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NUTRITIONAL ENHANCEMENT OF CULTIVATED FODDERS USING POTENTIAL PLANT BREEDING STRATEGIES - A REVIEW

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SUMMARY

Livestock sector plays a pivotal role in the economic growth of any agriculture based country. This sector is the major source of energy for mankind. Among livestock, milch cattle play a distinctive role to provide energy food to human beings. In developing countries livestock sector is major source of employment for rural youth also. However, due to rapid change in agricultural practices and increasing population pressure, there is drastic change in animal husbandry practices. Majority of available agriculture land is under food and cash crop cultivation. In rural areas, animal fodder demand is still fulfilled by naturally grown grasses and shrubs which are of low nutritional quality having low crude protein, IVDMD and available energy. Thus, they depend mainly on seasonal forage varieties which results in fluctuations of green fodder supply and milk yield round the year. Since last three decades, area under fodder crops is stagnant and it needs to be addressed timely. Creation of awareness among farmers regarding availability of nutritionally rich quality folder option especially in semi-arid tropics and development of good number of fodder accessions will certainly help to solve this issue to a great extent.

Key words: Livestock, green fodder, forage breeding and nutrition

Animal husbandry and agriculture are prime factors affecting GDP of any agriculture based country (De Graff et *al*., 2011). Large livestock population doesn't mean that particular country is leading in milk and other livestock products. The later mainly depends on three prime factors of livestock *i.e.,* animal breed, nutrition and health (Fig. 1). One of the main reasons for poor performance of livestock is their malnutrition, under nutrition or both, besides the low genetic potential of the animal. Better animal output mainly dependent on availability of quality green fodder (Sarnklong et *al*., 2010). Because forage crops provide nutritional base to the livestock and regular feeding of dairy animals with required quantity of nutritional green fodder is must. In spite of that, forages had never given importance in agriculture system and the major area is devoted to cereal and cash crops leading to stagnation of area under forage crops over the decades. In crop rotation system followed by farmers, fodder crops have negligible place due to small land holdings. There is spike in decline of area under permanent pastures, grasslands and cultivable wasteland due to industrialization. Furthermore, there is limited scope for enhancing area under fodder crops because there is requirement of producing more grain for rapid growing human population. In this situation, some management and breeding practices such as use of improved forage crop varieties, use of better production technology, agro forestry system, natural resources conservation and utilization of degraded and marginal lands under forage production might enhance fodder productivity (per unit time per unit area) and overcome such problems.

History of fodder cultivation

Fodder cultivation is old practice which started around 9000-7000 BC but forage crop domestication begin 1000BC-1300AD (Capstaff and Miller, 2018). In North India (including Haryana, Punjab and Himachal Pradesh), the 1st Forage Research Station was established at Agriculture College, Lyallpur (now in Pakistan) in 1926 to take up research for improvement of forage crops of this region. From 1926-1960, around 16 varieties of different fodder crops like JS 20, JS 263, JS 29/1 of sorghum; FOS-1 of cowpea, Mescavi of berseem, Weston 11, Brunker 10, FOSs 1/29 and Algerian of fodder oats were released. In 1962, Indian Grassland and Fodder Research Institute was established at Jhansi to take

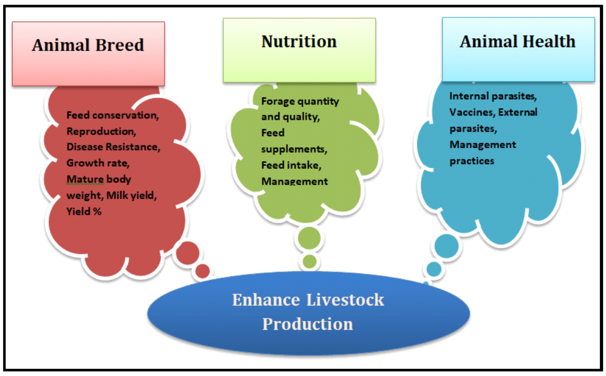

Fig. 1. Major techniques to enhance livestock production (Arora and Luthra 1992).

up training and extension activities related to fodder cultivation in India. Later on in 1970, Indian Council of Agriculture Research in India has launched a project with the aim to "boost forage production in diverse agro-ecological regions". Under AICRP program, various improved single cut and multicut varieties with good nutritional qualities of various cereal and leguminous crops have beene developed (Singh *et al.*, 2018).

