Journal of Rural Advancement
[ISSN 2347-2561 (P); 2583-6102 (E)]
Vol. 11, Issue 01, April 2023

Technological advancements in fodder production: a review

Awadhesh Kishore, Aman Parashar and Jai Dev Sharma

School of Agriculture

ITM University, Gwalior (Madhya Pradesh), India

[Received on: Feb 6, 2023; Accepted on: Mar 27, 2023]

Abstract

Livestock is a sub-sector of agriculture that plays an important role not only in the Indian economy but also in national nutritional security, particularly for small and marginal farmers. But the production potential of our animals is not comparable with that of the global average due to many reasons, feed and fodder deficiency being the major one. The feed shortage in India is due to the unavailability of land for quality fodder cultivation. Thus, there is a burning need to adopt innovative methods not only in production but also in the preservation of fodder. Unconventional methods in fodder production, including seed technology, system approaches, hi-tech farming and adopting mechanization in fodder production, can be considered for their advancement. Being the leader in cattle and buffalo populations and increasing livestock populations, current fodder production in our country is not able to meet the requirement. Improved technology in fodder preservation, including technical interventions in hay and silage like supplementation with additives for quality hay and silage, preserving as haylage and balage and making dehydrated products like pellets and cubes, can also be considered for increasing quality fodder production and utilization. Land under fodder cultivation is static and has little scope for expansion due to reduced per capita availability and human priorities. So, technological advancements both in the production and preservation of fodder should essentially be adopted to fight against fodder scarcity.

Keywords: BN hybrid, Dinanath grass, Guinea grass, hitech farming, system approach.

Introduction

India is fundamentally an agricultural country, with about two-thirds of the rural population directly depending on it for their livelihood. India has vast livestock resources, including poultry. Livestock is an important source of income for landless and marginal farmers and plays an important role in the national economy. Animal husbandry and dairying activities, along with agriculture, have continued to be integral parts of human life since the process of civilization started. According to the first revised estimates of the press note on "First Revised Estimates of National Income, Consumption Expenditure and Capital Formation for 2020-21" released by the National Statistical Office (NSO) and MoSPI on January 31, 2022, the gross value added (GVA) of the livestock sector is more than INR 11.14 billion at current prices during FY 2020-21, which is about 30.9%

of Agricultural and Allied Sector GVA and 6.2% of Total GVA (GOI, 2022). Livestock plays an important role in nutritional security, particularly for small and marginal farmers. The productivity of livestock in India is lower than the global average. The main reasons for it may be considered improper nutrition, inadequate health care, and management. The improper livestock nutrition reflects the unavailability of cultivable land for fodder production due to the priority of human nutrition. Being the leader in cattle and buffalo populations, the livestock population is increasing every year at a rate of 4.82% from 2012–19 (GOI, 2021). The current fodder production in the country is not meeting the requirements of the animals. The country has a deficit of 63.5% green fodder and 23.5% dry crop residues. If the present scenario continues, the discrepancy will increase to 65.5% by 2030 (ICAR-IGFRI, 2015).

Shortcomings in fodder production

The main constraints of fodder cultivation include the unavailability of land for fodder production, more labour needs, more growth time (approximately 45–60 days), the nonavailability of constant fodder quality round the year, uncertain rainfall, the requirement of manures and fertilizers and the insufficiency of water (Naik et al., 2015). The non-commercial status of forages and an unorganized small market without any government policy support like a minimum support price make fodder production a low-priority crop. As a result of the animal feed deficiency and unavailability of land for fodder cultivation, it is a burning need for the nation to adopt advanced technologies in fodder cultivation, both in production and preservation of fodder. The increased cost of packaged cattle feed adds to the cost of production in the dairy sector.

Advanced techniques in fodder production

Advanced techniques in fodder production can be considered in four aspects: seed technology, system approach, hi-tech farming and mechanization (Thomas and Thomas, 2019).

Seed technology

Only about one fourth to one third of the required quantity of quality seeds for cultivated fodder is available in India, which is capable of covering less than one tenth of the required area of range grasses and legumes. Thus, there is a need to evolve superior varieties of forage crops with high yield and quality and also develop new technologies for multiplication.

Planting material multiplication in the Bajra-Napier hybrid

Bajra-Napier hybrid (BNH) is an imperative perennial fodder that yields up to 250 t ha^{-1} of green fodder under irrigated conditions. As there is no seed formation in this interspecific hybrid, vegetative propagation is the only option for BNH cultivation. But multiplication and sale of planting material have major constraints: for example, high transportation costs, damage to the standing crop from where rooted slips are taken out and high labour costs.

