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A review: Promising forage crops grown in India and their quality importance

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Abstract

The development of the rural economy particularly the small and marginal farmers, animal husbandry and livestock sectors are the key component due to the small land holding of rural farmers in India. So forage crops are the main element to boost the income level and livestock animal health also the importance of forage crops can never be minimized due to their multipurpose role in foreign earning, achieving sustainable development goals, nutritional security, employment generation, etc. This review article describes the important forage crops cultivated in India and the diverse quality traits of these crops. These quality traits include the amount of Crude Proteins, Macro and Micronutrients, Dry Matter Digestibility, Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), and Crude Fiber contents. To understand the quality importance of specific forage crops, and use particular crop improvement techniques that is, Introduction, Hybridization, Mutation breeding, and Biotechnological tools to develop new cultivars which show adaptation to changing climatic conditions and bridge the gap of fodder deficit and supply and also contribute to nutritional security.

Keywords: Livestock, forage, nutritional security, hybridization, mutation and biotechnological tools

Introduction

The value of forage crops and livestock sector now a day play a vital role due to their comprehensive function in nutritional security, sustainable production, export potential, employment generation, drought proofing, and natural resource conservation. According to the 20th Livestock Census, the total livestock population in India was 535.78 million (<https://pib.gov.in>). The total number of milch animals (in-milk and dry) in cows and buffaloes is 125.34 million, which has increased by 6.0% over the previous census. The contribution of the livestock sector was nearly 25.6% of the value of the output at current prices of the total value of output in agriculture and allied sector and total GDP was nearly 4.11% at current prices during 2012- 13 (19th Livestock Census 2012, www.dahd.nic.in). India is the leading milk-producing country in the world, even though animal productivity is low (1538 kg/year) concerning the global average (2238 kg/ year), which can be associated with malnutrition of livestock animals due to a huge deficit of animal feed (Vijay *et al.*, 2018) ^[65]. The availability of fodder supplies has now dropped to approximately 50% of the total requirement as compared to what was estimated to be over 60% in the 1990s. With the increasing demand for other food crops rising competition between land uses for the cultivation of other crops and forage crops thus further increase in the land of fodder crops is not feasible (Kumar, Agrawal, *et al.*, 2012). Consequently, it is necessary to increase the production of cultivated fodder crops on the same piece of land to meet the future fodder requirements of the increasing livestock population. The viable option to balance the demand for fodder need is the utilization of non-arable land area for pastures in addition to vertical expansion from arable lands (Dahiya and Kharb, 2003; Vijay *et al.*, 2018) ^[14, 65] and the quality of forage is low and poor in protein, energy, and minerals. Quality of forage is also an important factor that affects the nutritional security of the country direct through dairy products and indirectly through animal health because 80–90% of the nutrient supplies of livestock are met from fodder crops. At present, India is facing a deficit of crude protein (CP) and total digestible nutrients (TDN), 24.6 and 19.9% respectively also the predictable scenario for the future of CP and TDN is 20.78 and 17.52% in 2030 and 16.81 and 15.47% in 2050, respectively (Anonymous 2020) ^[1, 2, 3]. So it is essential to consider the quality improvement as significant as another component of fodder or forage crops.

Major forage crops growing in India and its quality importance

Oat: Oat (*Avena sativa* L.) is one of the rapidly emerging and potential crops for a dual purpose and has enormous potential for fodder along with the provision of grain yield also. The oat has been well examined and resulted, in the opening new market "avenue" due to its unique characteristics, highly valuable nutritional traits, and advantages offered by oats as compared to other popular cereals (Chawala, *et al.*, 2022) [13]. For providing green fodder during the season multi-cut cultivars (3-5 cuts) of oat are typically used. During the summer season, oat is generally used as cut green and fed fresh to the livestock, and during the lack of fodder availability period, the surplus is made into silage or hay (Suttie and Reynolds, 2004) [58]. Green fodder contains about 30 to 35% dry matter and 10 to 13% protein. The dry matter digestibilities of oat are over above 75% (Burgess *et al.*,

1972) [11]. Crude protein (CP) content is the most important character among different parameters that contributes to the quality of fodder crop (Caballero *et al.*, 1995; Aseefa and Ledin, 2001) [12, 8]. It was studied that oats contain more crude protein in the first cut (12.10- 15.63%) as compared to the lower crude protein content reported in the second cut (9.63- 13.57%; Poonia and Phogat, 2017) [50]. The correlation studies of oat gave crucial information about, a positive and significant correlation of seed crude protein with fodder crude protein reported by (Poonia *et al.*, 2017) [51] and crude protein have a negative association with green fodder yield as shown by (Ahmad *et al.*, 2010; Mushtaq, 2013) [6, 36] which are important for further crop improvement programmers. Hulled cultivars had lower fat content than naked oat cultivars (Kourimska *et al.* 2018) [27]. Table 1 revealed recent quality parameters and micronutrients were analyzed in oat grains by (Poonia *et al.*, 2022) [49].

