Chapter 3

Biodiversity and varietal development of pulses in South Asia

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Introduction

South Asia (Afghanistan, Bhutan, Bangladesh, India, Maldives, Nepal, Pakistan, and Sri Lanka) is the largest producer, consumer and importer of pulses with 28% and 38% share in global production and acreage. It grows pulses on 32.63 million ha area and produces 21.68 million tons of chickpea (10.92 mt), dry beans (4.50 mt), pigeonpea (3.31 mt), lentil (1.51 mt), peas (0.84 mt) and grasspea (0.45 mt) (Table 1). Contribution of South Asia in global production is 77% chickpea, 68% pigeonpea, 31% lentil, 18% dry beans, and 7% pea. During the last five decades, production of pulses has increased from 11.63 million tons to 21.68 million tons in South Asia, thanks to addition of 5 million ha area under pulses and yield increase by 230 kg/ha.

Table 1. Area, production and yield of pulses in South Asian countries in 2014

Country	Area (million ha)		Production (million ton)		Yield (kg/ha)		Major pulse crops
	1964	2014	1964	2014	1964	2014	
Afghanistan	0.02	0.08	0.02	0.06	916	752	Mungbean, chickpea, lentil
Bangladesh	0.38	0.35	0.27	0.35	719	1000	Lentil, lathyrus, mungbean, urdbean, pea
Bhutan	0.002	0.004	0.001	0.005	452	1059	Common bean, urdbean, pea
India	24.40	25.21	10.30	19.25	422	764	Chickpea, pigeonpea, urdbean, mungbean, lentil, pea, grass pea
Nepal	0.19	0.29	0.09	0.31	490	1062	Lentil, urdbean, pigeonpea, grasspea
Pakistan	1.85	1.43	0.94	1.03	508	721	Chickpea, mungbean, urdbean, lentil
Sri Lanka	0.01	0.02	0.01	0.03	463	1298	Mungbean, cowpea, urdbean
South Asia	26.86	32.63	11.63	21.68	433	664	Chickpea, pigeonpea, mungbean, urdbean, lentil, pea, cowpea, lathyrus
World	72.88	85.63	46.80	77.60	642	906	

Among SAARC countries, India has the distinction of being the largest producer of pulses accounting for nearly 25% of global output. India grows pulses on nearly 25.20 million ha area with 19.25 million tons production. Pakistan is the second largest pulse producing country in the region with 1.03 million tons production. Bangladesh and Nepal grow pulses on nearly 0.3 million ha each. Though in limited areas, pulses are also grown and consumed in Sri Lanka, Afghanistan and Bhutan. The present productivity of pulses in South Asia is substantially low (664 kg/ha) as compared to global average of 906 kg/ha. To bridge demand-supply gap, South Asia imports about 5 million tons of pulses (Figure 1). In order to augment pulses production in the region, collaborative efforts are thus required for development of improved varieties of appropriate crop duration having resistance to key diseases prevalent in the region.

