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A review on breeding, global production and utilization of lentil

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Abstract
Lentil is an important legume crop with a large and complex. Most of the lentil growing countries face problem of abiotic and biotic stresses which cause substantial losses in crop growth, yield, and production. Till now, lentil researcher has used conventional plant breeding methods of selection to develop improved cultivars. These techniques have been successful for the improvement of monogenic traits. However, for improving complex quantitative traits, these conventional breeding methods are not that much useful. The genetic improvement of economic traits become difficult as most of these traits are complex, quantitative and often influenced by environments and genotype–environment interaction. Marker assisted breeding is relatively powerful and fast approach to develop high yielding varieties that are adaptive to adverse environmental conditions. New tools such as molecular markers and bioinformatics gives knowledge and improve our understanding on the genetics of complex traits for better improvement of our varieties. In the past, the genomic resources were limited in lentil which restricts the breeders to employ these tools in mainstream breeding program. The recent advancement of the next generation sequencing and genotyping by sequencing technologies made lentil genome sequencing project easier and speed up large discovery of genome-wide single nucleotide polymorphism (SNP) markers.

Keywords: Global, production, utilization, lentil, *Lens culinaris*

1. Introduction
Lentil (*Lens culinaris* Medik) generally known as masoor dal in India is derived from Southwest Asia and the Mediterranean region (Vavilov, 1949; Zohary, 1995) [73]. It is mainly a self-pollinated legume crop belonging to the Fabaceae family, with chromosome number 2n=2x=14 (diploid) (Ramsay, Von wettberg, Bett, 2018) [52]. In lentil, a high amount of protein (22-25%), vitamins, fibers, and complex carbohydrates are present (Adsule *et al*., 1989; Kumar *et al*., 2018) [2]. The demand of pulses is increasing rapidly and there is an estimation that by year 2050 lentil production will be doubled (Westhoek *et al.*, 2011). Lentil is one of the foremost and nourishing pulse crops.

Lentil is a well-known drought-tolerant crop, so it is cultivated globally. In the global production of lentils, India ranks 2nd position with a contribution of 39.79% of total production (Anonymous 2020-21; https://www.atlasbig.com/en-in/countries-by-lentil-production). It is significantly cultivated in a vast range of agro-ecology, yet its production is limited in tropical areas. It is cultivated by more than 52 countries (like India, Syria, Pakistan, Spain, etc.), with 6.15Mha. area and 63.15Million metric tonne production of grains in the world (FAOSTAT; 2021). The area under lentil cultivation in India is around 15.48 acres with a production of 10.55 million tonnes (Anonymous- 2021) (https://www.atlasbig.com/en-in/countries-by-lentil-production). In India lentil is cultivated in U.P., M.P., West Bengal, Bihar, and Rajasthan.

Lentil can cover the menace of rainfed farming and also helps to examine soil erosion in problematic areas, therefore in many areas; it is grown as a cover crop.Lentil residues or low food-grade seedsare also used to feed the cattle and other animals. The residues which are left in the soil can be used as mulch and can either mix in the soil as green manure, so they can provide nutrition to the soil, maintain the moisture and improve soil health. It is also a good source of nitrogen fixation in the soil approximately 10-33 kg nitrogen per ha is fixed by lentils (Muehlbauer *et al.*, 2002; Hossain *et al.*, 2019). It is effective in crop rotation, acts as a barrier for the rapid growth of weeds, and prevents the main crop from insects and pests attacks (Kumar *et al.*, 2013) [35]. Due to its quick maturity, it can be cultivated well in multi-cropping and relay cropping systems.Lentil is a rich source of digestive protein. Protein genetics or its components may provide a beneficial indication for further related improvement