In-vitro rooting in the Bajra Napier hybrid

A packing-friendly technique for BNH-rooted slips has been developed using suitable aged stem cuttings with 2-3 nodes and wrapping them in a specific material like paper or cloth. Keeping these wrapped cuttings at 25ºC and 80% humidity is safe for one week, and rooted slips can be produced from this bioplasm. The process reduces the difficulty of uprooting the material in the field and helps with easy transport over long distances. This technology is mainly convenient for clients with small requirements who need appropriate conveyance facilities for long distances. The *in-vitro* rooting of BNH 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 suitable bundles, it is very easy to transport them from one place to another over a long distance without much drying or damage (Vijay et al., 2018).

High-density nursery in the Bajra-Napier hybrid

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

In-vitro maturation of Guinea grass seeds

Among many perennial grasses, Guinea grass (*Panicum maximum*) is well adopted by Indian farmers. The reason is its multi-cut nature and high green fodder yield, reaching up to 80 to 100 t ha^{-1}. The seed maturity in this crop varies from plant to plant and branch to branch. Mostly different stages within an inflorescence, starting from anthesis to seed ripening, are observed. This makes it difficult to realize the full potential of seed production. The manually harvested seeds are characterized by a germination potential of only 15–30%. To overcome this limitation, *in vitro* maturation of guinea grass is done. The panicles are cut before the anthesis stage and dipped in suitable hormonal solutions like 100 ppm indole acetic acid to retain their viability for a longer duration, which thus helps in proper seed maturation. By using this *in vitro* procedure, the seed shedding in guinea grass may be diminished and the collected seed may be more homogeneously mature, resulting in improved seed filling. This technology helps the production of high-quality seed with reduced production losses and benefits the farmers by having a high germination percentage with superior chances of seedling establishment (Vijay et al., 2018).

De-fluffing of Dinanath seeds

Amongst annual range grasses, Dinanath (*Pennisetum pedicellatum*) is an important fodder crop, having high early vigour and adaptability to very poor soils (Kishore and Verma, 2000). The fodder yield potential of this perineal fodder is higher compared to sorghum with minimal inputs (Kishore and Singh, 2021). The feeding value of this forage has also been compared with that of sweet sorghum (Sharma and Kishore, 2022). The crop is a producer of a large number of seeds; however, the small seed, with its light weight enclosed in voluminous fluff leads, makes it difficult to transport as well as precise sowing in the field. Reducing the volume of the huge fluff and extracting true seed for precise sowing is the need of the day for large-scale, successful usage of Dinanath grass. The naked caryopsis from Dinanath seed fluff may be detached from the fluff using a cotton batting machine with minor alterations. Thus, the true seed occupies a much smaller volume and the weight is reduced from 7 kg to 450 g. This technique reduces the difficulty of transportation and sowing Dinanath grass to a great extent.

This technology is a boon to grass seed producers and farmers, as it reduces the volume of seed and improves the ease of carrying it over long distances. The de-fluffing process also benefits by providing the naked seed for pelleting (Vijay et al., 2018).

Modified method for seed pelleting in Dinanath

Dinanth grass seeds are very small and full of fluff or appendages. They are easily blown off and are supposed to sustain mechanical damage at a higher rate. Grass seed pelleting has long been thought to be a solution for addressing this issue. An experiment was conducted at the Indian Grassland and Fodder Research Institute (IGFRI), Jhansi, to pellet Dinanath grass in a specially fabricated tyre-based machine. Seed pelleting involved mixing fluffed seeds of this grass, soil and water at an appropriate ratio in a rotating tyre to make seed balls of 15–20 mm diameter. Six types of locally available pelleting materials, viz., soil, sawdust, wheat bran, charcoal, farmyard manure and limestone, were tried at the initial stage to make seed balls. An exact quantity of pelleting material was put in the rotating tyre, followed by a water spray onto the dry mix until it began to nucleate and form small beads. When the beads reached approximately one cm in diameter, the desired quantity of seeds was dusted slowly on the rotating beads. The seeds adhered to the bead's surface were given a water spray, followed by dusting with pelleting material to cover the seeds by making a pelleting layer. The pelleting has many advantages, like increasing germination potential to more than 90%, enhancing seed field performance, helping in mechanization and improving vigour as it is supplied with nutrients and water absorbents (Maity et al*.,* 2015).

