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Hydroponics: An alternative to cultivated green fodder: A review

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Abstract
The expansion in the livestock population along with the intensive rearing system has resulted in the increase requirement for feeds and fodder in the country. Hydroponics is a technology of sprouting grains or growing plants without soil, but only with water or nutrient rich solution in greenhouses under controlled environment within a short period. The advantages of hydroponics observed by the farmers, there were increase in fat and Solid Non Fat content of the milk, improvement in health and conception rate of the dairy animals, reduction in cattle feed requirement by 25%, increase in taste (sweetness) of the milk, reduction in labour cost, requirement of less space and water, freshness and high palatability.

Keywords: Livestock, hydroponics, green fodder, germination

1. Introduction

In India, livestock plays a major role for the nutritional security, particularly of the small and marginal farmers. As per 19th Livestock census, 2012 (GOI, 2014) India's livestock sector is one of the largest in the world with a holding of 11.6% of world livestock population. The livestock population of 512 million nos. which mainly includes cattle, buffaloes, goats, sheep and pigs. The growth rate during last 56 years in livestock is 80.91% [1] With increase in number of livestock population the problem to provide adequate feed and forage is becoming acute. The feed deficiency has been the main limiting factor in improving the livestock productivity [2]. The land allocation for cultivation of green fodder is limited to only 5% of the gross cropped area [3].

Livestock production and reproduction are adversely effected by the scarcity of good quality of green fodder. More growth time, non-availability of same quality round the year, requirement of manure and fertilizer, the uncertain rain fall, water scarcity and natural calamities due to climate change are the major constraints for green fodder production by the livestock farmers. Due to the above restraints of the conventional method of fodder cultivation, hydroponics technology is coming up as an alternative to grow fodder for farm animals [4, 5, 6].

The word hydroponics has been derived from the Greek word 'water working'. Hydro means 'water' and ponics means 'working' and it is a technology of growing plants without soil, but only with water or nutrient rich solution. The water which is used for sprouting of grains must be clean and free from chemical agents as the major source of microbial contamination is water. Fodder crops produced by hydroponics technology are also known as hydroponics fodder, sprouted fodder or sprouted grain. The hydroponics green fodder is produced from forage grains (such as malt barley or oats), having high germination rate and grown for a short period of time generally seven days. (Sneath and McIntosh, 2003) [7] As fodder sprouts are tender and young, the equivalent of fresh green grass with extremely high in protein and metabolisable energy. So that, they are highly palatable, highly nutritious and disease free animal food for all classes of livestock.

This process takes place in an intensive hydroponic growing unit where only water and nutrients are used to produce a grass and root combination that is very lush and high in nutrients. This greenhouse is a framed structure covered with a transparent material in which the crops could be grown under the conditions at least moderately controlled environment. In this greenhouse the requirement of plants for water, light, temperature and humidity is maintained by water fogging and tube lights controlled automatically through the sensor of the control unit [8].

Depending to the type of grain, the forage mat reaches 15 to 20 cm high where production rate is about 7 to 9 kg of fresh forage equivalent to 0.9 to 1.1 kg of dry matter [9, 10].

2. Fodder crops used for hydroponics

Different types of fodder crops *viz.* barley [11], oats, wheat [12]; sorghum, alfalfa, cowpea [13] and maize [4, 14] can be produced by hydroponics technology. However, the choice of the hydroponics fodder to be produced depends on the geographical and agro-climatic conditions and easy availability of seeds. In India, maize grain should be the choice as the grain for production of hydroponics fodder due to its easy availability, lower cost, good biomass production and quick growing habit. The grain should be clean, sound, undamaged or free from insect infestation, untreated, viable and of good quality for better biomass production.

3. Seed preparation

Soaking of seeds and the rapid uptake of water for facilitating the metabolism and utilization of reserve materials of the seeds for growth and development of the plants is a very important step for production of hydroponics forage. In case of barley [15] and maize [16] seeds, 4 hours soaking in water is beneficial. Under field conditions, farmers producing hydroponics maize forage have the practice of putting the seeds in a gunny bag tightly and then make it wet and keep for 1-2 days.

3.1 Seed rate

The seed rate also affects the yield of the hydroponics fodder which varies with the type of seeds. Most of the commercial units recommend seed rate of 6-8 kg/m2 [15], however, seed rate of 7.6 kg/m2 has been suggested by [6] for hydroponics maize fodder for higher output. If seed density is high, there are more chances of microbial infection in the root mat which affects the growth of the sprouts.