in order to increase the quality of protein in pulses. The normal recommended pulses for per capita per day consumption is 55 gm for adult females and 60 gm for males (Tewari and Shivhare, 2016) [57]. The protein present in lentils comprises of albumins, globulins, glutelins (Boye *et al.,* 2010, Jarpa-Parra, 2018) [8, 42]. Due to the high content of protein, it helps to overcome the issues like undernourishment or malnourishment and micro-mineral deficiency from the different populations or communities of developing and developed countries (Kumar *et al.,* 2016) [36]. Besides this, people who are suffering from long term diseaseslike cardiovascular, obesity, and diabetes can be cured by utilizing lentil seeds in their regular diet (Hu, 2003; Philanto and Korhonen, 2003; Tharanathan and Mahadevamma, 2003; Jacobs and Gallaher 2004; Boye *et al.*, 2010; Srivastava and Vasishtha, 2012) [47, 8, 59, 29, 69]. Lentils have the same calorie value as rice, but they contain four times as much protein and eight times as much riboflavin. As a result, today's health-conscious individuals espouse a plant-protein-based diet in place of meat, and their consumption rate has increased fivefold. The flour of lentils is useful in condensing of soups, cake, and bread baking, etc. (Farooq and Boye, 2011; Rathod and Annapure, 2017; Turfani *et al*., 2017) [13, 18, 49, 63]. In India, it is a part of daily diet, whereas, in other countries it is consumed on different occasions like marriages, and mourning ceremony. The starch of lentils is useful in the textiles and printing industries.

Therefore, through this review paper comprehensive info about seed composition and nutritional attributes of lentil, its utilization in different food preparation and in processing method are provided.

Lentil Taxonomy

Lentil cultivation took place about 8500 years ago. Lentil is basically a busy annual herb, with a height of 20-45 cm and pods with 1-2 seeds. According to Integrated Taxonomic Information System (ITIS), 2021 the classification of lentil is shown below:

Kingdom- Plantae
Subkingdom- Viridiplantae
Division- Tracheophtya
Class-Magnoliopsida
Order- Fabales
Family-Fabaceae
Sub-family-Faboideae
Genus-*Lens*
Species- *culinaris*.

2. Morphology of Lentil

Lentil plant is small, thin, semi-erect annuals with palmate leaves with curl at the tips. Average plant height of lentil is 12-20 inches, but sometimes the height increases due to temperature variation, moisture in excess and soil fertility (I.R.A.P., Asakura *et al*., 2013) [26]. Branches start to grow from ground level buds and goes upward. Its flower color varies from white or near white to violet, blue, and are self-pollinated.Lentil seeds are mainly small, oval or elliptical with convex lens kind of shape. Lentil seeds vary in colors from white to black, orange, yellow, green, etc., sometimes they also bear spots (Lentil Encyclopedia Britannica, 28 Apr. 2021). Harvesting oflentil crop is done after 90-120 days when plant becomes fully mature and pods color change to light yellow or brown.

2.1 Nutritional value and chemical composition of lentil

Lentil (*Lens culinaris* Medik) contains high amount of fibre, protein and low amount of fat. Brummer *et al*., 2015 illustrated that total soluble fibres and dietary fibre are highly present in lentil than peas, beans and chickpeas. In lentil, protein content is around 20.6% to 31.4% (Urbano *et al*., 2007) [64], nearly all these proteins are stored in cotyledons with a low percentage of Sulphur containing amino-acids. The chemical composition of lentil is shown in the table:

Table 1: Chemical composition of lentil (per 100 grams of dry matter

Parameters	Range
Total nitrogen (g)	3.72–4.88
Protein (N×6.25) (g)	20.6–31.4
Non-protein nitrogen (g)	0.49–1.049
Fat (g)	0.7–4.3
Carbohydrates (g)	43.4–69.9
Fiber (g)	5.0–26.9
Ash (g)	2.2–4.2

***Source*:** Urbano *et al*., 2007 [64].

Lentil proteins are encompassed of about 16% albumins with molecular weight 20kDa and 13 polypeptides, 11% glutelins with molecular weight 17-46 kDa and 4 polypeptides, 3% prolamins with molecular weight 16-64 kDa and 10 polypeptides. Other than these 70% globulins is also present (Boye *et al.,* 2010b) [10]. In globulin, legumin and vicilin-like proteins are present. In lentil all the essential amino acids are present, but Sulphur amino acids, tryptophanand threonine are present in limited amount (Shekib *et al.,* 1986) [53]. In lentil protein, approximately 39.3 g amino acid per 100 g protein is present (Shekib *et al*., 1986) [53]. The amino acids composition in lentil is showed in the following table:

Table 2: Essential amino acid composition of lentil protein (mg g^{-1} of protein)

