Forage Res., **44** (4) : pp. 217-223 (2019) **http://forageresearch.in**

INNOVATIVE TECHNIQUES IN FODDER PRODUCTION-A REVIEW

SRUTHI LIZ THOMAS AND USHA C THOMAS*

AICRP on Forage Crops & Utilization,
College of Agriculture,
Vellayani, Thiruvananthapuram, Kerala- 695 522, India
**(e-mail : ushacthomas@gmail.com)*

(Received : 2 March 2019; Accepted : 28 March 2019)

SUMMARY

Livestock is the sub-sector of agriculture which plays an important role in nutritional security, particularly of small and marginal farmers. But productivity of our animals is much less than global average due to many reasons, feed and fodder deficiency being the major one. Considering the feed shortage and unavailability of land for fodder cultivation, it is the need of the hour to adopt innovative methods in fodder cultivation both in production and preservation of fodder. Improved methods in fodder production can be considered under four aspects which includes: seed technology, system approach, hi-tech farming and adopting mechanisation in fodder production. Improved methods in preservation includes; technological interventions in hay and silage like additives for quality hay and silage, preserving as haylage, balage and making dehydrated products like pellets and cubes.

Key words : Hitech farming, BN hybrid, Deenanath grass, Guinea grass, System approach

India is basically an agricultural country with 2/3rd of rural population depending on it for their livelihood. Livestock is the sub-sector of agriculture which contributes about 4.5% to total GDP and 25.8% to the agriculture GDP (GOI, 2017). Livestock plays an important role in nutritional security, particularly of small and marginal farmers. But productivity of our animals is 20-60% lower than the global average due to improper nutrition, inadequate health-care and management. Among the responsible factors for the low productivity, feed and fodder deficiency is the major factor contributing 50% to this cause. Being the leader in cattle and buffalo population and livestock population increasing every year, current fodder production in our country is not able to meet the requirement of fodder. At present the country faces a deficit of 63.5% green fodder and 23.5% dry crop residues. If the present situation continues deficit will increase to 65.45% in 2030 (IGFRI, 2013).

Shortcomings in fodder production

The major constraints of green fodder production include unavailability of land for fodder cultivation, more labour requirement, more growth time (approximately 45-60 days), nonavailability of same quality fodder round the year, uncertain rainfall, requirement of manure and fertiliser and scarcity of water (Naik *et al*., 2015). The spiralling cost of packaged cattle feed adds to the cost of dairy farming. Non-commercial status of forage crops and unorganized small market without any govt. policy backup like MSP make fodder production a low priority activity. Considering the feed shortage and unavailability of land for fodder cultivation, it is the need of the hour to adopt innovative methods in fodder cultivation. Innovative methods are adopted both in production and preservation of fodder.

Innovative techniques in fodder production

Improved methods in fodder production can be considered under four aspects which includes :

(1) Seed Technology
(2) System Approach
(3) Hi-tech Farming
(4) Mechanisation

(1)Seed technology

Only 25-30% of the required quantity of quality seeds is available in India in cultivated fodders and less than 10% in range grasses and legumes. So, there is need to evolve superior varieties of forage crops with high yield and quality, and also development of new technologies for multiplication.

Planting material multiplication in Bajra Napier hybrid :

Bajra-Napier hybrid is an important perennial fodder which yields up to 250 t/ha/yr green fodder under irrigated condition. There is no seed formation in this interspecific hybrid. Hence, vegetative propagation is the only option for BN hybrid cultivation. Multiplication and sale of planting material have constraints, such as, high transportation cost due to high volume, damage to the standing crop from where rooted slips are taken out and involvement of high labour cost.

(A) In-vitro rooting in Bajra Napier hybrid

A packing friendly method of BN hybrid rooted slips was developed using suitable aged stem cuttings with 2-3 nodes and wrapping them in paper and cloth towel. By keeping these wrapped cuttings at 25^0C and 80% humidity for one-week, rooted slips can be produced. This reduces the difficulty of uprooting in field and helps in easy transport to long distances. This technology is mainly useful for the clients with small requirements and needs transport to long distances. The in vitro rooting of BN hybrid helps in the production of rooted slips within a short span of one week. As the rooted slips produced in the laboratory are already packed in bundles, it is easy to transport them for long distances without much drying and damage (Vijay *et al*., 2018).