System approach

In most parts of the country, it is common to observe farming systems integrated with forage crops and livestock production. Undoubtedly, it is the best alternative to increasing the area and production of forage crops, as there are constraints to bringing more land under forage crops (Thomas, 2003). Some of the prominent farming systems with forage crops practiced in the tropics, namely intercropping, sequential cropping and agroforestry, may be useful (Thomas and Thomas, 2019).

Intercropping

Dominant multiple-cropping systems have been practiced in the tropics. The main objective of this technique is to utilize the space between the main crops and produce additional yield. Important fodder crops suitable for intercropping are guinea grass, hybrid Napier, cowpea, congo, signal and gamba grass.

Sequential cropping

A system of growing two or more crops in the same field per year, one after the other, is called sequential cropping. A very common example of sequential cropping is growing fodder in summer rice fallows.

Agroforestry

Any land use system that includes both trees and agricultural crops on the same piece of land It is divided into subsystems, including the silvicultural system, the agri-silvicultural system, the silvi-pastoral system and the agri-silvi-pastoral system.

Silvi-pastoral system

A Silvi-pastoral system is a land management system involving trees and grasses. Mostly, the silvi-pastoral combinations are based on fodder trees or shrubs. The major well-known fodder trees are subabul, glyricidia, calliandra, agathi and hedge lucerne, whereas the major well-known fodder grasses are guinea grass, hybrid napier and congo signal. A study was conducted at IGFRI to evaluate the forage production of grasses and legumes in various combinations with fodder trees. Among the fodder crops, *Chrysopogonfulvus*, *Panicum maximum, Cenchrusciliaris and Stylosanthes seabrana* intercropped with the fodder trees *Ficus infectoria, Madhucalatifolia, Morus alba* and *Acacia nilotica green.* The combinations with *Panicum maximum* proved their seniority compared with others in terms of forage production (ICAR-IGFRI, 2018).

Hi-tech farming

In addition to conventional farming methods, certain advanced, hi-tech farming techniques are adopted in fodder production. The major hi-tech farming methods adopted are fertigation, vertical farming, fodder on terraces and hydroponics (Thomas and Thomas, 2019).

Fertigation

Fertigation is a technique of fertilizer application with irrigation. In fertigation, fertilizer is added to the irrigation water in the drip system. The application of nutrients to forages is negligible. But studies have shown that there is a substantial increase in fodder yield when fertilizers are added to the irrigation water, the maximum being when applied through the drip technique. Hassan et al. (2010) carried out experiments to test the impact of varying nitrogen levels from 0 to 180 kg ha^{-1} applied through different application methods, viz., broadcast, fertigation and side dressing, on fodder maize. Nitrogen fertigation proved to have better efficiency than broadcast and side dressing. Maximum leaves/plant, stem girth, green fodder yield, total dry matter, leaf area index, leaf area duration, N content and N uptake were recorded with the application of 140 kg N ha^{-1} through fertigation.

Vertical farming

Vertical farming is the specific practice of growing crops in vertical layers. The major objective of vertical farming is to produce crops in challenging, adverse environments; for example, arable land is rare or unavailable. Growables in irrigated grow bags, goats integrated for nutritional security with fowl, azolla, rabbit management vertically and intensively in limited land available (GIGGINS FARM VILLA) is an intensively integrated vertical farming system developed by the Kannur division of Krishi Vigyan Kendra (KVK) with the aim of convergence of agriculture, animal husbandry, and dairy farming. The system helps farmers overcome constraints posed by a lack of space. The unit can be set up on even one cent of land. Multifaceted nature makes it attractive wherein farmers can rear goats, hens, rabbits and quails while also cultivating vegetables, producing seeds, supplying saplings and catering to the production of organic manure. In short, it is a comprehensive unit of farming that assures guaranteed income for families.

It is structured like a pyramid and made of two galleries supporting each other to form the roof of the double-storied animal house. In GIGGINS FARM VILLA, the ground floor is used for poultry farming and the first floor for goats. Rabbits are accommodated in hanging cages, whereas azolla is grown in tanks over rabbit cages. Galleries accommodate bags with microirrigation to grow 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 ft^2. It gives an effective utility area of 44 sq ft (Giggin, 2015).

