Food and Agriculture Organization of the United Nations

2016 INTERNATIONAL YEAR OF PULSES

Proceedings of the regional consultation on the promotion of pulses in Asia for multiple health benefits

Bangkok, Thailand, 29 to 30 June 2015

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AEC	Asean Economic Community
AFTA	ASEAN Free Trade Area
AGLN	Asian Grain Legumes Network
AVRDC	World Vegetable Center
BADC	Bangladesh Agricultural Development Corporation
BARI	Bangladesh Agricultural Research Institute
BGM	botrytis gray mold
BINA	Bangladesh Institute of Nuclear Agriculture
BOAA	beta-oxalyl-amino-alanine
BSMARU	Bangabandhu Sheikh Mujibur Rahman Agricultural University
CAAS	Chinese Academy of Agricultural Sciences
CARDI	Cambodian Agricultural Research and Development Institute
CARS	China Agriculture Research System
CLAN	Cereals and Legumes Asia Network
CLIMA	Centre for Legumes in Mediterranean Agriculture (Australia)
CLS	cercospora leaf spot
CRISPRs	clustered regularly interspaced short palindromic repeats
YMV	yellow mosaic virus
DAE	Department of Agricultural Extension
DAP	Department of Agricultural Planning
DAR	Department of Agricultural Research
DANIDA	Danish International Development Agency
DARI	Dryland Agricultural Research Institute
DHSC	Department of Horticulture and Subsidiary (Cambodia)
DoA	Department of Agriculture
DSI	drought susceptibility index
FAO	Food and Agriculture Organization of the United Nations
FCRDI	Field Crops Research and Development Institute (Sri Lanka)
FSN	farming systems for nutrition
GDA	General Directorate of Agriculture (Cambodia)
GDP	gross domestic product
GI	glycemic index
GMO	Genetically Modified Organism
HI	harvest index
IAARD	Indonesian Agency for Agricultural Research and Development
ICAR	Indian Council of Agricultural Research
ICRISAT	Internatioal Crops Research institute for the Semi-Arid Tropics
ICARDA	International Center for Agricultural Research in the Dry Areas

ICM	integrated crop management
IDF	insoluble dietary fibre
IFAD	International Fund for Agricultural Development
IGP	Indo-Gangetic Plains
IITA	International Institute of Tropical Agriculture
ILETRI	Indonesian Legumes and Tuber Crops Research Institute
IPCC	Intergovernmental Panel on Climate Change
IPM	integrated pest management
MAFF	Ministry of Agriculture, Forestry and Fisheries (Cambodia)
MAS	marker-assisted selection
MOA	Ministry of Agriculture
MOAD	Ministry of Agricultural Development (Nepal)
MOAI	Ministry of Agriculture and Irrigation (Myanmar)
MSSRF	M.S. Swaminathan Research Foundation
MYMV	mung bean yellow mosaic virus
NAFRI	National Agriculture and Forestry Research Institute (Lao PDR)
NARC	Nepal Agriculture Research Council
NGS	next generation sequencing
OARD	Office of Agricultural Research and Development (Thailand)
OPV	open pollinated variety
PARC	Pakistan Agricultural Research Council
PAE	phosphorus acquisition efficiency
PDA	Provincial Department of Agronomy
QTL	quantitative trait loci
RDA	Rural Development Administration (Korea)
RFO	raffinose family oligosaccharides
RIL	recombinant inbred line
SPII	Seed and Plant Improvement Institute (Iran)
TAC	total antioxidant capacity
TPC	total phenolic content
TDF	total dietary fibre
UK	United Kongdom
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
WHO	World Health Organization
WTO	World Trade Organization
WUE	water use efficiency

Executive summary

A. Setting

To set the stage for activities in observance of the International Year of Pulses 2016, declared by the 68th session of the UN General Assembly, FAO's Regional Office for Asia and the Pacific, in collaboration with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the International Center for Agricultural Research in the Dry Areas (ICARDA), organized a regional consultation from 29 to 30 June 2015 in Bangkok, Thailand. The theme of the meeting was "Promotion of Pulses for Multiple Benefits in Asia." A total of 39 participants from 13 countries – Bangladesh, Bhutan, Cambodia, India, Indonesia, Islamic Republic of Iran, Lao PDR, Republic of Korea, Myanmar, Nepal, Pakistan, Sri Lanka and Thailand – attended the meeting in addition to FAO officials and senior scientists from ICRISAT and ICARDA.

Hiroyuki Konuma, Assistant Director-General, FAO Regional Office for Asia and the Pacific, in his opening address highlighted the important contribution that pulse crops have made and will continue to make to achieving food and nutrition security for the millions of people living in the Asian region. Konuma stressed that pulses are inextricably linked with the culture, beliefs and economy of the region. Pulses are also an integral part of Asian farming systems with direct involvement of women farmers. Konuma highlighted the relevance and timeliness of the consultation as a backdrop to declaring 2016 the "Year of Pulses" and said collaboration of ICRISAT and ICARDA, both involved in the field of pulses, highlights the importance of working together both regionally and nationally to provide support to the millions of pulse growers in the region.

He pointed out that pulse farming is being pushed out to more marginal and non-productive lands due to conflicts with competing crops such as rice and wheat and thus production of pulses remains low. The price of pulses is at least three times higher than rice and wheat.

The removal of pulses from age old cropping patterns is also believed to be one of the reasons for low productivity of soils. Being a crop of rainfed areas, pulses are also highly vulnerable to natural disasters and climate change. Therefore, effects of the changing environmental conditions on pulses have a greater impact on this crop, he said.

Four experts presented papers covering scientific and technical aspects of pulse cultivation such as research, development and outreach activities; impact of climate change and the importance of pulses for providing nutritional security. Outputs gathered from technical presentations, country reports, group discussions and open discussions were used in drafting the recommendations of the meeting.

B. Recommendations

1. Mobilize adequate government support and advocacy in support of policy formulation, institutional arrangements and research and development (R&D) of pulses with an emphasis on inclusion of pulses in cropping systems aimed at enhancing food and nutrition security.

