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Review Article

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Breeding Strategies and Conservation Techniques for Improvement of Buck Wheat under Cold Arid and High Altitude Conditions of Ladakh, Jammu and Kashmir

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ABSTRACT

Buckwheat (Fagopyrum esculentum) is one of the important unattended and unexposed crop cultivated in the regions of the high altitude arid zones of Jammu and Kashmir. Due to the low yielding potential output and cultivation constraints the crop is at the verge of extinction though it is of high medicinal and nutritive value. In this review we provide the vision for buck wheat improvement through conservation and various traditional and innovative plant breeding techniques and inter-spacefic hybridisation. Researchers also must be Characterise variability in buck wheat landraces and also identifies the genotypes with yield and yield attributing traits and quality and utilising these in future breeding programmes and transferring these desirable traits into improved germplasm of cold arid conditions of Ladakh. The genotypes or landraces collected through the exploration trips are being screened to develop and identify promising genotypes of the crop. An appropriate avenue for marketing of the crop is very limited and thus production has not been encouraged. An assured marketing channel can only encourage the farmer to grow this crop in a larger scale in this region.

Key words: *Buck wheat, Breeding methods, Conservation, Cold arid climate, Marketing.*

INTRODUCTION

The Ladakh region is one of the most elevated (2900 m to 5900 m asl) and coldest region (-30 0C to -70 0C) of the earth and lies between 310 44’ 57’’ to 320 59’ 57” N latitude and 760 46’ 29’’ to 800 41’ 34’’ E longitude. There are buckwheat growing areas namely Skurbuchan, Achinathang, Domkhar, Dha-Beema, Bogdang and Turtuk in Leh district and nearly all villages in Kargil district, which are low laying areas and located near L.O.C which remains land locked for more than six months in a year. The villages fall in Leh district were located around the famous river Indus. Similarly, the villages of Kargil district were inhabited near the Indus and Suru River which ultimately flows in Pakistan[1].

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Buckwheat is the most important life support, multi-purpose and nutritious crop of the tribes living in the Cold arid conditions of Kashmir valley mostly in district Kargil. Buckwheat contains some nutritionally beneficial components at high levels and may have many characteristics as a functional food. It is the only crop grown up to 4500 m elevation. *Fagopyrum esculentum* and *F. tataricum* are the two species cultivated in the Himalayas. Buckwheat breeding is quite complicated because of complicated system of selfincompatibility[2]. This is a possible explanation for relatively slow progress in achievements of higher yield in buckwheat. That is the reason currently the cultivation and production of buckwheat is declining. In some of the areas, it has been completely replaced due to change in land use pattern for quick economic gains. Due to the low yielding potential output and cultivation constraints the crop is at the verge of extinction though it is of high medicinal and nutritive value. The crop is economically important primarily due to its edible protein and carbohydrate rich grains, hardiness of plants, short growth span and foliage being used as a green vegetable. Buckwheat is also used for livestock and poultry feed, buckwheat honey and as cover for wild life. Buckwheat noodles are particularly used in Japan. Buckwheat protein quality is high due to high concentration of most essential aminoacids especially lysine, tryptophan and threonine; besides buckwheat contains a high content of albumins + globulins and a low content of prolamins. However, due to a high content of crude fibre and tannin the true digestibility is below 80%. Buckwheat foliage is one of the chief sources of rutin (quercetin 3- rutinoside). Rutin is used in medicine in the treatment of increased capillary fragility with associated hypertension; protects against the harmful effects of X-rays; counteracts the effects of drugs such as salicylates, thiocynates and sulphadiazines which cause weakening of capillarie's. Rutin can act as antioxidant of ascorbic acid that can trigger diabetes, cardiovascular diseases besides hypertension. The use of pure rutin from buckwheat is cosidered safe and harmless[2].