Table 1: Range of micronutrients and quality parameters in grains of oats

Crop	Phenol (mg/g)	Protein (mg/g)	Phytic (mg/g)	Beta-glucan (mg/g)	Zinc (mg/100g)	Iron (mg/100g)
Oats (<i>Avena sativa</i>)	11.90-31.3	138.70-160.50	3.70-8.00	31.00-53.50	4.96-6.50	2.48-4.89

β -glucan the dietary soluble fiber can help to restrain cholesterol build-up and finally reduce heart diseases as studied (Brown *et al.*, 1999; Whitehead *et al.*, 2014) [10, 66] and oat is the finest source of the β -glucan that making it important for human nutrition at a present scenario (Premkumar *et al.*, 2017; Varma *et al.*, 2016) [52, 63]. From the above preview, the oat has immense importance as a dual-purpose crop due to its vast quality parameters such as being highly palatable to livestock, high regeneration capacity, crude protein availability, a good source of both macro and micronutrients, and also contain β -glucan and other biochemical constituents. Therefore it is necessary to need to extensive research on the quality parameters of oat fodders and grains. To deal with current and future requirements or bridge the deficit of fodder the selection of superior dual-purpose oat genotypes gives a better solution for food insecurities and livestock sustainability.

Sorghum

For the Kharif season in India, Sorghum (*Sorghum bicolor*) is also the most promising crop and it is used as a forage crop to feed their livestock and provide food grain for human consumption. It is cultivated over a wide range of soil types (Narayanan and Dabadghao, 1972) [37]. Sorghum can be fed as fresh green and dry or in the silage form (Gupta *et al.*, 2000) [18] due to the non-availability of green forage during lean/summer months to feed the animals during this period

(Ranjhan, 1993) [54]. The key quality parameters in forage sorghum are protein, NDF, ADF, IVDMD, HCN, and tannin (toxic substances). Protein and IVDMD varied from 3.01 to 8.75 and 40.40 to 66.16%, respectively as reported (Grewal *et al.*, 1996) [20] and the protein content in a single cut (SC) and multi-cut (MC) genotypes varied from 5.24 to 10.06 and 4.81 to 12.47 percent, respectively which revealed by (Kumar *et al.*, 2011) [30]. The maximum limit above which causes harmful effects on livestock of HCN in green forage is 500 ppm on a fresh weight basis and 200 ppm on a dry weight basis (Karthika N. and Kalpana R. 2017) [25] thus selection of such genotype is crucial that contain a low level of HCN for crop improvement programme is an essential step.

Berseem

Berseem (*Trifolium alexandrinum*) is belonged to the Leguminosae family and is widely cultivated as a Rabi season forage crop in northern India because is also known as 'the king of fodder' and it has the high production capacity, succulence, palatability and nutritional content that preferred by livestock animals. It is grown on a maximum area among the fodder legumes of approximately (2 M ha) and the second largest area (2.5 M ha) among the fodder crops in India subsequently to fodder sorghum. The green forage of berseem contains a range of different quality parameters as shown in Table 2 on a dry matter basis (Praveen *et al.* 2022) [48].

Table 2: The range of quality parameters of fodder Berseem on dry weight basis

Crop	Crude Protein (%)	Neutral Detergent Fibre (%)	Acid Detergent Fibre (%)	Hemi-cellulose (%)	Cellulose (%)
Berseem Green Forage	17-22	42-49	35-38	7-10	24-25

The popularity of forage berseem is mainly due to its multi-cut (4-8 cuts) nature and providing fodder for a longer duration of seven to eight months (November to May). The genetic improvement of any crop mainly depends on the amount of variability that exists and berseem is an introduced crop in India and has less variability as reported (Malaviya *et al.*, 2007) [67]. Inducing genetic variability in berseem has been used many techniques *i. e.* through mutation,

polyploidization and interspecific hybridization, etc., and till now a day various improved varieties release for national and zonal basis which enlisted below.