2. Enhance funding of pulse research programmes, strengthen infrastructure and develop human resources, modernize research programmes with the use of genomic resources, bioinformatics and other modern tools and advanced methods.
3. Conduct research for development of labour-saving technologies (varieties suitable for machine harvesting, herbicide resistance); tools/machines to enhance mechanization; varieties and technologies for boosting resilience to climate change, enhancing nutritional quality attributes (protein, minerals, vitamins) and reducing anti-nutritional factors (phytate, RFOs, etc.).
4. In view of the markets for pulses being thin and fragmented, undertake a range of measures to improve market functions and the supply chain for pulses, including providing market intelligence and increased support to market chain development and R&D on value-added products with a focus on building adequate storage, grading, milling, and secondary processing facilities.
5. Taking into account the high vulnerability of pulse crops to both biotic (pests and diseases) and abiotic stresses (temperature extremes and aberrant rainfall driven by climate change), design and implement appropriate crop insurance schemes as a hedge against crop failures.
6. Improve economic attractiveness of cultivation of pulse crops through provision of incentives to famers, such as competitive price support through government procurement programmes, low-interest credit, and provision of subsidies on pulse-specific inputs.
7. Undertake focused extension efforts for popularization and expansion of pulse cultivation – strengthening linkages between research and out-scaling, village-level quality seed production by farmers and farmers' associations in addition to formal seed production; creating hubs for custom hiring of farm machineries by small and marginal farmers; ensuring participation of various stakeholders in consultation meetings, etc.
8. Conduct farmer-participatory trials to promote adoption of improved cultivars and technologies, including integrated crop management (ICM) practices along with the provision of input supplies. Develop and strengthen sustainable community-based seed production systems.
9. Where appropriate policies and capacities exist for the enforcement of biosafety guidelines for confined testing and environmental release, consider undertaking research on Genetically Modified Organisms (GMOs) in pulses.
10. To sustain continued focus on pulses, ensure the flow of international funding support for pulse R&D and exchange of information and experience, establish regional, inter-country networks in R&D; conduct periodic meetings to secure support from FAO, UN bodies, CG Centres, and other development partners.
11. Establish a Legume Asia Network (LAN) to facilitate sharing of germplasm/breeding materials, information and also to develop joint projects for funding.
12. Undertake educational and training programmes to create awareness among school children (include in school curriculum), farmers and extension personnel the value of pulses (human, animal and soil health) and its human health benefits.
13. Consider incorporating pulses as an essential ingredient in national food security programmes like mid-day meals etc.
14. Upgrade the value chain of pulses through (a) promotion of technology (post-harvest storage and milling, ICT for access to information, mechanization); (b) organizing smallholder producers (contract farming, farmer motivation, curtailing middleman

involvement in the marketing chain); (c) improving market information drawing on the study of different types of pulse value chains including indigenous value chains in the region.

I. Inaugural session

Following the opening address by Hiroyuki Konuma, Assistant Director-General, FAO Regional Office for Asia and the Pacific, M.S. Swaminathan, a renowned Indian geneticist, well-known internationally for his leading role in India's Green Revolution, delivered the keynote speech.

Professor Swaminathan explained that an increase in the production of protein-rich pulses such as lentils, chickpeas and other varieties could help feed the world as the global population is expected to surpass nine billion by 2050, and thus contribute to meeting the Zero Hunger Challenge introduced by the UN Secretary-General in 2012. Climate smart agricultural approaches would be necessary and make more efficient use of water to achieve 'more crop per drop.' He added that policy makers would also need to play a critical role to assist smallholders through remunerative price support and assured markets.

Subash Dasguptma, in stating the meeting objectives and programme, informed participants that from time immemorial people in many societies across Asia, Africa and Latin America grew pulses in their farming systems in a number of ways – as a rotation crop with staple cereals in the crop field, on field margins, as hedge crops in agro-forestry systems and in homestead backyards. In South Asia, pulses come next only to rice and wheat in importance as food, reflected in the term *dal-bhat* (pulse-rice), which resonates well in people's consciousness as the foundation of food and nutritional security. Pulse crops gradually lost their competitive edge, diminishing their prospect for sole cultivation as a commercial crop. Food security, in essence, turned into security in basic cereals creating a gaping hole in intake of essential nutrients, particularly by poor and low-income households. Although food security for some countries, by and large, is within reach, achieving nutritional security still remains a distant elusive goal.

Many countries have started attempts to reverse this scenario by rearranging research priorities and allocating budgets for research and development in pulses. Modern high-yielding varieties have been developed for major pulse crops such as chickpea, pigeonpea, mungbean, lentil, field pea and other crops. These varieties are yet to reach farmers' fields and they have to be adapted to the impacts of climate change, notably high temperatures above normal that prevailing during the pulse growing season. Although South Asia remains the largest producer and consumer of pulses in the world, none of these countries is anywhere closer to achieving self-sufficiency in pulses and they have to import substantial quantities to meet their demand for pulses. The scenario is similar in East Asia, where domestic production of pulses meets only a fraction of the demand.

In spite of their huge advantage, the area, production and productivity of pulse crops has been decreasing over the past decade. A reduction in the production and productivity of pulses is not a good sign. It has resulted in increased imports and affected the nutritional food security of poverty-stricken people, which is further deteriorating as per caput availability of pulses is shrinking. The pulse production scenario must be changed urgently and a strategy for meeting the future demand of pulses should be developed giving emphasis to research, resource availability and technology transfer.

Keynote speech

Pulses and the zero hunger challenge
Professor M.S. Swaminathan
UNESCO Chair in Ecotechnology, MSSRF, Chennai, India

Introduction

The Zero hunger challenge rests on five pillars – 100 percent access to adequate food all year round, zero stunted children less than 2 years of age, all food systems are sustainable, 100 percent increase in smallholder productivity and income, zero loss or waste of food (Ban Ki-moon, UN Secretary-General). The three major dimensions of hunger are calorie deprivation, protein deficiency and micronutrient deficiency. The M.S. Swaminathan Foundation has developed the concept of farming systems for nutrition (FSN) to address the issue of eradication of hunger. FSN involves the introduction of agricultural remedies to the nutritional maladies prevailing in an area through the mainstreaming of nutritional criteria in the selection of the components of a farming system involving crops like pulses, farm animals and, where feasible, fish. While finalizing the components of a farming system, the gender and age dimensions of human nutritional needs are kept in view, such as the special needs of pregnant women and nursing mothers, and new born babies during the first 1 000 days after birth. Biofortified crops are introduced in FSN, wherever available. The introduction of FSN paves the road to sustainable agriculture.