Reason of fodder shortage

Fodder crops can be fed directly as green fodder to livestock and they can also be processed by pre-digestion /partial drying prior to feeding. According to 20th livestock census, 20% of the livestock population of the world is supported by India on 2.3% geographical area only. Availability of green and dry fodder plays an important role in livestock security of any country. SAT regions have long summers and less rainfall so we need to develop climate resilient varieties of various fodder crops suitable for the region. Even after release of number of varieties of various *kharif* and *rabi* fodder crops in last five decades, gap between green and dry fodder demand and supply is continues to persist. According to IGFRI data country faces 63.5 % green fodder deficit (Halli et *al*., 2018). There are various reasons behind the fodder shortage in semi-arid tropics. Stagnation in area under fodder crops over the years due to heavy competition for land and food crops is the major one (Rao and Hall, 2003) and least attention towards fodder production and productivity may be another. Lack of transportation and storage facilities and abrupt climatic change is also playing spoilsport, because, in some regions, rain becoming erratic and many regions are suffering from unprecedented floods, drought etc., which also affects fodder availability. Due to decline in area under pastures, fallow and common lands, the availability of area under major grasslands is continuously declining over the years. Presently, due to adverse impact of poor quality fodder on animal health and indirectly on human health, some government and non-government organizations had paid attention and launched many projects all over the country for fodder quantity and quality improvement especially focused on quality animal-by-products production (e.g. National Fodder Mission, India). Thus, only solution to step up fodder cultivation is the adoption of some fodder conservation practice and step up of genetic improvement of forage crops.

Effect of feed and fodder quality on animal health and human health

Quality food narrates that folder given to animal must consist of minerals and nutrients essentially required for animal health and its growth and these nutrients are easily digestible in animal rumen. Green fodder not only fills its stomach but also fulfill its nutritional requirements in addition to this green fodder crops are cheap as compared to concentrates and also help to bring down cost of feed at the time of surplus green fodder availability (Tassew Dassie, 2018). In addition to nutritional composition palatability of fodder like sweetness, salty, bitter, acidic, olfactory and textural characteristics also play an important role (especially when the animals have a choice) in fodder consumption by animal. So in this context cereal fodder mixed with leguminous one like forage sorghum + cowpea, fodder pearl millet + cowpea and oats + berseem are some mixed cropping patterns which are good source of micro and macro minerals (Tewatia & Yadav, 2010), which are essentially required for rumen microbes as well as animal system. These crops can also be stored in the form of hay and silage and provided later on to animals to fulfill its nutritional demand.

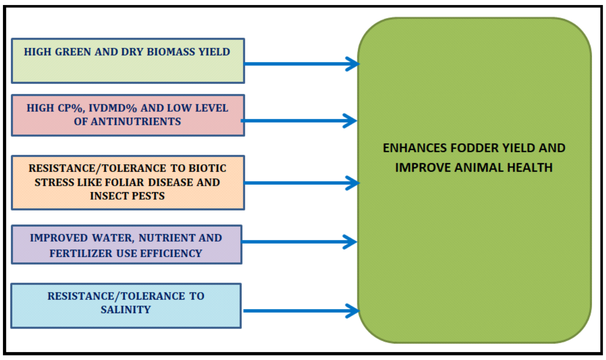

Fig. 2. Major breeding objectives for forage crop improvement programme.

Released varieties of various forage crops of *kharif* and *rabi* season in India

Various annual and perennial fodder crops are available in nature which is under cultivation in different regions all over the world. However, fodder production and its utilization depend on the available cropping pattern, climatic conditions, socioeconomic status and type of livestock. Green fodder demand of livestock in summer and *kharif* season is mainly fulfilled by sorghum, pearl millet, maize and bajra napier hybrid. Similarly, oats, berseem, chinese cabbage, lucerne etc. are grown during *rabi* season. During last five decades, several improved varieties of fodder crops were released and some of them have revolutionized the fodder production of country. Some popular varieties of fodder crops are mentioned in Table 1.

Crop residues as a promising option to livestock feed and its quality improvement

In SAT regions, crop residues are the most important source of animal fodder and are mainly obtained from the rice, wheat, sorghum, pearl millet, oats, and oilseeds etc. (Rao et *al*., 2016) which are dual types. Crop residues are important fodder sources used by farmers for raising livestock especially in Sub-Saharan Africa and Southern Asia due to limited availability of alternative sources (Vanlauwe *et al*., 2014).

Livestock feed resources based on crop residues can be divided as follow:

- Grasses from forests, fallow lands, pastures and wastelands
- Stover/straw from wheat and rice
- Stover from sorghum, millets and maize coarse grains
- Haulms from pulses and oilseeds

Breeding programs having special focus on improvement of these crop residues are almost ignored with main emphasis directed towards grain yield improvement of cereal and leguminous fodders. It is noteworthy that various high grain yielding varieties and hybrids were developed over the years and still under process of development. However, in existing breeding programs we should focus on nutritional quality improvement of crop residues also like stover yield and quality enhancing traits because they are low in metabolized energy and crude protein. Majority of cereals, in addition to major saleable product produces large quantities of stem and leaf (stover) which is almost half of the harvestable vegetative part of the crop (Suttie, 2000) and cannot be eaten by humans, but can be used as such or transformed into economic products for livestock by saving time, labor and inputs under the environmental constrains and prevailing production system. These residues are like coarse roughages, but they are often no worse in term of quality and possibly better than most of the mature tropical grasses (Chenost, 1995). Due to environmental legislation and development of straw treatment techniques to improve digestibility, has reduced straw burning in most developed countries upto 70-80% where it is either used to fed the livestock, for bedding, mixed in manure, for conservation agriculture and for bio-energy production (Momayez et al., 2018). Zerbini & Thomas (2003) reported that an increase of 1% in fodder digestibility of sorghum stover, 5% milk production increased. Therefore, continuous research efforts are required to improve crop residues nutritional composition through crop management, biological, chemical and physical treatment of stover, as well as complementation with green fodder, high protein oil cakes and fodder tree leaves.