Growing fodder on the terrace

Scientists from the KVK, Kannur, have developed an advanced technique to grow fodder grass on the roof tops of cattle sheds to help dairy farmers solve space constraints and fodder scarcity. The technique, called high density double planting with drip irrigation, involves growing fodder grasses in plastic 'grow bags," usually used for vegetable cultivation. The grasses grow to a height of six to eight feet in a span of two months. The fodder grasses are cultivated in stabilized bags, placed equidistantly, with a foot's space left between the bags. Water and fertilizers are supplied using drip irrigation. The first harvest can be done after 10 weeks of planting and thereafter every 30 days. Different varieties of grass can be grown using this technique. This advancement is attractive because of the additional financial gain for the farmers. A cow, which is usually given concentrate feed costing INR 22 per kg, can easily be given five kg of green grass at INR 5 per kg. Such a huge saving in production costs may be a boon for the dairy sector. Apart from growing forage crops, the producers can also go in for selling the root slips of the green grasses, which can give them an additional handsome income. A single root costs INR 2 and there is quite a demand for procuring fresh green grass. An investment of INR 100 a month produces fodder costing INR 6,000 in six months. Grass grows faster with this technique because of the ample sunlight available. Moreover, the nagging problems of pests and weeds are almost absent. A single bag has a life expectancy of three years.

Hydroponics

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

Hydroponics techniques have proven beneficial and efficient for producing food for animals. Fodder is grown year-round under controlled climatic conditions and is rich in minerals, proteins, amino acids and vital nutrients. The forage is free of diseases, residues of pesticides or chemicals and organic in nature. It improves the health, productivity, fertility and longevity of the livestock and saves land, water and labour (Khanna, 2014). Sneath and McIntosh (2003) reported that grain sprouts are not only highly digestible but also nutritious feeds. The energy in grain is largely starch and while sprouting, the grains convert much of the starch to sugars. The sprouting of grain also increases fibre levels. Khanna (2015) concluded that replacing farm-made concentrate mixtures with hydroponic maize fodder resulted in improved digestibility of gross nutrients (except dry matter and organic matter) and fibre fractions.

There are numerous grains that can grow in hydroponics. Grain crops like oats, barley, wheat, sorghum and corn have been cultivated hydroponically. When choosing a grain, the main characteristics that come into play are its nutritional value, speed of grain growth and protein levels. Naik et al. (2015) suggested maize may be used for the production of hydroponic fodder due to its easy availability, lower cost, good biomass production and quick growing habit. In comparison to conventional green fodders, hydroponic green fodders contain more protein, ether extract and nitrogen-free extract but less fibre, total ash and acid-insoluble ash. Naik et al. (2012) compared the chemical composition of conventional fodder maize and fodder maize grown in hydroponics systems and reported that there was a considerable increase in crude protein, nitrogen-free extract and ether extract in maize grown in hydroponics systems compared with conventional.

Jolad (2018) experimented to evaluate suitable crops for hydroponics. Twelve crops, including fodder and grain maize and barley, wheat, oats, fodder cowpea, grain cowpea, horse gram, soybean and lucerne, were taken for the study. The fodder maize produced the maximum seed yield of green fodder. It was almost similar to grain maize, grain cowpea and horse gram.

Mechanized farming

Fodder production requires intensive labour during processing and utilisation, a time-consuming and energy-intensive operation. The emphasis is given that variable costs can be reduced by good mechanization planning, which leads to more profitable fodder production with the effective use of agricultural machinery (Türer and Yildiz, 2023). Optimal production and utilization of forage crops require minimal, critical and timely operation. Delay in forage production operations usually causes loss of moisture and thus deteriorates fodder quality. There are some specialized mechanization requirements for fodder. Many cultivated fodder crops are multi-cut and produce volumes of green and dry matter during the time of harvest. Large volumes and mass handling require suitable machinery. Major farming communities fall under small land holdings (1-3 ha field size). A small farmer, usually possessing 2–10 animals, assigns a small portion (up to 10 per cent) of his cultivated land to fodder cultivation. Accordingly, mechanization is required to fulfil their needs (Sahay et al., 2016).