Cow Pea: Cowpea (*Vigna unguiculata* L.) is known as "Vegetable meat" because of its high protein content and high grain and biological value on a dry weight basis. It is commercially grown throughout India and is utilized for a

variety of purposes including as long green pods, seeds as pulses, leaves as milch animal fodder, green manuring, and cover crop etc. It is also cultivated as fodder during the Kharif season and in some parts of Punjab, Haryana, Delhi and western Uttar Pradesh along with a considerable area in Rajasthan it is grown in the summer season (Tiwari and Shivhare, 2016) [60]. Cowpea grain has a strong nutritional profile and contains 23.4 percent protein, 1.8 percent fat, 60.3 percent carbohydrates, and also it is an essential source of vitamins and phosphorus (Venkatesan *et al.*, 2003) [64], and the crude fiber content of cowpea 18.2% As reported (Khan *et al.* 2007) [26]. Cowpea is acknowledged for its low fat and high fibre content, and the protein in pod legumes has been proven to lower low-density lipoproteins, which leads to heart disease when harvested at the optimum maturity stage (Prasad *et al.*, 2018b) [47]. Also, the contribution of Cowpeas is valuable towards livestock fodder and supply nitrogen to the soil analyses (Lai *et al.* 1978) [34].

The above paragraphs show the importance of cowpea's nutritive value for forage purposes to feed the livestock animals thus improvement of forage cowpea crop has to be measured in terms of forage yield, quality of forage and palatability are to be taken into consideration altogether and For effective selection programme aiming at the improvement of yield and quality of the various quantitative as well as qualitative characters the knowledge of the association is, therefore, essential (Kumar *et al.*, 2015) [31]. A breeder's genetic progress will be aided by the variety of qualitative and quantitative characteristics of breeding material. Because cowpea improvement is concerned with the selection of superior genotypes for which the most suitable individuals are determined based on their phenotypic expression, estimates of genotypic and phenotypic variance for various quantitative characters, as well as their heritability, are required (Jogdhande *et al.*, 2017) [24].

Table 3: The nutritional value of fresh Lucerne, whole meal and leaf meal

Lucerne	Moisture (%/100g)	Protein (g/100g)	Fat (g/100g)	Fiber (g/100g)
Green Forage	80	5.2	0.9	3.5
Whole Meal	7.5	16	2.5	27.3
Leaf Meal	8	20.4	2.6	17.1

Cluster Bean

Cluster Bean (*Cyamopsis tetragonoloba* L.) is a major underutilized leguminous vegetable in the Fabaceae family. In the different locations of the country, it is known by various local names such as Guar, Chavlikayi, Gorkayi, Khutt, Govar, and Kothavare. It is a drought-tolerant, tough, deep-rooted summer annual legume that is farmed mostly for sensitive vegetable and seed endospermic gum grown in India's dry and semi-arid regions (Kumar, 2005) [28]. India contributes 80 percent of the total production of the world (Tripathy and Das, 2013) [61]. And within the country, Rajasthan occupies the largest area (82.1%) under guar cultivation. It is also cultivated as a legume fodder crop during the Kharif season in many regions of the country because it is highly nutritious and palatable fodder for cattle (Kumar V. and Ram R.B. 2015) [29]. Guar is also used as a green fodder or green manure crop, enriching the soil by fixing atmospheric nitrogen (50-60 kg/ha) and adding organic matter (Lal, 1985) [33]. The nutritional and quality important properties of Cluster Beans are explained by various researchers, in the seed: the range is given as crude protein - 28.3 to 35.0%, ash content - 3.5 to