Nutritional status of forage crops and their impact on animal health

Nutritional composition of the major biomolecules like carbohydrates, proteins and lipids reflects nutritional status of any forage crop. Digestibility of any fodder crop is determined by the composition of these organic nutrients which along with vitamins and minerals provide energy to the animal which can be derived by any animal (Coleman & Henry, 2002). In addition to the genetics, crop type and crop stages had major effect on composition of quality traits of any forage crop. The stage of crop growth is the most important factor which determines fodder quality. Fodder quality and chemical composition of various crops based on dry matter basis (at 50% flowering) is given in Table 2. Among fodder crops maximum green fodder yield and nutritive value is obtained at 50% flowering crop stage (Gebreyowhans & Gebremeskel, 2014). Further delaying in harvesting time lowers L:S ratio (leaf:stem) and increases lignification's, crude protein (CP) concentrations, digestibility and intake would be significantly reduced as the forage advanced towards

TABLE 1
List of some popular cultivars of forage crops in India

S. No.	Major fodder crops	Released varieties/ hybrids popular in India	Main characteristics (GFY and DFY in tones/ha)
***Kharif* crops**			
1	Sorghum (*Sorghum bicolor* L. Moench)	SSG 59-3 (multicut) India	GFY: 75; DFY: 22 and tolerant to drought and water logging, sweet stalked, high early vigor
		CSV 33MF (multicut) India	GFY: 104; DFY: 28; it is tall, pyramidal and very loose panicle, resistant to all major diseases and pest infestation, resistant to lodging
		CSH 24MF (multicut) India	GFY: 100; DFY: 34 having tan plant color, resistant to major foliar diseases and insects, lodging resistant, good hybrid seed yield
		CSH 43MF (multicut) India	GFY: 96.5; DFY: 21.9 tall, juicy, sweet, high IVDMD%, resistant to foliar disease
		CSV 21F (Single cut) India	GFY: 41-45; DFY: 12-14; tall, flower in 76 days, resistant to shoot fly and stem borer
		CSV 32F (Single cut) India	GFY: 46.3; DFY: 17.8 ; sweet, juicy, resistant to foliar spot
		CSV 53F (Single cut) India	GFY: 48.3; DFY: 15.3 ; sweet, juicy, resistant to foliar spot
		CSV 40F (Single cut) India	GFY: 56.0; DFY: 15.5; sweet, juicy, superior quality having IVDMD 53%.
2	Fodder bajra (*Pennisetum glucum*)	Giant Bajra (India)	GFY: 50-75; plants are leafy with profuse tillering and have 9-10% protein at boot stage. The variety is good for hay and silage making
		Proagro No. 1 (FMH-3) (India)	GFY: 75; flower at 50- 55 after sowing and matures in 90-95 days. The variety is highly resistant to downy mildew.
		Raj Chari Bajra-2(India)	GFY: 30-40; is resistant to foliar diseases and insect-pests.
		FBC-16 (India)	GFY: 70-80; multi-cut variety, resistant to major diseases and having low concentration of oxalates.
		SBF 15-4 (India)	GFY:42.67; superior quality having IVDMD 56.5% and CP 9.8%.
		TSFB 15-8 (India)	GFY:42.02; superior quality having IVDMD 57.7% and CP 10.1%.
3	Fodder maize (*Zea mays*)	African tall (India)	GFY: 60-70; DFY: 30 having more dry matter and crude protein content, more number of leaves/plant, more leaf area, good grain and seed yield potential
4	Bajra Napier Hybrid (*Pennisetum americanum* L.)	NB-21 (India)	GFY: 250-300/year. It is fast growing variety with high tillering capacity. Stems are thin and non-hairy with long, smooth and narrow leaves
***Rabi* fodder crops**			
1	Oats (*Avena sativa*)	Haryana Javi-8 (India)	GFY: 65; fast growth, better regeneration and suitable for two cuts
		Bundel Jai 2001-3 (India)	GFY: 51; DFY: 10.4; fodder quality is better, CP (9.23%), ADF (40.5%) and IVDMD (60.4%)
		OS 6 (India)	GFY: 50.0; DFY: 11.0; tall, broad light green color leaves and medium bold seed size, moderately resistant to diseases
		OS 403	GFY: 53.0; DFY: 18.0; tall, broad light green color leaves and bold seed size, moderately resistant to *Helminthosporium* leaf blight
		HFO 707	GFY: 69.6; DFY: 13.5; tall, broad light green color leaves and bold seed size, moderately resistant to *Helminthosporium* leaf blight
		HFO 611	GFY: 16; DFY: 2.6; dual purpose, broad light green color leaves and bold seed size, moderately resistant to powdery mildew
		HFO 607	GFY: 62; DFY: 13; tall, single cut, broad light green color leaves and bold seed size, moderately resistant to Helminthosporium leaf blight
2	Berseem (*Trifolium alexandrinum* L.)	Wardan (India)	GFY: 70-75 t/ha; DFY: 12-15 t/ha, its plant habit is erect, flower color is white, days to 50% flowering is 150-165 days
		Bundel Berseem-3 (India)	GFY: 50-55 t/ha; DFY: 8-10 t/ha, its plants are erect with white flowers achieving 50% flowering in 155-170 days
		Mescavi	GFY: 65 t/ha; DFY: 8.2 t/ha its plant habit is erect, light green foliage
		HB 2	GFY: 78.5 t/ha; DFY: 10.8 t/ha its plant habit is erect, resistant against stem rot, long duration, light green foliage, high L/S ratio, better regeneration potential

