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Migration patterns and evolutionary trends in Indian alfalfa

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Introduction

The indigenous material of alfalfa or lucerne (*Medicago sativa* L.) shows a vast heterogeneity possibly due to the long period of its evolution. Among its three life forms available in the Indian subcontinent, the winter very high non-dormant (VND) types or Deccan or Penisular types are confined to the arid and semi-arid north-west India. The intermediate VND types are restricted to the north-west frontier region of Pakistan and Haryana, western Uttar Pradesh and Punjab states of India. The winter dormant (WD) types are localized to the Ladakh region of Jammu and Kashmir state. Cluster analysis based on agronomic and morphological data on VND forms collected from the low elevations of the western, central and northern regions of India and also from some location of the Middle East, revealed seven clusters with three clusters containing only Indian accessions. Thus, the VND forms of the Indian alfalfa stand distinct. This also indicates its antiquity and the evolutionary trends independent of the VND forms of the Middle East and Africa.

Highly complex breeding behavior of alfalfa and difficulties faced in its genetic improvement call for a deeper look into its migration history, evolution of different geographical forms and their connectivity with those in the countries having geographical, historical and linguistic linkages with the Indian subcontinent. A deeper insight provide a better understanding on the remarkable degree of resilience in its adaptation ranging from the plains to the high altitudes of the Himalaya. The present communication deals with such an attempt which can also help better understand its breeding behaviour and formulation of genetic improvement programme.

Origin and domestication

Alfalfa is essentially a crop of the temperate regions. According to Klinkowsky (1933) the geographical areas where alfalfa grows wild include temperate regions of western Asian countries, south–east of Caucasus range, north-west part of Persia. In Asia Minor, Trans Caspian, Iran and highlands of Turkmeinistan, the alfalfa land forms are available in such a large number as perhaps no where else in the world (Belov, 1929; Klinkowsky, 1933).

It is believed that spontaneous occurrence of the tetraploid lucerne in oasis of desert areas may have attracted attention of ancient tribals and early agriculturists who domesticated it to obviate the need of seasonal migration (Bolton *et al*., 1972)

The regions where alfalfa grows wild shows a great diversity in climate but these geographically contiguous areas may have encouraged inter and intra-species variability resulting from the intermixing of the species. Over the past several millennia, the yellow flowered cold tolerant wild species *M. falcata* has played a major role in the enrichment of germplasm and in increasing the agronomic value of alfalfa.

M. hemicycla Grosh which has morphological forms similar to the German hybrid lucerne, occur along with *M. sativa* in a limited area in the interior district of the Caucasus region where *M. falcata* also grows wild. Many hybrid forms of *M. falcata* and *M. sativa* may have originated as a result of natural hybridization between the allied taxa in the regions as far placed as Turkmenistan to southern Europe and northern Africa (Bolton, 1962; Michaud *et al.,* 1988). It appears that *M. sativa* cultivated in the temperate regions also contains characters from allied taxa. Indian lucerne is of Irano-Turanian origin. The Iranian upland with Iran occupying the western two-third, and the remaining shared by Afghanistan and Pakistan, is an important alpine segment of the Himalayan mountain system.

The cold desert region of the north–west Himalaya, which is the home of the Laddakh lucerne, lies within the climatic zone of the Asiatic Mountain Plateau. From the floristic point of view, it belongs to Western Asiatic region comprising Armenian highlands, south Russia – Trans Caspian, Turkistan and Mongolia.

The Indian cold desert, which is a part of Tibetan plateau (Good, 1953) abounds in *M. falcata*, which is one of the progenitors of the lucerne, covers part of states of Jammu and Kashmir and Himachal Pradesh and further extends eastward into Humla and Mustang districts of Nepal.Two distinct centers of origin of Lucerne are the mountainous regions of Trans Caucasia and Asia Minor and adjoining areas of north-west Iran. Lucerne evolved in these areas as winter hardy crop adapted to temperate regions of northern latitudes.

