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Genetic improvement of fodder legumes especially dual purpose pulses

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Abstract

Cultivated forage legumes and range legumes are crucial for the nutritional security for mankind as they are integral component for increased availability of animal protein and product which has higher biological value than the plant proteins. Genetic improvement programme in forages in general and forage legumes in particular could not gain due impetus probably due to the nature of the crop and also because the economically important plant part is vegetative biomass. Although crop specific objectives need to be taken care of, forage legumes have some common problems and possible strategies. In the present article, common issues as well as crop specific improvement issues are discussed. The common improvement objectives include utilization of plant genetic resource and broadening genetic base; enhancing digestive quality; tolerance to abiotic and biotic stress; quality seed production in cultivated species while specific features such as increased persistence, tolerance to abiotic stresses, easy establishment, good seeding ability and grazing tolerance among range species. Developing terminal drought tolerant, early maturing, pest tolerant and erect type Cowpea; drought tolerant dual purpose Guar; moisture stress tolerance with standing ability and harvestability, disease/pest resistance and tolerance to herbicide in field pea and forage pea; short duration, resistance to biotic stress and low β-ODAP content in grass pea; drought and biotic stress tolerance in addition to increased biomass yield in Rice bean, perennial soybean, *Vicia sativa,* Faba bean; improved drought tolerance, anthracnose resistance, nutritional parameters such as high methionine and regenerative potential in Stylosanthes; high tillering quick regeneration, cold and drought tolerance, diseases and pest resistance in Lucerne and broadening genetic base, improved first cut yield, root rot and stem rot resistance and dry matter content in Egyptian clover could be some of the objective in major crops.

Key words: Forage legumes, range legumes, palatability, forage seed, livestock nutritive value

Since the dawn of civilization and domestication of animal and plants, forages occupy a unique position because a well-knit combination of agriculture and animal husbandry sustains the rural economy and employment opportunities in India and elsewhere. In India, twenty major cultivated forage crops are cultivated on 9.0 m ha area. An additional 48 m ha of wastelands and degraded soils has the potential to be used for increasing forage resources. Besides cultivated legumes, range legumes are important component in pasturelands of over an area of 12 Mha which constitute the main grazing resources in India. Nearly 30 pastoral communities in hilly or arid/semi-arid regions in northern and western parts of India, depend on grazing-based livestock production (Roy and Singh 2013). Incorporation of legume forages in crop rotation have several benefits such as increased soil fertility, soil quality, water filtration, lesser disease in subsequent crops, reduced weed population, carbon sequestration. In temperate grassland, need for non-traditional legume species and their improved persistence was highlighted (Goff et al. 2015). The large root systems of perennial forages can store up to 2.7 times more carbon than annual crops, and sequester it deeper into the ground for better longer-term storage.

The leguminous crops are important for consumption by both human and animal. From utilization point of view, forage legumes can be grouped

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into four major categories i.e. i) dual purpose grain legumes used as feed and grain; ii) dual purpose legumes of which aerial parts (leaf and stem) used as fodder while grains used as feed or grain; iii) pasture legumes which are part of naturally occurring or improved grasslands/rangelands and iv) annual or perennial cultivated fodder. Of the four categories, the first two can be grouped as forage pulse. Since, from animal consumption point, many of the forage legume crops have common problems and common possible strategies, in the present article, common issues are discussed in beginning followed by crop specific issues. Although, in the present article major focus is on forage pulses, the forage legume and forage range legumes are also discussed in brief because of their significant direct and indirect impact on nutritional security. There has been recent good reviews on grain legumes (Sharma et al. 2013; Latef and Ahmad 2015) but reviews on forage legumes especially tropical legumes of forage value is lacking. The list of improved varieties developed in India and nutritive value of important forage legumes are given in Tables 1 and 2 respectively.

Use of forage legumes has multiplicity with regional, climatic, ecological adaptability. Common pulses used as forage include pea (*Pisum sativum*), guar (*Cyamopsis tetragonoloba*), pigeon pea (*Cajanus cajan*), soybean (*Glycine max*), hyacinth bean (*Lablab purpureus*), cowpea (*Vigna unguiculata*), groundnut (*Arachis hypogea*) etc., perennial legumes used as fodder crops include: alfalfa/Lucerne (*Medicago sativa*), red clover (*Trifolium pratense*), white clover (*T. repens*), etc. Annuals legumes used as forage include Egyptian clover (*T. alexandrinum*), crimson clover (*T. incarnatum*), Persian clover (*T. resupinatum*), vetches (*Vicia* spp.) etc.

Forage crops are different from food crops because firstly the economically important plant part is its vegetative biomass and secondly their economic value depends upon the attributes that are suited to the livestock. Hence, breeding of forage crops is quite different than the grain crops. Forage crop improvement has its own unique problems quite different from the grain crops. Improvement of forage legume crop, forage pulse and forage range legume require following common objectives.

Cultivated forage legumes

Quality including palatability and digestibility: Forages are to be first utilized by animal and then by human in the form of animal product. Hence, digestible quality crude protein content, *in-vitro* dry matter digestibility, better amino acid composition need to be considered while developing a variety. As the product is to be fed to animals, nutrition, palatability and digestibility takes the crucial role in deciding the cultivars. These traits are crucial for intake by livestock, its growth and production. Presence of hard leaf surface, hairiness, stiffness, serrate margins, odour and smell etc. decreases palatability whereas lignin, fibre, and alkaloids decreases digestibility.

Anti-nutritional attributes : Most of the legumes contain some toxic substances which cause problem

Table 1. Legume varieties for fodder or dual-purpose developed in India

Crop	Varieties developed in India
Berseem	Pusa Giant, Mescavi, Wardan, BL-22, BL-2, UPB-110, Bundel Berseem-2, Bundel Berseem-3, BL-180, HB-1, HB-2
Lucerne	Chetak, Type-9 , LL Composite-3 (LLC-3), Anand-2,, Anand Lucerne-3, Anand Lucerne-4, Anand-23, RL-88 , RRB-07-1, Lucerne CO-1, Lucerne CO-2
Cowpea	Kohinoor , Type-2, EC-4216, GFC-1, GFC-2, GFC-3, GFC-4, UPC-5286, UPC-5287, UPC-8705, UPC-9202,UPC-607, UPC-618, UPC-622, UPC-625,UPC-628,UPC-287, UPC-4200, Bundel Lobia-1, Bundel Lobia-2, IL 1177,MFC -08-14, MFC-09-1, Cowpea CO-5, Cowpea CO (FC)-8, , KBC-2, Vijaya
Guar	HFG-119, HG-75, Bundel Guar-1,Bundel Guar-2,Bundel Guar-3, FS-277,HFG-156, HG-258, HG-884, HG-2-20, HG-182, HG-365, HG-563, HG-870,
Rice bean	Bidhan-1, RBL-6, KRB-19, JRBJ-05-2, Jawahar Rice bean-1, Shyamalima, Bidhan-3
Methi	HM-65
Senji	FOS-1, HFWS-55
Lablab bean	Bundel Sem-1 (JLP-4)