(B) High density nursery in Bajra Napier hybrid

The stem or tillers from BN hybrid grass were collected and chopped into pieces of one, two and three nodes called as setts. A slant basal cut was given to increase the area of contact during planting. The setts were closely planted in upright position with at least one node inside the soil at 5 cm × 5 cm row-to-row and plant-to-plant distance. The shoot buds started transforming into leafy shoots within 10 days and roots emerged after 15 days. The setts were ready for transplanting in 4 to 5 weeks with proper root and shoot. Original tussocks are saved (Vijay *et al*., 2018).

In vitro maturation of guinea grass seeds

Among many perennial grasses, Guinea grass (*Panicum maximum*) is well adopted by farmers, because of its multi-cut nature and high green fodder yield (80 to 100 t/ha). The seed maturity in Guinea grass varies from plant to plant and from branch to branch within a plant. Even within an inflorescence, different stages starting from anthesis to seed ripening are observed. This makes it impossible to realize the full potential of seed production. The manually harvested seeds are characterized by 15% to 30% germination only. To overcome this constraint, invitro maturation of guinea grass was done. The panicles were cut before anthesis stage and dipped in different hormonal solutions. Dipping the cut panicles in 100 ppm IAA solution retained their viability for longer duration and thus helped in seed maturation. By using this technique, the seed shedding in guinea grass was minimized and the collected seed was more uniformly matured resulting in enhanced seed filling. This technology helps the production agencies to produce high quality seed with reduced production losses and benefits the users to have high germination percentage with greater chances of establishment of seedlings (Vijay *et al*., 2018).

Defluffing of deenanath seeds

Among annual range grasses, Deenanath (*Pennisetum pedicellatum*) is an important fodder species, because of high early vigour, adaptability to very poor soils and high productivity with minimal input. This grass is also a high seed producer; however, the lightweight small seed enclosed in voluminous fluff leads to difficulties in transport as well as precise sowing in the field. Reducing the volume and extracting true seed for precise sowing is the requirement for large-scale successful usage of this annual forage grass. The naked caryopsis from Deenanath seed fluff was separated using cotton batting machine with minor modifications. The true seed occupies much smaller volume and the weight could be reduced from 7 kg to 450 g. This reduced the difficulty of transport and sowing in Deenanath to a great extent. This technology is a boon to the grass seed producers and users as it reduces the volume of seed and enhances the ease of carrying to long distances. Also helps in providing the naked seed for pelleting (Vijay *et al*., 2018).

Modified method for seed pelleting in deenanath

Grass seeds are small with fluff or appendages. They are easily blown off and chances of mechanical damage are more. Grass seed pelleting has long been thought as a solution to address these problems. An experiment was conducted to pellet

Deenanath grass in an indigenous tyre-based machine fabricated in IGFRI. Seed pelleting involved mixing of fluffed seeds, soil and water at right proportion in a rotating tyre to make seed balls of 15- 20 mm diameter Initially six types of locally available pelleting materials viz. soil, saw dust, wheat bran, charcoal, farm yard manure and limestone were tried to make seed balls. Specific quantity of pelleting material was put in the rotating tyre and water was sprayed onto the dry mix until it begins to nucleate and form small beads. When the beads became approximately one cm of diameter, desired quantity of seed was dusted slowly on the rotating beads. When the seeds adhered to the bead's surface, again water was sprayed followed by dusting with pelleting material to cover the seeds with another pelleting layer. Pelleting had many advantages like improving germination to more than 90%,enhances seed field performance, helps in mechanization and increase vigour as it is supplied with nutrient and water absorbent (Maity *et al.,* 2015)

(2) System approach

In most parts of the country, it is common to see farming systems integrated with forage crops and livestock production. In fact, it is the best alternative to increase the area and production of forage crops, as there are constraints in bringing more land under forage crops (Thomas, 2003). Some of the prominent farming systems with forage crops practiced in tropics are :

(a) Intercropping
(b) Sequential cropping
(c) Agroforestry
(a) Intercropping

Dominant multiple cropping system practised in tropics. Main objective is to utilise the space between the main crops and to produce more yield per unit area. Important fodder crops suitable for intercropping are guinea grass, hybrid napier, cowpea, congo signal and gamba grass.