Among the crops, pulses are a relatively cheap and affordable source of protein and other nutrients that can play an important role in providing nutritional security for countries with a sizeable population living at or below the national poverty lines. India is the world's largest producer and consumer of pulses. Pakistan, Canada, Myanmar, Australia and the United States of America (USA), in that order, are significant exporters and are India's most significant suppliers. Canada now accounts for approximately 35 percent of annual global pulse trade. The global pulse market is estimated at 60 million tonnes.

The major pulse crops of India, in order of importance, are chickpea (*Cicer arietinum*), pigeonpea (*Cajanus cajan*), lentil (*Lens culinaris*), mungbean (*Vigna radiata*), blackgram, also called urad bean, (*Vigna mungo*), pea (dry pea *Pisum sativum*) and greengram (*Lathyrus sativus*). The growth in area under pulses in India follows a positive trend with considerable year-to-year fluctuations. Between 1980/81 and 2012/13, the total cropped area under pulses increased from 22.46 million hectares (mha) to 23.47 mha with the peak 26.40 mha attained in 2010/11. Growth in production of pulses over this period was increasing faster from 10.63 mha in 1980/81 to 18.34 mha in 2012/13 driven primarily by an increase in yield from 473 kg/ha to 781 kg/ha over this period.

Despite the increases, average pulse yields in India are much lower than the world average. The Government of India provides policy support in the form of minimum support prices to farmers in order to boost pulse production (Figure 1). The government has recently announced a bonus of Rs. 200 per quintal (100 kg) of pulses produced in order to provide an incentive to farmers. Maintaining a sustainable growth in productivity and production of pulses is an important priority of the government given a stagnant scenario of per capita net availability of pulses (Figure 2).

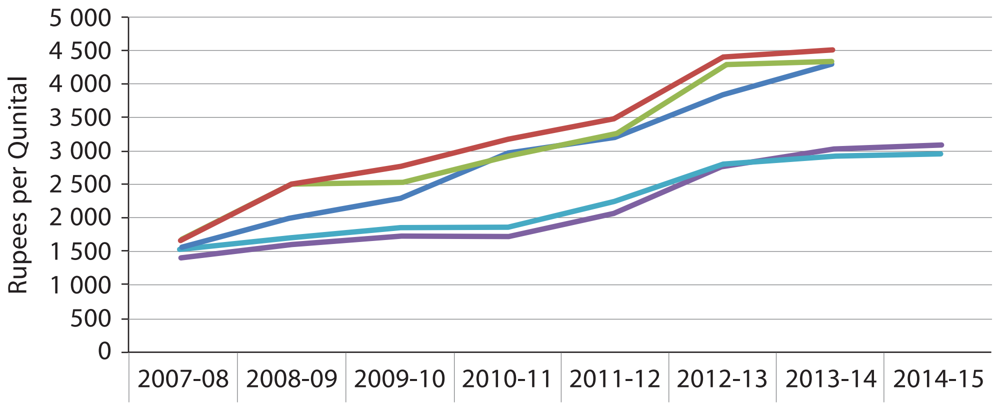

Figure 1. Trend in minimum support prices for pulses

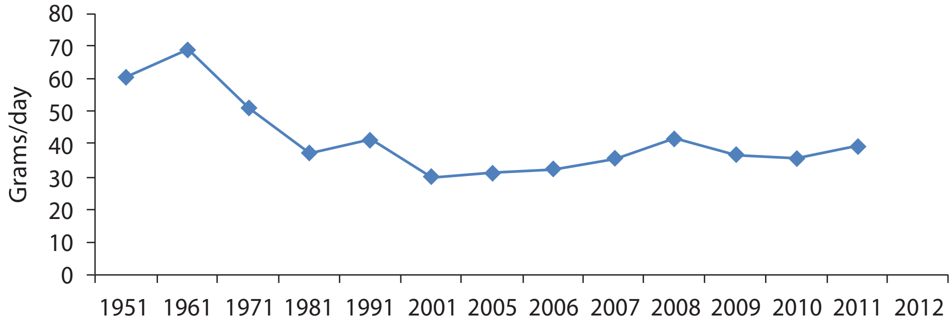

Figure 2. Per capita net availability of pulses

To meet the persistent deficit of domestic production of pulses, India imports about 4 million tonnes of pulses annually from various sources – yellow/green peas from Canada and Russia, chickpeas from Australia, lentils from Canada, green and blackgrams from Myanmar and pigeonpeas from Myanmar, Tanzania, Mozambique and Malawi.

Farming system for nutrition: components

- Cropping of greengram
- Intercrop of cotton and pigeonpea
- Overcoming protein hunger

As was the case with grain cereals, a revolution is needed to stimulate a sustainable long-term growth in productivity and production of pulses capitalizing on opportunities for both vertical and horizontal expansion. To drive home this point, the FAO has declared 2016 as the International Year of Pulses. The use of modern technologies of plant breeding remains the key to addressing this challenge. The technological platform rests on the following:

- Development of high-yielding improved cultivars of major pulse crops.
- Increased use of the tools and methods of precision breeding.
    - Use of genome sequence data of chickpea (*Cicer arietinum*) for trait improvement.
    - Marker-assisted breeding.
- Functional genomics
    - Exploring the CRISPR system. It is a prokaryotic adaptive immune system that uses a RNA guided nuclease/Cas9 (isolated from *Streptococcus pyogenes*) to silence viral nucleic acids. Recently it has been engineered for genome editing.

- The CRISPR/Cas9 system recognizes the DNA through an RNA-DNA interaction between the target site and a CRISPR based guide RNA.
- Cas9 nuclease makes a double-strand break in DNA at a site-determined by a short 20 nucleotide guide RNA.

Advantages of the CRISPR gene editing technology

- Targeted mutagenesis/non-GMO.
- Desired mutations at intended, specific loci.
- Multiplex genome editing can be achieved.
- End-product is often indistinguishable from conventional mutation breeding.
- More efficient screening and breeding (homozygous mutant plants can be achieved in T_2 generation).
- More importantly, no foreign DNA will be present in the plant genome (foreign DNA will be eliminated in subsequent generation).