Table 2. Nutritive value in some important forage legumes

Component	Unit	Aerial part (fresh)												Seed		
		Pea	Berseem	Vicia saliva	Vicia faba	Lathy-rus	Lab lab	Perennial soybean	Pigon pea	Rice bean	Alfalfa hamata	Stylo	Cow-pea	Lathy-rus	Lab lab	Rice bean
Dry matter	% as fed	15.6	12.5	19.3	19.4	21.7	22.1	33.3	31.8	21.4	19.9	29.0	20.9	90.9	90.0	91.1
Crude protein	% DM	17.7	19.9	23.0	17.8	21.4	18.4	17.1	19.0	19.0	20.6	15.9	18.1	30.0	26.1	21.0
Crude fibre	% DM	22.9	22.3	25.4	26.0	25.8	28.2	30.4	30.6	30.8	26.7	33.2	24.1	6.4	9.5	4.0
NDF	% DM	31.1	44.8	36.7	46.9	38.2	44.6	50.7	47.5	59.7	39.3	51.6	38.6	20.1	36.8	23.5
ADF	% DM	23.1	27.6	28.5	29.7	27.1	32.0	37.4	30.5	38.9	30.9	40.1	27.1	7.1	14.3	-
Lignin	% DM	4.8	5.1	6.1	-	-	7.2	7.9	15.1	-	7.6	9.1	4.6	1.3	1.2	-
Ether extract	% DM	3.1	3.2	2.5	-	2.9	2.6	2.4	4.3	1.8	2.9	2.6	2.8	1.2	2.4	2.3
Ash	% DM	9.1	15.4	9.8	9.0	10.5	11.1	10.0	6.1	10.4	11.5	8.1	11.3	3.2	4.0	4.3
Gross energy	MJ/kg DM	18.5	17.4	18.6	-	18.5	18.2	18.4	19.7	18.3	18.1	18.9	18.1	19.1	19.1	18.5
Ruminant nutritive value																
OM digestibility	%	72.3	73.0	69.8	74.1	69.4	67.0	64.8	64.6	64.4	68.5	61.5	71.2	92.0	77.8	59.9
Energy digestibility	%	69.2	69.8	66.7	70.8	66.4	64.0	62.0	61.7	61.6	65.5	58.8	68.0	91.0	76.8	58.0
DE	MJ/kg DM	12.8	12.2	12.4	-	12.3	11.7	11.4	12.1	11.3	11.9	11.1	12.3	17.4	14.6	10.7
ME	MJ/kg DM	10.2	9.6	9.8	76.5	9.7	9.2	9.1	9.6	8.9	9.4	8.8	9.8	13.8	11.7	8.7
Nitrogen digestibility	%	79.3	74.9	78.9	-	77.7	75.0	-	64.5	-	78.5	-	70.0	90.0	65.2	68.9

Information compiled from feedipedia 2016. Animal feed resource information system. www.feedipedia.org

to animal health and thereby reduce the productivity e.g., Mimosine in *Leucaena*, Vicine-covicine in *Vicia,* ODAP in *Lathyrus etc.* Hence, the new high yielding varieties should not contain such anti-quality factor or they should be present in limited quantity.

Abiotic stress tolerance: Forage legumes mostly occupy marginal lands in cropping systems, hence, extreme drought and moisture tolerance, acidic/ saline soil tolerance, water logging tolerance is needed.

Quality seed production: Seed production in forage legumes are adversely affected due to overlapping of vegetative and reproductive growth phases, uneven pod setting, non-synchronous maturity and seed shattering, pollination behaviour, low seed setting, inherent heterozygosity, self incompatibility etc. As crops are bred for vegetative part, mostly they are poor seed producers, or produce seed with low viability and/ or with low seedling vigour and competitive ability. Most of the species used as forages are not properly domesticated, hence, the wild traits like seed dormancy; seed shattering etc. affect their commercial use.

Genetic improvement: Fertility barriers are common in tropical forage crops, owing to the wild nature of the species and inadequate knowledge of inter- or intra-specific variation. Narrow genetic base and inadequate germplasm base is also common for many crops. Most of the forage legumes are not properly studied for genetics and phylogeny. Hence, uses of modern and conventional techniques are difficult. Many forage legume species especially medics, clovers, Stylosanthes have small floral parts, making artificial hybridization tedious.

Range legumes

Establishment and persistence: Persistence of perennial forage legumes is a complex of traits dependent on various factors, such as disease, insects, abiotic stresses, or management stress. For pasture species, easy establishment at economical cost and greater aggressiveness/fast growth and competing ability or complementation with the companion crop are required in addition to profuse seeding, grazing and trampling tolerance, and adaptation to grazing management.

Productivity: The range crops have to be in non-arable marginal soils with poor water availability, hence, optimizing productivity through selection of species/genotype/crop management needs to be considered. Regeneration ability, defoliation tolerance and competitiveness with companion crops also have impact on productivity. For developing range varieties, competitiveness and allelopathic effects need to be given due consideration as pastures are mixtures of several genotypes and species in a highly dynamic biotic and abiotic environment. Long term continuity enables selection to be continuous and cumulative.

Constraints in quality seed productivity: Availability of quality seed along with many socio-political issues is a constraint in increasing area under range legumes. Only a few range species have been domesticated while rest still possess traits of wild plants such as seed shattering, small seed size, and seed dormancy, slow germination etc. making seed production difficult and costly.

Forage genetic resources

Indian sub-continent is endowed with a rich genetic diversity of forage plant species due to diverse eco-climatic conditions and a variety of habitats and niches. Indian gene centers hold rich diversity in native grasses and legumes, browse species and shrubs. *Desmodium, Lablab, Stylosanthes, Vigna, Macroptelium, Centrosema* are amongst 30 leguminous species, which comprise most of the managed pastures.

The main centre of genetic diversity of temperate legumes is the Mediterranean (e.g., *Hedysarum spp*, *Lotus* spp., *Medicago* spp., *Onobrychis viciifolia*, *Trifolium* spp.). For tropical species the main centres of genetic diversity are South and Central America (e.g. *Arachis*, *Stylosanthes*, *Desmodium*, *Centrosema*, *Leucaena* and *Gliricidia*), whilst Africa and Asia are important for the genus *Neonotonia*, Asia for *Pueraria* and some species of *Desmodium*; Africa for *Lotononis*. Most pasture legumes, are of recent domestication, except alfalfa/lucerne, *M. sativa*, (which was domesticated before the Christian era), and Egyptian clover (*T. alexandrinum*). Around 400 forage legume species belonging to 35 genera are naturally occurring in India (Arora and Chandel 1972).