Amino acids	Content
Lysine	362–481
Threonine + Glutamic acid	1 049–1 370
Methionine + Valine	294–442
Phenylalanine	272–410
Leucine + Isoleucine	500–611
Histidine	138–167
Tryptophan	7–10

***Source*:** Shekib *et al*., 1986 [53]; Wang and Daun, 2006 [70].

3. Limitations in Lentil's cultivation

In India more than 60% population is based on agriculture,

while about 70% rural population livelihood is depending on agriculture (Sharma and Sharma, 2019) [66]. Lentil is cultivated in all over world and able to grow in drought stress conditions. But there are still some problems faced by the farmers during and after the cultivation of lentil. These problems associated with technical issues, social issues, environmental, economical, etc. (Patidar, 2012) [45]. Problems faced by farmers are like lack of labors, low market price, high freight charges (Rajput *et al.*, 2000) [48], unavailability of improved varieties, infestation of diseases and pests (Burman *et al*., 2008) [11], ignorance of weed control (Kumar *et al*., 2010) [34]. India has exported 296,169.83 MT of pulses to the world for the worth of Rs. 2,116.69 Crores/ 284.26 USD Million during 2020-21 (https://apeda.gov.in/apedawebsite/SubHead_Products/Pulses.htm).

3.1 Limitations in Lentil's consumption

Lentil provide ample amount of dietary proteins, complex carbohydrates and minerals, which is consumed in developing countries. While in developed countries like Europe, North America, Australia lentil's consumption hasdecreased in the past few years (Dostalova *et al*., 1998) [17]. The factors which are responsible for less red lentil consumption are like steady hydration and taking time during cooking (Bhatty, 1984) [5], distasteful flavor, impoverished protein digestion, soreness and pain in intestine, and presence of anti-nutritional factors (Khan *et al*., 1987) [33]. Excess consumption of red lentils, can causethe risk of increase in flatus, which is somewhat awkward. There are also specific side effects associated to amino acids like nausea, headache, pain and affect our sugar level

In some instances, because of the high potassium content of red lentils, people also end up with having potassium toxicity. It can also cause detrimental effects on the kidneys and can also cause kidney stones leading to urinary tract infections. Red lentil also has a considerable amount of calories and carbs. High consumption of lentil can cause increase in fat which result in obesity. (https://nirogstreet.com/blog/herbs/masoor-dal-health-benefits)

4. Water uptake behavior and cooking quality of lentil seeds: For the utilization of lentil as food, cooking quality is one of the most important factors. Normally lentil is consumed in cooked form by human. Lentil cooking time differ according to its variety, time of maturity and cooking conditions, so cooking time approximately ranges from 30-70 minutes (Bhatty, 1995) [7]. Excess water is absorbed by lentil seeds during cooking and the high temperature ease the starch gelatinization and a soft structure is form due to protein denaturation process (Abu-Ghannam, 1998; Deshpande and Bal, 2001) [1]. It is described by Deshpande and Cheryan, in 1986 that those seed varieties which are having high absorption rate take less time for cooking. For removing anti-nutritional factors, hydration and cooking are the best methods. The relationship between cooking quality of lentil and hydration coefficient had been scrutinize by Bhatty in 1984 [5]. The results of various seeds showed that if the increase in temperature of soaking medium increases the speed of water uptake and deceases the cooking time (Kon, 1979). Anti-nutritional factors such as tannins, phytic acid and phenolic compounds can be removed by extending the hydration period. But due to prolong hydration and soaking of lentil seeds some metabolic reaction occurs, which leads to the change in components contents (Vidal-Valverde *et al*., 1992) [64]. Batra *et al*., 1986, reported that when the lentil seeds are soaked in distill water for 24 hours the inhibitory activity of trypsine is decreases from 58 to 66%. Heat sensitive factors like trypsin and chymotrypsin inhibitors became inactivate due to cooking and eliminate effects of volatile compounds. The dehulling technique is broadly adopted to decrease the hydration, anti-nutritional factors and cooking time and also increases value of it.