Improving soybean oil quality through a precise genome engineering approach

- Soybean oil is high in polyunsaturated fat (PUF) and is often partially hydrogenated to increase its shelf life and improve oxidative quality.
- The trans fat produced through hydrogenation pose a health threat.
- Consuming trans fat increases low-density lipoprotein (LDL or bad cholesterol), which contributes to the leading cause of coronary heart disease.
- Soybean lines that are low PUFs were generated by introducing specific mutations using TALENs in two fatty acid desaturase genes (*FAD2-1A* and *FAD2-1B*).

Examples of genes that could be targeted for pulse improvement using a genome engineering approach

- Creation of disease tolerant genotypes (e.g. mutations in Mildew Resistance Locus O (MLO) genes for powdery mildew resistance, a common fungal disease in pulses.
- Improving pulse seed quality by targeting antinutrients. Example: Reducing phytic acid content by targeted disruption of phytic acid pathway.
- Generation of abiotic stress tolerant crops.

Enhancing pulse production in India: challenges

- Achieve production at 32 million tonnes by 2030. Close the gap between demand and supply.
- Bringing an additional 3-5 million hectares under pulse cultivation.
- Doubling the yield from 700 kg/ha.

Strategies for enhancing pulses production

- Widen the genetic base
  - Characterize genetic resources of pulses using molecular and taxonomical tools.
  - Undertake prebreeding using exotic, landraces and wild species to create wide variability for plant types, disease and pest resistance and abiotic stress tolerance.

- Expand area of pulses
  - Promote pulses cultivation in rice-fallows through introducing short-duration varieties of pulses as a main/catch crop.
- Enhance adoption of improved cultivars
  - Promote farmer-participatory varietal selection trials (FPVS).
- Climate smart agricultural practices
  - Grown in rainfed conditions in marginal lands by small and marginal farmers.
  - Farmer producer company.
  - Ensure conservation and equitable sharing of water resources.
  - Value chain-based Integrated Crop Management – Soil Health and Biological software for sustainable agriculture.
- Knowledge management (ICT)
  - Knowledge development and dissemination through Village Knowledge Centers using ICT tools.
  - Farmers Field Schools/Farmers Plant Clinics/Pulse Entitlement Cards/Technical flyers – Mass dissemination.
- Post-harvest – storage, processing and value addition, branding and marketing
  - Implemented through Farmer Organizations.
  - Establishment of Pulses Panchayats.
  - Linkages with financial institutions for input, credit procurement, value addition, branding and marketing.

Monsoon and agriculture

- Promote community or individual rainwater harvesting and conservation in farm ponds. Community conservation and use will require assurance of equity in sharing the harvested water. The conserved water will help to provide crop life-saving irrigation when and where needed.
- Establishment of seed bank which will provide seeds of the same or alternate crops, in case there is early withdrawal of monsoon or the inter-spell duration is long.
- In rainfed areas, farmers can take to the cultivation of climate smart pulses, millets and oilseeds so that some income accrues even under conditions of uncertain rainfall.
- Arrangements for suitable agricultural machinery which can help to prepare the soil speedily for sowing. This is particularly important in the heavy black cotton soils of central India.

Strategies to improve pulse productivity and production

- Develop short-duration, high-yielding varieties.
- Develop varieties with improved drought tolerance.
- Expand new niches – chickpea in rice fallows.
- Introduce pigeonpea in rice wheat cropping systems.
- Improve seed systems through creating seed villages.
- Improve input supply, micronutrients and fertilizer.
- Introduce crop life-saving irrigation.
- Introduce mechanization.
- Provide remunerative support price and assured marketing.

II. Technical session

A. Summary of technical papers

Pooran M. Gaur from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) presented a paper titled "Research, development and outreach activities for enhancing pulse production in Asia". The paper focused on opportunities that Asian countries can take advantage of in boosting productivity and production of pulses. The emphasis was on futher development of improved cultivars and production technologies to cope with the emerging challenges of sustaining production of pulses in farming systems of Asian countries.

Gaur identified restructuring of plant types of pulse crops as it was accomplished with cereals as a major technological option to break new ground in elevating the yield potential of pulses. Distinct plant types need to be developed to suit both irrigated and rainfed growing conditions. Currently available improved varieties tailored to rainfed cropping and minimum application of external inputs respond poorly to a high level of fertilization and irrigation. The new varieties should also have erect to semi-erect plant stature to allow mechanized harvesting given the high cost and relative scarcity of human labour.

To cope with anticipated negative impacts of climate change, there is a need to develop climate-smart varieties that are endowed with improved capacity for recovery after exposure to stress. In essence, this means varieties with enhanced tolerance to a range of abiotic (high temperature and drought, waterlogging, soil salinity) and biotic stresses (insect-pests and diseases) the severity of which may be enhance, with the progress of climate change.

The presenter highlighted the options for breeding new varieties of pulses with improved traits. Hybrid technology has become feasible in pigeonpeas. Recently released hybrids of pigeonpeas in India have demonstrated a 30–40 percent yield advantage in farmers' fields. Pod borer continues to remain a major and challenging insect-pest of pulses. It has not been possible to develop varieties with high levels of resistance to pod borer due to the non-availability of sources with high levels of resistance in the germplasm of cultivated species. In this respect, wild species of pulses and transgenics need to be exploited in breeding programmes to improve pod borer resistance.

Wide variation has been observed for iron and zinc content in the germplasm, which can be exploited for developing high iron and zinc varieties. This would allow a higher amount of protein and other nutrients from the same amount of pulses consumed. Early/extra-early maturity is an important trait for breeding pulse varieties suitable for expanding cultivation of pulses in non-traditional seasons or between two cereal crops as catch crop.

One of the constraints in growing pulses in rainfed rice-fallows is crop establishment. Current field preparation methods lead to losses of moisture. Thus, sowing pulses in rice-fallows has to be done with minimum or zero tillage. The agronomic practices need to be standardized including seed priming and seed treatment with fungicides/insecticides, application of rhizobium inoculant, and sowing method (relay cropping, seed dibbling and sowing with zero till seed drill).