The landraces needs to be properly evaluated and conserved as original diversity, plus accumulated mutations and genetic recombinations are conserved in these landraces. Precise phenotyping, for important quantitative traits, abiotic and biotic stress tolerance should be done. Gap analysis should be done in major forage crops which involves identification of priority taxa and also genetic or ecogeographic diversity and complementary hotspots and matching them with current *in situ* and *ex situ* conservation. The multi-genepool approach, irrespective of individual genepool results, has been used by Maxted et al. (2012) for the temperate legume. Analysis of six genera namely wild *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* has shown that the judicious location of a single genetic reserve could ensure the long-term conservation of multiple crop gene pools (Maxted et al. 2012).

Climate change and adaptation of forage crops

Global climatic change has necessitated understanding response and adaptations of forage species to changing environmental parameters. From the early stages of domestication, most of the selection was by farmers for better adaptations to very specific environments. In the breeding plans, instead of one specific aim, several alternative options must be included. One key requirement is that all germplasm should be tested under near optimum conditions for its yield potential followed by multilocational testing for yield and stress tolerance. It will allow pyramiding of a large number of multiple resistance genes for wide spectrum of biotic and abiotic stress. Genetic adaptation implies the shaping of population and species gene pools in response to environmental challenges. Adaptability to specific environments is determined both by major and minor genes and their complex interaction and co-adapted gene complexes. The adaptive features are controlled by multiple genes. Most important genetic mechanism in adaptation is the assembly of favourable epistatic combinations of alleles of different loci by means of recurring cycles of selection, intercrossing superior plant types, selection and selfing to near homozygosity. Understanding adaptation mechanism and breeding for environmental adaptedness is very difficult because of involvement of several genes in the response to a given environmental factors. The same gene(s) may be involved in different adaptive response. Plants follow environmental changes in two ways - by individual processes of phenotypic plasticity expression or by population processes over generation (evolutionary changes) (Allard 1997; Vega 1997). Forage legumes, particularly the range legumes are adapted to very harsh climate. This provides them ample opportunity to adapt in case of change in climate.

Breeding for adaptation in cropping systems: Area under cultivated forages is stagnant hence, there is need to develop varieties which can well be adapted to different cropping systems. Various studies involving breeding for intercropping reveals that genotypes bred for sole crop conditions may not be equally good for mixed crop. However, breeding for interaction with other plant species (intercropping etc) needs understanding of co-evolution which has been defined as reciprocal genetic changes that occur in two or more ecologically interacting species (Futuyma and Slatkin 1983). It involves study of important influences impacting an organism arising from its relationship with other organisms, at the same or at different, trophic level. Co-evolution occurs when a trait of one species evolves in response to a trait of another species, which has itself evolved in response to the trait in the first species. The process is both reciprocal and specific (Janzen 1980).

A few traits like disease resistance may confer advantage in both systems but physiological adaptation characteristic may be specific. Interactions among cultivars and cropping systems require specific plant ideotypes, such as erect type or climbing type legume in intercropping. The suitable breeding approach may involve early generation selections in sole crop for qualitative traits followed by yield tests in the systems under growing cultivable environment. It should involve the ability of one component to obtain limited resources in competition with another component, compared to similar ability in pure stands (Hill 1997).

Domestication of forage legumes: The domestication of legumes includes changes in plant architecture, reduced seed dispersal and loss of seed dormancy. Seed dormancy or hard-seededness affects the cultivation of crop but has an added advantage in pasture or rangeland condition. Genetic analysis performed in wild to cultivated mungbean and pigeonpea crosses resulted in the identification of quantitative trait loci (QTLs) for 38 domestication-related traits or single-nucleotide polymorphisms derived from 670 genes (Isemura et al. 2010.).

Cowpea

Cowpea (*Vigna unguiculata* (L.) Walp. (2n=22) is native to West Africa which is also the primary centre of domestication. It is cultivated in tropics and subtropics across Asia and Oceania, the Middle East, southern Europe, Africa, southern USA, and Central and South America. In India, cowpea is cultivated in 6.5 lakh ha (including 3 lakh under fodder) in Rajasthan, Gujarat, Maharashtra, Karnataka and Tamil Nadu. Cowpea is a self-pollinating herbaceous, annual grown for vegetables (leaves and flowers), grain, as fresh cut and carry forage, and for hay and silage. It is drought tolerant, susceptible to water logging. It can be grown throughout the year with short duration and fast growing nature. It is suitable for inter, mixed and relay cropping system.

Fodder cowpea crude protein content in the grain ranges from 22 to 30% on a dry weight basis, and from 13 to 17% in the haulms with a high digestibility and low fibre level (Tarawali et al. 1997). Green fodder of cowpea on dry matter basis contains crude protein 13.21 %, Crude fibre 40.80% and *in vitro* dry matter digestibility 42.72 % (Shah et al. 1988). Even the crop residues contains 6-8% CP. IVDMD of fresh foliage is >80% whereas that of crop residues is low (55-65%). The forage is highly palatable and cattle intake is very good. The productivity of green fodder cowpea is approximately 25-45 t/ha in India. Much genetic diversity is conserved *in situ* as cowpea is cultivated in wide range of climatic conditions. The flowering initiation is reported to vary from 30 to 90 DAS and maturity from 55 to 240 DAS. Many cultivars mature uniformly although there are determinate and indeterminate genotypes. It is a short-day plant, but there are also day-neutral cultivars.

International Institute of Tropical Agriculture (IITA) has developed high-yielding varieties for both sole and intercropping, with resistance to major diseases, insect pests, nematodes, and parasitic weeds. Thirty three accessions of cowpea from IITA, Nigeria and 10 of guar from the PGR Conservation Unit, Griffin, (USA) were evaluated. Significant differences were observed among the cowpea accessions in vine length, days to flowering, pods per plant, pod length, 100 seed weight and seed yield, indicating considerable genetic variability for these traits (Rao and Shahid 2011).

In India also large numbers of varieties for vegetable, pulse and fodder purpose have been developed. The breeding objectives have focused around developing lines with terminal drought tolerance, early maturity, erect growth to fit in cropping systems and enabling improved radiation use efficiency, high harvest index and resistance to diseases. The desirable traits in forage cowpea varieties are leafiness with indeterminate growth to get green fodder for a longer period. High harvest index required for pulse crop is in contrast to forage variety. Cowpea is highly susceptible to many pests and diseases, which needs to be a priority in breeding.