(b) Sequential cropping

System of growing 2 or more crops in same field per year one after the other. Major example of sequential cropping is growing fodder in summer rice fallows.

(c) Agroforestry

Any land use system which includes both tress and agricultural crops on the same piece of land. It is divided into sub systems:

- Silvicultural system,
- Agri-silvicultural system
- Silvi-pastoral system
- Agri-silvi-pastoral system

Silvi-pastoral system

The land management system involving trees and grasses. Most of the silvi-pastoral combinations are based on fodder trees or shrubs. Major fodder trees grown are subabul, glyricidia, calliandra, agathi and hedge lucerne and the major grasses grown are guinea grass, hybrid napier and congo signal. A study was conducted in IGFRI, Jhansi to assess the forage production of grasses and legumes in combination with fodder trees. Among the fodder crops *Chrysopogonfulvus, Panicum maximum, Cenchrusciliaris and Stylosanthes seabrana* intercropped with fodder trees *Ficusinfectoria, Madhucalatifolia, Morus alba* and *Acacia niloticag*reen forage production was higher from *Panicum maximum* (IGFRI, 2018).

(3) Hi-tech farming

Apart from the conventional farming methods certain innovative farming methods are adopted in fodder production. The major hi-tech farming methods adopted are :

- Fertigation
- Vertical farming
- Fodder on terraces
- Hydroponics

Fertigation

Fertigation is a method of fertilizer application in which fertilizer is incorporated within the irrigation water by drip system. Application of nutrients to fodder crops is negligible. But studies have shown that there is considerable increase in yield when fertilizers are added, the maximum being when applied through drip system. Hassan *et al* (2010) carried out field studies to test the effect of varying levels of nitrogen (0, 60,100, 140 and180 kg/ha) applied through different application methods viz., broadcast, fertigation and side dressing on fodder maize. Nitrogen fertigation had better efficiency over broadcast and side dressing.

Maximum leaves/plant, stem girth, green fodder yield, total dry matter, leaf area index, leaf area duration, N contentand N uptakewere noted with the application of 140 kg N ha^{-1} through fertigation.

Vertical farming

Vertical farming is the practice of growing produce in vertically stacked layers. Vertical farms attempt to produce food in challenging environments, like where arable land is rare or unavailable. GIGGINS FARM VILLA (Growables in Irrigated Grow bags, Goats Integrated for Nutritional Security with Fowl, Azolla, Rabbit Management Vertically and Intensively in Limited Land Available) is an intensive integrated vertical farming system developed by the Kannur division of Krishi Vigyan Kendra with the aim of converging agriculture, animal husbandry and dairy farming. It helps farmers to overcome constraints posed by lack of space. The unit can be set up even on one cent of land. What makes it attractive is its multifaceted nature, wherein farmers can rear goats, hens, rabbits and quails, while also cultivating vegetables, gathering seeds, supplying saplings and catering to production of organic manure. In short, it is a comprehensive unit that assures guaranteed income for families (The New Indian Express, 2016).

The structure is pyramid like and is made of two galleries supporting each other which forms the roof of the two-storey animal house in which ground floor is for poultry and first floor is for goats. Rabbits are accommodated in hanging cages and azolla is grown in tanks over rabbit cage. Galleries can accommodate grow bags with micro irrigation for cultivating fodder for animals. The structure is 16 ft in height, 32 ft in length and 10 ft in width with a floor area of 384 sq. ft but gives effective utility area of 44sq.ft (Giggin, 2015).