Non-conventional fodder resources for livestock feeding

During periods of scarcity of feed and fodder for livestock, there is a need to consider the available alternatives to the common feed and fodder resources to cope with the daily needs of the livestock. Azolla (*Azolla sp*.), a fern, has been reported to be a very good source of protein, essential mineral elements and vitamins for livestock. Among the several species of Azolla, *Azolla microphylla* has been found to be best suited for dairy animal feeding in tropical zones. The fresh yield of azolla was around 200–250 g m^{-2} day^{-1} (Singh, 2016). Cactus, a member of the plant family Cactaceae, has flat oval stems known as cladodes or paddles that remain green and succulent throughout the year and contain on average 90% moisture. As a dairy animal feed, cactus can be used as a substitute. A large quantity of green fodder from cacti throughout the year can be produced if managed properly. It is also capable of providing sufficient amounts of water, energy and vitamins during the panic period of the dry seasons. Opuntia have spineless types and spiny types, but both have similar feeding values. The spiny-type cacti, however, pose certain utilization issues due to the physical damage to the alimentary tract of the grazing animal. Therefore, spines are required to be removed by burning or scraping before feeding them to animals. Opuntia contains low levels of fibre and protein; hence, it needs to be supplemented with fibre and nitrogen-rich sources to meet nutritional requirements and enhance animal performance. All the cacti are drought-tolerant and make use of little moisture in rainy seasons to produce large quantities of green forage. The cactus has a high carrying capacity compared to any other drought-tolerant forage in arid or semi-arid zones. The cacti have not only drought tolerance but high water use efficiency as well; hence, they are in a position to produce large quantities of forage that remains green and succulent for long periods of drought. The cacti are easy and cheap to establish. All of these properties make it the best fodder option in changing climatic situations, especially in arid and semi-arid zones (Singh, 2016).

Advanced techniques in fodder preservation

Forage conservation is a key element for productive and efficient livestock farms. Forage conservation permits a better source of quality feed resources when forage production is low or dormant. Forage conservation also offers farmers a means of preserving forage when production is higher and faster compared to requirements. Additionally, the preservation of fodder prevents lush growth from becoming too mature. Consequently, forage conservation provides a more uniform level of high-quality forage for livestock throughout the year (Muck and Shinners, 2001). Forages are preserved as either hay or silage. During hay production, the plants are dried to 15 per cent dry matter (DM) content to make them biologically inactive with respect to plant enzyme activities and microbial spoilage. The low moisture content also permits easier transportation by reducing the weight per unit of DM. The making of hay is leading in areas of the world where good natural drying conditions are present. Hay is also very common in humid climates where ensiling has been considered too difficult because of forage characteristics, high temperatures, or tradition. Normally, haymaking is completed by the traditional sun-curing method, but in some areas, the mechanical drier method is also in use (Thomas, 2003). In silage making, or ensiling, anaerobic fermentation of green fodder in specific structures called silos takes place. It is commonly called pickles of green fodder for the dairy animals (Borreani et al*.,* 2018). Advanced techniques in preservation include technological interventions in hay and silage, additives for quality hay and silage, haylage, balage, dehydrated products, pellets and cubes (Thomas and Thomas, 2019).

Additives for quality hay and silage

Preservatives are added to silage. The major preservatives may be enlisted as sodium metabisulfite, which helps in partial sterilization and checks bacterial growth; salt, which makes silage more palatable and improves fermentation; and non-protein nitrogen, ammonia, and urea, which are added. It decreases the growth of yeast and molds and propionates *from Propionibacterium* spp. are added, which reduce plant respiration and heating (Kaiser, 1999). The biopreservatives may be enlisted as bacterial inoculants and include *Lactobacillus, Pedicoccus and Streptococcus*. It increases lactic acid bacteria, decreases DM and protein degradation losses and sugars (molasses, glucose and dextrose) are usually added. It increases lactic acid content by providing more sugar for bacteria (Muck and Shinners, 2001). Based on a study conducted to assess the harvesting intervals and additives for quality silage production, it was found (Ishrath, 2016) that quality silage can be prepared by ensiling the hybrid Napier harvested at a 45-day interval and fortifying it with 2% urea or 1% urea + 1% jaggery as additives. The mixing of corn-cowpea or oats-alfalfa at a ratio of

75:25 proves an effective way to make quality silage, ensuring the supply of nutritionally rich silage throughout the year (Goyal and Tiwana, 2016).