Central Asia : In these regions lucerne evolved under the influence of irrigation in a climate characterized by low humidity, hot dry summer and moderately cool winters. Low humidity accounted for low resistance to leaf diseases and low drought tolerance in lucerne. However, valuable series of characteristics including resistance to several diseases, insects and nematodes evolved in these regions as well (Michaud *et al.,* 1988). The two most important species involved in the evolution of cultivated lucerne are *M. sativa* and *M. falcata*. Genetic polymorphism in cultivated alfalfa is generally attributed to factors like divergence within and between species, genome intermixing and seggregation. Over period of time, evolutionary forces like natural selection, migration and genetic drift apparently played an important role in changing gene frequencies as per requirement of the growing conditions.

The nomenclature

Alfalfa or lucerne (*Medicago sativa* L.) is well known fodder crop for cattle/ horses and widely distributed in countries with arid, semi-arid, tropical to temperate, tropical situations. It may be known by various names in different ecogeogrphical regions of the world. The name of crop is itself traceable to the ancient Iranian / Sanskrit names *viz.*, Asposti, Aspesti, Usdpest, Asfist which literally mean horse fodder (Table 1).

Evolutionary trends and patterns

Divergence from diploid to tetraploid form

M. sativa in its diploid form, known as *M. coerulia* (2n, 2x = 16), grows wild in Iran, eastern Anatolia and under semi-desert conditions in places around the Caspian Sea which fall in the southern regions of 42^0N Latitude. Another wild species *viz.*, *M. falcata* or yellow flowered lucerne which also exists in diploid and tetraploid forms has a wider natural distribution than the common lucerne (*M. sativa)* in regions 42^0 to 62^0N latitude. It is believed that *M. sativa* (2n, 4x = 32) evolved from its diploid state through natural autopolyploidy. Natural selection in tetraploid lucerne apparently brought about evolutionary changes in morphological and physiological characteristics of the plant favouring maximum adaptive fitness under different ecological conditions in the regions of its primary centre of origin and adaptation.

Hybrid swarm

The north–west and the Trans Caucasus regions fall in the transitional zone of distribution of the endemic forms of *M. sativa* and *M. falcata*. Bee mediated natural outcrossing in these species are known to produce hybrid swarm of fertile / semi-fertile, freely inter-breeding plants, the genotypes and phenotypes of which are intermediate between the parental texa. Other species such as *M. glutinosa* and *M. glomerata* also hybridize with *M. sativa* and *M. falcata* and it may be possible that such forms as *M. gaetula* and *M. glutinosa* are of hybrid origin derived from crosses between *M. glomerata* and *M. falcata*. The two species *viz*., *M. glomerata* which is indigenous to southern Europe and *M. glutinosa* which is indigenous to the Caucasus region may also have contributed to formation of some strains of lucerne. All these species have apparently been hybridizing for several millennia attaining their own evolution and thereby increasing their adaptation and also diversity greater than their respective parental taxa.

Introgression

Introgression of many local ecotypes of *M. falcata* undoubtedly played a major role in enriching the gene pool of *M. sativa* for natural selection under temperate climate, leading to a great evolutionary success and expansion of these winter hardy forms of lucerne into northern areas of Europe and America (Busbice and Wilsie, 1966 and Michaud *et al.*, 1988). The most important characteristics contributed by *M. falcata* are winter hardiness, drought resistance, disease resistance and creeping rooted or rhizomatous forms. The overall effect of introgressive hybridization on later evolution in lucerne may have been similar to that of maize such as (1) formation of many land races or forms with unique recombination of two or more alleles (2) evolution of new plant types to suit specific niches (3) continuous recombination within loci probably resulting in multiplicity of alleles at each locus (4) activating mutating transposes (mobile elements) in hybrid swarm adding to the diversity and (5) establishing many bridges between land races and other allied taxa. The cultivated lucerne (*M. sativa*) is therefore a conundrum of species, as its divergent forms

Table 1: Nomenclatural clues of alfalfa/lucerne to historical and geographical links