There are a lot of advantages and scope to grow this crop in the cold desert region at high altitudes in Jammu and Kashmir, the crop is used as a staple food, where cereal crops like rice cannot be grown due to extreme low temperature. The prevailing agro-ecological condition of the region is very suitable to producing such an under-utilized crop as buckwheat. Cultural practices to grow this crop are simple and economical. To maintain the large and dense population, a higher seeding rate is necessary and can be used to prevent lodging. Sowing time is very important to produce this crop effectively and susceptibility to diseases and pest is less important due to cool climate during the growing season. Local farmers need to advance to improved seed varieties. There is a need to undertake scientific improvement work of buckwheat for increasing its production and on farm conservation to benefit the poor and marginal farmers of the cold desert[3].

Generally, one ploughing, single weeding and 4-6 times irrigations were required for the crop. On the basis of average over three locations, Himpriya gave the highest yield of 13.8 q/ha, but the farmers used local types and got an average yield of 10-12 q/ha. The most intensive cultivation areas have been identified for on farm conservation and participatory plant breeding to raise its production, highlighting the future exploration and conservation needs[4].

In this review we provide the vision for buck wheat improvement through various traditional and innovative plant breeding techniques and also Characterise variability in buck wheat landraces and also identifies the genotypes with yield and yield attributing traits and quality and utilising these in future breeding programmes and transferring these desirable traits into improved germplasm of Ladakh[5]. So the need of the hour is Promoting the conservation, Characterisation and utilisation of Buck Wheat (*Fagopyrum esculentum* Moench) neglected crop under high altitude cold arid regions of Ladakh. Buckwheat can become an important crop in the feeding of mankind and domestic animals to meet the ever increasing demands of rapidly expanding population stressing upon the importance of research scope on the crop.

Common buckwheat *(Fagopyrum esculentum* Moench) has been a crop of secondary importance in many countries and yet it has persisted through centuries of civilization and enters into the agriculture of nearly every country where cereals are cultivated. The main producers are China, Russian Federation, Ukraine and Kazakhstan. The species *F. tataricum* - or Tartary buckwheat - is also produced in many areas of the world but generally is consumed or traded locally. The crop is not a cereal, but the seeds (strictly achenes) are usually classified among the cereal grains because of their similar usage. The grain is generally used as human food and as animal or poultry feed, with the dehulled groats being cooked as porridge and the flour used in the preparation of pancakes, biscuits, noodles, cereals, etc. The protein of buckwheat is of excellent quality and is high in the essential amino acid lysine, unlike common cereals. This, coupled with the plant's ability to do well on poorer soils, probably accounts for its widespread usage. It is also a multipurpose crop. The small leaves and shoots are used as leafy vegetables, the flowers and green leaves are used for rutin extraction for use in medicine. The crop produces honey of a very good quality.