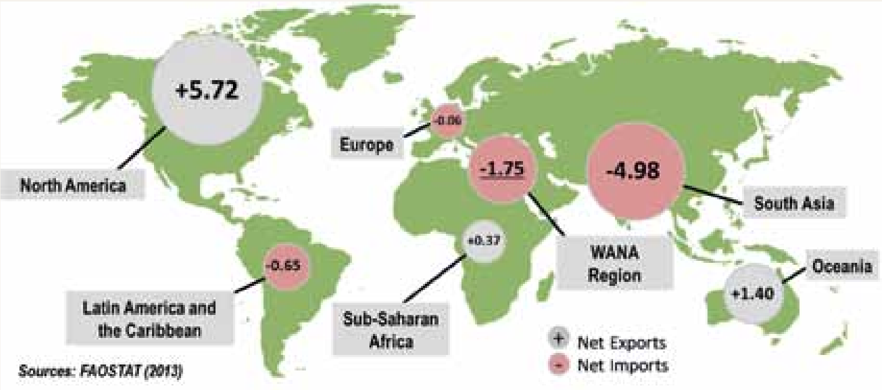

Figure 1. Regional import and export of pulses on global map

Varietal Development

Past breeding efforts for development of improved varieties have been successful with more than 1000 varieties of different pulse crops released for cultivation in SAARC countries (Table 2). Some of the improved varieties released in one country have been introduced and found wide acceptance and adaptability in neighboring countries. In spite of a large number of improved varieties, narrow genetic base has been identified as a major constraint for spectacular genetic gains in pulses. This is basically due to bottlenecks during the process of evolution and domestication, which was further compounded during the directed breeding programs undertaken at various research stations (Kumar et al. 2004). Pedigree analysis of varieties of different pulse crops released in India clearly showed extensive and repetitive use of the superior genotypes as one of the parents in hybridization (Kumar et al. 2007). This suggests that there is an urgent need to broaden the genetic base of cultivated species of different pulse crops. The detail list of varieties released in SAARC region is given in Annexure-1.

Table 2. Number of improved varieties of pulse crops released in SAARC countries

Crop	Afghanistan	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka	Total
Chickpea	5	18		171	7	27		**228**
Lentil	2	16		52	10	11		**91**
Mungbean	2	16	2	141	3	15	3	**182**
Common bean	4			31	2			**37**
Black gram		4		89	1	7	2	**103**
Grass pea		5		4				**9**
Field pea		1		78	3			**82**
Cowpea		2		82	6		6	**96**
Pigeon pea				112	2			**114**
Others			2	41			3	**46**
Total	**13**	**62**	**4**	**801**	**47**	**60**	**14**	**1001**

Compiled from country report

Pulses Genetic Resources

To improve the genetic yield potential of pulse crops, immediate steps are required to collect, exchange, evaluate and utilize germplasm as well as improved breeding material among the SAARC countries. India has reported a large collection of germplasm. The present plant genetic resources conserved at NBPGR includes 14704 accessions of chickpea, 12859 of pigeonpea, 9989 of lentil, 5549 of Vigna species, and 2797 of lathyrus (Table 3). Considerable unexplored biodiversity still exists for pulse crops in the region which requires immediate exploration and collection. While it is important to collect and preserve genetic resources in gene banks, more important is to utilize them for widening the genetic base through pre-breeding efforts. In the past, dependence on limited variability has resulted in narrow genetic base for many important traits. Major reason for dismal use of genetic sources has been lack of precise information on economic traits. Precise evaluation of germplasm for important traits is the weakest link in pre-breeding activities. It is estimated that 80-95% accessions in the world collection lack proper characterization and evaluation data. To facilitate easy accessibility and use of germplasm available with gene banks, core and mini core sets and Focused Identification of Germplasm Strategy (FIGS) sets can be of great help.

Table 3. Germplasm accessions of various pulse crops in SAARC countries

	Global Status	CG Center	India	Bangladesh	Nepal	Pakistan	Sri Lanka
Chickpea	98285	33359	14704	752	-	2333	-
Lentil	58405	10864	9989	406	489	808	38
Vigna species	-	-	5549	581	650	1442	203
Common bean	261963	35891	1514	551	650	109	222
Grass pea	26066	3225	2797	1845	-	148	-
Field pea	94001	6129	3070	-	-	-	-
Cowpea	65323	15588	3317	-	-	212	-
Pigeon pea	40820	13289	12859	79	-	-	-
Faba bean	43695	9186	-	-	-	-	-
Others	183078	13690	19579	-	-	238	-
Total	**1069897**	**141221**	**73378**	**4214**	**3357**	**5290**	**463**

Source: http://www.fao.org/agriculture/seed/sow2/

Research Achievements

Food legumes improvement program at ICARDA is built upon the foundation of its vast germplasm collections and its use to breed new varieties better adapted to different agro-ecological conditions. ICARDA genebank holds 38,000 accessions of chickpea, faba bean, lentil, pea and grass pea. Except for a few traits, sufficient variability for important economic traits is reported in the existing germplasm. To increase the use of germplasm in breeding programs, the Focused Identification of Germplasm Strategy (FIGS) is recently being pursued at ICARDA with robust geographical datasets. The strategy has proven successful for various adaptive traits such as tolerance to heat, drought, cold, and salt, besides resistance to insect pests and diseases. Such FIGS sets in chickpea, lentil and faba bean are now available to NARS partners to discover and deploy the useful genes into desired agronomic background.

