will be possible with the strong policy support and technology back up. When used as supplement in the feeding of dairy animals, it will improve health and reproduction; boost productivity as well as nutritional quality of milk and other foods of animal origin, thus improving the income and profits of the farmers. However, before adoption of hydroponic feed/fodder on wider scale, several issues pertaining to HPFP technology, namely, economics, viability, sustainability and superiority of hydroponic fodder require further research on priority.

REFERENCES

Anonymous (2001) Draft Report of the Working Group on Animal Husbandry and Dairying for the Five Year Plan 2002-2007.

Anonymous (2011) Report of the Sub Group III on Fodder and Pasture Management Planning Commission, Government of India, New Delhi. pp. 22.

Anonymous (2015) Resilience promising practice, March 2015. A Final Report for FAO Project OSRO/GAZ/202/CAN.

Chavan, J. and Kadam, S.S. (1989) Nutritional improvement of cereals by sprouting. *Crit. Rev. Food Sci. Nutr*. **28**:401-37.

DAHDF (2012) 19th Livestock Census, 2012 – All India Census Report, Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture and Farmers Welfare, Government of India, New Delhi; pp 130.

DAHDF (2015) Annual Report. Department of Animal Husbandry, Dairying and Fisheries-2014-15, Government of India, Ministry of Agriculture & Farmers Welfare, New Delhi.

DAHDF (2016) Basic Animal Husbandry and Fishery Statistics – 2016. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi pp 166.

Fazaeli, H., Golmoihammadi, H.A., Tabatabayee, S.N. and Asghari, T. (2012) Productivity and nutritive value of barley green fodder yield in hydroponic system. *World Applied Sci. J*. **16(4):** 531-539.

Ghosh, P.K. and Mahanta, S.K. (2014) Forage resource development in India: Looking ahead. *Agriculture Year Book* – 2014, pp. 134-140.

ICAR (2013) Feed and Fodder Technology. Handbook of Animal Husbandry, Directorate of Knowledge Management in Agriculture, ICAR, New Delhi pp. 246-277.

IGFRI (2011) Vision 2030. Indian Grassland and Fodder Research Institute, Jhansi (www.igfri.res.in).

Khanna, R.S. (2014) Fodder of the future: A Review of the Hydroponics Technique, *Indian Dairyman* **66(5&6)**: 1-5.

NAAS (2016) Augmenting Forage Resources in Rural India: Policy Issues and Strategies. Policy Paper No. 80, National Academy of Agricultural Sciences, New Delhi, 16 p.

NABCONS (2007) NABARD Consultancy Report cited in the Annual Report (2013-14) of the Department of Animal Husbandry, Dairying and Fisheries, Government of India, Ministry of Agriculture & Farmers Welfare, New Delhi, 24 p.

Naik, P.K., Dhuri, R.B., Karunakaran, M., Swain, B.K. and Singh, N.P. (2014) Effect of feeding hydroponics maize fodder on digestibility of nutrients and milk production in lactating cows. *Indian J. Anim. Sci.* **84(8)**: 880-883.

Reddy, G.V.N., Reddy, M.R. and Reddy, K.K. (1988) Nutrient utilization by milch cattle fed on rations containing artificially grown fodder. *Indian J. Anim. Nutr.* **5(1)**: 19-22.

Shipard, I. (2005) How can I grow and use sprouts as living food, Stewart Publishing; cited by Verma *et al.* (2015).

Verma, S., Singh, A. Kalra, A. and Saxena, M.J. (2015) Effect of feeding hydroponics barley (*Hordeum vulgare*) fodder on nutrient utilization, growth, blood metabolites and cost effectiveness in Hariana male calves. *Indian J. Anim. Nutr.* **32(1)**: 10-14.

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Note: *The designations and affiliations of the participants are as on the date of BSS.*

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52. Biosafety Assurance for GM food Crops in India - 2011
53. Ecolabelling and Certification in Capture Fisheries and Aquaculture - 2012
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