Foreign languages	Indian languages
Persian : Aspest, Apoasti, Uspest, Aposti,	Rijka in Punjab, Haryana and western Uttar Pradesh.
	Rijka or Rajako in Rajsthan
	Gadah rajako in Gujrat and Maharastra.
Arabic : Alfalfa may be derived from Arabic word Alfisat (Alf - soft and Fsat - food)	"Rijka" is similar to the Pushto name Rizka (Rizk - horse)
	Kuddre menthi (Kudre - horse, menthi - mentha), Kuddre masala in Karnataka
Other Arabic names are; Berseem Hagasi (clover from Hagas), Hidjas, Hasawi, De jet etc **(**Klinkowski,1933**)**	"Ole" or Yarkendi ole Hol , Holu Al- Buksuk in Laddakh
Palestenian : Fussa	Bukseer, Buksukand Al-buksuk in Lahaul and Spiti region of Himachal Pradesh and northern Uttar Pradesh hills.
Afgani : Duresta	
	Sanskrit Aswabal; Asvapust and Asvahariput
Chinese : Musu Nepalese : known as Kote.	

do not fix into a firm taxonomic structure due to intermixing of different species.

Natural selection

Heterozygote advantage and wide genetic variability created by the hybrid swarm ostensibly offered much wider amplitude of climatic adaptation than the parental taxa. The adaptive shifting of gene frequencies as necessitated by the variable edaphic conditions of the different habitats helped evolve new landforms in *M. sativa and M. falcata* complex. The structure of species is thus broken into various geographical sub-units or race complexes, with discernible differences in agronomic and morphological traits, winter (frost) hardiness, photoperiod, temperature and moisture responses in addition to tolerance to diseases and pests. Michaud *et al*., (1988) offered following explanations to the great evolutionary success of Lucerne crop in the temperate regions of Asia, Europe and America. Development of deep tap root system that enabled plants to use soil moisture from 6 meters or more; an obvious advantage to escape prolonged period of drought. In addition plant has capacity to become dormant in periods of drought and cold, and resume growth when conditions become favourable.

In the arid and semi-arid regions of the old world, the major factors responsible for the evolution of Lucerne are light intensity and temperature which show an increasing trend in the direction from north latitudes to southern latitudes. The chief distinguishing features (Klinkowsky, 1933) which follow a definite pattern of geographical distribution relate to progressive change in plant structure from erect to prostrate growth and decrease in duration of crop growth and sprouting ability of plants growing in the direction from low to high latitudes and /or from low to high altitudes. The erect growth forms is particularly suited as an irrigated crop in warm sunny and drier climates and occupy vast geographical areas which include north west India and Pakistan, southern and central Iran, Iraq, Arabian peninsula and northern Africa. The other growth forms like sub erect, ascending types exist along with erect types in Turkmenistan, Turkey, northern Africa and southern Europe mainly the Medterranean region. Alfalfa apparently migrated south ward (<42 degrees North Latitude) from its primary place of origin and diversification occurred to low latitude and low elevation countries, including warmer climates of Arabian and Indian peninsula wherein winter dormancy is not a prerequisite to the survival of alfalfa as an irrigated crop. Lucerne evolved as a winter very non-dormant type (VND) in the warm arid regions of north west India and Arabia. A contiguous low to high temperature gradient from northern Himalaya to southern low elevation regions may also have encouraged maintenance of winter intermediate VND types in the northern plains of India wherein winters are longer and severe frost may occur.

Geographical forms of alfalfa

The long term effect of specific environment of the original habitat on the lucerne plants in the Central Asia, resulted in the evolution of different geographical forms. Based on the morphological and physiological peculiarities, the following geographical types were identified (Klinkowwsky, 1933).

1. *Mountain type* : Distributed in mountainous regions of Armenia, Persia, Central Asia *etc*. along the tract (2000 to 3500m above sea level);

- High degree of winter tolerance connected with deep positioning of vegetational bunds in the soil
- A late small seeded type which regenerates slowly
- Spreading habit, almost prostrate, fine and much branched stems

2. *Khivian type* : Distributed in Khivian oasis, Western Semiryenchensk in middle Asia where it exists as an admixture of types;

- Winter hardy form, spring growth starts earlier than the mountain type
- Medium seeded type, spreading growth, numerous coarse and much branched stems with high leafiness, leaves are round medium size, the snail shaped pods spirals are dense
- Susceptible to *Pseudopezia* leaf shoot disease

3. *Central Turkmenistan type* : Distributed in Eastern part of seven river district and middle parts of several districts Turkistan mainly, Tashkant, Farghana and Bokhra)

- In winter hardiness it is inferior to Khivian form
- The best crop amongst all Lucerne because of its long vegetational period extending upto August.
- Semi-erect, numerous stems branched to a medium extent, and has long elliptical leaves longer than Khivian types.
- Seeds are small, smooth, greenish in colour and are rarely hard seed coated.
- Several intermediate forms occur in other parts of the seven river district which are characterized by large hard seed content.