physiological maturity. In major cereal fodders, midrib color is an indicator of good quality. Gene mutations in maize, sorghum and pearl millet have been identified that result in a brown midrib controlled by a single recessive gene (Harinarayana, 2005). This mutation was significant as plant tissues have less lignin than normal tissues, and higher digestibility of *bmr* types than normal ones. The extent of lignin reduction due to the presence of this gene is up to 51% in the stem and 25% in leaves (Porter *et al.,* 1978). Lignin inhibits fiber digestibility, which reduces milk production in animals.

Antinutritional factors

All fodder crops have some anti-nutrients, where the concentration above thresholds under certain environment or management conditions may be harmful to animal health. Sometimes livestock deaths occur due to lack of awareness of factors causing toxic compounds to accumulate in fodder crops (Keeler et al., 2013). Sorghum contains tannins, nitrates and HCN; pearl millet contains oxalates, and oats have nitrates and phytic acids, adversely affecting quality as given in Table 3.

Tannin

Tannins cause bitterness and affect the palatability and digestibility in forage crops (Muir, 2011). A significant negative relationship exists between tannin content and digestibility. In fodder plant, it decreases after 20 days of growth and again increased at 50-55 days of growth with concomitant increase of soluble sugars. Leaves contain higher amount of tannin than the stems in forage sorghum. Severity of leaf spot disease in forage sorghum has direct positive correlation with tannin content which results in marked decrease in digestibility of sorghum leaves (Vijaylaxmi *et al.,* 2019). Tannin is mostly present in forage sorghum and pearl millet with conc. of 2.0-10% on dry wt. basis.

Nitrate

Nitrates are present in oats**,** maize, pearl millet and sorghum but C_4 forages are known as nitrate accumulator. Mostly soil nitrogen is absorbed by plant roots in the form of nitrate. Enzyme nitrate reeducates rapidly converts amino acids into nitrate (Crawford, N. M. (1995).). This reduction absorbs energy from sunlight, favorable temperature, adequate water and nutrient. But under stress conditions like drought, salinity etc. the nitrate to protein conversion process is disturbed and nitrates begin to accumulate in plant. Some genotypes can accumulate potentially toxic nitrate levels. Heavy nitrogen fertilization especially in the late growing season increases the chances of nitrate accumulation (Salvagiotti, 2009). Nitrates concentration is normally high during plant growth period; but remains high always in mature sudangrasses and sorghum. Ruminant convert nitrate to nitrite to ammonia, which is then synthesized into protein by microbes present in the rumen (Wang et al., 2018). Excess nitrite enters the bloodstream and changes hemoglobin to methemoglobin, which is mainly responsible for carrying oxygen (Rasby et al., 2014). Generally, forages are considered potentially toxic if nitrate concentration is more than 6,000 ppm (Table 3).

HCN (Prussic Acid)

Hydrogen cyanide (HCN) is also known as

TABLE 2
Chemical composition (% of dry matter) of various fodder crops*

Nutrients	Forage Sorghum	Fodder Oat	Fodder Pearl Millet	Fodder cowpea
Crude Protein (%)	6-8	6.26-10.06	5.25-9.27	9.6-18.63
Dry matter digestibility (%)	45-60	59.7-71.1	52.1-64.1	59.6-7.09
Neutral detergent fiber (NDF %)	65-72	52.6-70.3	58.12-68.48	46.7-58.2
Acid detergent fiber (ADF %)	40-45	30.8-45.4	30.10-36.45	32.34-41.26
Lignin (%)	7.6	3.9-7.0	3.0-7.8	9.6-13.4
Cellulose (%)	34.6	20.9-25.4	20.2-29.8	20.8-29.3
Silica (%)	2.2	1.0-2.0	1.1-3.2	0.6-1.5
Hemicellulose (%)	26.3	21.8-24.8	28.0-32.0	14.5-16.9

*Modified from Aruna et al. (2011), AICRP on Sorghum Reports.

Prussic acid. HCN poisoning is mainly caused by forage sorghum and Sudan grass hybrids. HCN poisoning is caused by cyanide production in sorghum. It is found in sorghum at early stage (30-35 days) of crop growth and decreases after 45 days, the HCN content is reduced below the toxic level. HCN concentration of more than 200 µg/g (on fresh weight basis) should be considered potentially toxic (Aruna et al., 2013). Factors affecting HCN in forage sorghums include plant morphology, plant age, genotype, environmental stress (such as light intensity, salinity, drought and frost), and soil fertility.