In his presentation, Gaur stressed the application of novel methods and tools in breeding programmes and the use of controlled environment facilities (green houses, growth chambers) for rapid generation advancement of breeding materials and phenotyping platforms for high throughput screening of genetic materials and use of electronic field books and data management systems for increasing efficiency. There has been rapid progress in the development of low cost genotyping platforms and genomic resources in recent years. The draft genome sequence is now available for most of the pulses. Integrated breeding involving genomic approaches needs to be used for higher precision and efficiency of breeding programmes.

A strategy was outlined for outreach activities with available improved cultivars and technologies. This consisted of (1) promoting pulse cultivation in rice-fallows; (2) bringing additional area under pulses through intercropping and sequential cropping; (3) promoting the ridge and furrow method of planting pulses in the rainy season; (4) integrated nutrient management; (5) promoting micro-irrigation; (6) integrated pest management; (7) faster mechanization of pulse cultivation, (8) policy support and (9) further strengthening of collaboration among Asian countries for development and exchange of technologies on pulses.

P.S. Basu from the ICAR-Indian Institute of Pulses Research presented a paper titled "Impact of climate change on pulses development in Asia." The paper explored the impacts of climate change primarily in the context of rainfed cultivation which is being increasingly exposed to higher temperatures. The deficit of soil moisture further amplifies the impact and as a result potential yields of most pulses are reduced. The majority of pulse growing countries like India, Pakistan, Bangladesh, Nepal, Bhutan, Myanmar, Viet Nam, Cambodia and Thailand are particularly vulnerable to the impacts of climate change due to their strategic geographical locations in the mid-north latitude nearer to the equator where maximum threshold temperature for tolerance of pulses has already reached 35ºC. A further rise in temperature, as it is evident now, will adversely affect the productivity of pulses in these areas. Increased CO_2 level in the atmosphere is not beneficial for pulses grown under a stressful the environment.

Both drought and heat are recurrent phenomen in South and Southeastern Asian countries. Gene mining for stress tolerance from diverse germplasm collections, including wild species will remain the great strength for evolving newer varieties tolerant to multiple abiotic stresses. The mechanisms of heat and drought tolerance in pulses have been deciphered. Drought-specific genes, Dreb 1A, Dreb 1B and Osmotin, are being used to develop drought-tolerant chickpea and pigeonpea. Drought-specific signal molecules ABA and its role in drought tolerance have been characterized. Identification of linked quantitative trait loci (QTLs) for root and high yield and marker-assisted selection (MAS) have opened new horizons in the field of drought research.

Rapid advancements in genomics provide an opportunity of molecular mapping of QTL controlling heat tolerance and using marker-assisted breeding for development of heat tolerant varieties with suitable agronomic background and desired seed traits. Molecular markers will be soon available for major heat tolerance QTL in some legumes which will further facilitate breeding for heat and drought tolerance. Root-based traits are being used to improve drought tolerance in major pulse crops. However, yield stability of pulses requires less genotype × environment interaction and wider adaptability across the environment. The physiological trait such as water use efficiency is considered to be the most important to contribute to grain yield and biomass under drought condition. A large pool of pulse germplasm is available which needs to be evaluated for drought tolerance and high water-use efficiency.

Jagdish Singh and N.P. Singh from the Indian Institute of Pulses Research presented a paper titled "Importance of pulses as a source of nutrition in the Asian region". In their presentation, the authors focused on the unique nutritional profile of pulses – low-fat source of digestible protein, (typically contain about twice the amount of protein found in whole grain cereals like wheat, oats, barley and rice), dietary fibre (containing both soluble and insoluble fibres), complex carbohydrates, resistant starch and low glycemic index and a number of essential vitamins and minerals such as iron, potassium, magnesium, zinc and selenium.

Pulse carbohydrates are slowly digested which allows some of the lowest Glycemic Index (GI) among carbohydrate-containing foods. Pulse GI typically range from about 29 to 48 (using glucose as the standard). The relatively slow digestibility and hence low GI of pulses has been attributed to several constituents, including carbohydrate composition, protein content and protein-starch matrix, and antinutrient factors such as enzyme inhibitors (e.g. amylase inhibitor, trypsin inhibitor), phytates, lectins, saponins, and tannins. Pulses are also particularly abundant in B vitamins including vitamin B9 (folate), thiamin and niacin. In addition to contributing to a healthy, balanced diet, pulses contain a number of bioactive substances, including enzyme inhibitors, lectins, saponins, phytates, oligosaccharides, and phenolic compounds which makes them particularly helpful in the fight against some non-communicable diseases often associated with diet transitions and rising incomes.

Enzyme inhibitors can diminish protein digestibility, and lectins can reduce nutrient absorption, but both have little effect after cooking. Phytic acid can diminish mineral bioavailability. Some phenolic compounds can reduce protein digestibility and mineral bioavailability, and galactooligosaccharides may cause flatulence. On the other hand, the same compounds may have protective effects. Phytic acid exhibits antioxidant activity and protects against DNA damage, phenolic compounds have antioxidant and other important physiological and biological properties, and galactooligosaccharides may elicit prebiotic activity. Encouraging awareness of the nutritional value of pulses can help consumers adopt healthier diets and also could be an important dietary factor in improving longevity.

B. Summary of country reports

Bangladesh

Major pulse crops grown in Bangladesh are grass peas, lentils, mungbeans, blackgrams and chickpeas. They occupy about 93 percent of the total pulse area and contribute 97 percent to total production. The area, production and yield of different pulse crops in Bangladesh exhibited a declining trend over the period 1985–2005. The total area under pulse cultivation dropped from 734 500 ha to 275 300 ha (37.5 percent) over the period 1985/90–2005/06 and production fell from 510 520 tonnes to 208 500 tonnes (41 percent) during this period. The main reasons for the decline of pulses is crop competition in Rabi season as well as yield instability of pulses due to biotic and abotic constraints. Cultivation of boro rice expanded to the areas growing grass peas, chickpeas and field peas in the medium low land, while wheat, potatoes, maize and vegetables have taken over the lands of lentils, mungbeans and blackgrams.

The present cropping intensity is 190 percent and the scope of expansion for pulses as a sole crop is very limited. Therefore, the strategy for expansion of pulses cultivation should be built on (1) increasing productivity through adoption of improved varieties and cultural practices (vertical expansion) and (2) increasing area through introduction of new cropping patterns and utilization of fallow lands (horizontal expansion).