Silage

The terms haylage and silage are often confused and used interchangeably. Silage is defined as "material produced by the controlled fermentation of a yield with a high moisture content" (McDonald et al., 1991). The forage nutrient contents and sward structure have different influences on the intake of dry matter, average daily gain and methane emissions by grazing ruminants (da Cunha et al., 2023). The ensiled forages show little potential to reduce enteric methane emissions when fed to growing beef cattle (Meo-Filho et al., 2023). The ensiling is based on the transformation of water-soluble carbohydrates, which must be transformed into at least 10% of the dry matter in lactic acid. This favourable condition is an anaerobic environment, created by the work of anaerobic lactic acid bacteria and other microorganisms, with adequate moisture (65-70% in forages and 33–38% in the concentrated feed) and temperature (35–380°C). The silage quality was satisfactory, with moisture content ranging between 51.5 and 52.5% and crude protein between 4.8 and 5.6% (Jugovic et al., 2014).

Haylage

Haylage is also called hay crop silage, low moisture silage, or drylage. It contains 40–60% moisture. Important aspects to be considered while making haylage include wilting, dry matter content, chopping, and the exclusion of air. The process has many advantages over hay and silage; for example, storage losses are reduced, weather-associated risks are low and palatable feed is liked by animals devoid of objectionable odours. Haylage can be made successfully in conventional silo structures. Large plastic bags are also becoming popular among dairy farmers for haylage storage. Haylage is wrapped or anaerobically stored feed containing more than 500 g DM kg^{-1} (Müller 2005; Harris et al., 2017). Chemical analysis of haylage samples is reported to be moisture 51.46 and 52.45%, ash 3.30 and 4.69%, crude cellulose 17.82 and 18.48%, crude protein 4.82 and 5.57%, crude fat 1.21 and 1.32%, NFE 21.39 and 17.13% and energy value 429.65 and 457.69 KJ/100g, made in silo-trenches and wrapped bales, respectively (Jugovic et al., 2014). The influence of sowing time on the nutritional value of haylage from annual grasses has been studied. The crude protein and metabolizable energy transformations are at a higher rate in the crops sown early, followed by mid- and late-season (Kondratenko et al., 2021).

Multi-species haylages are more productive and stable than single-species ones and provide a well-balanced, nutritious food (Artemiev, 2010; Merzlikina, 2010; Khramoj et al., 2019). The limiting factors in multi-species haylage are decreased to result in an increase in animal productivity (Mironova et al., 2019). The nutritional value of haylage obtained from the green mass of cereals and legumes is very high. (Karamaev et al., 2019).

Balage

Balage, also called "round-bale silage," is baled fodder at a higher moisture content and then stored in sealed plastic wrap. A high moisture level and an airtight environment are needed for a male perfect fodder bale (Borowski et al., 2021). Balage is a fermented product preserved by acids. Storing silage in round bales is a commonly used method for preserving forage for use as stock fodder, which has a higher nutritional content than hay. In the case of the balage, good density ensures ideal conditions for fermentation (Jamroz et al., 2001; Han et al., 2006; Nowak, 2013). The moisture content of the plant material has a big impact on the compacting process. Humid blades or stalks bend fodder much more easily than dry ones. Attention is given during the compaction of bales formed from green forages with a DM content of 63 to 64 per cent. This material has low elasticity and is easily pressed into the working chamber of a round baler, resulting in a high concentration within the cylindrical bales (Coblentz and Hoffman, 2009). The addition of shredding assemblies to the round balers produces bales of high concentration (Charmley and Firth, 2004; Lötjönen, 2008). The production of feed with the use of different additives to support the silage and balage making processes is very popular because of the cheaper supplies of valuable feed with low nutrient losses that are suitable for long-term storage (Dulcet and Woropay, 2000; McEniry et al., 2006; Doroszewski, 2009; Muck, 2012). Liquid feed additives are applied to the plant material by applicators fitted to a baler. Applicator nozzles are mounted on the baler at points to allow for optimum distribution of liquid feed additives in the collected plant material and low additive losses (Dulcet et al., 2006; Nysand and Suokanns, 2012; Wyss et al., 2012).

Dehydrated products

The dehydration of fodders is due to their agronomic potential. The dehydrating industries are using dehydrators to meet the requirements of the dried fodder markets. In Spain, lucerne, raygrass, fescue and forage corn are very common causes of dehydration (Marrugat, 2001). Artificially dried chopped forage can be made dense for storage by compressing it into wafers or cubes extruded from a ram press or rotary die press, respectively. It may be milled or pelleted. Pellets and cubes are the most common dehydrated products in India (Bakshi et al*.,* 2018). Alfalfa pellets are now widely available in local markets. A power-operated feed pelleting machine was developed by IGFRI to produce value-added feed pellets. It includes azolla-added feed pellets (groundnut cake was replaced with dried azolla leaves) and value addition through berseem and moringa leaves (chopped and dried berseem was added in place of Leucaena leaf). Dried moringa (*Moringa oleifera*) leaves are very successful in preparing firm pellets (ICAR-IGFRI, 2018).