4. *Khorasan and Turkmen type* : Distributed in the Persian province of Khorsan, Afgan Turkistan, the Herat province, some parts of Kushka district and Tehta – Basra;

- Khorsan tpes have longest period of vegetation of all central Asiatic lucerne but is inferior to Central Turkistan type in number and leafiness of the stems and does not form rosette after cutting and are frost susceptible. The divergent form of lucerne distributed in the different geographical regions in Turkistan are believed to be closely related to Chinese Lucerne or “Mu-Su” (*M. sativa Chinensis*) which was brought to Russia somewhere in fifties.

5. *Asia Minor Type* : Distributed in all regions of Asia Minor of which Kesari or Vilayati strain from district of Koyan or from land lying further west are winter hardy and adapted to extreme variation in temperature of the Anatolian spring.

- Plants are very vigorous and coarse stemmed and tends unless cut early. It contains very broad leaves.
- Early spring growth followed by subsequent vigorous growth.
- It is very resistant to frost and sudden temperature variation.
- Requires abundance of moisture for summer growth, but thrives in the mountain climate, snowy winters, short summer and low rainfall.

During the course of distribution and adaptation in different parts of the world, natural selection has segregated varieties into great diversities of distinct types showing specific adaptation to varying soil-climatic conditions. For example, the Turkistan alfalfa is distinctly different in disease resistance and winter dormancy from the north African – Egyptian – Arabian types that have evolved under different climatic conditions. Based on different plant characteristics *viz*., flower colour, origin, winter hardiness, disease and pest resistance and agronomic characters, Whyte (1957) produced the following workable classification of types and varieties :

The common group : Consists of pure *M. sativa* types with purple flowers and limited winter hardiness. The growth habit is shorter and more spreading than the common group. It has slow recovery after cutting, early winter dormancy, low seed yield, and resistance to cold and bacterial wilt;

The variegated group : The strains in this group have variegated flower colour and are thought to have originated as hybrids between *M. falcate* and *M. sativa*. The varieties generally are winter hardy. The varieties such as Grim, and Ladakh are in this group.

The non-hardy group : The non-hardy group is adapted to short days and a long growing season. It is characterized by erect growth habit, quick recovery after cutting, susceptibility to cold injury, bacterial wilt and leaf diseases. This group includes Peruvian, Indian, Egyptian, Arabian north African and certain strains of Argentina.

Migration routes

Ancient Indo-Iranian links

The contact between Near East Asian regions with the Indian mainland was maintained through several mountain passes *viz*.; Khyber, Bolan, Tochi *etc*.

Trade routes to Kabul and Kandhar

Kabul and Kandhar in Afganistan owe their age old pre-eminence as cities of great strategic and commercial importance. The Vedas mention Kabul as an important town and transport centre, commanding all passes from north through Hindukush and from south through Kandhar and Gardez and controlling the main approaches, through the Khyber pass to Pakistan and India. Kandhar is located at a strategic site on main route to Central Asia, to Kabul and to India (Chandra, 1977).

Sea trade with the middle east

The sea ports of western India were used by the Arab traders (Chandra, 1977) who worked as trade agent between Europe and India. Maritime trade was well developed in eastern Mediterranean as early as 4000 BC (Hendry, 1923) and the plains of Mesopotamia (Iraq) was the traditional meeting place of ancient races of Asia, Africa and Europe. The Lucerne was known to ancient Babylonians (people of present day Iraq) by the name Aspesti. In ancient Budhist Text 'Jatak Katha; Babylon is described as 'Babroo'.

The Himalayan routes

The Himalayan chain of mountains has been the pathway for the flora of temperate region of the Pamir and the Central Asia from the north and the Sino- Japanese species from the north-east. The western Himalaya being the meeting ground of floristic elements from different directions has species from north temperate and arctic regions from Eurasia, the highlands of cold deserts of Central Asia, the Mediterranean mountains and the high plateau of Tibet. Several common pasture plants, weeds of cultivated field and other herbaceous elements of Europe and other temperate regions are well represented in the western Himalayan flora (Gupta, 1972). While Himalayan ecosystem offered sanctuaries for floristic elements from temperate north, it was also a crucible for the evolution of new species complexes of which "Laddakh lucerne" is an example. Many phyto-genetically important species including *M. media, M. varia, M. sativa, M. falcata* could escape extinction due to isolation and inaccessibility.