Fifty-six varieties have been released by the national agricultural research system, most of which are high yielding and tolerant to major diseases and other stress factors. At research stations the yields of these varieties are high but in farmers' fields the yields are much lower. The seed yield of new lentil varieties ranged from 2 000 to 2 200 kg/ha at research stations and averaged

1 350 kg/ha at on-farm trials, whereas the national average yield of lentils is only 738 kg/ha, which is about one third of the potential yield. These varieties along with their production technologies should be extended to farmers to replace the low-yielding local cultivars, which will ultimately enhance productivity.

Rabi pulses should be introduced as intercrop/mix crop/relay crop in the cropping system. Research should focus on developing disease resistant, short-duration and high yielding varieties that are suitable for existing cropping patterns. To popularize improved pulse varieties, production technology and technical support should be extended to farmers.

Bhutan

The Kingdom of Bhutan is a small landlocked mountainous country located on the southern slopes of the Eastern Himalayas and surrounded by two giant countries – China in the north and India in the south. According to the Bhutan Land Cover Assessment 2010, only 2.93 percent of the country's total geographical area is cultivated agriculture land, of which 61.9 percent (69 670.79 ha) is dry land, 27.9 percent (31 361.23 ha) is wetland (irrigated paddy field) and 10.2 percent (11 524.19 ha) is horticultural land. The average cultivated agriculture landholding is about 3 acres (RNR statistics, 2012). Pulses or grain legumes have played and will continue to play a diverse role in Bhutanese farming systems, e.g. as a food crop through direct consumption as grain, green pod and leaves thereby contributing towards food security and dietary diversity goal, as a cash crop through sales, which helps reduce poverty and as fodder crop, thereby contributing to livestock productivity and as a rotation crop. They are grown in diverse land use systems, but more than 75 percent of the national legumes or pulses are grown on dry lands (National Legumes Survey, 1999). While the survey of 1999 has recorded 16 species, the most widely grown pulse species in Bhutan are rajma beans (*Phaseolus vulgaris*), mungbeans/green grams (*Vigna radiata*), urd beans/black grams (*Vigna mungo*), lentils (*Lens esculenta*) and soybeans (*Gycine max*). Pulses or grain legumes are either intercropped with maize or mono cropped as a succeeding crop following crop rotation. Unlike in maize, in rice-based systems, legume crops, largely urd beans, are planted along the terrace bunds following the paddy transplantation.

Cambodia

The major food legume crops grown in Cambodia are mungbeans, soybeans and peanuts. The results of recent research conducted by the Cambodian Agricultural Research and Development Institute (CARDI) indicated that mungbeans and peanuts were potentially high-yielding crops suitable for growing on the sandy soil in the rainfed lowland areas after harvesting wet season rice. Four mungbean varieties (*CMB1, CMB2, CMB3* and *CARDI's Chhey)* have been released by CARDI since 2009 which are grown after harvesting wet season rice. These are short-duration varieties requiring 50–55 days from planting to the first harvest.

Field demonstrations on integrated technology for growing mung beans in sandy soil after wet season rice, including land preparation, planting techniques, application of recommended fertilizer rates, crop management and the released new variety were conducted from 2009 to 2014 in the rainfed lowland areas following wet season rice in three provinces (Kampong Thom, Kampot, and Takeo).

The results of field demonstrations showed that with the application of CARDI's technology package, farmers obtained an average 561 kg/ha grain yield of mungbeans. However, with proper crop management practices yields increased up to 1 062 kg/ha. The average grain yield was nearly double compared with only 275 kg/ha obtained using farmers' traditional practices. Similarly, gross income also doubled to 2.93 million Riels/ha with the use of CARDI's technology compared with 1.07 million Riels/ha obtained using traditional practices only.

China

China is one of the biggest producers of pulses in the world. Major pulse and food legume crops grown in the country are soybeans, broad beans, peas, chickpeas, lentils, common beans, cowpeas, adzuki beans, peanuts, pigeonpeas, mungbeans, lima beans, etc. China accounts for 39.7 percent of the global production of broad beans, 37.3 percent of peanuts, 60 percent of green peas, and 75 percent of common beans (green). Except for soybeans and peas, average yields of most pulses obtained in China are higher than the world average.

The demand for pulse crops is projected to grow significantly along with the rising living standards of the people and increasing awareness about consumption of healthy food. Since China became a member of the World Trade Organization (WTO) in 2001, the import of soybeans and peas from the USA, Canada, Brazil and Argentina was increasing rapidly, which depressed the market price of dry pulses. This has resulted in driving down the returns in domestic production of dry grain pulses and a decrease in the sown area and total production. At the same time, the increasing trend of Chinese consumers to eat traditional food based on vegetable pulses, as well the as growing appreciation of health benefits of vegetable pulses has led to a sharp increase in vegetable pulse production in China. This also benefits the cropping systems by reducing crop duration as pulses are grown for consumption as vegetables.

In the future, pulse-based cropping systems that include dry pulse production will likely remain static or decline and the vegetable pulse production is likely to increase rapidly. Therefore, breeding research on genetic resources and genetic studies in China will be oriented to supporting vegetable pulse production and strengthened at national and provincial levels.

India

In India, over a dozen pulse crops including chickpeas, pigeonpeas, cowpeas, mungbeans, urd beans, lentils, French beans, horse grams, field peas, moth beans, lathyrus, *etc*. are grown. However, the most important pulse crops are chickpeas (41 percent), pigeonpeas (15 percent), urdbeans (10 percent), mungbeans (9 percent), cowpeas (7 percent) lentils (5 percent) and field peas (5 percent).

India has been a world leader in production as well as consumption of pulses. The country harvested a record 19.27 million tonnes of pulses in 2013-2014. Notwithstanding an impressive growth of pulse production in the country, import has also shown a positive trend over the years, while exports remained almost stagnant.

The area under pulse cultivation in the country is estimated to be about 25-26 million hectares and realized productivity is less than 1 tonne/ha. Because major pulses are largely cultivated under rainfed and monsoon-dependent areas where soil moisture is the critical factor determining the productivity, the production trends keep fluctuating every year depending upon rainfall. The major constraints to realization of potential yield of pulses include biotic and abiotic stresses prevalent in the pulse-growing areas besides socio-economic factors.