Lucerne

With the increasing demand for green food, scientists are focusing more on Lucerne or Alfalfa (*Medicago sativa* L.) in the food sector. Lucerne is a hardy perennial herbaceous forage legume and drought-tolerant crop (Lenne' and Wood, 2004) [35] and has a play huge role in the fodder security of the country. It is grown in an area of approximately 45 million hectares worldwide. It is the oldest plant that has been grown solely for forage and cattle feeding, dating back more than 3,300 (Pioneer Brand Products, 2011) [46]. Lucerne contains a range of 15% and 22% crude protein on a dry matter basis. The protein content in the leaf meal has 20.4 grams per 100 grams (Aganga and Tshwenyane, 2003) [7] as indicated in Table 3 as well as all macro- and trace minerals and all fat and water-soluble vitamins (Scholtz, 2008) [56], making it acceptable for poultry and swine feeding (Adapa *et al.*, 2007). Because of its high production, quality, and adaptability to varied climates and soil types, Lucerne is mostly used to make hay and silage, although it can also be used for grazing (NLO, 2010) [39]. The increased media coverage of Lucerne's health advantages has raised consumer awareness and interest in the study. It is therefore critical for food scientists to become aware of: the nutritional importance and entrepreneurial potential of Lucerne for future human needs. Research on the potential of Lucerne for industrial uses in the food area could help in food security, human nutrition, breeding programmes, and easy sources of money for effective and sustainable development. So a country like India needs to have huge livestock animal populations to provide theme quality fodder and in the required amount for their holistic development and also needs to development of new cultivars' that coup up with changing climatic conditions and provide resistance or tolerance to disease and insect-pest incidence.

6.0%, fat – 1.8 to 5.2%, carbohydrate - 38.8 to 59.1%, crude fiber - 4.1 to 8.0 and gum content – -23.9 to 34.2% (Pathak *et al.*, 2011) [45]. The lower value for carbohydrate [23.7%] and higher values for crude fiber [9.3%] was reported by (Ahmed *et al.*, 2006) [5]. Guar is a multipurpose crop also uses in the diverse field such as industrial uses (emulsifiers, food additives, food thickeners and gelling agents, etc.), dried immature pods are salted and preserved for future use, immature green pods are used as a vegetable, plants are used as cattle feed and the beans are used as high protein feed for livestock (Bhatt *et al.*, 2015) [9]. Even though the vast importance of this crop, very less attention has been given to its genetic improvement and limited breeding work has been done so far, so, therefore, it is necessary to identify the genetic combinations that are superior in green fodder yield and other quality-related traits for achieving research-oriented objective and to narrow the fodder deficit of the country.

Fodder Maize

Maize (*Zea mays* L.) is an important cereal and fodder Kharif crop grown in various parts of India to meet the growing

demand for fodder and feed for livestock as well as human being due to its importance in food, feed, specialty corn, starch quality parameters, etc. Maize is generally a monoecious plant and native to America. Though maize contains more forage quality characters *i.e.* highly palatable, high nutrient contents (Iqbal *et al.* 2006) [23], longer storage and easy digestibility often receive far less consideration than it deserves. It is quality-wise better than sorghum and pearl millet because it doesn't contain any anti-quality components such as hydrocyanic acid (HCN) and oxalate. Maize contains a high amount of protein and minerals and other nutritional components with other non-legume fodders is explained in Table 4 (Gupta *et al.* 2004) [19].

Two promising maize varieties are developed and released for commercial cultivation of fodder in India, namely, J-1006 and African tall. As given below table that maize contains more nutritional and quality characters and is given less importance as forage crops, so a maize scientist needs to change the behavior of people to grow maize for fodder purposes due to its vast quality parameters and now a day more extensive research work to be needed for fodder maize to develop improved varieties and hybrids of higher fodder yield and also quality wise better so the livestock animal shows its full potentials.

Table 4: Comparative nutritional quality of non-legume fodders

Fodder crop	Harvesting stage Days after sowing (DAS)	Crude Protein (CP) (%)	In-vitro dry matter digestibility (IVDMD) (%)
Maize	55–65	11–8	68–52
Sorghum	70–80	8–7	60–57
Bajra	45–55	10–7	62–55
Teosinte	80–85	9–7	62–58

Source: Gupta *et al.* (2004) [19]

Teosinte: Teosinte (Mak Chari) (*Zea diploperennis*, *Z. perennis*, *Z. luxurians*, *Z. nicaraguensis*) is belonging to the family Poaceae has grown as both annual and perennial species in India and also resembles maize for some morphological characters to identify it as teosinte. It contains a good amount of crude proteins, crude fiber, ether extract and nutrient contents and also has good In-vitro dry matter digestibility, etc. Compared with fodder maize is less nutritious and palatable but due to its profuse tillering behavior it is cultivated as a fodder crop for livestock animal feeding. The grains of teosinte are not suitable for human consumption so it is generally used for green fodder, dry fodder and also as biofuel production. Table 5 is shown the quality importance of teosinte (Mak Chari).