ICARDA breeding program generally uses parents of diverse origin with an aim to combine traits contributing to yield, appropriate phenology, adaptation to major biotic and abiotic stresses and market preferred traits. Following a selection-hybridization-selection cycle, ICARDA constructs new breeding lines to deliver to the NARS partners in the form of international nurseries (IN). These nurseries comprise a range of genetically fixed materials and segregating populations to provide opportunities to NARS partners for selection. On the basis of phenological adaptation, agronomically desirable traits, resistance to prevailing stresses, quality aspects, farmer's and consumer's preference, NARS partners identify and select promising lines/single plants for eventual release as variety for commercial cultivation.

Over 368 varieties of lentil (137), kabuli chickpea (162), faba bean (75), and grass pea (7) have been released for cultivation in target countries. During the last ten years, NARS partners have released 85 varieties of these crops using ICARDA material (Figure 2). Focused programs on breeding have shown profound effect on production and productivity. These gains become more spectacular when viewed with markedly reduced crop duration of these varieties. This has increased the per day productivity comparable to any rainfed crops besides making them suitable for introduction in new niches and diversification of the existing cropping systems. Some of the specific success stories of ICARDA partnership with NARS are well documented. In South Asia, one of the major achievements is the breaking of an ancient bottleneck of narrow genetic base in lentil. Genetic base has been broadened through introgression of genes from ICARDA germplasm in the region. In Bangladesh, adoption of improved varieties like BARImasur-4, BARImasur-5, BARImasur-6 BARImasur-7 and BARImasur-8 has helped in improving lentil productivity in the country. Impact study showed that these improved varieties are cultivated over 110,000 ha in Bangladesh, delivering an annual extra production gain of some 55,000 tons, and valued at US$ 38 million annually. In grass pea, two varieties BARIKhesari-3 and BARIKhesari-4 are recently developed for rice systems. Development of extra-early varieties of chickpea and lentil offers opportunities for intensification and diversification of existing cropping systems in addition to introduction in new niches such as rice fallows in South Asia. Identification of new sources of extra earliness in lentil from a wild accession, ILWL118 having less than 90 days maturity has resulted in development of new breeding lines which can fit in rice-lentil-boro rice system in South Asia.

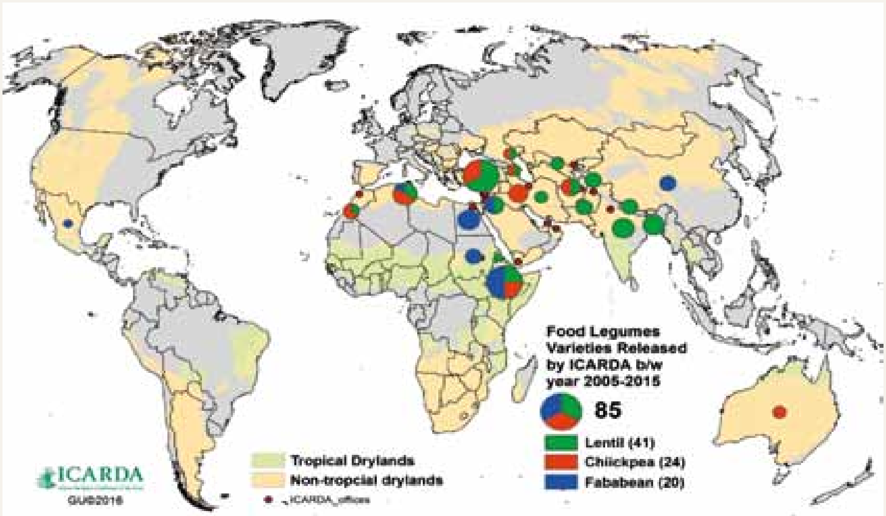

Figure 2. Improved varieties of pulses released in different regions using ICARDA germplasm

Pre-breeding for widening the genetic base: There is a growing concern on limited genetic diversity due to frequent use of limited germplasm in breeding improved varieties. Genetic enhancement through pre-breeding is proposed for increasing the extent of useful diversity available to breeders through introgression of desirable traits from exotic material and wild species. ICARDA in collaboration with NARS partners in India have initiated a prebreeding program on chickpea and lentil which has been instrumental in introgressing useful genes in the mainstream breeding (Kumar et al. 2011). Identification of a new source of extra earliness in lentil from a wild accession, ILWL118 having less than 90 days maturity has resulted in development of new breeding lines which can fit in rice-lentil-boro rice system in South Asia. Pre-breeding efforts in chickpea, pigeonpea and Vigna crops have started showing its results in releasing enormous variability for useful traits in breeding materials. Some of the varieties released through pre-breeding efforts are HUM 1, Pant Mung 4, Meha and UPM 02-17 in mungbean, and Mash 1008 in urdbean. Some of the promising lines like Mash 114 emanating from inter-specific cross have shown yield superiority of 40% in multi-location trials. With rapid generation advancement and recent successes and availability of new biotechnology tools have brightened the prospects of transferring useful traits from exotic materials as well as primary and tertiary gene pools in pulses.