Oxalates

Oxalic acid is synthesized in forage plants. It causes oxalate poisoning in ruminants under certain conditions which is a complex issue. It occurs in the form of soluble and insoluble oxalates. Soluble oxalate usually bind with monovalent counter ions like sodium (Na+), potassium (K+) and ammonium (NH4+), however insoluble oxalate bind with divalent ions like calcium (Ca2+), magnesium (Mg2+) and iron (Fe2+) ions (Rahman et al., 2013) making them unavailable for assimilation. Several factors like the chemical form of oxalate, the age of animal, the rate of oxalate consumption, the quantity and quality of other feed consumed concurrently affects the oxalate intoxication (Ramteke et al., 2019). This causes disturbances in Ca and phosphorus (P) metabolism leading to excessive mobilization of bone mineral and it also forms an insoluble salt that precipitates in the kidney, causing kidney failure (Smitha, 2013).

Strategies to avoid HCN poisoning (Sher *et al.,* 2012; Schneider and Anderson, 1986):

- Selecting a cultivar with low HCN content
- Avoiding grazing on Sudan grasses or sorghum sudangrasses hybrids upto 45 days after sowing and irrigation of crop 2-3 days before harvesting in summer season.
- Avoiding grazing of forage sorghum from frost or drought damaged pastures.
- Leaving the green fodder 3-4 hours in sun after its harvest to reduce HCN content.

Major breeding objectives for fodder crop improvement

All breeding programs share one common objective *i.e.* to improve any species for use within a target n in environments whether it is food or fodder crop. Beyond this common goal, the major objectives of any forage breeding programs vary depending upon plant species and its uses thereof. Breeding objectives are framed within the agricultural context and the environment in which the species will be used. But breeding forages is more difficult and time consuming due to plurality of species, differences in life cycle varying from annual to perennial, apomixes, seed shattering etc. General breeding objectives associated with fodder crops improvements are as follows;

(1) High green and dry fodder yield
(2) Good fodder quality
(3) Low concentration of anti- nutrients
(4) Biotic and abiotic stress resistance
(5) Enhanced water use efficiency

(a) Breeding objective for forage sorghum improvement -Breeding is performed in forage sorghum to achieve following objectives as per circumstances:

1. High green and dry biomass yield
2. Profuse tillering and good regeneration potential
3. Wide adaptability
4. Juiciness
5. Foliar disease resistance
6. Insect pest resistance
7. Lodging resistance
8. High palatability and digestibility
9. Low HCN content with good quality protein and high *in-vitro* dry matter digestibility and low lignin.

(b) Breeding objectives for fodder oats –Fodder oat breeding programs mainly focus with aims of achieving the following objectives:

(1) High green and dry fodder yield with rapid growth with greater economic competitiveness
(2) Multicut potential
(3) Dual purpose
(4) Good tillering ability with high harvest index
(5) Green stems over 120 cm height at maturity with high crude protein contents
(6) Resistant to biotic stresses like leaf spot and powdery mildew
(7) Resistant to abiotic stresses like drought, salinity and lodging

(8) Low amount of lignin (completely indigestible)
(9) High metabolisable energy

(c) Breeding objectives for Forage Bajra-Breeding bajra for forage purpose aims with following objectives:

(1) High yield, fast growth and profuse tillering
(2) Drought tolerance
(3) High sugar contents in stem juice
(5) Increased leaf number with more breadth
(6) High digestibility
(7) Short day type with photo sensitiveness so that they remain in vegetative phase for longer periods
(8) Dwarf varieties with reduced stem height to maintain juicy and sweetness for fodder purpose.
(9) High crude protein content.
(10) Tolerant to saline and sodic soils.

Conventional and molecular breeding strategies for fodder improvement:

Use of breeding methods depend upon type of pollination, whether self or cross *i.e.* autogamous or allogamous forage species. Use of conventional methods in case of self-pollinated species mainly pure line selection is utilized to throw transgressive segregants in respect of the desirable traits. In addition to these, other selection procedures viz., Pedigree, Bulk and Single seed Decent are followed by breeders. Selective diallel mating systems shown in figure described by Jelson (1970) is used by forage breeders to obtain additional recombination by intercrossing of selected genotypes (Moreno-Gonzalez & Cubero, 1993 & Kang et al., 2007). Later on various workers combined selective diallel mating system, single seed decent method and screening honeycomb design for superior genotype identification in forages. In case of cross pollinated species development of improved synthetics and composites was taken up by breeders and their base parental lines were selected based on general combining ability. Population improvement based on recurrent selection among various populations helps in favorable gene selection in desirable population for traits like higher yield potential (fodder/grain), resistance to abiotic & biotic stresses and wide adaptability received major attention of breeders. Use of various genetic male-sterility facilitated populations and pure-line varieties among fodder crops have improved resistance breeding programs and new improved resistance sources were also identified. After 1970s, development of hybrids among forages using CMS system, polyploidy, haploid production, and mutagenesis have revolutionized the breeding programmes because in forages sterility of interspecific hybrids does not have any issue if the hybrid can be propagated vegetatively. Hybrid of *Pennisetum americanum* and *P. purpureum* resulted in development of many napier bajra hybrid varieties in India. Similarly, in forage sorghum various hybrids and varieties were released using diverse sources having good quality, high biomass and biotic and abiotic stress résistance. Several promising good quality varieties/hybrids were developed using conventional breeding approaches in different fodder crops and are popular among farmers (Table 1).Use of combining ability in any breeding program also offers a big fodder yield advantage as it helps in parental selection for construction of synthetics, suitable F1's for a multiple crossing or composite breeding programme and the possibility of