5. Processing of lentil

Lentil is primarily consumed as a whole grain or in dehulled and/or split form as a healthy meal product. Most countries like Latin America, Europe and the Middle East consume it as soups and curries serve with some other cereal-based staple crops like rice and wheat; however, in recent years, lentil flour, starch, or protein concentrates are becoming popular ingredients in many foods. The processing of lentil is divided into three stages; Primary, secondary and tertiary processing. Cleaning, grading, and packaging are all procedures in primary processing that supply the complete seeds for direct sale to customers or downstream processing. The basic premise of primary processing is to utilize a succession of mechanical separation processes to extract complete lentil seeds in their purest form, as well as the desired quality characterized by size, shape, density, and color (Vandenberg, 2009) [66]. Later, these pure and graded seeds are use for the secondary processing, in which, seed's decortications, splitting, sorting and polishing of the whole or split seeds is done. Thermal processing of entire seeds into cans and jars is also done in some situations. Likewise, in the tertiary level of lentil processing, whole or decorticated seeds are grinded, and protein and starch-rich components are separated in order to use them in a wide range of food products.

5.1 Lentil Protein extraction

Lentil is a good source of protein, starch, fibre, etc., which are beneficial for human health. These protein, fibre, and starch concentrate or isolate can be extracted and separated from lentil and other pulses (Boye *et al.*,2010a) [9], and then used as ingredients in a variety of food products preparation like lentil Chips, Lentil soup, pasta plus, pet food, etc.

Pulses protein (20-30%) is highly soluble under alkali and acidulous state, so wet process is the easiest way to extract proteins. Pulse proteins are mostly extracted by alkaline solubilisation. In this process, firstly pulse flour is scatter in water at pH 8.0-10.0, and then the scattered flour is stirred. After stirring for some time, the insoluble material is discarded by centrifugation method and proteins are retrieved by balancing supernatant pH around 4.5, here proteins are triggered isoelectrically. Finally, by using spray method, drum method, or freezing method the final concentrate or protein are dehydrated (Lee *et al*., 2007a) [39].

There were different research works done by many scientists on lentil protein extraction with diluted sodium hydroxide (Bhatty, 1988) [6] under a same pH state which differ from one research work to another. In 2010 [8], Boye *et al*., extracted lentil protein at pH 9.0 and 25 ^{0}C temperature, which was triggered by using ultrafiltration or isoelectric. In it 1:10 solid-to-solvent ration was used from red to green lentils and their yield and protein contents was compared. Likewise, in 2012, Joshi *et al*., extracted lentil protein by alkaline extraction at pH 8.0, 25 ^{0}C temperature with solid-to-solvent ratio 1:10. In

it three methods of drying *viz.* freeze, vacuum and spray drying were used to obtain isolated proteins. Later their physiochemical characteristics were compared. On the other hand, in 2007 Aloshaimy *et al*., extracted lentil protein by utilizing 7 different pH values (from 6.0 to 12.0), 3 distinct processes *viz*., ammonium sulphate precipitation, alcohol precipitation and isoelectric precipitation for protein recapture at 26 ^{0}C temperature and solid to solvent ratio is 5:100. The preeminent protein recapturing (93% to 100%) is obtained at optimum pH 12.0 with ammonium sulphate and alcohol precipitation. In 2007, Lee *et al*., enacted an extensive examination on extraction conditions. They concluded the foremost parameters of protein extraction of green to red lentils, acknowledging 5 pH values *viz*. distill water, pH 8.0, 8.5, 9.0, 9.5 and 4 different temperatures *viz*., 22, 30, 35, 40 ^{0}C while the solid-to-solvent ratio was constant, i.e., 1:10 then the result was estimated according to how much percent of starch damaged and how much protein content is present. After the assessment of all extraction conditions, for green lentil (56.6% of protein) pH 9.0 at 30 ^{0}C and for red lentil (59.3% of protein) pH 8.5 at 35 ^{0}Care regarded as optimum extraction conditions.