Buckwheat is confusing to many as it seems to convey relationship to wheat, which is not true. The name is probably a modification of "beech-wheat" (German Buckweizen) from the resemblance of its - grains with beechnuts, Fagus *grandi/oUa*[6]. Buckwheats "Trumba" *(Fagopyrum spp.,* Fam. *Polygonaceae)* are distinct from monocot cereals (Fam. Poaceae) and belong to the category of dicot pseudocereals which also include millet (Ping or China, *Panicum miliaceum)* and foxtail millet (Shol or Kangni, *Setaria itahca).* The genus is represented by about fifteen species distributed mainly in the temperate regions[3]. The grain of buckwheat is a dry fruit-, structurally and chemically the endosperm resembles cereals as it has a nonstarchy aleurone layer and a starchy endosperm. The crop is economically important primarily due to its edible protein and carbohydrate rich grains, hardiness of plants, short growth span and foliage being used as a green vegetable. Buckwheat is also used for livestock and poultry feed, buckwheat honey and as cover for wild life. Buckwheat noodles are particularly used in Japan. Buckwheat protein quality is high due to high concentration of most essential aminoacids especially lysine, tryptophan and threonine; besides buckwheat contains a high content of albumins + globulins and a low content of prolamins. However, due to a high content of crude fibre and tannin the true digestibility is below 80%. Buckwheat foliage is one of the chief sources of rutin (quercetin 3- rutinoside). Rutin is used in medicine in the treatment of increased capillary fragility with associated hypertension; protects against the harmful effects of X-rays; counteracts the effects of drugs such as salicylates, thiocynates and sulphadiazines which cause weakening of capillarie's. Rutin can act as antioxidant of ascorbic acid that can trigger diabetes, cardiovascular diseases besides hypertension. The use of pure rutin from buckwheat is cosidered safe and harmless[2]. However, there is a danger of the disease "fagopyrism" when grains are consumed in large amounts. The pigment which causes the disorder is present only in theflowers and hulls but not in leaves, stem or flour (De Jong 1972). The literature on buckwheat has been extensively reviewed (The wealth of India 1956[7,8,]. Buckwheats In Kashmir The first descriptive record of buckwheat cultivation in Kashmir is found in the writings of nineteenth century[2]. According to Lawrence the "trumba" or buckwheat *(Fagopyrum esculentum) is a* most useful plant, as it can be sown late in almost any soil, and when the cultivator sees that there is no hope of water coming to his rice fields he will at once sow the sweet trumba. The sweet trumba *(F. esculentum)* often grown as a substitute for rice has white pinkish flowers can be sown upto middle of July and the bitter trumba *(F. tataricum)* in the higher villages fonns the only food grain of the people eaten as bread or porridge [4,5]. However, with time there seems to be a gradual decline in the interest of the people to grow buckwheat because of the agricultural awareness about other crops including the irrigation facilities. The buckwheat crop in Kashmir is thus regarded to be the crop of the poor. So the domestication of buckwheat in Kashmir is still in the primitive stages and the crop has not been subjected to intensive experimentation. The research interest on buckwheat in Kashmir started quite recently. Four species of Fagopyrum *viz* common buckwheat (*F. esculentum* Moench), coarse buckwheat (*F. sagittatum* Gilib.), Kashmir buckwheat *(F. kashmirianum* Munshi) and tartary buckwheat (*F. tataricum* Gaenn.) have been reported in populations from various high altitude areas of Kashmir[9], The populations abound either in *F. esculentum* or *F. sagittatum.* The perennial species *F. cymosum* Meissn. grows wild and can be propagated through rhizomes. Munshi[22] believes that *F. kashmirianum is* allied to *F. tataricum.* The four cultivated species are diploid with 2n = 16 and the wild growing *F. cymosum* is a tetraploid with 2n = 32[5,8].

Breeding stratgies

Breeding objectives

The major objective in buckwheat breeding programmes worldwide has been the improvement of seed yield. Other objectives that have been stressed in various breeding programmes include:

- increased seed size (1000-seed weight)
- increased seed-shattering resistance
- early maturity
- easier dehulling ability
- determinant flowering
- increased groat percentage
- seed coat colour
- flower colour
- leaf size, both small and large
- lodging resistance.