TABLE 3
Levels of anti-nutrients present in forages and their potential effect on animals*

S. No.	Anti-nutrient and crops	Concentration (unit)	Effects on animals
1	Nitrate (ppm) (on dry wt. basis) present in Sudan Grass, Pearl millet, Oats	0- 3,000	Virtually safe
		3,000-6,000	Moderately safe in most situations; limit use for stressed animals to 50% of the total ration.
		6,000-9,000	Potentially toxic to cattles depending on the situation; should not be the only source of feed.
		9,000 and above	Dangerous to cattle and often cause death.
2	HCN (µg/g on fresh wt. basis) present in Forage Sorghum	0 -200	Generally safe, should not cause toxicity
		600-1000	Potentially toxic, should not be the only source of feed
		Above 1000	Dangerous to cattle and usually will cause death.

*Modified from Samtiya et al. 2020; Aruna *et al.,* 2011.

using an appropriate selection technique like modified mass selection, reciprocal and recurrent selection (Fasahat, 2016). It also contributes to high heritability (Serba et al., 2020) and is very important in hybrid programs especially for forage sorghum and bajra.

Due to rapidly changing climatic conditions susceptibility to various abiotic and biotic factors is increasing in various forages (Lamichhane et al., 2018). In this situation genetic enhancement of forages for fodder and grain yield is a major challenge to forage breeders. Application of advanced molecular approaches such as *in-vitro* selection, wide hybridization, molecular marker assisted breeding and transgenic for mapping and dissection of complex traits in forages will certainly help in addressing the challenges of biotic/abiotic stresses more efficiently (Saha et al., 2013). A little work is done on forages using biotechnological approaches (Roy et al., 2019). In forage crops few markers/QTLs were identified related to tillering, regeneration potential and for some quality traits. Molecular mapping of economically important traits facilitates the use of marker assisted selection in forage breeding programs. These approaches in combination with conventional ones can increase the overall selection gain and thus the efficiency of a breeding program.

Genetic erosion of forage crops and steps for their improvement

Due to industrialization, population growth and urbanization, major focus is on cereal and cash crops leading to great deterioration of grasslands. In addition to this, spread and use of modern commercial agriculture techniques led to a continuous erosion of genetic stock of forage crops. Major effect of the introduction of any new cultivars of any crop has been the replacement/loss of highly adapted local landrace/cultivars. The loss of genetic diversity is directly correlated with the loss of access/knowledge about that material (Ten Brink et al., 2010). Due to continuous negligence genetic base of forage crops has become narrow and delimiting the possibility of genetic improvement of fodder crops. It is the need of time to start some strong and traits specific programme to strengthen the economic support to research, breeding and maintenance of forage genetic resources for extreme events such as global warming, desertification, soil erosion and climate change especially in developing countries (Fig. 4). Because in these countries fodder crops are least prioritize for research and development due to heavy demand of food and cash crops. Pasture and fodder crops are play an important role in maintaining soil fertility in mixed farming systems. Perennial grasses prevent soil erosion and excellent protectors of the soil surface so we have to promote perennial varieties of forage crops for environmental sustainability (Marshall et al., 2016). For rehabilitation of available lands which have been devastated by industries such as oil extraction, mining, other industrial uses or due to extensive grazing are important catchments and fodder trees and shrubs play an important role in their reestablishment. Development of forage herbarium in every state (conserving state forage biodiversity) may be a step for forward conservation of forage biodiversity.

Future prospects

There is enormous gap between demand and supply of green and dry fodder in country but from above discussion it might be concluded that there is huge potential among forage crops for improvement because almost negligible molecular work is done on forage aspects of almost all fodder crops. Development of new genotypes of forage crops highly efficient in water and nutrient use along with good quality must be the target for future forage improvement. Among forages there is huge potential to develop gene markers that can indicate the nutritional status of each forage crop, cutting/grazing decisions, protein content, biomass production etc. Better fertilizer use efficiency could also be a target trait due to threat of legislation for overuse of fertilizer for forage crops. There is plenty of scope for improving the fertilizer and nitrogen use efficiency of forage crops particularly as breeding programs have not focused yet on such traits. In addition to this forage seed production programme should be strengthened. Emphasis may be given on adoption of improved forage varieties with high biomass. Following strategies should be adopted in developing improved cultivars:

(i) Emphasis should be given on adoption of improved forage varieties with high biomass.
(ii) Dual purpose genotypes should be developed.
(iii) Multi-cut cultivars with high tillering ability and fast regeneration should be developed.
(iv) Bio-fortified genotypes should be preferred.
(v) Anti-nutritional constituents should be kept at minimum level.
(vi) For single cut: tall, sweet, tan type and leafiness should be preferred.