Etana et al. (2013) stressed upon need to develop dual purpose lines for future animal feed improvement programme. An ideal dual-purpose cowpea cultivar for intercropping/mixed farming would be a type with semi-determinate growth habit and intermediate maturity (85-95 days) and several such varieties have been developed at IITA that yield 1.5-2.5 t/ha grain and 3-5 t/ha fodder and most of them are of erect growth habit. Development of transgenic cowpea lines with resistance to major insect pests can also be a breakthrough in cowpea breeding. Breeding for resistance against various forms of root-knot nematode, cowpea aphids and *Fusarium* wilt, is also important area.

Guar

Guar or cluster bean (*Cyamopsis tetragonoloba* L. Taub.) (2n=14), is grown for high yield, nutritional value and drought tolerance. The crop originated in India-Pakistan area (Purseglove 1981) and further spread to arid/semiarid parts of the world. In Asia, it is grown as a vegetable, forage, gum and green manure. It is an important arid legume cultivated in marginal and submarginal soils receiving 300-400 mm rainfall. India accounts for 80% of world's production of which 70-80% is cultivated in Rajasthan (Prakash et al. 2008). The galactomannan gum present in the seed is used as food and also in textile, paper, petroleum, mining, pharmaceutical and cosmetic industries (Undersander et al. 1991).

Sporadic efforts have been made in the direction of breeding high yielding varieties for grain, for forage or for gum. Rai et al. (2012) evaluated 31 genotypes and developed selection criteria based on biometric parameters. Sultan et al. (2012) also identified elite guar genotypes identified on the basis of important agro-morphological traits such as days of maturity, pods per plant, seeds per pod, seed yield per plant and 100-seed weight in Pakistan. Prakash et el. (2008) concluded that simple selection program could be effective for genetic improvement of Guar due to high estimates of variation coupled with high heritability for various traits. Kumara et al. (2015), found that the percent contribution towards genetic diversity was highest from grain yield per hectare (41.3 %). Grouping of genotypes based on agromorphological characters has been reported not to be always associated with their geographical origin (Kumara et al. 2015; Rai et al. 2012; Sultan et al. 2012; Grish and Gasti 2012).

Peas

Peas (*Pisum sativum* L.) are one of the four most important legume crops next to soybean, groundnut and beans. Peas are thought to have originated from south-western Asia. Peas spread westwards to Russia, Europe and the Mediterranean Basin and also eastwards to China (Chittaranjan 2007; Oelke et al. 1991) to Western Hemisphere and Africa. They are particularly important in temperate areas with numerous food (dry seed, vegetable) and feed (seed, fodder) usages. As forage, peas are a high-yielding, short-term crop with high protein content (Fraser et al. 2001). Peas grow in a wide range of environments and soil (FAO 2011). Ideal soil pH is 5.5-6.5. Hot weather and drought stress are particularly damaging to peas during the flowering period (Oelke et al. 1991). Pea varieties can be classified into garden peas (green peas as vegetables), field peas (dried peas for feed and food) and forage peas.

Major breeding objectives in field pea and forage pea include improved yield potential, water productivity and stability; standing ability and harvestability; disease/pest resistance to Downy mildew, Powdery mildew, Black spot, Pea weevil and tolerance to herbicide. There has been good progress in breeding efforts and plant types with desirable traits such as semi-leafless *afila* type, improved stem strength, partial resistance to black spot, weevil resistance transferred from *P. fulvum.* Efforts are on to develop doubled haploid in order to enhance breeding process. Pea as forage can be used either as whole pea crop, fed fresh, as hay or ensiled or as crop residues. For forage production, a leafy and tall plant type is favoured. Anderson et al. (2016) found that field peas make excellent quality forage for cattle. Field peas are a highly palatable grain for all classes of livestock and are a nutrient dense energy and protein source. Maximum forage pea yields may can be obtained if harvested at the flowering or flat pod stage (FAO 2011).

The hay contains 15-20% DM protein, 38-56% DM NDF, 32-39% ADF and about 5% ADL, 60-65% OM digestibility depending on the stage of maturity (Hayashi et al. 2007). Pea straw with 5-10% DM protein, 1.5-2% calcium, 7-12% DM minerals is most common fodder (Leclerc 2003). In temperate region, pea straw is suitable for livestock that have low nutritional requirements. In Egypt, pea straw replaced Egyptian clover hay in the complete diets of weaned lambs. Nutrient digestibility and feed conversion were similar for both forages (Abdel-Magid et al. 2008). Whole-crop pea silage is considered as an excellent feed for ruminants as they provide both protein and starch. Pea-oat silage was liked by cattle over corn silage and was easy to incorporate in growing and finishing rations Anderson et al. (2016). Pea forage may contain condensed tannins, saponins depending on the variety (Zaza et al. 2009).

Grass pea

The genus *Lathyrus* comprises of nearly 150 species of annual/perennial and autogamous or allogamous herbaceous creeping plants divided in 13 sections (Kupicha 1983). Genus is predominantly diploid ($2n$ = 14) (Campbell 1997). *L. pratensis* and *L. venosus* are tetraploid ($2n$ = 28), whereas *L. palustris* is hexaploid ($2n$ = 42). Grasspea (*Lathyrus sativus* L.) is believed to have originated in the Balkan Peninsula and subsequently spreading to eastern Mediterranean (Kislev 1989). The main centers of diversity of the crop are the Mediterranean region, Asia Minor, North America, South America and East Africa (Simola 1986). The largest collections of *L. sativus* are maintained in France (4477 accessions) and by ICARDA (3239 accessions) (Vaz Patto and Rubiales 2014).

Grasspea is a popular food and fodder crop across the world, especially in Bangladesh, China, Ethiopia, India, Nepal and Pakistan because of its resistance to drought, moderate salinity and low input requirements. The crop is grown primarily as a winter pulse crop for animal feed or sometimes as human food. In India, major grasspea growing states are Chhattisgarh, Bihar, Madhya Pradesh, West Bengal and Maharashtra. The crop is quite hardy with tolerance to many diseases. It is usually grown by poor farmers under poor management because of its suitability to extreme environmental conditions (Campbell 1997). Grass pea possesses high levels of protein, carbohydrates and minerals, although deficient in some essential sulphur containing amino acids. The presence of homoarginine could make this an invaluable pulse since it could contribute to a sustained generation of NO, well recognized for its role in cardiovascular physiology and general well-being and for possible therapeutic role in Alzheimer's disease, hypoxia etc. These novel approaches to both ODAP and homoarginine might entirely change our perception of this poor man's pulse (Rao, 2011).