Breeding principles

Common buckwheat is a self-incompatible species and this therefore dictates the breeding patterns most used on it. Owing to its outcrossing characteristics, all lines that are being developed must be kept in isolation, either spatial or in cages, from each other. Tartary buckwheat crop improvement programmes can be handled in the same manner as other self-pollinating crops. It is thus much easier to generate and maintain the high numbers of segregating progeny and advanced lines that are required in a plant breeding programme. The self-incompatibility of buckwheat is of the dimorphic, sporophytic type and thus seed production is dependent on cross-pollination between 'pin' (long pistil, short stamen) and 'thrum' (short pistil, long stamens) flowers. Flower forms with reduced style length have been found and self-fertile homomorphic lines have been developed[4,5,9]. Certain of the lines that were developed were especially adapted to self-pollination since the flowers have equal pistil and stamen heights. However, the introduction of this character into other buckwheat lines almost always results in severe inbreeding depression. This is probably due to a large number of deleterious recessive genes being carried along with the thrum gene, as this gene never occurs in the homozygous state. Many breeders have looked to the development of self-pollinating buckwheat as a means of increasing the ease of selection in buckwheat and also as this allows for an extensive search for spontaneous recessive mutations that are normally hidden in the cross-pollinating form[10]. Fesenko also reports that a study done on Zamyatkin's homostylous long-styled buckwheat form showed it to be a facultative cross-pollinator. It was found that the degree of self-pollination under conditions of free cross-pollination of plants of the same type was 54.5 and 58.6% under field conditions and even higher at 88% when done under greenhouse conditions. This higher seedset under greenhouse conditions may in part be due to the manual pollination that was performed. However, it was shown that the homostylous form was highly self-compatible and capable of self-fertilization not only when individually isolated but when pollen from other plants of the same or heterostylous forms predominated. Induced mutants have been used to increase the polymorphism of buckwheat[1,2,3].

The basic selection method that she used was the individual familial type where families characterized by similar traits and properties are combined and then studied as a single strain. Individual mutants isolated during the breeding process on the basis of definite economically valuable traits and properties or complexes of such traits and properties are studied for varietal testing. She also used biologically valuable mutants in hybridization. She reports that most high-yielding mutants have been produced with the aid of irradiation. The frequency with which desirable mutants appear among forms created by chemical mutagenesis is significantly lower[11]. The varieties were produced through gamma irradiation in doses of 30 and 40 kR. Breeding stock obtained through combined treatment of seeds with chemical mutagens and radiation was of particular value. Application of the familial-group selection technique to this stock resulted in creation of the Podolyanka variety. It is of interest to note that valuable mutants with high contents of protein and of individual amino acids such as lysine, phenylalanine, methionine, proline, arginine and glutamic acid were found in material subjected to chemical mutagens and to combined chemical and radiation mutagenesis [4,6]. Forms that have an increased content of rutin have also been found after mutational treatment. This allows the development of individual desirable traits that then can be introduced into high-yielding or lines with other desirable traits through backcrossing. The improvement of the species *F. tataricum,* although secondary in many breeding programmes, is of major importance in the areas of the world that rely on this crop, these areas being mainly the mountainous regions above 2500 m in altitude that present a danger of frost damage to the crop. Although the species is being evaluated in several breeding programmes for the improvement of common buckwheat, little direct work is taking place on the improvement of this species through crop improvment programmes or by interspecific hybridization. As pointed out by Tundup *et al*[12]., and Zakir *et al*,[13]., a putative progenitor species that has a self-incompatible pollination mechanism has still not been found. This would appear to have high priority in future collections of wild buckwheat species. The finding of the closely related wild and weedy Tartary buckwheat species and types has made it so that crosses are now possible between these species and types. It is of interest to note that in any programme for the improvement of common buckwheat that involves interspecific hybridization with Tartary buckwheat, there also exists the possibility of improving Tartary buckwheat with very little extra effort. This opens up a broad new area, with its accompanying challenges, in the collaborative breeding of buckwheat. Although Tartary buckwheat has several characteristics that are desirable, including frost tolerance and self-pollination, it contains a bitter component that must be removed from any hybrid that utilizes it as a parent. There is a need therefore to determine the bitter component and to develop a screening technique that can be used in identifying it in segregating progeny. Buckwheat improvement in the Russian Federation has producedmany cultivars for different purposes (Fesenko, pers. comm.). He reports that buckwheat in parts of Russia and Siberia is more photoneutral and earlier maturing than in most countries of the world. They have produced ultra early maturing cultivars that can be used as forecrops for winter cereal production under the conditions of a short Russian summer. They have also produced larger-grained cultivars and cultivars with improved growth habit. These include determinate cultivars, cultivars with limited secondary branching and small-leaved cultivars. Only *F. esculentum* is grown countrywide, with photosensitive types being produced in the far east of the country[9,10,11].