Growing fodder on terrace

Scientists from the Krishi Vigyan Kendra, Kannur have developed an innovative method to grow fodder grass (CO-3 variety) on roof tops of cattle sheds to help dairy farmers grappling with space constraints and fodder scarcity. The technique, called high density double planting with drip irrigation, involves growing fodder grass in plastic 'grow-bags' usually used for cultivating vegetables. The grass grows to a height of six to eight feet in a span of two months. At the KVK campus, the grass is grown in around 300 UV stabilized bags, placed equidistantly, with a foot's space left between the bags. Water and manure are supplied using drip irrigation. The first harvest can be done after 10 weeks of planting and thereafter harvest can be done every 30 days. Different varieties of grass can be grown by this method.

The innovation is attractive because of the financial gain it can give the farmers. A cow, which is usually given concentrate feed costing Rs.22 a kg, can easily be given five kg of green grass at Rs.5 kg^{-1}. Such a huge saving in production cost will be a boon for the dairy sector which faces regular decline in number of dairy animals every year. Apart from growing, farmers can also take up selling the root slips of the green grass that can give them some additional income. A single root costs Rs.2 and there is quite a demand for procuring fresh green grass. An investment of Rs.100 a month produces fodder costing Rs.6,000 in six months. Grass grows faster in this method as ample sunlight is available. Moreover, nagging problems of pests and weeds are mostly absent. A single bag has a three-year utility span (The Hindu, 2013).

Hydroponics

To overcome the area constraints in fodder production, hydroponics is now emerging as an alternative technology to grow fodder for farm animals. Fodder produced by growing plants in water or nutrient rich solution but without using any soil is known as hydroponics fodder or sprouted grains or sprouted fodder. (Dung *et al.*, 2010).

Hydroponics techniques have proven useful and efficient for producing food for livestock. Fodder is grown year-round under controlled climatic condition and it is rich in minerals, proteins, amino acids and vital nutrients. Fodder is free of diseases, residues of pesticides or chemicals and organic in nature. It improves the health, productivity, fertility and longevity of all livestock, and saves land, water and labour (Khanna, 2014). Sneath and McIntosh (2003) reported that grain sprouts are both highly digestible and nutritious feeds. The energy in grain is largely starch and sprouting converts much of the starch to sugars. Sprouting also increases fibre levels. Khanna (2015) based on his studies concluded that replacement of farm made concentrate mixture with hydroponic maize fodder at 25% level resulted in improved digestibility of gross nutrients (except dry matter and organic matter) and fibre fractions.

There are many types of grain that can be grown hydroponically. Grain such as oats, barley,

wheat, sorghum and corn have all been tried. However, when choosing a grain, the main characteristics that come into play are their nutritional value, speed of grain growth and protein levels. Naik *et al*. (2015) suggested maize to be the grain of choice for production of hydroponic fodder due to its easy availability, lower cost, good biomass production and quick growing habit. In comparison to conventional green fodders, hydroponics green fodders contain more protein, fat (ether extract) and soluble carbohydrates (nitrogen free extract); but less fiber, total ash and acid insoluble ash. Naik *et al* (2012) compared the chemical composition of conventional fodder maize and fodder maize grown in hydroponics system, and found out that there is considerable increase in crude protein, nitrogen free extract and ether extract in maize grown in hydroponics system compared with conventional.

Jolad (2018) conducted an experiment in Tamil Nadu Agricultural University to evaluate the suitable crops for hydroponics. Twelve crops including fodder maize, grain maize, fodder bajra, grain bajra, barley, wheat, oats, fodder cowpea, grain cowpea, horse gram, soybean and lucerne were taken for the study. Comparing the green fodder yield, it was found that fodder maize produced maximum green fodder yield of 5.48 kg GFY/kg seed. It was on par with grain maize (5.37 kg GFY/kg seed), grain cowpea (5.29 kg GFY/kg seed) and horse gram (5.24 kg GFY/kg seed).