Broadly, grasspea germplasm divides into two groups; from Asia with small seeds and average high ODAP content and from the Mediterranean with lower average ODAP content. ICARDA holds 'in-trust' global *Lathyrus* germplasm from more than 45 countries (Robertson and Abd El-Moneim 1995). The germplasm base is also conserved in many countries across the globe. In India, the major germplasm base is at Indira Gandhi Krishi Vishwavidyalaya, Raipur. Improved grass pea lines show low ODAP content compared to the local lines. The primary gene pool of grasspea, is limited to cultivars, landraces (Yunus et al. 1991). *L. amphicarpos* and *L. cicera*, forms the secondary gene pool (Yunus and Jackson, 1991). The remaining *Lathyrus* species comprise the tertiary gene pool. Several studies including morphological, isozyme and molecular level have revealed that considerable genetic diversity exists in grass pea primary gene pool (Singh and Roy, 2013).

Although *L. sativus* is predominantly self pollinating, outcrossing by bees has been reported to the extent of 4-16% (Kaul et al. 1986). Interspecific hybridization involving *L. sativus* has been reported as successful with two species, *L. amphicarpos* and *L. cicera* but viable F_1 hybrids presented low fertility (Yunus and Jackson 1991). High amounts of somaclonal variation for several traits (plant growth habit, ODAP content) could be found in the regenerated plants (Mehta 1997; Abd El Moneim et al., 2001; Zambre et al. 2002). Traditional breeding programmes were directed mainly towards developing cultivars with low *â*-ODAP content in the seed. This included hybridization of selected lines followed by screening and selection to transfer low ODAP content into adapted, high yielding cultivars (Campbell 1997).

The grass pea improvement has been attempted in India, Bangladesh, Chile, Australia, Ethiopia and at ICARDA. Low toxin varieties (Khesari-1 & 2) have been developed by breeding with locally adapted genotypes in Bangladesh. ICARDA has released variety 'Wasie' in Ethiopia which can yield up to 1.7 tonne ha-1 with an ODAP content of 0.08 %. Another ICARDA variety released in Kazakhstan, 'Ali-Bar' can produce 1.2 tonne ha-1 with only 200-300 mm of rainfall (Kumar et al. 2011). The varieties 'Chalus' and 'Ceora' have been released in Australia for animal feed. Cultivars with low neurotoxin (< 0.1%) like Mahateora, Prateek, Ratan and Moderate neurotoxin (< 1.0%) varieties like Pusa 24 and Nirmal have been evolved in India.

The work carried out towards biotic stress primarily involved selection of resistant source in wild species and germplasm followed by hybridization. Resistance to powdery mildew (*Erysiphi pisi* syn. *E. polygoni*) has been reported in *L. sativus*, *L. ochrus* and *L. Clymenum* (Gurung et al. 2002) and in *L. Aphaca.* Quantitative resistance to *E. pisi*, due to resistance to epidermal host cell penetration and not associated with host cell necrosis was described in *L. sativus* and *L. cicera* accessions by Vaz Patto et al. (2006). Downy mildew (*Peronospora lathyri-palustris*) is a serious grass pea disease in South Asia. A few landraces/accessions of *L. sativus* have shown tolerance to this disease (Asthana and Dixit 1997). Ascochyta blight (*Mycosphaerella pinodes*) resistance has been recorded on accessions of *L. Sativus, L. ochrus* and *L. clymenum* (Gurung et al. 2002). For Thrips resistance source has been identified in *L. aphaca* and in Indian accessions of grass pea JRL6 and JLR41 (Asthana 1995). Root knot (*Meloidogyne artiella*) and cyst nematodes (*Heterodera ciceri*) resistance has been identified in *L. sativus* at ICARDA (Campbell 1997).

Future thrust includes introduction of short duration high biomass varieties in rice-fallows; development of short duration cultivars, resistance to biotic factors and high yielding varieties with low ODAP and increased methionine; standardization of resistance screening methods.

Rice bean

Rice bean (*Vigna umbellate* (Thunb.) Ohwi & Ohashi), belongs to subgenus Ceratotropis genus *Vigna.* Mung bean (*Vigna radiata),* black gram (*V. mungo*) and azuki bean (*V. angularis*) are other economically important species in this sub genus. Rice bean is a tropical to temperate grain legume grown for food and fodder in Asia. The vegetative parts can be fed fresh or made into hay or as crop residue and the seeds used as concentrate. It is a multipurpose legume, which is neglected and underutilised. In Asia, rice bean is widely planted after the harvest of rice crop, hence the name 'Rice bean' (Rajerison 2006). It originated in Indo-China and further domesticated in Thailand. (Tomooka et al. 2011). It evolved from its wild form, *Vigna umbellata* var. *gracilis.* Rice bean is distributed in southern China, Indochinese peninsula, India and Nepal and to a limited extent in Mauritius, West Indies, East Africa, Australia and USA.

In India, Ricebean is cultivated in humid tropical to sub-tropical, to sub-temperate climate of Himachal Pradesh, Uttarakhand, NEH, Odhisha, West Bengal, Madhya Pradesh, Chhattisgarh and Haryana because of wider adaptability, high production and winter persistence. Generally, late maturing and photo-sensitive landraces are cultivated as fodder crop with average green fodder yield ranging from 250 to 350q/ha. Rice bean possesses drought tolerance, resistant to many pests and diseases and can be grown in marginal soils to provide fodder during scarcity periods. It is often grown as intercrop or mixed crop with maize. In India and Nepal, rice bean is sown in February-March for harvest during summer and in July-August for harvest in December. Dual-purpose varieties are cut when the pods are half-grown. In Bengal (India), fodder yields range from 5-7 t DM/ha in May-June to 8-9 t DM/ha in November-December. Rice bean hay increases DM intake, digestible protein and N retention along with positive effect on rumen microflora resulting in increased VFA production and lower CH_4 emissions (Chanthakhoun and Wanapat 2010;Chanthakhoun et al. 2011).

The crude protein content of rice bean cultivars varies from 15-27%. It is rich in limiting amino acids methionine and tryptophan and also valine, tyrosine and lysine (Mohan and Janardhan 1994). The seeds contain vitamins such as thiamine, riboflavin, niacin and ascorbic acid (Joshi et al. 2006). In fodder varieties, methionine content varied from 0.74 to 0.99% and starch content ranged from 58.2 (in RBL-1) to 71.1% (in RBL-50) (Khabiruddin et al. 2002). Fresh rice bean forage contains 17-23% protein on DM basis and 2% calcium. It is relatively rich in lysine but poor in sulphur-containing amino acids. It has a high starch concentration, (52 to 57% of DM), with variable amylose content. Rice bean forage contains variable amounts of condensed tannins (Wanapat et al. 2012; Chanthakhoun and Wanapat 2010), trypsin inhibitors and low levels of phenols and phytic phosphorus.