The requirement of pulses has been projected to reach 32 million tonnes by 2050 taking into account the estimated growth of the population to 1.69 billion by 2050 and the availability of protein in diets from some other sources such as milk products. Reaching this goal requires the annual production of pulses to grow at 2.2 percent against the current growth rate of 3.5 percent. This target seems to be well within reach despite the myriad looming challenges such as climate change-driven distribution of rainfall and temperatures, decreasing water and land resources, etc. A tangible step in this direction will be increasing the average productivity of pulses above 1 200 kg/ha and bringing an additional area of about 3.5 mha under pulss cultivation. Reducing post-harvest losses by 10–15 percent from the current losses will also add another 1 mt of pulse grains.

Vertical expansion of pulses in the country through yield enhancement can be achieved by development of input-responsive and climate-resilient varieties of pulses, varieties with multiple resistance to diseases and insect pests, short-duration varieties that fit well in different cropping systems and increasing the harvest index. Similarly, development of new plant types for different agro-climatic situations, and development of photo-thermo insensitive cultivars in crops like mung beans and urdbeans will help expand the area of these crops in to non-traditional areas of the country. This will also help develop varieties that could perform equally well in different seasons and locations.

Indonesia

Among the various pulses grown in the country, mungbeans (*Vigna radiata*) occupy the largest area followed by cowpeas and pigeonpeas. During the last seven years, the cropped area and grain production of pulses showed a decreasing trend. The area declined to 182 075 ha in 2013 from 306 207 ha in 2007. During this period, no significant change in productivity of pulses was observed with 1.109 tonnes/ha in 2013 as against 1.053 tonnes/ha in 2007.

Research and development of pulses in Indonesia is still limited. The constraints to pulse development trace their origin to agro-ecological factors, production systems, farmers' socio-economic conditions, product development, and marketing. Breeding research on pulses in Indonesia is focused on developing and releasing new varieties with high yield potential for various sub-optimal agroecologies, early maturity, and resistance to pests and diseases. Research on mungbeans attracts priority over other pulses. Because pulses are not considered a staple food, serious attention and efforts are needed to raise the status of pulses in Indonesia, which is now considered a neglected crop.

Opportunities for improving productivity and production of pulses lie in modernizing breeding programmes to develop and release new varieties, organizing quality seed production, implementation of the full recommended technology packages, and their rapid dissemination to farmers. Post-harvest research, especially on the development of pulse-based food products, remains central to driving the market demand for pulses. The development of potential areas for expanding pulse cultivation should be directed to provinces with the most favourable agro-ecological conditions, such as Bali, East Nusa Tenggara, Yogyakarta, West Java, Central Java, East Java, and South Kalimantan.

Islamic Republic of Iran

Chickpeas and lentils are the two major pulse crops grown in the Islamic Republic of Iran. Most of the chickpea (97 percent) and lentil (94 percent) areas are planted under rainfed conditions and are grown in rotation with cereals, mainly wheat and barley. Beans, faba beans and mungbeans are planted on about 150 000 ha under irrigated conditions in the Islamic Republic of Iran.

The major constraints influencing the productivity of chickpeas and lentils include poor agronomic practices, drought, heat, ascochyta blight, fusarium wilt and cold. The agronomic practices for chickpea and lentil cultivation, including date of sowing, seed rate, method of sowing, plant population, weed control, and method of harvesting have been researched and recommendations developed for different areas.

Improved chickpea varieties (Hashem, Arman, Azad, Adel, Saral and Sameen), lentil varieties (Gachsaran, Kimiya, Bilesevar) and bean varieties (Dorsa, Sadri, Pak and Shekofe) were released in the last decade. Efforts are being made to transfer these recommendations to farm level with the help of extension specialists. Research on exploration of the possibility of winter planting of chickpeas and lentils in milder environments and *entzari* planting in harsh (severe cold) environments has yielded promising results. Transfer of these technologies to farmers is in progress and in some areas farmers are getting almost 50 percent or more productivity with the adoption of winter- or *entezari* sowing. Research in pulses is conducted by DARI (Dryland Agricultural Research Institute) and SPII (Seed and Plant Improved Institute) in collaboration with other research organizations in the Islamic Republic of Iran and with international research centres such as ICARDA, ICRISAT and CIAT.

Lao PDR

Mungbeans, cowpeas, soybeans and peanuts are the most common grain legumes grown in Lao PDR. Farmers widely grow mungbeans in low-lying areas and mostly during the rainy season. Soybeans are grown in rainfed upland areas and irrigated lowland after harvesting rice. Peanuts are grown on sandy soil along the Mekong river bank and the banks of other major rivers. They are also grown, to some extent, in irrigated rice fields, most peanuts are grown in the dry season.

Increases in pulse production are achieved through the promotion of short-duration pulse crops. A focused attention on Integrated Pest Management has also triggered interest and facilitated the increase of productivity and production of pulses. Better access to water through irrigation and access to quality seeds and credit for growers also are critical factors to the development of pulse production.

Currently, the Agricultural Research Center (ARC) under the National Agriculture and Forestry Research Institute (NAFRI) of the Ministry of Agriculture and Forestry of Lao PDR is conducting research on legumes such as germplasm collection and breeding, improving cultivation tehnology and extension of legume cultivation.

ARC has developed a breeding programme for high yield, early maturity varieties that show tolerance to biotic and abiotic stresses, and are adaptated to a large spectrum of weather conditions for peanuts, soybeans and mungbeans. ARC has promoted intercropping and crop rotation systems on farmer field plots, including legumes (peanuts, soybeans and mungbeans) and major crops such as rice, maize and cassava. Also, the ARC has introduced soil nutrient improvment practices by using pigeonpeas as green manure.