The Ladakh route

Ladakh, situated in the high mountain regions at the foot of Karakorum, has been on the cross roads of Asia for centuries. It's capital Leh being an important caravan centre was a typical Central Asiatic trade mart for Bactrian camels, donkeys, mules, sheep and goats. It is believed that the ancient traders introduced "Yarkendi Ole" (*M. sativa*) from Yarkand and "Bukusuk" (*M. falcata*) from Iskardo in Afganistan (Klinkowski, 1933; Misri, 1981). Ladakh alfalfa is very vigourous in growth, resistant to heat and cold and distinguished by high seed production.

Alfalfa in the northern Himalaya

Neolithic site – pit dwellers (2375 BC) – at Burzahom in Kashmir, about 16 kms north-west of Srinagar revealed seeds of several weeds including that of *M. denticulata* and *M. falcata* (Vishnu Mittre, 1968). These species are still common in the dry pasture wastelands and cultivated fields. Lucerne is found wild in several provinces of Anatolia to the south of Caucasus, in several parts of Persia, Afghanistan, Biloochistan and Kashmir. The period of lucerne introduction in India can not be ascertained.

The section 'Transactions' in the Journal of Agric – Horticulture Society of India throws light on the origin of lucerne in India and describes, striking differences between the condition of yellow lucerne, near the summit of the dry mountain of Lama Yaroo (in Ladakh) and the condition of Lucerne near the water course of the river Indus. It states that lucerne in its natural state bears yellow flower (*M. falcata*) of a rich scent and has greater longevity; under the influence of cultivation, it runs through diminishingly sulfur tint into whiteness, becomes green with a strain of red and permanently into pink or purple (*M. sativa*); it also looses fragrance and becomes short and of red flowers. Some early authors assume *M. sativa* to be a cultivated state of *M. falcata* and *M. media* whereas others admit these forms as varieties of *M. falcate*. Several authors pronounced *M. media* (*M. varia*) as a hybrid between *M. sativa* and *M. falcata*. The Yarkendi ole, a productive winter drought hardy form from the Central Asia appears to have crosses with the local biotypes of *M. falcata*, thus creating a mini cradle of evolution of winter hardly forms of the Ladakh Lucerne. Three species of Lucerne *M. falcata*, *M. media* and *M. sativa* are very distinct both in yield and stability of the environment. lucerne cultivation in the temperate regions of the world would never have reached its present position of importance but for the hybrid Lucerne forms emanating from the near-far-east, Central Asia, European and Ladakh regions, which were taken up in countries like the United States of America and Canada.

Yellow Lucerne grows naturally in Ladakh alongwith Prango (*Prongo pabularia*) and maintains its vigour for many years. The joint yield of prongo and Lucerne is vastly higher than that of richest meadow and it is produced on the earth surface of most sterile nature.

Alfalfa in the Himalayan cold desert

The Himalayan cold desert regions where *M. falcata* grows wild, covers part of state of Jammu and Kashmir, Laddakh, Himachal Pradesh, Humla and Mustang districts of North Nepal. Laddakh exhibits a great diversity of climate soil and topography. The rugged terrain of these regions consists of countless bare mountain peaks with coverage into sandy valleys that form part of the drainage system. The entire districts of Leh, Kargil, and upper areas of Lahul and Spiti districts cover, respectively, the catchments of rivers Indus and Sutlej above 3000 m. Laddakh, Drass, Kargil and Leh represent three climatically major contrasting regions; Drass a cold (-22^{0}C) humid region (756 mm rainfall) – represent seasonal variation and has short bright summer; Leh – a typical cold desert (115 mm rainfall) while Kargil is cold (-14^{0}C) semi arid (400 mm rainfall) with higher precipitation than Leh (Misri, 1981).