Improving plant type: Pulses are grown under varying agro-ecological conditions and each set of conditions needs a specific plant type for higher productivity. Most pulse crops still have wild traits like indeterminate growth habit, pod shattering, pre-harvest sprouting and sensitivity to photoperiod and temperature regimes. It is presumed that the determinate types under good management would partition photosynthate to yield components with greater efficiency. Similarly, photo and thermo insensitive varieties will be able to have wide adaptability with minimum seasonal and regional effects on their phenology and yield potential besides a more synchronous reproductive ontogeny and greater harvest index. Breeding objectives need to be directed keeping in mind the impact of altered plant types on the yield of the component crops. Simulation models developed recently for some of the legume crops offer the potential to interpret and predict the performance of individual genotypes in different environments thus offering a possible role in decision-making regarding suitability of the proposed plant type in the target environment and prevailing cropping systems.

Short duration varieties: Expansion of area under irrigation and availability of more productive cereal varieties and production inputs have resulted in substantial reduction in area under pulses in South Asia. With cereal yields projected to double over the next 30 years, pulses would likely to be further pushed out, unless extra-early varieties are developed that can fit in the short season windows of the existing cereal based systems. Extra-early varieties (<90 days) escape end-of-season drought and heat stresses in addition to fitting the crops in available short windows of these cropping systems. After the harvest of wheat, fields are commonly left fallow as insufficient moisture prohibits the reliable production of rainfed summer crops in South Asia. Planting mungbean in summer/spring is one of the key components for obtaining a reduced or negative carbon footprint besides increased rice-wheat yields, enhanced soil fertility, increased water use efficiency, as well as decreased losses in yield and quality from weeds and soil borne diseases.

Managing weeds: Weeds (parasitic and non-parasitic) pose serious challenge to food legumes production. Non-parasitic weeds compete with crops for light and nutrients, often leading to significant yield losses of up to 40% in legume crops. Use of non-selective herbicides is effective in removing all types of weeds in a single application; however, herbicide resistant varieties need to be developed. Recent progress in identifying herbicide tolerant germplasm within the cultivated species has shown promise for development of herbicide-tolerant varieties. For example, varieties with improved tolerance to herbicide metribuzin have been developed by screening the advanced breeding lines for herbicide tolerance in faba bean, lentil and chickpea. Genotypic differences have been reported for tolerance to imidazolinone class of herbicides in chickpea, lentil and faba bean.

Conclusion

Population in South Asia is rising and is about 1.55 billion at present which, by any standard, is overpopulation accounting for one fourth of the current global figure. Natural resources like land and water on which food grains production relies are limited, and competition from other sectors is causing enormous pressure on their availability to agriculture. This will be further challenged by changing climate which may manifest itself in the form of shifting rainfall pattern, untimely and erratic rains, extreme temperatures, etc. which may also change the cultivation pattern of pulses. For developing climate smart varieties, landraces and wild relatives which are rich reservoir of useful alien genes can play an important role. There is a strong need to formulate strategic planning to achieve the goal focusing on broadening the genetic base of pulses for breaking yield barriers, hybrid development in pigeonpea, and transgenics in chickpea and pigeonpea. In the past it may have been sufficient to develop a variety well adapted to a particular agro-ecological region taking into account the well understood abiotic and biotic constraints and end-product quality. With climate and farming system changes are becoming a reality, a dramatic shift in production base is expected to take place. Wide genetic base of cultivated varieties provides a kind of insurance against the epidemics of diseases and insect pests besides, of course, making the cultivated germplasm more amenable to breeding advances through conventional and biotechnological approaches. For efficient utilization of large germplasm, core and mini-core sets representing maximum variability of the germplasm collection needs to be phenotyped precisely and efficiently followed by their utilization in breeding program and multi-location evaluation.

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