Conclusion

Being the leader in cattle and buffalo populations and increasing livestock populations, current fodder production in our country is not able to meet the requirement. Land under fodder cultivation is static and has little scope for expansion due to reduce per capita availability and human priorities. So, technological advancements both in the production and preservation of fodder should essentially be adopted to fight against fodder scarcity.

References

Artemiev A A. 2010. Productivity and quality of annual grass mixtures depending on the ratio of components. *Achievements of Science and Technology of the AIC*. **3**:40-42.

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

Borowski S, Kaszkowiak J and Dulcet E. 2021. How to Harvest Haylage Bales in Sustainable Agriculture. *Appl. Sci.* **11**(23):11508. [DOI]

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. [DOI]

Charmley E and Firth S. 2004. Comparison of flail-harvested, precision-chopped and round-bale silages for growing beef cattle. *Ir. J. Agric. Food Res*. **43**:43-57. [DOI]

Coblentz W K and Hoffman P C. 2009. Effects of bale moisture and bale diameter on spontaneous heating, dry matter recovery, in vitro true digestibility, and in situ disappearance kinetics of alfalfa-orchard hays. *J. Dairy Sci.* **92**:2853–2874. [DOI]

da Cunha L L, Bremm C, Savian J V, Zubieta Á S, Rossetto J and de Faccio Carvalho P C. 2023. Relevance of sward structure and forage nutrient contents in explaining methane emissions from grazing beef cattle and sheep. *Science of the Total Environment.* **869**(15):161695. [DOI]

Doroszewski P A. 2009. *Effectiveness of Silaging Additives' Application in Preservation of Green Forages from Legume–Grass Mixture and the Whole Corn Plants.* No. 136; Publishing House of the Univ. of Technology and Life Sciences: Bydgoszcz.

Dulcet E and Woropay M. 2000. Analysis of liquid additives loss when applied to green forage in a forage harvester. *Appl. Eng. Agric.* **16**:653–656. [DOI]

Dulcet E, Kaszkowiak J, Borowski S and Mikołajczak J. 2006. Effects of Microbiological Additive on Baled Wet Hay. *Biosyst Eng*. **95**:379–384. [DOI]

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. [DOI]

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, 2021. *Annual Report 2020-21.* Department of Animal Husbandry and Dairying. Ministry of Fisheries, Animal Husbandry and Dairying. [DOI]

GOI, 2022. *Annual Report 2021-22.* Department of Animal Husbandry and Dairying. Ministry of Fisheries, Animal Husbandry and Dairying. [DOI]

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

Han K J, Collins E S, Vanzant E S and Dougherty C T. 2006. Characteristics of baled silage made from first and second harvests of wilted and severely wilted forages. *Grass Forage Sci*. **61**:22–31. [DOI]

Harris P, Ellis A D, Fradinho M J, Jansson A, Julliand V, Luthersson N, Vervuert I. 2017. Review: Feeding conserved forage to horses: Recent advances and recommendations. *Animal*. **11**:958–967. [DOI]

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. [DOI]

ICAR-IGFRI. 2015. *Vision 2050*. ICAR Indian Grassland and Fodder Research Institute, Jhansi, 40p. [DOI]

ICAR-IGFRI. 2018. *Annual Report 2017-18*. 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. [DOI]

Jamroz D, Podkówka W and Chachułowa J. 2001. *Animal Nutrition and Animal Feed Science*. Polish Scientific Publishers: Warsaw.

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

Jugovic M, Radivojevic D, Lalovic M and Trifkovic J. 2014. Effect of different haylage lines on haylage chemical composition. In: Fifth International Scientific Agricultural Symposium, pp. 104-108. [DOI]

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

Karamaev S, Karamaeva A, Soboleva N and Bakaeva L. 2019. Milk productivity of cows when haylage with biological preservatives is included in the diet. *Earth and Environmental Science*. **403**(1):012081. [DOI]

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. [DOI]

Khramoj V K, Rakhimova O V and Sikharulidze T D. 2019. Photosynthetic activity of two-and three-component vetch and grasses mixed crops in Central Non-chernozem zone. *Agrarian Science*. **4**:52-54.