(4) Mechanisation

Fodder production, its processing and utilization is labour intensive, time consuming and high energy intensive operation. Optimum production and utilization of forage crops demand minimum, critical and timely operation. Delay in fodder production operation often causes loss of moisture content and deterioration of fodder quality rapidly. There are some specific mechanization requirements of fodder crops. Number of cultivated fodder crops are multi-cut and produce volume of green and dry matter during the time of harvest. Large volume and mass handling require suitable machinery for operation. In Indian conditions, major farming community falls under small (1-3 ha field size) land holding. A small farmer, usually possessing 2-10 numbers of animals allocates small portion (up to 10 per cent) of his cultivated land to fodder cultivation. Accordingly, machinery and their size is required in Indian condition to fulfil their needs (Sahay *et al.*, 2016).

Non-conventional fodder resources for feeding livestock

In deficit status of feed and fodder for livestock there is need to think for alternate feed and fodder resources to cater the need of livestock in India. Azolla has been reported to be a very good source of protein, essential mineral elements and vitamins for livestock. Out of several species of Azolla, *Azollamicrophylla* has been reported to be best suited for tropical climate and livestock feeding. The fresh yield of azolla was around 200-250 g/sqm/day (Singh, 2016).

Cactus flat oval stem known as cladodes or paddles remain green and succulent throughout the year and contain about 90% moisture. As a livestock feed, cactus can produce a large quantity of green forage throughout the year if properly managed. It also provides the much-needed water, energy and vitamins in the dry seasons. Two main types of Opuntia are spineless types and spiny types, but both have similar nutritional value. The spiny types however, pose certain utilization challenges due to the damage it can inflict on alimentary tract of the animal grazing on it. Therefore, spines must be removed by burning or scrapping them with a machete before feeding them to animals. Opuntia has low fiber and protein content and has to be supplemented with rich source of fiber and nitrogen in order to enhance animal performance. Cactus is drought tolerant and makes use of little moisture in rainy season to produce large quantities of forage. It has high carrying capacity than any other drought tolerant fodder in arid and semi-arid areas. The fact that cacti combine drought tolerance and water use efficiency, it produces large quantity forage that remain green and succulent in drought period, it is easy and cheap to establish, makes it the best fodder option in the changing climatic situations (Singh, 2016).

Innovative techniques in fodder preservation

In most parts of the world, forage conservation is a key element for productive and efficient ruminant livestock farms. Forage conservation permits a better supply of quality feed when forage production is low or dormant. Forage conservation also provides farmers with a means of preserving forage when production is faster than can be adequately utilized by grazing animals. This prevents lush growth from becoming too mature. Consequently, forage conservation provides a more uniform level of high-quality forage for

ruminant livestock throughout the year (Muck and Shinners, 2001).

Forage is preserved as either hay or silage. In hay production, the crop is dried to about 15 % so that it is essentially biologically inactive both with respect to plant enzyme activity and microbial spoilage. The low moisture content also permits easier transportation by reducing the weight per unit of dry matter (DM). Haymaking is dominant in those areas of the world where good drying conditions prevail. However, it may also be used in humid climates where ensiling has been considered too difficult because of forage characteristics, high temperatures or tradition. Hay making is done by traditional sun-curing method and mechanical drier method (Thomas, 2003). In ensiling, anaerobic fermentation of green fodder in special structures called silo takes place. It may be called pickles of green fodder for the dairy animals (Borreani *et al.,* 2018).

Improved methods in preservation includes :

(1) Technological interventions in hay and silage
   (a) Additives for quality hay and silage
   (b) Haylage
   (c) Balage
(2) Dehydrated products
   (a) Pellets
   (b) Cubes

Additives for quality hay and silage

Preservatives are added to silage. The major ones include :

- Sodium metabisulphite- helps in partial sterilization and checks bacterial growth
- Salt-Make silage more palatable and improves fermentation
- Non-protein nitrogen -Ammonia and urea are added. It decrease the growth of yeast and molds.
- Propionates- *Propioni bacterium* spp are added which reduces plant respiration and heating (Kaiser, 1999).