4. Production of hydroponics fodder Principle

The basic principal for hydroponic fodder production is that cereal grains responds to moisture and nutrient solution for germination and growth in the absence of a solid growing medium. And produce green plants in short time. Nutrient solution containing important nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium and sulfur etc. The resulting green shoots and root mat are harvested and fed to livestock. Various cereals can be used as animal feed, including barley, oats, wheat, corn and sorghum. The grain producing a 200 – 250mm long vegetative green shoot with interwoven roots within 5 to 8 days. There are a range of chemical and structural changes that take place within the cereal grain through the hydroponic growing process. Activation of enzymes within the grain leads to hydrolysis of proteins, carbohydrates and lipids into their simpler components [17]. This hydrolysis increases the concentrations of amino acids, soluble sugars and fatty acids within the grain and resulting shoot [18]. The amount of sprouts produced (yield) and quality of the fodder is influenced by a number of factors including:

1. Grain - grain quality, grain variety and treatments
2. Growing environment - temperature, humidity and incidence of mould
3. Management of the system - water quality and pH, soaking time, nutrient supply, depth and density of grain in troughs, and growing duration [7].

5. System Set Up

Fodder sheds consist of two areas – a growing area where the fodder is grown, and a pump area where grain is prepared for sowing and is where nutrient tanks, pumps and associated systems are located. In a 100sqm shed, the growing area represents approximately 70% of the total floor area [19]. The shed environment is actively controlled to ensure optimal temperatures and appropriate ventilation levels are maintained. Climate control consists of air conditioning units, and in colder environments, under floor heating. The growing area of the shed consists of stacks of food quality PVC channels in which the grain is 'sown' and the fodder grows. Each of these stands holds 28 trays measuring 4m long and 400mm wide. These trays are fed with nutrient nozzles which periodically supply a precise measure of nutrient solution to each single tray. These nozzles are adjusted throughout the growing stages to supply the appropriate quantity of nutrient solution to each tray. This nutrient solution then flows through the bottom of the trays, which are set with a very slight fall, and is accessed by the grain and resulting roots. This is technique is commonly referred to as Nutrient Film Technique (NFT). Nutrient solution that is not absorbed by the sown grains flows into a recirculation system that returns the solution back to the solution storage tank. This minimizes wastage and optimizes efficiency of water use within the system. The pump area of the shed houses a range of equipment critical to the fodder shed. In it mixing and storage tank for the nutrient solution is housed, along with pumps and the automation controls for climate as well as nutrient solution concentration, pH and temperature [19]. A soaking tank, where grain is soaked in a nutrient solution for a day prior to sowing, also resides in this area. The soaking assists with the metabolism of reserve material in the grain and the use of those reserves for the growth and development of the fodder [7].

6. Digestibility

Sneath and McIntosh (2003) [7] report that there is conflicting evidence as to whether sprouting improves or reduces DM digestibility as compared to the raw grain. This comparison takes account of some basic processing of the grain. To optimize the utilization of grains, they need to be processed e.g. rolled or cracked, to improve its digestibility. When grains are not processed, it is estimated that only 60% of the starch is digested [7]. Dung *et al.* (2010) [20] studied the *in sacco* digestibility of sprouted barley fodder visa vis grain. They found the loss of DM and no difference in *in sacco* digestibility disproved there being an advantage in sprouts rather than the original grain. They found that the initial degradation of the whole sprout was significantly higher than for cracked grain after six hours of incubation in the rumen, but from 12 – 96 hours there were no significant differences between the whole sprouts and cracked grain.

A significant difference existed in the digestibility of the shoot portion versus the root portion of the fodder. The plant shoots were more easily degraded in the rumen. Dung *et al.* (2010) [20] reported that ruminant animals prefer diets that are leafy and having no stem and with leaves have a low to intermediate tensile strength.

7. Energy

While an analysis of DM provides a good indication of the ability of fodder production to produce feed, it is the detailed analysis of that feed that provides the most accurate analysis of the value of fodder relative to alternative feeds. Processed grain (cracked) and sprouts are highly digestible and nutritious feeds. The process of sprouting the grain converts the starch present in the grain to sugars in the sprouts [7]. Work by Dung *et al.* (2010) [20] found that the energy value of the sprouts was also less than that of the grain on a DM basis, with a gross energy loss of 2% recorded after comparing the sprouts with the original grain. In addition to this nutrient analysis, they had also analyzed the digestibility of the fodder versus original grain in situ. In line with the already presented material, they found that there was no significant difference in the digestibility and concluded loss of total DM without a significant improvement in digestibility, which represents that there was a considerable reduction in the total digestible energy [20].

8. Protein

Protein is a critical element for the growth of animal and performance of animal and is very important in analyzing the feed value of fodder. The effect of sprouting on protein content isn't clear, while some studies depicted increases in protein, and others decreases in protein. In one of the latest fodder studies, [20] Dung *et al.* (2010) found crude protein, ash and all other minerals except potassium were higher in concentration on a DM basis in the sprouts than in the barley grain [20]. This illustrates an advantage to the fodder.

9. Vitamins

The vitamin content is generally improved by sprouting. This may make little difference to the feed value though, with [7], reporting that the increases in individual vitamins are so small that its practical significance in meeting the nutritional requirements of cereal-based diets is difficult to evaluate in feeding trials.

10. Animal performance on hydroponic fodder

A wide range of trials have been done to assess the livestock performance on sprouts, globally. These have included the performance of dairy cattle, beef cattle, pigs and poultry [7]. In their comprehensive review of hydroponic fodder in relation to beef cattle, [7] reported that most of the trials on livestock performance from hydroponic sprouts showed no advantage to including them in the diet, especially when it replaces highly nutritious feeds such as grain.