Interspecific hybridization

Although the genus *Fagopyrum* contains at least 15 species of buckwheat, only two are utilized as food or feed and wild buckwheat

(F. cymosum), mainly found as tetraploid, is used on a sporadic basis as a green vegetable or as cattle forage. The development of hybrids between two different species of buckwheat has now been demonstrated several times. *Fagopyrum cymosum* and *F. tataricum* hybrids as well as *F. cymosum* by *F. esculentum* hybrids have been produced at the tetraploid level. *Fagopyrum esculentum* by *F. homotropicum* hybrids have proven to be fertile at the diploid level. *Fagopyrum esculentum* by *F. tataricum* hybrids have been developed at the tetraploid level and are presently being developed at the diploid level. This will allow movement of characteristics from one species to another in the development of improved cultivars[14, 4].

The creation of interspecific hybrids between buckwheat species has opened up a new area for plant breeders. These crosses can now provide a means of transferring traits, not available within some species, from one species to another and transferring desirable traits into improved germplasm. The selection of specific desirable traits and the elimination of undesirable ones requires a rapid method for the identification of these traits. This would allow for early selection of desirable plants having the specific traits or combinations of traits without having to verify their presence using older and much slower methods. This will thus allow the plant breeder to make much more rapid progress in the improvement of buckwheat and in the development of new cultivars. The identification of molecular markers linked to individual chromosomes and to specific genes has been demonstrated in many species. This usually utilizes random primers in conjunction with polymerase chain reaction (PCR) technology. Primers can be identified that amplify DNA fragments that are polymorphic between lines having different genes as well as being linked to known markers on different chromosomes. This type of analysis, combined with rapid leaf disc DNA extraction techniques, offers a very effective means of applying the knowledge gained to practical plant breeding[12, 15].

Limitations of the crop

One of the major limitations in common buckwheat appears to be the high amount of seed abortion that occurs. The causative factors for the abortion are not fully understood even though this has been an identified problem for over 30 years. There also have been no reports of decreased percentage in accessions from different parts of the world. While this problem does not exist in Tartary buckwheat or in the species *F. homotropicum*, it does not appear that genetic variability in this trait can be readily found. Therefore, any improvement in it must come from mutational or interspecific breeding. Common buckwheat, however, is susceptible to spring and fall frosts and therefore care must be taken to avoid this problem. This lack of frost tolerance is a major restraint in many production areas. Although screening of accessions has shown very little variability to frost damage, this aspect is now being addressed through interspecific hybridization. The frost tolerance found in *F. tataricum* and *F. homotropicum* is being evaluated to determine if it can be transferred between species. If the character can be transferred then a major constraint to the production of this crop could be altered or removed[14, 16].

Further research needs and recommended plan of action

Collecting, characterization, evaluation and utilization of buckwheat germplasm to date have taken place, generally in an uncoordinated fashion. No major designated repository has accepted the mandate for this very important task. At the present time there are no coordinated efforts in the area of collecting, characterization and utilization of the wild species for crop improvement programmes. Characteristics that are highly desirable in such programmes must be considered both in the collecting of wild species and the sampling of general variability. This must be addressed for the benefit of those who have expended so much effort in the collecting and characterization of these species, and also for the benefit of the plant breeders and others who utilize the material.

The long-term storage aspects of these collections urgently need to be addressed. As the number of researchers working on buckwheat improvement is limited, compared with those working on primary food crops, it is even more important that their efforts be coordinated in some fashion, it is realized that this coordination can only be facilitated through a network or facilitating agency. It will depend on the development of collaborative projects, both small and large, between individual buckwheat programmes that will allow for the maximization of their efforts for the benefit of both. The collaborative projects can vary from formal to informal but will only be successful if both sides desire the results and are prepared to work together to achieve them[4,5, 7.]