6. Breeding approaches for Lentil

Plant breeding has improved the productivity and quality of legumes and other grains and forage crops. Many cereal legume breeding programs have resulted in very high yield improvements over time, but for selective selection focused only on limited breeding and yield potential caused close domestication (Lombardi *et al*., 2014; Foyer *et al.*, 2016) [41, 21]. Domestication of lentils resulted in a 40% loss of genetic diversity, resulting in a small gene pool and low genetic acquisition in breeding programs (Danecekb *et al*., 2011). For example, most of Canada's registered lentil varieties are linked to the two previous varieties that established the Canadian lentil industry, "Laird" and "Eston" (Khazaei *et al*., 2016; Wright *et al*., 2021) [32]. The limited genetic basis of cultivars made them more susceptible to biological and abiotic stress (Singh *et al*., 2018). Exploring genetic diversity and introducing new alleles of native species and wild relatives of crops are essential for the development of high-yield, disease-resistant, and stress-resistant varieties. New breeding approaches, such as hybrid breeding, can maintain genetic diversity and accelerate genetic progress in cereal legumes (Varshney *et al*., 2015) [67]. So far, the classic selection-recombination-selection plant breeding approach has succeeded in introducing some of the easy-to-manage monogenic traits into the lens. However, this approach is less accurate and time consuming when it comes to quantitative traits that breeders are interested in. Some of the economic traits are quantitative in nature and are strongly influenced by the environment-genotype-environment (GE) interaction (Kumar and Ali, 2006). Identification of such traits become an intense and tedious task then and these even complicates the use of different biotechnological approaches *viz*., MAS, MABC, molecular breeding etc., in plant breeding. Current lentil breeding programs lack genomic resources; limiting their ability to implement MAS. The pace of development of lentil genomic resources is slower than that of major legumes such as soybean, common bean, pigeon pea, and chickpea (Kumar *et al*., 2014). Large genome size, narrow genetic basis, lack of candidate genes, sparse linkage maps, and difficulty in identifying useful alleles are major limiting factors for lens genome improvement. Lens bean breeders and geneticists have found some biotic (ascochyta blight, anthracnose, rust, fusarium wilt, stemphylium blight) and abiotic (drought, frost, cold, boron, salinity) related. Molecular tools can be used to understand the genetic basis of the trait emphasized (Kumar *et al*., 2014). Recent developments in Next-Generation Sequencing (NGS) technology have facilitated the development of array-based high-throughput (HTP) genotyping platforms using SNP marker. Bet *et al.*, (2014) performed a large numberof next generation sequences on CDC Red Berry Lentil varieties. This review describes all breeding methods that can be used to improve lentils.

6.1 Selection methods for Lentil improvement

Most of the cultivars introduced in the early phases of lentil varietal development were obtained via selection within diverse landraces. New lentil cultivars/genotypes are presently being generated through crossbreeding as a result of increased efforts in lentil breeding at both the national and international levels. Lentil breeding techniques are comparable to those used to breed other self-pollinated crops, and include pure line selection or hybridization, followed by the bulk method, pedigree method, single seed descent, or a combination of these approaches. A bulk–pedigree approach is employed at the ICARDA, where single plants are selected from F_1, F_2, F_3, F_4 bulks to create F_5 offspring. Various schemes launched by ICARDA are as follows:

- Hybridization (parent Aparent B) at Tel Hadya, Lebanon, and Morocco (year 1)
- Confirmation of hybridity (F_1) at summer nursery, Lebanon (year 1)
- Growing F_2 bulks at Terbol, Lebanon (year 2)
- Growing F_3 generation at summer nursery, Lebanon (year 2)
- Growing F_4 generation: single plant selection in Terbol, Lebanon, and Morocco (year 3)
- Selection among F_5 progenies for uniformity, agronomic traits, and Fusarium wilt reaction at Terbol and Morocco (year 4)
- F_6 homogeneous progenies are evaluated in preliminary screening nursery for yield, agronomic traits, and F. wilt reaction in Morocco (year 5)
- Preliminary yield trial in F_7 at three contrasting locations: Kfardan and Terbol (Lebanon) and Merchouch (Morocco)
- Enhanced yield trial in F_8 at three sites under rain-fed and irrigated conditions except those bred for southern latitude countries
- Seed increase of selected lines in F_9 and their integration into international nurseries in F_{10} generation

The ICARDA's breeding program has a decentralized method. For example, targeted segregating populations are supplied to national programs for single plant selection in their particular edaphoclimatic conditions when breeding for early and extra-early genotypes for southern latitude nations. Similarly, in hot locations, selection for rust, stemphylium blight, and Ascochyta blight resistance is carried out in collaboration with applicable national programs.