Germplasm evaluation shows wide range of variation and high GCV for grain yield per plant, grain protein content, number of clusters per plant and shattering (Jadhav et al. 2001; Verma et al. 2005). High heritability and high genetic advance was observed for many traits suggesting that characters are governed by additive gene action and selection may be effective (Chakraborty and Mukherjee 2001; Jadhav et al. 2001; Chakrabarti and Bhattacharya 2005). It was reported that variances due to GCA and SCA were highly significant and the estimates of GCA components were higher in magnitude than estimates of SCA components for most yield related traits except seeds/pod. Likewise, additive gene action for seed yield per plant was reported. Sonone et al. (1999) developed selection criteria for yield improvement. Grain yield/plant, plant height and test weight showed very high and positive effect on green forage yield, (Chakrabarti and Bhattacharya, 2005). Advances in mutation research have provided an opportunity to induce and identify different types of mutants such as early maturing, determinate, erect plants, mutants with abnormal leaves and colored seeds (Prakash and Shambulingappa, 1999).

Hybridity, through conventional or embryo rescue, among *V. radiata, V. mungo, V. umbellata* and *V. angul*aris has been established by Rashid et al. (1988) although amphipolyploids were needed for improving fertility. Based on crossability between tetraploid *V. glabrescens* (2n=44) and the three diploid (2n=22) species, *V. radiata, V. mungo and V. umbellata*, Egawa (1988) suggested that *V. radiata* is more closely related to *V. mungo* than to *V. umbellate*, although cross between *V. mungo* × *V. umbellata* show significant differences for yield contributing traits (Pal et al. 2005). Siriwardhane et al. (1991) reported that the cross combination *V. nakashimae* × *V. angularis* was successful in both directions, while the cross with *V. umbellata* was not successful. Further, *V. riukiuensis* is cross-compatible with adzuki bean and rice bean only when *V. riukiuensis* is used as male parent. Thus, it could be useful as a bridge species between adzuki bean and ricebean hybridization programme. Kaga et al. (2000) developed a genetic linkage map from an interspecific cross between azuki bean and rice bean. Isemura et al. (2010) reported a genetic linkage map and QTLs for domestication-related traits in rice bean. A total of 326 markers comprising of 223 SSR markers from related legume species and 103 AFLP markers were used to make 11 Linkage groups corresponding to n = 11. Using this map, 31 domestication-related traits in rice bean were dissected into 69 QTLs, but the differences between cultivated and wild parents were found to be controlled by only a few major QTLs. The high level of genome synteny between rice bean and azuki bean was observed which might be useful to broaden the genetic variation in both species.

Perennial soybean

Perennial soybean (*Neonotonia wightii* (Wight & Arn.) J.A. Lackey) originated in Africa and further spread to East Indies, tropical Asia; and east, central and southern Africa (FAO 2011). It has been introduced to many islands of the South Pacific, including the highlands of Papua New Guinea. It is also found in Cuba, Brazil and in subtropical Australia (Ecoport 2011; Cook et al. 2005). It is a herbaceous legume used as pasture and has tolerance to drought, salinity, biotic stress coupled with high yields. The crop yield is between 3.85 and 10 tons DM/ha, depending on environmental conditions. Regular grazing or cutting is required for normal yield. (Cook et al. 2005, FAO 2011). It can also be cut at flowering stage and stored as hay. Its forage contains 14-20% DM crude protein. The fibre content is relatively high (crude fibre 26-35% DM; NDF 45-60%; ADF 33-40%; ADL 8-10%). Fibre and lignin content increases with age while pectin decreases (Vera et al. 1989).

Palatability and digestibility is comparable with alfalfa and other legumes forages (FAO, 2011) with 55-65% organic matter digestibility (Mero and Uden, 1998), which decreases with the stage of growth. In sheep fed with its hay, DM and protein digestibility decreased from 53 to 44% and from 66 to 52%, respectively, between pre-bloom (71 d) and late flowering (112 d) (Vera et al. 1989). In India, it has not received attention of breeders.

Vetch

The vetch beans belong to genus *Vicia* and the most common forage species are Common vetch or garden vetch (*Vicia sativa*), Faba bean (*Vicia faba*), Narbon vetch (*Vicia narbonensis*), *Purple vetch* (*Vicia benghalensis*), Hairy vetch (*Vicia villosa*) (Abd Al Moneim and Saxena, 2015).

Vicia sativa

Vicia sativa L. is an annual climbing legume. It provides palatable forage (fresh, hay and silage) and grain to livestock. Due to the presence of certain anti-nutritional factors, seeds may be used only in limited quantity in the diets of monogastric species (including humans). *Vicia sativa* originated from southern Europe and is now widespread in the Mediterranean basin, West and Central Asia, China, eastern Asia, India and USA. It is moderately tolerant of cold and shaded conditions and does well as an understory cover crop in orchards (UC SAREP 2006). Seeds contain cyanogenic amino acids and cyanogenic glycosides mainly γ-glutamyl-β-cyanoalanine that are toxic to nervous system of monogastric animals (Tate and Enneking 2006). The amount of toxicants is inversely correlated to the seed size. Development of low cyanogenic varieties is essential for feeding to monogastric animal (Tate and Enneking 2006).

V. sativa forage does not normally contain anti-nutritional factors when grazed or cut frequently enough to prevent flowering and seed-heading. Fresh forage at early flowering has 24% DM crude protein content and 74% OM digestibility in sheep. Nutritive value decreases with maturity but digestibility remains relatively high (69%) at mature seed stage (Tisserand and Alibes, 1989). At flowering, hay is a valuable forage with high OM digestibility (69%) and 20% crude protein. *In sacco* N degradability is quite high at flowering (78%) and decreases with maturity (65% at seed filling) (Haj Ayed et al. 2001). At the vegetative stage, the high concentration of tannic polyphenols could be useful to decrease lipolysis and biohydrogenation of polyunsaturated fatty acids in rumen and thus contribute to a higher transfer efficiency of polyunsaturated fatty acids to ruminant dairy products (Cabiddu et al. 2010). The straw, has a nutritive value higher than cereal straws (barley, oat or wheat), with an OM digestibility of 53% and a crude protein content > 6% DM (Tisserand and Alibes 1989).

Vica faba

Faba bean (*Vicia faba* L.) is grown primarily for fodder as well as beans (edible seeds). The crop originated in the Middle-East (McVicar et al. 2013) and spread to Europe, North Africa, Central Asia, China, South America, the USA, Canada and Australia. China alone produced 34% of all faba beans in 2013 (FAO 2014). In the EU, faba bean ranks 2nd after field peas for legume seed production and is mostly used for animal feeding (FAO 2014). *Vicia faba* var. major (broad beans) produces large seeds and is used for human and livestock whereas *Vicia faba* var. minor (horse beans, field beans) produces smaller seeds and is used mainly for livestock feeding. It is a multipurpose crop used for both food and fodder (hay, silage and straw) (Prolea, 2014). Faba bean with its valued straw is a much appreciated food legume in the Middle-East, the Mediterranean region, China and Ethiopia. For livestock feeding, small-seed varieties with low-tannin, low vicine-convicine and low-trypsin inhibitor contents are preferred (McVicar et al. 2013).