Recommended plan of action

A collecting system must be developed that will allow for the systematic sampling of the germplasm in areas that have not yet been adequately sampled so that collecting in these areas can be organized. There should be a review of present collections so that areas can be identified that have been adequately sampled to avoid duplication of effort. This must take into account the present condition of the accessions that are being stored as well as any regeneration of germplasm that is required.

Emphasis must be placed on collecting wild and weedy species. This will not only allow these to be utilized in the breeding programmes now and in the future but will allow a clearer understanding of the site of origin and the differentiation that has taken place between buckwheat species. This should also allow for a more systematic approach to be taken in collecting individual characteristics in species that are closely related to the two economically important species presently being cultivated. Mutant forms that have been developed or found in many of the breeding programmes have not been adequately stored on any systematic basis. These are very important in the variation of both morphological characters and also in quality or value-added characteristics of the species. Cultivars that have been produced over the past several decades appear not to be stored according to any coordinated method. Although many of these are probably in working collections or in long-term storage, their status should be determined. An electronic database should be developed that will allow for faster updates and faster dissemination of the data that are available in the present germplasm storages. Although approximately one-half of all accessions are documented on computer, but many of these systems are incompatible. The development of a compatible system and Internet access would allow much better utilization of these data. Germplasm storage sites should be developed or appointed that have the mandate for storing buckwheat and its closely related species. Collaboration must be encouraged and supported between the collection sites and the breeders utilizing these sites. This will often mean between developed and developing countries. This is very important as many buckwheat breeding programmes are decreased in size in many countries because of monetary constraints. This will also make the utilization of the stored germplasm by the breeding programmes more efficient on a global basis. This must include not only not only Government, University and International sites but also private companies[17].

There must be developed a means of having, for the collections now in place and those of the future, standardized evaluations on many of the characteristics that the breeders or those utilizing the germplasm deem to be the most important. As funds decrease for breeding programmes this will become increasingly more important from a global viewpoint. It will also make the entire system more efficient as it will reduce duplication of effort between breeding programmes. This should also allow for faster dissemination of the data obtained.

A more coordinated effort should be made in the area of crop improvement through the utilization of stored germplasm. This, although difficult to implement, would make the utilization of the present germplasm collections, both long-term and working, much more efficient. This could include the initial evaluation of the germplasm, and the early generations of crosses involving specific characters[11, 12, 15].

Importance of wild relatives as a source of diversity

To the present time the only known species that have been crossed at the diploid level in an attempt to allow transfer of attributes to common buckwheat are *Fagopyrum homotropicum* and *F. tataricum.* These appear to be the most closely related to common buckwheat and therefore should be the most important as a source of further diversity for common buckwheat. The self-pollinating mechanism as well as increased frost resistance appear to be the characteristics of greatest importance at the present time.

Collections

Many collections have taken place and a great deal of total variability that is present in the two main species has been sampled by these collections. There is, however, a lack of basic passport data for many of the collections as well as uniform characterization of the accessions[15,18].

Condition of existing collections

There are some major collections, such as those in India, China and in Russia, that are under medium- and long-term storage conditions. However, many of the collections are being stored at room temperature in paper bags. Some of the collections have been stored at 15°C for up to 10 years and therefore seed viability would be considered to be very low after this interval of time. A detailed evaluation of the material presently in storage would allow for the development of future storage conditions, regeneration of the material if required and a more coordinated approach to storage conditions. Unfortunately, many of the stores of germplasm are limited by the facilities that are present at or near the place of the active collections. This has been addressed recently in Canada with the active collections now being given the mandate of long-term storage as nodes of the National Plant Genetic Resources Program. This allows the researchers who are the most intimately involved with the utilization of the species to direct the evaluation and regeneration of the species as well as the collection of accessions. These nodes, however, must be supported financially or else they will become a direct drain of resources from the crop improvement aspects of the programme[19].