6.2 Marker- Assisted Selection for Lentil improvement

Marker assisted selection (MAS) is the approach wherein we pick and breed for an acceptable trait with the help of a marker, or suite of markers, from inside a plant genotype. The

use of markers for lentil breeding applications is presently very limited, due to the fact that the traits can be phenotyped economically. The first genetic map of lentil was constructed using morphological and isozyme markers in early 1980`s (Zamir and Ladizinsky, 1984; Tadmor *et al.*, 1987) [72, 55]. After the invention of molecular markers, which began from the Restriction Fragment Length Polymorphism (RFLP); a pronounced progress has been made in field of molecular marker development and genotyping of lentil crop. Now we have hybridization based DNA markers consisting of RFLP (Havey and Muehlbauer, 1989) [25] and PCR based markers: Random Amplified Polymorphic DNA (RAPD), Amplified Fragment Length Polymorphism (AFLP) and Simple Sequence Repeats (SSR) markers for genotyping the lentil crop. Among the numerous PCR based markers, SSR markers have made vast contribution to the current improvement of lentil genome maps. A set of 122 purposeful SSR markers have currently been included in the genomic library enriched for GA/CT motifs for lentil breeding program (Verma *et al*., 2014) [69].

Recently, the PCR based markers are being swiftlychangedto DNA chip and SNPs. There arenumeroustechnology for assessment of SNP loci and a lot ofthose are amenable to automation for SNP calling and record collections. The availability of sizablecollection database has paved a way for construction of High Throughput (HTP) marker device for genome mapping studies. Recent efforts in re-sequencing alleles to find out SNPs in lentil have facilitated computerized HTP markers. As a result, SNPs have emerged as potential markers for the NGS approach. Approximately 44,879 SNP markers were identified in lentil crop using the Illumina Genome Analyzer (Sharpe *et al*., 2013) [52]. Temel *et al*., (2014) [56] identified another set of 50,960 SNPs and created an SNP-based connection map for the lentil crop. Recent discoveries of high-density SNP markers have facilitated the establishment of ultra-HTP genotyping techniques such as the Illumina Golden Gate (GG) capable of supporting over 1000 SNPs on the GG platform (Sharpe *et al*., 2013; Kaur *et al*., 2014) [52, 31].

The development and utilization of SNP markers in lentil crop is still limited due to the need for expensive and sophisticated platforms for SNP discovery and genotyping. Techniques for detecting SNPs such as allele-specific PCR, single nucleotide extension, and array hybridization methods are available. These are inexpensive and can contain small to medium doses of SNPs for each particular application by using allele-specific PCR (KASPar) markers (Fedoruk *et al*., 2013; Sharpe *et al.*, 2013) [20, 52]. ICARDA is working to develop a MAGIC population with eight parents from different backgrounds in Lentil crop. These multiparent populations can be used asexcellent genetic resources for gene identification, isolation and transfer of key candidate genes, and development of widely adapted lentil cultivarsfor future lentil crop improvement programs (Kumar *et al*., 2021) [37].

6.3 Mutation Breeding for Lentil improvement

Lentil production has many limitations, such as the low yield and susceptibility to diseases. To address these limitations, creation of genetic variability is a very important factor. As the crop itself lacks much variability. Mutation breeding; an alternative/artificial way of creating genetic variability in field of plant breeding can come as a rescue; in such conditions. Mutagens (physical/chemical) have been used, and chemical mutagens are more effective in inducing a higher frequency of mutant plants in M_1 and M_2 generations than gamma rays (Solanki and Sharma, 1994) [62]. Among different physical methods used; Gamma rays were the most common mutagen used to create mutants in plants.

Sharma and Sharma (1986) [50] found that the 50% reduction in germination (LD_{50}) occurred between 13.5 and 18.6 kR for lentil microsperm and between 9.2 and 10.7 kR for lentil macrosperm. (Malik *et al*. 1998) found that the LD_{50} for plant survival was 25 kR. Chlorophyll mutations were found to be induced at 6kR, 10kR and 15kR. (Paul and Singh, 2002, Sharma and Sharma, 1984, and Malik *et al*., 1998) found that the dose range for induction of mutation in chlorophyll production and morphological traitsvaried from crop to crop. The character which were improved using mutation in lentil were high yield, seed and pod size, cooking quality, drought tolerance, early maturity, resistance to lodging and resistance to blight and rust. As per the mutant variety database (www.iaea.org),13 lentil mutant varieties were released: Auris, Binamasur-1, Binamasur-2, Binamasur-3, Djudje, Elitsa, Mutant 17 MM, NIAB MASOOR 2002, NIAB MASOOR 2006, Rajendra Masoor 1, S-256 (Ranjan),Verzuie, and Zornitsathe. The first one WBL-256 (Ranjan) was released in Indiain 1981 by using X-rays from parent variety B 77 (Tuhin *et al*., 2016). TILLING(targeting induced local lesions in genomes) has largely replaced the direct approach in studies involvingscreening for gene function. TILLING has been applied to many legumes such as lotus, peanuts and soybeans (Perry *et al*., 2003, Guo *et al.*, 2015, Cooper *et al.*, 2008) [46, 24, 13]. The inexpensive TILLING technique was developed by the IAEA (The International Atomic Energy Agency) to detect mutation (Till *et al.*, 2015).