Table 5: The quality parameters of teosinte (mak chari)

Crops	Crude Protein (%)	Dry matter (%)	Crude fiber (%)	Ether extract (%)	Neutral Detergent Fiber (%)	In vitro dry matter digestibility (%)
Teosinte (Mak Chari)	6-7	22-24	28-30	1.4-2.0	60-63	50-55

In addition to above given major forage crops various other field crops were also cultivated for fodder purposes that included forage pearl millet, Napier grass (*Elephant grass*), Napier × bajra hybrids (NB hybrid) and Sem (Lablab bean), etc.

Major challenges faced by forage crops

India is the highest milk producing animal population country despite having approximately only 4.9% of gross cropped land for growing green fodders and also a huge fodder deficit *i.e.* green fodder, dry fodder and concentrate feed ingredients 35.6%, 26% and 41% respectively (Rachel Jemimah *et al.* 2015) [53]. The forage research is directly or indirectly related to the livestock sector of the country hence here to give the key focus is on the study of the issues of fodder production concerning or in correlation with livestock sectors. When we compared the productivity of cattle and buffalo in Europe, the United State, and Israel the result is shown as 1000 kg in India, and 4500 kg in Europe, 7000 kg in the United State and 10000 kg in Israel of Milk production per lactation so such low productivity of Indian livestock's is a major issue of both forage research and livestock sectors (Ghosh *et al.*, 2016) [17]. The other major challenge of fodder production are less cultivated area come under forage crops approximately in India fodder cultivation is only 8.4 million ha also these areas was steady over the last two decade and there is no probability to increase the area further due to increasing pressure of human population for food and replacing the traditional cereal crops with commercial crops (Ghosh and Palsaniya, 2014a) [15, 16]. Efforts are made on studies fodder research and supply or availability at the local level because the transport of fodder from long distances is not suitable for livestock farmers on an economic basis, here

we can say that fulfills the demand for forages on the regional and seasonal deficiencies are more important than the national deficiencies. (Palsaniya *et al.*, 2008; Palsaniya *et al.*, 2009; Palsaniya *et al.*, 2010a) [40, 43, 41]. Quality aspects of fodder production are also a matter of concern because quality parameters of forage crops are crucial elements for supporting the nutritional security and overall development of livestock animals thus more effective steps were needed for the improvement of forage crop varieties about provide all essential nutrients. The quality parameters are includes Crude Proteins, Micro and Macro nutrients, In-vitro Dry Matter Digestibility, Detergent Fiber, Acid Detergent Fiber, Crude Fiber contents and low HCN and other anti-nutritional components, etc. For improvement of forage crop resources in our country is given less attention compared with cereals or field crops due to this there is a need of huge constant efforts for the development of improved varieties of forage crops. In addition to above given issues, there are seed related constraints that also affect the yield or growth of forage crops which are seed some forage crops lack seed standards due to grass like nature and also some forage crops are shy seed producers, these affect the certification /legislation procedure concerning to these crops. Changing climatic conditions is also a major challenge in the current scenario for the sustainability of forage crops (Sunil Kumar *et al.*, 2014c; Palsaniya *et al.*, 2012c; Ghosh and Palsaniya, 2014) [57, 15, 16]. So it is essential to develop high yielding varieties, better quality fodder, wider adaptation and environmentally sustainable cultivars of forage that deal with such vast changing climatic conditions. These are the major challenges that hinder the growth of forage and livestock production. Lastly to counter these described challenges have to decide specific objectives related to your local or regional needs and

choose precise objectives specific plant materials or genetic resources with appropriate breeding methods and develop new high yielder cultivars.

Way ahead

The research and development work related to foraging crops and livestock sectors is not sufficient as compared with other countries at the global level in the current scenario and need of hours is that to understand the potentials of livestock and forage production sectors and their effects on the rural economy and dairy industries which necessitates paying more comprehensive attention on these sectors regarding research and development agenda. To make essential efforts to bridge the gap of fodder deficiency in the country and transfer the innovation or technology to farmer's field for achieving high yield and quality fodder also transformation the forage crops as other commercial crops. In the end, the main objective of the article is to compare the different forage crops on quality wise, choose the best forage crops for their regions based on climatic condition suitability, availability of good planting materials and storability of fodder.

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