The North Himalayan region, J&K habited by local highlanders even above 4000 m altitude is one of the coldest inhabited place on earth possibly next only to Siberia. These highlanders depend on native pastures for summer grazing by their animals *viz*., Yak, ponies, mules, donkey, cow, sheep, pashmina goats *etc*. In these regions alfalfa grows as a component of native pastures. This wild growing alfalfa plant (*M. falcate*) has vast potential on undulating land with poor soil fertility, fallow cultivated fields having natural growth of yark (*M. sativa*) and ole (*M. falcata*) provide grazing during April-May (Gupta, 1994). The excellence of its hay is due to its stem being very fine and leafy. In semiarid and cold desert regions of north Himalayas it is a common practice of farmers to cut and store alfalfa hay along with grass hay on roof tops, and the amount of hay is also a status symbol of farmers. Traditionally much importance is also attached to the cultivation of ole in Laddakh. The local people will never use an iron sickle to harvest a crop of ole to as well as *M. sativa* avoid wrath of gods, instead a sickle like implement made of yak horn (pods like of *M. falcata*) is used (Misri, 1981).

As a summer season crop, lucerne known as 'Bukusak' (*M. falcata,* Sirsa -9 (*M. sativa*) is cultivated on the government farms located in the rain shadow areas of the high mountain regions of northern Himalayan in India. In North Nepal lucerne known as know (*M. falcata*) is also cultivated on government farms.

Winter non dormant Indian alfalfa
Adaptation and distribution

Indigenous types are winter very non-dormant (VND) forms of alfalfa characterized by erect growth, rapid regeneration and short term perennials (2-3 years). These are grown in low elevation plains of north-west India and Pakistan which have semi-arid/arid climate, low precipitation, extremes of temperature and low humidity. Alfalfa is extensively cultivated in Pakistan in the districts of Quetta, Jaglot, Islamabad and Mustang under irrigated conditions. In these areas alfalfa is grown preferably in October. It gives three to four cuttings but in dry areas only one cutting is possible.

Alfalfa is a highly productive crop in semi-arid regions of India, provided a large quantity of water is available for maintaining an irrigation schedule of 10-12 days during summer and 15 to 20 days during winter months. Under optimum soil fertility and moisture conditions, 5 to 10 cuttings at an interval of 25 to 35 days, starting from 10 to 12 weeks after planting, may be obtained. Annual productivity is region specific, largely controlled by length of growing period, soil fertility availability of water, freedom from excess of heat and cold, diseases, insect pests and competition from weeds under warm conditions.

Indigenous types of VND forms in India are poor in persistence and economic yields can be obtained up to 2 to 3 years, only under warm condition otherwise stands some times survive only for one year (Bondale and Chatterjee, 1982). Water saturated soils, immediately after a long spell of hot dry summer cause major losses in stand density of Lucerne swards, through root rot and crown diseases. During the warm wet conditions, the alfalfa crop is completely overshadowed by fast growing annual weeds. Alfalfa in low elevation plains of India is essentially a crop of dry climatic conditions, mild winter season and annual rainfall not exceeding 500 mm. With these limitations the non dormant alfalfa in north India is cultivated as an annual crop (October to May).

The Indian literature on the source and period of introduction ND (non dormant) and VND forms of alfalfa in the Indian subcontinent is too imperfect to allow a critical account being written. However, a few references dating back to the early part of the nineteenth century are available in the botanical flora published in the latter part of the 19th century. It seems certain that alfalfa entered India from its neighboring northwestern countries, and in these countries it is grown on a large scale. Scanty reports dating back to early 19th century, suggest that in all probability lucerne cultivation have been tried in the Indian subcontinent much before the British colonization. The extension of its cultivation In this country has closely followed the need of the military horses and until now the military cantonments are good centers of alfalfa in India (Mollison, 1901).

In the proceedings of the Agriculture Horticulture Society (1838) a mention is made of Mr. Hodgson having sent seed of lucerne from Nepal. In the proceedings of the succeeding year, Lieutenant Nicolson mentions that in meadow near Kabul lucerne is very commonly grown for food for horses and cattle. It was very difficult to differentiate morphologically in 'Kelat lucerne' (now in Pakistan) and the common type 'Deccan lucerne'. Its superior luxuriance in growth at Kelat must be owing to climate rather than the species. He further stated that his observations are extremely interesting as indicating an early cultivation of lucerne in western India. Lucerne was grown from English seed at Saidpet (Madras) and Benaras (U.P.) and the writer reported failure of the crop.