6.4 Major Achievements

6.4.1 Varietal Releases at Global level: To present, 34 nations have registered 137 lentil varieties for better yield, disease resistance, and other features in this effort.

6.4.2 Widening the Genetic Base of Lentil Cultivars in South Asia

Introgression of genes from the ICARDA into the area where lentil cultivation is undertaken extended the genetic base. In Bangladesh with collaborations of ICARDA, early maturing, high-yielding, and disease-resistant cultivars have been developed: BARI M4, BARI M5, BARI M6, and BARI M7;in national programs, which has aided in enhancing lentil productivity in Bangladesh.

6.4.3 Reconstruction of Genotypes Suitable for Mechanization

According to on-farm trials and demonstrations Mechanical harvesting paired with superior cultivars decreases harvest costs by 17–20 percent on average.

7. Conclusion

Lentil is an essential legume crop that contributes to human and animal nutrition as well as soil enhancement. It is one of the most important food legumes and which is least affected by change in climate and soil. Over the last decade, global lentil output has gradually increased. Lentils' nutritional value is undeniable due to the abundance of minerals, polyphenols, proteins and other essential components. Lentil is nutritionally rich and most important it is part of daily diet of Indian food system. India grow pulses; still import a sizeable amount of pulses: India exported nearly 0.3 million MT of pulses while

imported 2.5 million MT worth of 1.63 billion USD (https://agriexchange.apeda.gov.in/). Such figures give an alarming bell to increase the pulse production in India including lentil. In milieu of aforementioned conditions, pulse production can be increased by accelerating the breeding prphran in lentil; for which: identifying desired variability for target traits;creation of genetic variability if lacked in available germplasm with the help of mutation breeding, hybridization based breeding methods; use of molecular biology etc., can be carried out. Traditional breeding approaches have proved usefulin exploiting available genetic variability, which we can witness in form of several red and yellow cotyledon lentil cultivars with tolerance/resistance to cold, Ascochyta blight rust, and wilt. In the last decade several linkage maps have been developed to identify QTL / genes for traits of interest the Lens genus. This opens up room for improved consistent genomics compliance in the lentil breeding program.

8. Abbreviations

% – Percentage
AFLP – Amplified Fragment Length Polymorphism
cDNA – Complementary Deoxyribonucleic acid
cm – Centimeter
DNA – Deoxyribonucleic acid
et al. – and others
FOASTAT – Food and Agriculture Organization Corporate Statistical Database
GA/CT – Guanine Adenine/ Cytosine Thymine
GE interaction – Genotype Environment interaction
GG – Golden Gate
HTP – High Throughput Phenotyping
IAEA – The International Atomic Energy Agency
ICARDA – International Centre for Agricultural Research in the Dry Areas
ITIS – Integrated Taxonomic Information System
kDa – Kilodalton
LD – Lethal Dose
MAGIC population – Multiparent Advanced Generation Intercross population
MAS – Marker Assisted Selection
MABC – Marker Assisted Backcrossing
NGS – Next Generation Sequence
PCR – Polymerase Chain Reaction
pH – Potential of Hydrogen
QTLs – Quantitative Trait Loci
RAPD – Random Amplified Polymorphic DNA
RFLP – Restricted Fragment Length Polymorphism
RIL – Recombinant Inbred Lines
SNP – Single Nucleotide Polymorphism
SSR – Single Sequence Repeat
TILLING – Target Induced Local Lesions in Genomes
viz – that is to say; namely

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