REFERENCES

Arora , S. K. and Y. P. Luthra, 1992 : Present status and future strategies for improvement of quality of forages. *Strategies for Forage Production and Improvement*, pp 195-210.

Aruna, C., B. Venktesh, A.V. Umakanth, G. shyamprashad, I. K. Das and J. V. Patil, 2011 : Forage sorghum, Directorate of Sorghum Research, Rajendernagar, Hyderabad 500030, Telangana, India, ISBN: 81-89335-36-7

Aruna, C., P. K. Shrotria, S. K. Pahuja, A. V. Umakanth, B. V. Bhat, A. V. Devender, and J. V. Patil, 2013 : Fodder yield and quality in forage sorghum: scope for improvement through diverse male sterile cytoplasms. *Crop and Pasture Science*, **63**(12), 1114-1123.

Capstaff, N. M., and A. J. Miller, 2018 : Improving the yield and nutritional quality of forage crops. *Frontiers in plant science*, **9**: 534-535.

Chenost, M., 1995 : Optimizing the use of poor quality roughage through treatments and supplementation in warm climate countries with particular emphasis on urea treatment. In *Proceedings of the 1st Electronic Conference on Tropical Feeds with Particular Emphasis on Urea Treatment.*

Coleman, S. W., and D. A. Henry, 2002 : Nutritive value of herbage. *Sheep nutrition*, 1-26.

Crawford, N. M., 1995 : Nitrate: nutrient and signal for plant growth. *The plant cell*, **7**(7), 859.

De Graaff, J., A. Kessler and J. W. Nibbering, 2011 : Agriculture and food security in selected countries in Sub-Saharan Africa: diversity in trends and opportunities. *Food security*, **3**(2), 195-213.

Fasahat, P., A. Rajabi, J. M. Rad and J. Derera, 2016 : Principles and utilization of combining ability in plant breeding. *Biom Biostat Int. J.*, **4**(1), 1-24.

Gebreyowhans, S., and K. Gebremeskel, 2014 : Forage production potential and nutritive value of cowpea (Vigna unguiculata) genotypes in the northern lowlands of Ethiopia. *Journal of Agricultural Research and Development*, **5**(4), 066-071.

Halli, H. M., S. S. Rathore, N. Manjunatha, and V. K. Wasnik, 2018 : Advances in Agronomic Management for Ensuring Fodder Security in Semi Arid Zones of India - A Review. *Int. J. Curr. Microbiol. App. Sci.*, **7**(2), 1912-1921.

Harinarayana, G., N. P. Melkania, B. V. S. Reddy, S. K. Gupta, K. N. Rai and P. S. Kumar, 2005 : Forage potential of sorghum and pearl millet. *Forage potential of sorghum and pearl millet*, 292-321.

Kang, M. S., P. K. Subudhi, N. Baisakh, and P. M. Priyadarshan, 2007 : Crop breeding methodologies: classic and modern. *Breeding major food staples*, 5-40.

Keeler, R. F., K. R. Van Kampen and L. F. James, (Eds.). 2013 : *Effects of poisonous plants on livestock*. Elsevier.

Lamichhane, J.R., Debaeke, P., Steinberg, C., You, M.P., Barbetti, M.J. and Aubertot, J.N., 2018. Abiotic and biotic factors affecting crop seed germination and seedling emergence: a conceptual framework. *Plant and soil*, *432*, 1-28.

Marshall, A. H., R. P. Collins, M. W. Humphreys and J. Scullion, 2016 : A new emphasis on root traits for perennial grass and legume varieties with environmental and ecological benefits. *Food and energy security*, **5**(1), 26-39.

Momayez, F., K. Karimi and I. S. Horváth, 2018 : Enhancing ethanol and methane production from rice straw by pretreatment with liquid waste from biogas plant. *Energy Conversion and Management*, **178**: 290-298.

Moreno-Gonzalez, J., and J. I. Cubero, 1993 : Selection strategies and choice of breeding methods. In *Plant Breeding* (pp. 281-313). Springer, Dordrecht.

Muir, J. P., 2011 : The multi-faceted role of condensed tannins in the goat ecosystem. *Small Ruminant Research*, **98**(1-3), 115-120.

Porter, K. S., J. D. Axtell, V. L. Lechtenberg and V.F. Colenbrander, 1978 : Phenotype, Fiber Composition, and *in vitro* Dry Matter Disappearance of Chemically Induced Brown Midrib (bmr) Mutants of Sorghum. *Crop Science*, **18**(2), 205-208.

Rahman, M.M., Abdullah, R.B. and Wan Khadijah, W.E., 2013: A review of oxalate poisoning in domestic animals: tolerance and performance aspects. *Journal of animal physiology and animal nutrition*, ***97*(4)**: 605-614.