Gaps in existing collections

The buckwheat germplasm that has been collected, characterized and stored to date is expected to contain a large proportion of the variability that is present in the local material. The collection of the N.I. Vavilov All-Russian Research Institute of Plant Industry is the only large collection that has attempted to obtain representation from many parts of the world. There also exist several collections that possibly contain duplication as they were collected from the same localities. These include the collections that have be made in Nepal, which are backed up in Canada, one of the few collections that do have a duplicate backup, but are possibly also duplicated with the collections stored in Japan. Collections from Nepal have been made by several researchers from Japan and several were made from similar localities with probably similar ecological conditions. This type of duplication, however, appears to exist very infrequently in present buckwheat germplasm collections. The collection of Tartary buckwheat has lagged behind that of common buckwheat as can be seen from the listing of buckwheat collections where *F. Tataricum* accessions (1006) are far less (approximately one-eighth) than *F. esculentum (7820).* This is in large part because common buckwheat is the most economically important species. However, in many parts of the world, including the mountainous areas where buckwheat originated[17,19], Tartary buckwheat is extremely important as a foodstuff for the indigenous population. If the collection of buckwheat germplasm were on a species basis then it is readily apparent that there needs to be a much larger effort in collecting this species, compared with common buckwheat, to effectively sample the existing germplasm.

It must be recognized, however, that the areas in which this collection should take place are in the mountainous areas of the Himalayan where it is often difficult to obtain ready access. The recent effort that has been made in collecting and characterization of the related species of buckwheat deserves due recognition. This has allowed a more complete understanding of the origin of the species and their distribution. It will also undoubtedly lead to further findings in this area. Although there have been a number of reports of evaluation and characterization of related species of *Fagopyrum* from China, there has not yet been any reported collecting of these species. This is urgently required if the origin and distribution of these very important species are to be determined. It also appears that the very important and useful collections that have been made up to the present are seriously lacking in long-term storage of the collections. Although there is a need to have working collections of these species, a long-term conservation programme for them should be developed. There exists a need to collect and document varieties that have been developed in many countries as well as the locally collected and exotic germplasm that is usually reported. Although in many cases it would be expected that these cultivars actually have been collected and do exist in germplasm collections, there still exists the need to report them as an integral part of the germplasm under storage. The development of many mutant forms of buckwheat has been reported from the former USSR, especially from the Ukraine. These have not yet been reported as stored as have some of the forms found in Japan. It would appear that there is a large need to determine which of these mutants are in storage, their characterization and their availability. There also would seem to be large areas where either inadequate collecting has taken place to sample the existing germplasm or where collecting has not yet been done. A large area of southern Europe has few, if any collections presently in storage. This concern must be addressed at an early date so that systematic sampling of the existing germplasm that has not yet been collected can take place[20, 21].

Conservation techniques and methods used

The cultivation of common buckwheat is widespread, but in many of the countries where it is produced for home use it occurs in small scale only as crop improvement programmes produce more cultivars the result will probably be more or less genetically uniform cultivars replacing many of the local types. This would be expected in areas where common buckwheat is produced as an economic crop but also have effects in neighbouring regions.

Even in areas of small holdings, rapid change can be expected with the introduction of improved types thus genetic erosion can be expected in these areas as well. *Ex situ* collections of common buckwheat are difficult to maintain because of the incompatibility system of the crop. Therefore, seed increases must occur under spatial or screen isolation. It is imperative that screen enclosures are doublescreened to prevent the 'working' of the plants by insects from outside the cages. Large numbers of accessions in some collections put extreme pressures on facilities to accommodate seed increases as plant populations must be large enough to be a true representative sample of the collection and at the same time small enough to be contained in an enclosure [18, 22].