Mollison (1901) described three types of lucerne being grown in India. these are;

Kandhar or Quetta varieties : Trailing habit of growth, thin stems, small leaves and slow growing plants;

Persian or Arabic varieties : upright and vigorous in growth;

Pune lucerne and Meerut type: locally grown lucerne in north west India.

Mollison (1901) further describes that the small seeded Quetta or Kandhar variety is difficult to manage under irrigation. It gives fewer cuttings per year than the commonly grown lucerne. The only area where it was successfully grown was the alluvium (gurdu) area of north Gujrat.

The British introductions of drought hardy lucerne from exotic sources in the early part of the 20th century appear to have led to the presumption that lucerne was first introduced from Arabia to low elevation India around 1900 (Narayanan and Dabadghao, 1972 and Michaud *et. al.*, 1988). High water requirement of local types during warm dry summer season prompted the British to import exotic drought hardy varieties.

In 1906- 07, four strains of Turkistan lucerne was imported from America as a drought resistant variety and was planted in semi arid regions Dharwar and Dhulia (in central India) just before the rainy season (June). The seed germinated at Dharwar and the crop flourished during rains, but after the rains the crop suffered very badly and had to be ploughed up in December. There was no advantage of these exotic types over the locally grown lucerne as regards yield and drought resistance.

Argentine lucerne, imported as drought resistant variety was grown at Manjri from during the period 1909 -11 in an area where local types of lucerne were being regularly grown. The lucerne grew tall giving fair return in the early cuttings, but it failed as a drought resistant crop. At Poona Agriculture college farm, Turkistan varieties gave higher yield than the local varieties in the early cuttings, as it has larger root stocks but it had to be frequently irrigated and was of no use as a dry crop. The stocks were thinner than the local varieties and it did not seem to have enough advantages as an irrigated crop to make it worthwhile pushing its cultivation.

Variability in VND alfalfa

Barnes *et al.* (1977) proposed classification system for alfalfa germplasm that used criterion such as origin, fall dormancy, and floral variegation. Of the nine basic group identified by him, the 'Indian' and 'African' groups, are considered as the primary source of very non dormant germplasm (VND). But subsequent studies on VND alfalfa from Arabia, Middle East, North Africa and India show a definite relationship between the plant forms and the ecological conditions under which they are grown. Question relating to the ultimate origin and relationships among regional germplasm collections are especially important when decisions to be made regarding subdivision of large germplasm collections, as in the construction of the core collection. Frankel and Brown, (1984) challenged the very legitimacy of African-Indian classification because assembling very non-dormant alfalfa germplasm only on the basis of region of origin and fall dormancy might result in highly artificial groupings with excessive variability within the group. These studies showed that ecotypes from unique isolated environments such as those from areas of southern Arabia, which would be placed in the African groups may be sufficiently unique to justify independent conservation in their own germplasm groups. Improved understanding of genetic diversity in the regional materials of non-dormant alfalfa from North Africa (Egypt), Middle East, Arabia, and India may enhance conservation and utilization.

Genetic diversity studies were carried out based on the agronomic and morphological characters in the very non-dormant alfalfa accessions from low elevation in western central and northern India, Middle-East regions and Arabia. The results of the cluster analysis of the first three principal components showed that at least six regional germplasm groups exist among non dormant north African, Middle Eastern, Arabian and Indian alfalfa germplasm. The first three cluster groups *viz.*, A, B and C contained only the Indian accessions and all but one accession of the 21 Indian entries belonged to other group and may be the result of a more recent introduction than the endemic types. Most of the north Indian entries were contained in cluster B and C. The north Indian accessions displayed much higher persistence and forage yield, and substantially lower frost damage than that from western India. A majority of the western Indian accessions contained in cluster A was characterized by very rapid maturity, low total forage yield, very high frost damage, high spring yield fractions, and high crown mortality. All these traits are consistent with adaptation to a subtropical, frost free environment such as that of Gujrat state in west central India. The studies, further revealed that the very non dormant Indian alfalfa are phenotypically distinct from the middle eastern germplasm included in the experiment. Northern Indian germplasm was generally more similar to the majority of the middle eastern accessions than to the accessions from western India.