Ramteke, R., Doneria, R. and Gendley, M.K., 2019: Antinutritional factors in feed and fodder used for livestock and poultry feeding. *Acta scientific nutritional Health*, ***3*(5):** 39-48.

Rao, C. S., K. A. Gopinath, J. V. N. S. Prasad and A. K. Singh, 2016 : Climate resilient villages for sustainable food security in tropical India: concept, process, technologies, institutions, and impacts. *Advances in Agronomy*, **140**: 101-214.

Rao, P. P., and A. J. Hall, 2003 : Importance of crop residues in crop–livestock systems in India and farmers' perceptions of fodder quality in coarse cereals. *Field Crops Research*, *84*(1-2), 189-198.

Rasby, R. J., B. E. Anderson and P. J. Kononoff, 2014 : Nitrates in livestock feeding. *2007-2014: The Board of Regents of the University of Nebraska on behalf of the University of Nebraska–Lincoln Extension*

Roy, A. K., D. R. Malaviya and P. Kaushal, 2019 : Genetic improvement of dominant tropical Indian range grasses. *Range Management and Agroforestry*, **40**(1): 1-25.

Saha, M. C., H. S. Bhandhari and J. H. Bouton, (Eds.). 2013 : *Bioenergy Feedstocks: Breeding and Genetics*. John Wiley & Sons.

Salvagiotti, F., J. E. Specht, K. G. Cassman, D. T. Walters, A. Weiss and A. Dobermann, 2009 : Growth and nitrogen fixation in high-yielding soybean: Impact of nitrogen fertilization. *Agronomy Journal*, **101**(4), 958-970.

Samtiya, M., Rotimi E. Aluko and D. Tejpal, 2020 : Plant food anti-nutritional factors and their reduction strategies: an overview. Food Production, Processing and Nutrition. https://doi.org/10.1186/s43014-020-0020-5

Sarnklong, C., J. W. Cone, W. Pellikaan and W. H. Hendriks, 2010 : Utilization of rice straw and different treatments to improve its feed value for ruminants: a review. *Asian-Australasian Journal of Animal Sciences*, **23**(5): 680-692.

Serba, D. D., R. S. Yadav, R. K. Varshney, S. K. Gupta, G. Mahalingam, R. K. Srivastava,... and T. T. Tesso, 2020 : Genomic Designing of Pearl Millet: A Resilient Crop for Arid and Semi-arid Environments. In *Genomic Designing of Climate-Smart Cereal Crops* (pp. 221-286). Springer, Cham.

Sher, A. H. M. A. D., M. Ansar, G. H. U. L. A. M. Shabbir, and M. A. Malik, 2012 : Hydrocyanic acid content variation amongst sorghum cultivars grown with varying seed rates and nitrogen levels. *International Journal of Agriculture & Biology*, **14**: 720-726.

Singh, T., S. Ramakrishnan, S. K. Mahanta, V. C. Tyagi, and A. K. Roy, 2018 : Tropical forage legumes in india: status and scope for sustaining livestock production. *Forage Groups*.

Smitha PA. 2013. The anti-nutritional factors in forages. A review. *Current Biotica* **6:** 516-526.

Suttie, J. M., 2000 : *Hay and straw conservation: for small-scale farming and pastoral conditions* (No. 29). Food & Agriculture Organization.

Tassew Dassie, B., 2018 : Effect of four varieties of vetch hay supplementation on feed intake, digestibility, body weight change and carcass characteristics of arsi-bale sheep fed a basal diet of fodder oat hay. (Doctoral dissertation, Haramaya university).

Ten Brink, B., S. Van der Esch, T. Kram, M. Van Oorschot, J. C. M. Van Meijl, A. A. Tabeau and E. J. M. M. Arets, 2010 : Rethinking global biodiversity strategies: exploring structural changes in production and consumption to reduce biodiversity loss. Netherlands Environmental Assessment Agency.

Tewatia, B. S., and K. R. Yadav, 2010 : Nutritional potential and quality evaluation of legume fodders in ruminants. *Forage Legumes*, 340.

Vanlauwe, B., J. Wendt, K. E. Giller, M. Corbeels, B. Gerard and C. Nolte, 2014 : A fourth principle is required to define conservation agriculture in sub-Saharan Africa: the appropriate use of fertilizer to enhance crop productivity. *Field Crops Research*, **155**: 10-13.

Vijaylaxmi, S. K. Pahuja P. Kumari and U. N. Joshi, 2019 : genetic divergence studies for agro-morphological, insect pest and quality parameters in mini core collection of forage sorghum. *Forage Res.,* **32**(2): 150-157.

Wang, R., M. Wang, E. M. Ungerfeld, X. M. Zhang, D. L. Long, H. X. Mao,... & Z. L. Tan, 2018 : Nitrate improves ammonia incorporation into rumen microbial protein in lactating dairy cows fed a low-protein diet. *Journal of dairy science*, **101**(11), 9789-9799.

Zerbini, E., and D. Thomas, 2003 : Opportunities for improvement of nutritive value in sorghum and pearl millet residues in South Asia through genetic enhancement. *Field Crops Research*, **84**(1-2): 3-15.