Major constraints in conservation

Buckwheat is cultivated in many countries, but in many of these it is cultivated on a small scale or on small holdings. This is especially true of the hilly or mountainous areas of Ladakh, Nepal, India and Bhutan. Recent studies in Ladakh indicate that many of their landraces are under threat, especially for common buckwheat, as the area of production is declining and is being replaced with other crops that are seeing more rapid improvements due to plant breeding. This appears to be also true in China. Crop improvement through plant breeding of buckwheat will probably result in a much faster replacement of the local landraces with more uniform or genetically pure varieties. This has already been documented in Europe where in about 100 years ago light pink flowering buckwheat was predominant [23]. However, at the end of the last century, the higher-yielding white flowered buckwheat was imported from a European country and gradually replaced the pink-flowered buckwheat. [23]reports that buckwheat from the Himalayan regions has never been introduced into Europe. However, the Himalayan buckwheat has often been influenced by buckwheat coming from China. Therefore, a more detailed evaluation of the spread and distribution of buckwheat species should allow the designation of areas that should contain buckwheat having a high prevalence of certain characteristics. When this information is taken together with present-day production trends it should identify areas that are at high risk of erosion as well as areas that are at low risk and thus serve as a guide in future protection of or collecting from these areas Possibly the major constraint that exists in the conservation of buckwheat germplasm at the present time is the fact that it is a crop of secondary interest in the agriculture of most countries where it is grown. Therefore, it has been very rare that the type of effort that has been expended on the major crops has been expended on buckwheat as well. This has become increasingly evident under conditions of reduced budgets for agricultural research in many countries. This research effort, or sometimes reduced effort, manifests itself in that the germplasm that has been collected to date is not being utilized effectively in the improvement of the crop. Little between-country cooperation has been developed for duplicate or back-up storage or in collecting efforts. These issues must be addressed and rectified so that the research efforts presently being expended on this crop will produce maximum results from the minimum resources available[21, 23, 18, 24].

Future Needs

- Screening of germplasm for frost resistance and selection of short duration varieties should be carried out to allow production in high mountain where growing period is limited for 2 to 3 months due to early winter and snow fall.
- Cultivation of buckwheat should be encouraged, instead of millets and other crops to check soil erosion.
- Buckwheat cultivation promotes improved soil texture and increases production of fallow crops.
- Buckwheat is the most suitable crop for marginal and degraded lands and is also important for crop diversification in the foot hills of the Himalayas.
- It is important to promote ancient nutritive food crops like buckwheat for various health reasons.
- Buckwheat cultivation in the cold desert region should be encouraged as it does not require high input technology and can be raised with lower management costs in marginal and degraded lands on a sustainable basis. Introduction of exotic germ plasm, particularly large seeded, early maturing types to fit in areas having a short growing period.

CONCLUSION

There are a lot of advantages and scope to grow this crop in the cold arid conditions of Ladakh. Low rainfall, low temperature and abandoned areas due to shifting cultivation *can* be utilized effectively to grow the crop as it requires little inputs. It can be grown twice during the period from April to November in each year, es-pecially in the higher altitudes of Kargil. Basically, the species is heterostylus and cross-pollinated. Honey production can be effectively developed in large cultivated areas of the species. At high altitudes in Ladakh, the crop is used as a staple food, where cereal crops cannot be grown due to low temperature. The prevailing agro-ecological condition of the region is very suitable to producing such an under-utilized crop as buckwheat in a large scale. Human population multiplication is less in the hills than in the plains. However, in future any higher production can be utilized in the food processing industry, the brewing industry as well asbeing exported to other countries. In the rural areas, honey production can be established based on cultivation of this crop. Cultural practices to grow this crop are simple and economical. To maintain the large and dense population, a higher seeding rate is necessary and can be used to prevent lodging. The genotypes or landraces collected through the all cold arid conditions of Ladakh and exploration trips are being screened to develop and identify promising genotypes of the crop. Agro-ecological situation and sowing time are very important to produce this crop effectively. Susceptibility to diseases and pest is less important. An appropriate avenue for marketing of the crop is very limited and thus production has not been encouraged. An assured marketing channel can only encourage the farmer to grow this crop in a larger scale in this region.

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