Early research showed rise in animal performance on hydroponics fodder, which they put down to a grass juice factor [21]. This is supported by Finney (1982) [22], who showed that hydroponic sprouts are a good source of nutrients, which leads to improved animal performance. In contrast, some research has also showed that there is no improvement in animal performance with the feeding of hydroponic sprouts [23]. In a trial looking at the performance of feedlot calves fed on hydroponic fodder, [24] Fazaeli *et al.* (2011) found no significant difference in live weight gain or feed conversion efficiency between a fodder diet and a control diet, consisting of barley grain. Tudor *et al.* (2003) [25] stated that steers supplemented with hydroponic barley sprouts performed higher than expected for a period.

Mincera *et al.* (2009) [26] conducted a trial in which they fed lactating Comisana sheep on hydroponically germinated oats. They found that the integration of hydroponic oats into the sheep diet did not change the biochemical and hematological parameters, but resulted in improvement in the animal welfare and milk yield. Marisco *et al.* (2009) [27] completed a parallel study with goats where they found no change in biochemical and hematological profiles. Unlike the sheep trial, they also did not find any change in milk yield between those fed on hydroponic sprouts and those fed on traditional diets.

There are reports of increase in milk yield of 7.8% and 9.3% (FCM yield) [11] and 13.73% [28] due to feeding of hydroponics fodder to lactating cows. The feedback from the farmers of the Satara district of Maharashtra revealed that there was increase in the milk production by 0.5-2.5 liters per animal per day and net profit by Rs. 25-50/- per animal per day due to feeding of hydroponics fodder to their dairy animals. Besides, the other advantages observed by the farmers, there were increase in fat and SNF content of the milk, improvement in health and conception rate of the dairy animals, reduction in cattle feed requirement by 25%, increase in taste (sweetness) of the milk, whiter milk, reduction in labour cost, requirement of less space and water, freshness and high palatability of the hydroponics fodder etc [6].

11. Economics of production of hydroponic fodder

The cost of production of the hydroponics green fodder maize is mainly influenced by the seed, electricity and labour. Seed cost alone contributes about 25% of the total cost of production. It is observed that in the hydroponics green fodder production unit of 600 kg daily production potential, approximately 1500-1600 liters of water (if water is not recycled) and about 15-16 units of electricity are utilized. In the existing condition, the cost of production of the hydroponics green fodder of maize is approximately 4.50/kg on fresh basis [16], which is almost same to the market price of the conventional green fodder. It is worth mentioning here that if the seeds are produced by farmers, the cost of production of the hydroponics fodder will be decreased significantly. To produce about 100 kg hydroponics green fodder maize daily, approximately 6.5 tons maize seeds will be required annually, for which about 0.7-1.0 ha land is required to produce maize seeds depending upon the number of crops per year. Besides, sifficient dry fodders (stovers) can also be available for feeding the dairy animals.

During the initial stage, though the cost of fodder produced by hydroponics system and traditional method may be the same; but in future, when there will be non-availability of land for production of fodder to the animals, this alternative technology should be able to provide required fodder with very limited land area. Further, with the advancement of time, the cost of machine and its operational cost may go down on a similar manner as has been observed with the mobile phone technology. However, the greatest advantage of hydroponics technology over conventional practices for production of green fodder is that farmer can produce as per the requirement and there is no post-harvest loss. No doubt, cost of production is the key determinant for the success of any technology, but the most important fact is under which circumstances we are using technology.

12. Challenges in producing hydroponic fodder

There are a number of challenges in producing hydroponic fodder. A common challenge that causes many problems for those with fodder sheds is mould. The warm moist environment within a fodder shed helps mould to easily take hold, ruin the crop and cause livestock health issues if fed. Thus, active management of mould risk is important. Mouldy sprouts have decreased livestock performance in trials [23], and has been known to cause of animal mortality. Mould is actively managed within sheds through pre treatment of the seeds. Additives to the water are used for pre-soaking the grain to minimize the risk of mould. Shed hygiene is also very important and thus considerable attention is paid to ensuring the growing trays are well cleaned following each crop and prior to the sowing of the new crop.

13. Conclusion

Hydroponic fodder production systems produces a large quantity of green, palatable livestock feed in limited space/available land. However, the research reviewed and analysis undertaken in this report shows that there are challenges associated with the production and economic competitiveness of hydroponic fodder as an alternative feed sources. The costs associated with the establishment and daily operation of a fodder shed, coupled with dry matter yield losses during the sprouting make hydroponic fodder an expensive feed source. This, coupled with a lack of concrete evidence around animal performance on hydroponic fodder will limit the adoption of hydroponic fodder production systems.

There is an opportunity for some research to be undertaken to examine the performance of livestock on hydroponic fodder and the attributes of the final product. The production of a product with preferable attributes that could generate significant premiums in top level markets may go some way in making hydroponic fodder an economic feed. This would have to be accompanied by a positive production response in the give class of livestock also.

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