The bio preservatives added are:

- Bacterial inoculants- include *Lactobacillus, Pedicoccus, Streptococcus*. It increases lactic acid bacteria, decrease DM and protein degradation losses
- Sugars-molasses, glucose and dextrose are usually added. It increases lactic acid content by providing more sugar for bacteria (Muck and Shinners, 2001).

Bases on a study conducted by Ishrath (2016) to assess the cutting intervals and additives for quality silage production, it was found that quality silage can be prepared by ensiling the hybrid napier harvested at 45 days interval with 2% urea or 1% urea + 1% jaggery as additives. Mixing of corn - cowpea or oats-alfalfa at the ratio of 75: 25, proved to be an effective way to make quality silage ensuring the supply of nutritionally rich silage round the year (Goyal and Tiwana, 2016).

Haylage

Haylage is also called as hay crop silage or low moisture silage or drylage. Contains 40-60% moisture. Important aspects to be considered while making haylage are :

- Wilting
- Dry matter content
- Chopping
- Exclusion of air

It has many advantages over hay and silage like storage losses are reduced, weather associated risks are low and palatable feed liked by animals devoid of objectionable odours. Can be made successfully in conventional silo structures. Large plastic bags have become popular for haylage storage.

Balage

Balage is also called as round-bale silage. Fodder is baled at a higher moisture content and then stored in sealed plastic wrap. High moisture level and air-tight environment is needed. It is fermented and preserved by acid.

Dehydrated products

Artificially dried forage can be made denser for storage by compressing it into wafers or cubes (chopped forage) extruded from a ram-press or rotary die press respectively, or it may be milled and pelleted. Pellets and cubes are the common dehydrated products (Bakshi *et al.*, 2018). Alfalfa pellets are now available in markets. Power Operated Feed Pelleting Machine is developed by IGFRI. Value added feed pellets are also made. It includes :

- Azolla added feed pellet-groundnut cake (0-40%) was replaced with dried Azolla (10-50%) leaves
- Value addition through berseem and moringa leaves-Dried and chopped berseem (10-50%) was added in place of leucaena leaf. Firm pellets were successfully prepared with dried moringa leaves (IGFRI, 2018).

CONCLUSION

Being the leader in cattle and buffalo population, and livestock population increasing at a rate of 1.23 % per year current fodder production in our country is not able to meet the requirement. Land under fodder cultivation is static and little scope of expansion due to reducing per capita availability. So, innovative technologies, both in production and preservation of fodder, should be adopted.

REFERENCES

Bakshi, M. P. S., Wadhwa, M., and Makkar, H. P. S. 2018 : Feeding strategies during natural calamities. *Indian J. Anim. Nutr*. **35** : 1- 21.

Borreani, G., Tabacco, E., Schmidt, R. J., Holmes, B. J., and Muck, R. E. 2018 : Silage review: Factors affecting dry matter and quality losses in silages. *J. Dairy Sci*. **101** : 3952-3979.

Dung, D. D., Godwin, I. R., and Nolan, J. V. 2010 : Nutrient content and in sacco digestibility of barley grain and sprouted barley. *J. Anim. Vet. Adv*. **9** : 2485-2492.

Giggin, T. 2015 : Giggins farm villa-Vertical farming integrated with animal husbandry for sustainable livelihood. In: *International Magazine on Vertical Farming*, Vertical Farming Association, India, pp. 67-69.

GOI [Government of India]. 2017 : *Agricultural Statistics at a Glance 2016* [on-line]. Available: https://eands.dacnet.nic.in/PDF/Glance-2017.pdf [3 Jan. 2019].

GOK [Government of Kerala]. 2018 : *Farm Guide 2018*. Farm Information Bureau, Thiruvananthapuram, 366p.

Goyal, M. and Tiwana, U. S. 2016 : Ensiling Legume with Cereal Fodder Influences Quality of Silage Mixtures. *Indian J. Anim. Nutr.* **33** : 228-232.