Kishore A and Singh L, 2021. Nutritive evaluation of Dinanath grass (*Pennisetum pedicellatum*) at pre and post flowering stage for crossbred heifers. *Journal of Rural Advancement* 9(2):24-29. [DOI]

Kishore A and Verma M L. 2000. Comparative feeding value of Dinanath grass and sorghum fodder for crossbred heifers. *Indian J Anim Nutr.* **17**(4):311-314. [DOI]

Kondratenko E P, Soboleva O M, Berezina A S, Miroshina T A, Raushkina D and Raushkin N. 2021. Influence of sowing time on chemical composition and nutritional value of annual herbs in mixed crops. *J* **Biochem Technol**. **12**(4):6-11. [DOI]

Lötjönen T. 2008. Harvest losses and bale density in reed canary grass (*Phalaris arundinacea* L.) spring-harvest. *Asp. Appl. Biol*. **90**:263–268. [DOI]

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. [DOI]

Marrugat F O 2001. The evolution of fodder dehydration in Spain: Future prospects. In: (I Delgado and J. Lloveras (eds) *Quality in lucerne and medics for animal production*. Zaragoza: CIHEAM, pp. 13-18. [DOI]

McDonald P, Henderson A R and Heron S J E. 1991.*The Biochemistry of Silage*. 2nd ed, Chalcombe Publications: Marlow.

McEniry J, O'Kiely P, Clipson N J W, Forristal P D and Dogle E M. 2006. The microbiological and chemical composition of baled and precision-chop silages on a sample of farms in County Meath. *Ir. J. Agric. Food Res*. **45**:73–83.

Meo-Filho P, Hood J, Lee M R F, Fleming H, Meethal M.E and Misselbrook T. 2023. Performance and enteric methane emissions from housed beef cattle fed silage produced on pastures with different forage profiles. *Animal*. **17**(4):100726. [DOI]

Merzlikina Yu A. 2010. Formation of highly productive agrocenoses in the conditions of the Altai forest-steppe. *Achievements of Science and Technology of the AgroIndustrial Complex*. **6**:31-32.

Mironova I, Nigmatyanov A, Radchenko E and Gizatova N. 2019. Effect of feeding haylage on milk and beef quality indices. *Web of Conferences*. **135**:01100. [DOI]

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

Muck R. 2012. Microbiology of ensiling. *In Proceedings of the XVI International Silage Conference, Hämeenling, Finland, July 2–4*. MTT Agrifood Research, University of Helsinki, pp. 75–86. [DOI]

Müller C E. 2005. Fermentation patterns of small-bale silage and haylage produced as a feed for horses. *Grass Forage Sci.* **60**:109–118. [DOI]

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. [DOI]

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

Nowak J. 2013. *Machines for Forming Cylindrical Bales*. Publishing House of the Univ. of Life Sciences: Lublin.

Nysand M and Suokanns A. 2012. Optimising the application technique for silage additive in harvesting machinery. *In Proceedings of the XVI International Silage Conference*, Hämeenling, July 204. MTT Agrifood Research Finland, University of Helsinki, pp. 73–74. [DOI]

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.

Sharma T and Kishore A. 2022. The feeding value of Dinanath grass and sweet sorghum fodder at the post-flowering stage for crossbred heifers. *YMER.* **21**(5):511-516. [DOI]

Singh S. 2016. Non-conventional fodder resources for feeding livestock. In: P K Pathak, S K Singh, C S Sahay, R K Sharma, M Chaudhary and A Maity (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. In: C G Thomas (ed.) *Forage crop production in the tropics*. Kalyani publishers. New Delhi. 226p. [DOI]

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

Thomas S L and Thomas U C. 2019. Innovative techniques in fodder production-a review. *Forage Res*. **44**(4):217-223. [DOI]

Türer H and Yildiz T. 2023. Total Costs, Labor Requirements, and Work Efficiencies in Rice Production Mechanization in Turkey: A Case Study From Samsun Province. *Research in Agricultural Sciences*. **5**(1):9-14. [DOI]

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. [DOI]

Wyss W, Thaysen J, Pauly T and Rubenschuh M. 2012. Testing inoculant and chemical additives in round bales in comparison to laboratory silos. *In Proceedings of the XVI International Silage Conference*, Hämeenling, July 2-4; MTT Agrifood Research Finland, Univ. of Helsinki, pp. 294–295. [DOI]