Faba bean seeds being rich in protein (25-33% DM) and starch (40-48% DM) are valuable source of protein and energy for livestock. Seeds have high lysine content but deficient in sulphur-containing amino acids such as methionine (Marquardt et al. 1975). Fresh faba bean forage is of good quality, with protein content ranging from 14% to 20% DM. The highest protein content occurs at full flowering stage and decreases thereafter (Alibes and Tisserand 1990). Faba bean straw has low protein content (5-11% DM) with high concentrations of lignin and ash.

Seeds contain anti-nutritional factors such as tannins, pyrimidine glycosides (vicine and convicine), protease inhibitors, lectins and phytic acid. Tannin-free cultivars have higher protein and amino acid digestibility (Crépon et al. 2010). Vicine and convicine are pyrimidine glycosides responsible for favism, an acute haemolytic disease resulting from oxidative damage in red blood cells that affects human populations suffering from glucose-6-phosphate dehydrogenase deficiency (Enneking 1995). Trypsin and chimotrypsin inhibitors and lectins although present in the beans, their activities are low compared to other legume seeds. Faba bean seeds are highly digestible in ruminants (OM digestibility 91%). The voluntary intake of fresh forage is high among dairy cows which decreased when ensiled although remained higher compared to other silages (INRA 2007).

Stylosanthes

Stylosanthes is one of the best options as tropical pasture legume and is extensively utilized in pastoral, agro-pastoral and silvipastoral systems for animal production. The genus *Stylosanthes* (Fabaceae) comprising of approximately 40 species (Kirkbride and de Kirkbride 1985), is distributed in the tropical, subtropical and temperate America, Africa, and Southeast Asia. Most species are diploid (2n = 20) but polyploid species (2n = 40 and 2n = 60) also exist. Stylo is used in many Asian countries as a cut-and-carry fodder, a cover crop and provide forage under plantations of horticulture and forestry species. Six species, namely *Stylosanthes scabra, S. seabrana, S. hamata, S. guianensis*, *S. humilis* and *S. viscosa*, are predominantly used as fodder legume are adapted to varying climatic conditions in India. These are adapted to poor soils, and improve soil physical properties and provide permanent vegetation cover. As compared to earlier popularity of *S. hamata* in India (particularly in humid tropical parts), in the recent years *S. seabrana* is gaining popularity in tropical semi-arid region because of its high persistence during harsh summer. Another species *S. scabra,* due to its high drought tolerance, is also being adopted. In spite of high demand for seeds of the two former species, the crop faces serious problem of seed production owing to non-synchronous flowering and maturity coupled with shedding of mature seed. Thus, collection becomes difficult and even if done carries a lot of dirt or inert material with seeds.

As regards breeding objectives, there is need to develop varieties with improved drought tolerance, nutritional parameters such as high methionine and regenerative potential. Phylogenetic studies utilizing both biochemical and molecular marker techniques are available (including linkage maps and QTL for leaf diseases and drought) for the genus and breeding programme can be well planned (Chandra and Kaushal 2009; Chandra et al. 2010, 2011). The most important challenge for *Stylosanthes* has been the susceptibility to anthracnose disease by most of its species.

Medics

Medicago includes annual and perennial forage species of temperate and tropical environments. Lucerne (*Medicago sativa* L.) is cultivated throughout the world in diverse environmental conditions. It is the third important forage crop in India following Sorghum and Berseem which produces 60-130 tonnes green fodder per hectare and occupies more than one million hectare area. The crop is highly palatable enriched with protein (15.2%), calcium (1.5%), phosphorus (0.2%) and vitamins (A, B and D). Lucerne is a native to South west Asia as indicated by occurrence of wild types in the Cancasus and in mountainous region of Afghanistan, Iran. *M. sativa* complex, comprises of several members at the same ploidy level (e.g., *M. falcata*, *M. media* and *M. glutinosa*), which freely intercross, without any hybrid sterility in the progenies (Lesins and Lesins 1979).

Most of the perennial and outcrossing species are tetraploids (2n = 4x = 32) although hexaploid (2n = 6x = 48) are also reported. Lucerne growing area include India, Australia, France, Japan, USA, Russia, Bulgaria. In India, it is grown in Maharashtra, Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu, Haryana, Madhya Pradesh, Rajasthan, Punjab. As regards breeding, Australia achieved up to three times increase in Lucerne yields during early 1980s by developing varieties with multiple pest and disease resistance (aphids, *Phytophthora*, *Colletotrichum*), however, since that period, irrigated Lucerne yields have reached plateau (Irwin et al. 2001). The major breeding objectives in the crop include vigorous tall growing plants, better tillering, quick regeneration, and balance between seed and forage yield, and persistence. The future strategies should include development of cold and drought hardy Lucerne with degree of persistence for pasture and meadows, increasing genetic base, high seed production, stress tolerance, diseases and pest resistance etc. Weevil (*Hypera postica* Gyll.) infestation is one of the major problems in the tropics. After screening 197 global germplasm encompassing 50 *Medicago* species for weevil tolerance, 22 lines representing 13 species were identified where leaf damage was less (Chandra 2009). *Medicago falcata*, of the *M. sativa* complex, has contributed substantially to Lucerne improvement in North America, for tolerance to freezing injury (Irwin et al. 2001). In India, recent efforts have been to develop high yielding lines with improved persistence and resistance to abiotic stress (drought and salinity) and abiotic stress (root rot and Lucerne weevil). Intra-species tolerance for weevil is not available, however, it has been reported in annual species such *M. scutellata* and *M. prostrata* (Chandra et al. 2006; Chandra and Pandey 2008). Due to post fertilization barrier, interspecific hybridization is difficult, so we may need to use biotechnological tools like ovule-embryo culture and electroporation.

This species has displayed low rates of genetic gain for forage yield compared with other crops (Woodfield and Brummer 2001). Breeding limitation can be attributed to various factors such as autotetraploidy, high rate of non-additive genetic variance, primarily cross pollination and perennial nature. A lot of molecular information has been generated across species. However, information from *M. truncatula* on marker-trait association it unlikely to be exploitable in Lucerne, considering the large differences between annual and perennial (Volenec et al. 2002) in addition to the differences due to the ploidy level which may further contribute to the inconsistent genetic control of some morphophysiological traits between the two species (Bingham et al. 1994). Annicchiarico et al. (2010) considered some breeding goals such as region-specific adaptation; drought-tolerance; improvement for forage quality.