Cross pollination, inbreeding depression and heterosis

Alfalfa is a naturally out- crossing tetraploid species that depend on pollinators (bees) for pollination. Under open pollination by bees around 75% cross pollination has been reported by Knapp and Teuber (1993) and Brown and Bingham (1994). Within the species complex, *sativa-falcata*, there is a large pool of genetic variability with individual infertility varying within and between the different species complexes. All these features contribute to its genetic heterogeneity. Part of the variability can be traced to the introgression of the yellow lucerne *M. falcata* with purple flower *M. sativa*.

Intense inbreeding depression on selfing has been reported in cultivars 'Grimm', 'Hardistan' and 'Ladakh' (Tysdal, 1942). In mixed plantings of cross and mixed seed, the selfed seeds are thought to be eliminated by competition in the first 1 to 2 years of stand. In most combination of paired clones under cages with honey bees, 50 to 90 percent of the progenies have been reported to originate from selfing (Busbice and Wilsie,1966). The inbreeding depression is attributed to the rapid loss of multiple allelic interactions at many loci (Busbice and Wilsie, 1966). But, the current view on inbreeding depression is that there is a rapid loss of complementary gene interaction of linked dominant alleles as "Linkats" become homozygous (Bingham *et al.,* 1994). Autotetraploid alfalfa has greater potential for complementary gene action than diploids, and severe inbreeding depression in autotetraploid is due to rapid loss of complimentary gene action in the first few generations of inbreeding (Bingham *et al*., 1994; Jones and Bingham 1994). Tetraploid inbreds have been useful in population improvement and studies on gene action. Selection during inbreeding has resulted in population improvement in cultivated alfalfa. Unlike diploid species, where maximum hybrid vigor occurs in single cross generation, in autotetraploid alfalfa, maximum heterosis is not achieved until double-double cross (a cross between two double cross) generation (Groose *et al.,* 1989). In alfalfa maximum heterogeneity among gene is necessary to achieve higher yield. As true amount of cross pollination is not possible to ascertain, the data on general and specific combining ability of clones is likely to be misleading. Thus the conventional methods usually applied to cross pollinated crops may not always be effective in alfalfa breeding.

Alfalfa improvement programme in India

Crop improvement research in Lucerne or alfalfa started with a great challenge during late sixties and multilocation trials were initiated in 1971 when All India Coordinated Research Project (AICRP) on Forage crops came in existence. The main breeding centers for alfalfa were; Indian Grassland and Fodder Research Institute, Jhansi, Haryana Agriculture University (HAU), Hisar, Gujrat Agriculture University (GAU), Anand and Mahatma Phule Krishi Vishwavidayala (MPKV), Rahuri in Maharastra. Number of varieties were tested in multilocational trials at various locations in the different parts of India including the foot hill regions of Himalaya. Over the years, the number of varieties were identified and released as high yielding perennials and annual types for zonal or at all India cultivation.

In all the crops production status have already been increased by using the newly developed technologies, improved varieties and newly evolved plant protection measures and it is evident by the national production significantly increased in important crops. To meet out the demand of nutritive fodder to our animals, some efforts should be made mainly the transfer of the improved technologies/ varieties to the farmers means the" lab to land" programme is to be made strong. In present days the alfalfa / lucerne crop occasionally grown mostly in arid and semi-arid situations (with 400-500 mm rainfall) mainly in central –southern Rajasthan (Chittorgarh, Bhilwara, Jodhpur. Pali, Kakroli, Udaipur *etc.*), salt effected area of Gujrat (Mehsana, Anand and Bhuj and adjoining areas), Ahmadnagar sector of Maharastra state and Coimbatore area of Tamilnadu. The seed production in Lucerne crop is being taken mostly in patches such as Bilada (Jodhpur), Bhilwara & adjoining areas, Mehsana and Bhuj in Gujrat but know how about the improved varieties, newly evolved technologies and plant protection measures is very poor. In these areas farmers are generally using the seeds of land races for growing the crop which are maintained with the farmers since generations together. To solve such short coming, the extension units of national base, state, university and institutes level should be made effective and strengthen so that this important fodder crop reach every door.

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