Hassan, S. W., Oad, F. C., Tunio, S. D., Gandahi, A. W., Siddiqui, M. H., Oad, S. M., and Jagirani, A. W. 2010 : Impact of nitrogen levels and application methods on agronomic, physiological and nutrient uptake traits of maize fodder. *Pakistan J. Bot.* **42** : 4095-4101.

ICAR-IGFRI [Indian Grassland and Fodder Research Institute]. 2013 : *Vision 2050*. ICAR Indian Grassland and Fodder Research Institute, Jhansi, 40p.

ICAR-IGFRI [Indian Grassland and Fodder Research Institute]. 2018. *Annual Report 201718*. ICAR-Indian Grassland and Fodder Research Institute, Jhansi, 132p.

Ishrath, P. K. 2016 : Cutting intervals and additives for quality silage production. M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 92p.

Jolad, R. 2018 : Economical green fodder production through hydroponics. M.Sc.(Ag) thesis, Tamil Nadu Agricultural University, Coimbatore, 86p.

Kaiser, A. G. 1999. *Silage Additives*. Department of Primar Industries, Wagga Wagga Agricultural Institute, Wagga Wagga, NSW, 4p.

Kallungal, D. 2016 : New vistas open up in integrated vertical farming. *The New Indian Express*, 03 Aug. 2016, p. 7.

Khanna, C. H. 2015 : Effect of feeding rations supplemented with hydroponic fodder on nutrient utilization and milk production in lactating graded Murrah. M.V.Sc. and AH thesis, SriVenkateswara Veterinary University, Tirupati, 118p.

Khanna, R. S. 2014 : Fodder of the future- A review of the hydroponics technique. *Indian Dairyman* 66: 5-6.

Maity, A., Vijay, D., Malaviya, D. R., Gupta, C. K., Ahmed, A., and Singh, S.K. 2015. Seed Ball Technology: Way forward to revitalizing rangelands in Bundelkhand region. In: *Proceedings of the Second International Conference on Bio-Resource and Stress Management*, January 07-10, 2015, Hyderabad, pp. 345-352.

Muck, R. E. and Shinners, K. J. 2001. Conserved forage (silage and hay): Progress and priorities. *Int. Grassl. Cong.* **19** : 753-762.

Naik, P. K., Dhuri, R. B., Swain, B. K., and Singh, N. P. 2012. Nutrient changes with the growth of hydroponics fodder maize. *Indian J. Anim. Nutr.* **29** : 161-163.

Naik, P. K., Swain, B. K., and Singh, N. P. 2015. Production and utilisation of hydroponics fodder. *Indian J. Anim. Nutr*. **32** : 1-9.

Prabhu, M. J. 2013 : Cutting fodder costs by adopting an innovative method. *The Hindu*, 04 Sept. 2013, p. 6.

Sahay, C. S., Pathak, P. K., and Singh, S. K. 2016 : *Mechanization in Fodder Production*. ICAR-Indian Grassland and Fodder Research Institute, Jhansi, India, 42p.

Singh, S. 2016 : Non conventional fodder resources for feeding livestock. In: Pathak, P. K., Singh, S. K., Sahay, C. S., Sharma, R. K., Chaudhary, M., and Maity, A. (eds), *Recent approaches in crop residue management and value addition for entrepreneurship development.* ICAR-Indian Grassland and Fodder Research Institute, Jhansi, UP, pp. 7-12.

Sneath, R. and McIntosh, F. 2003 : *Review of Hydroponic Fodder Production for Beef Cattle.* Department of primary industries, Queensland, Australia, 84p.

Thomas, C. G. 2003. *Forage crop production in the tropics*. Kalyani publishers. New Delhi. 226p.

Vijay, D., Gupta, C. K., and Malaviya, D. R. 2018 : Innovative technologies for quality seed production and vegetative multiplication in forage grasses. *Curr. Sci*. **114** : 148-154.