Attempts have been made to produce transgenic alfalfa containing fungal chitinase gene for resistance against fungal pathogens (Hipskind and Paira 2000), tolerance to abiotic stresses such as salt and cold (Winicov 2000; McKersie et al. 2000), improved forage quality (Xie et al. 2003), and sulfur-containing amino acids (Tabe et al. 1995), value addition by making it an edible forage vaccine (Carrillo et al. 2001). In recent years the breeding strategies for Lucerne are more towards utilizing potential of polycross methods followed with phenotypic selection. It has resulted in development of a few cultivars in recent years.

Clovers

Clover is a group of 237-290 annual and perennial species of *Trifolium* of tribe Trifolieae Leguminosae (Fabaceae) of which *T. repens* (white clover), *T. hybridum* (alsike clover), *T. pratense* (red clover), and *T. ambiguum* (Caucasian clover) are perennial pasture clovers distributed in the temperate and subtemperate regions of the world whereas the annual *T. alexandrinum* (Egyptian clover or Berseem), *T. resupinatum* (Persian clover or Shaftal), and *T. subterraneum* (subterranean clover) are commonly cultivated in the subtropical regions such as Egypt, India, Pakistan, Turkey, and the Mediterranean countries, which is also considered the main centre of origin. Berseem, cultivated in an area of around two million ha with average national productivity of 85t/ha, is the most popular and important winter season legume widely cultivated in India for increasing milk yield of the dairy animals. The crop is accepted by the farmers because of its multicut nature (4-8 cuts), long duration (November to April), high quality (>20% crude protein), high palatability, and digestibility (up to 65% IVDMD).

In spite of many good traits the crops needs to be improved for resistance to diseases especially root rot (caused by *Rhizoctonia solani* and *Fusarium semitactum*), stem rot (caused by *Sclerotinia trifoliorum*); tolerance to abiotic stresses (salinity), adaptability in varied climates; dry matter in early cuts and water productivity. Self-incompatibility is prevalent in the genus and is controlled by a single multiallelic gene expressed gametophytically in the pollen. Malaviya et al. (2005) while screening of 20 species for disease tolerance at IGFRI identified several tolerant/resistant lines across the genus such as *T. repens*, *T. lappaceum*, *T. subterraneum* (EC 401717 and EC 402167), *T. vesiculosum* (EC 401716), *T. glomeratum* (EC 402170), *T. incarnatum* (EC 402164), *T. cherleri* (EC 401703) and *T. hybridum* (EC 401701) which were almost free from all the diseases.

In Egyptian clover, pollination studies have indicated existence of several groups having different pollination mechanism (Roy et al. 2005). However, the breeding efforts are hampered due to narrow genetic base. Hence, the foremost objective of any breeding efforts has to be generation of variability for efficient selection and to achieve it one may have to resort to interspecific hybridization which too has limitation of interspecific incompatibility. Interspecific hybridization in the genus *Trifolium* by conventional crossing techniques has been largely unsuccessful. Nevertheless, interspecific crosses have been developed using embryo rescue technique (William and Verry 1981; Phillips and Collins 1984; Roy et al. 2011). Many interspecific hybrids in *Trifolium* involving *T. alexandrinum* as female and *T. constantinopolitanum*, *T. apertum, T. resupinatum* as female are reported (Roy et al. 2004; 2011; Malaviya et al. 2004, 2005; Kaushal et al. 2005) which has resulted in creation of diversity.

Conclusion

Forage legumes, in spite of their importance as improving forage quality as well as nutritional security through increased availability of animal protein, soil fertility, soil quality, water filtration and carbon sequestration could not gain due impetus in crop improvement. The breeding objective and strategies are quite different from the grain crops because of the fact that economically important plant part is vegetative biomass to be consumed by animal. Some of the common breeding objectives include better quality components in terms of crude protein, *in-vitro* dry matter digestibility, minimum anti-quality constituents; persistence, biotic and abiotic stress tolerance; tolerance to overgrazing; aggressiveness and competing ability. Improvement objectives of forage legume crops, forage pulse and forage range legume should focus on following approach to achieve disruptive gains in a shorter period.

Utilization of plant genetic resource and broadening genetic base: Some of the cultivated forage legumes like Berseem are introduced in the country, hence represented with poor genetic resource. Efforts should be made to enrich the genetic base either by introduction from exotic sources, collection/ exploration, or pre-breeding. Some are rich in landraces because of their occurrence in marginal lands wherein original diversity, plus accumulated mutations and genetic recombination are conserved. This diversity needs to be evaluated in target environment such as shade, salinity, water logging in addition to different cropping system because the possibility of area increase under forage crops appears meagre which compels to take forage crops in non-crop lands. Greater emphasis is needed to go far inter-specific or distinct inter-varietal crossing programme and handle the segregating population in more sharing mode so that efforts made at one place are will utilized in the country. Use of modern biotechnological in developing interspecific hybrids through embryo rescue or transgenic; and molecular tools for assessment of genetic variability is also required. Conservation of genetic resource in participatory mode is also an area which has not been duly utilized in forages.

Enhancing quality: Forage legumes in general are good in protein, however, the feeding value depends on digestibility, palatability, rumen degradation rates etc. Hence, new varieties suited for slow protein degradation in rumen, higher crude protein, less fibre, high digestibility, better quality amino acid composition needs to be developed. Additionally, most of the legumes have some anti-quality constituents which need to be eliminated or minimized through breeding efforts.

Multicut, quick regeneration: Farmers have adopted certain legumes like Berseem, Lucerne etc. because of their multicut nature with good regeneration ability, meeting the need of daily requirement of green fodder. Breeding efforts utilizing the germplasm resources should be directed in these areas.

Tolerance to abiotic and biotic stress: As the forage legumes are grown under marginal conditions under poor soil and moisture stress, the varieties have to be abiotic stress tolerant. Crop specific biotic stress can be addressed through breeding efforts mainly by utilizing secondary and tertiary gene pools.

Quality seed production: Seed shattering and seed dormancy, indeterminate habit, uneven pod ripening, low fertility are the common problems in most of the forage legumes, making their commercial cultivation quite difficult. These factors affect the availability and production of quality seed as well as important reason for their non-adoption by farmers. These problems need to be address through breeding efforts including selection, crop specific seed production atlas and calendar along with suitable package of practice.

Breeding range legumes: Breeding range legumes is still a difficult task because of their altogether different requirement. There has to be compromise at many levels because of antagonistic morpho-physiological traits for different agronomical traits. These crops need to be bred for increased persistence, tolerance to abiotic stresses, easy establishment and good seeding ability in addition to grazing and trampling tolerance.

Declaration

The authors declare no conflict of interest.

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