Myanmar

Pulses are grown throughout Myanmar, but 92.0 percent of total pulses growing in the country are concentrated in the Ayeyarwaddy, Magwe, Pegu, Mandalay, Sagaing and Yangon regions. The major pulse crops of the country are mungbeans, blackgrams, pigeonpeas, chickpeas, soybeans, butterbeans, kidney beans, cowpeas, lab lab beans, sultani and sultapya. More popular among these are mungbeans, blackgrams, pigeonpeas, chickpeas, soybeans and cowpeas. In general, pulses are mostly grown in two seasons: (i) monsoon season (May–July), and (ii) post-monsoon season (October–December). Mungbeans, pigeon peas and soybeans are grown in the monsoon season, while blackgram, chickpeas, and cowpeas are grown during post-monsoon season. And also mungbeans are grown in the post-monsoon season after the rice harvest in the lower part of Myanmar.

Production of major pulses is constrained by both biotic and abiotic stresses. In mungbeans and blackgram, mungbean yellow mosaic virus, root rot (*Rhizoctonia bataticola*), maruca (*Maruca testularis*), armyworm (*Spodoptera litura*), common hairy caterpillar, and leaf roller are among the biotic stresses. Pod borer (*Helicoverpa armigera*) infestation occurs every year throughout the growing season.

There are a number of technological options available for increasing the productivity and production of pulses. These use short-duration and high-yielding varieties with resistance to diseases and pests, improved varieties with drought tolerance, adoption of good cultural practices (pest and disease management, weed control methods) and introduction of new adapted crop varieties, new cropping pattern for fallow land area and supplies of quality seed and improved varieties to farmers. Moreover, on-farm research and development programme can enhance participation of farmers and securing their cooperation in improving pulse productivity and production.

Nepal

Grain legumes are grown mainly as a rainfed crop (dependent on residual soil moisture) both in the terai and in the hills. Winter legumes such as lentils, chickpeas, and grasspeas are grown mainly in the rice-based system of the terai and inner terai. Warm season grain legumes such as soybeans, blackgram, pigeonpeas and horse grams which are produced in the maize-based system of the hills. In the higher mountainous regions, peas and phaseolus beans are the two most important summer legumes. Winter grain legumes crops are grown dependent on residual soil moisture after the harvest of rice or seed broadcasted on standing rice about 7–15 days prior to rice harvest (relay cropping). Warm season grain legumes are grown during summer months (monsoon rain) in mono, mixed with maize/finger-millet or on paddy bund.

Legume crops can be attractive commodities for Nepalese farmers to earn cash for better living conditions. Diverse climate and environmental conditions of Nepal offer opportunities for growing many species of food legumes and these crops fit well in the Nepalese cropping systems prevailing in most of the agro-ecological zones and can be grown in various seasons (winter, spring and summer seasons).

The cultivation of lentils is increasing because of the increasing preference for its internal consumption and potential for export markets. Nepalese lentils are much in demand in the international market. Bangladesh, Singapore, Sri Lanka, Germany, Republic of Korea, United Kingdom (UK) and Indonesia are its major export markets. Soybeans are identified as an industrial crop and important ingredient for the poultry industry.

Pakistan

Four major pulse crops – chickpeas (*Cicer arietinum*), lentils (*Lens culinaris* Medik), mungbeans (*Vigna radiata*) and mashbeans (*Vigna mungo)* – are commonly grown in Pakistan. Among these, chickpeas are the major winter food legume and mungbeans are the major summer legume. Chickpeas occupy 76 percent of the total pulses area contributing 73 percent to total production and mungbeans occupy 12 percent of total pulses area contributing 14 percent to total pulses production. More than 80 percent of pulses are grown in Punjab and the rest of the area is spread in to other provinces.

Th production of pulses can be increased by adopting high-yielding varieties and production technology developed through coordinated research. Major outputs of the coordinated efforts was the release of 27 varieties of chickpeas, 11 of lentils, 15 of mungbeans and 7 of mashbeans for commercial cultivation. Development of chickpea varieties resistant to blight (*Ascochyta rabiei)* and release of short duration mung and mashbean varieties coupled with matching agro-technologies brought expansion in new niches and diversification in the existing cropping systems. There is great potential in central Punjab and Sindh to intercrop mungbeans with sugarcane. Similarly, short duration varieties of mungbeans can be successfully grown as catch crop in rice-wheat cropping systems to expand the area of cultivation and improve soil fertility. Development of high-yielding, early maturing and disease resistant genotypes along with viable seed production and dissemination systems will play a major role in pulse crop production in future.

Republic of Korea

The Republic of Korea is one of the most important pulse crop producing countries in Asia. The most edible pulses grown in the Republic of Korea are soybeans, adzuki beans, mungbeans, cowpeas, common beans, and peas. About 89 percent of the total pulse production in the Republic of Korea comes from soybeans. They are grown on a range of land types from the plains to the mountainous regions. The cropped area remained fairly constant for all pulse crops between the early 1970s and the late 1980s followed by a steady decline in subsequent years.

Over the last 30 years, extensive breeding efforts to improve the yield led to higher production from less land depending on specific use. For example, even though the area of soybean cultivation decreased from 188 431 ha in 1980 to 85 270 ha in 2004, improved varieties such as Hwangkeumkong, Taekwangkong, Daewonkong, and Daepungkong for tofu and soy sauce allowed soybean yields to increase. The major constraints to productivity are: limited size of land holding, condition of land, unfavourable weather conditions, and management. Pulse crops, considered as poor-income crops, are grown mostly in the middle to high mountainous regions because these areas are unfavourable for growing most other crops.

As the total demand of pulse crops increases, researchers are currently working on the development of varieties to improve food quality in the Republic of Korea. There has been much research associated with identification of important agronomic QTLs in soybean. Significant progress has been made by institutes and universities in molecular marker development because they have great potential in improving breeding efficiency. In fact, with the advent of next generation sequencing (NGS) technologies, the Republic of Korea has recently released the whole genome sequence of mungbeans and adzuki beans that will be very useful in pulse crops breeding programmes. However, a combination of marketing and scientific approaches will still be inadequate to achieve 100 percent self-sufficiency in soybeans, mungbeans, adzuki beans, cowpeas, common beans, and peas in the foreseeable future. This demands that efforts remain focused on steady development of agricultural research and administration policies to support the production of pulse crops in the Republic of Korea.

Sri Lanka

Pulses such as mungbeans, cowpeas, soybeans and blackgram play a prominent role in the cropping systems of dry and intermediate zones in Sri Lanka owing to their wide ecological adaptability. More than 85 percent of pulse crops are grown under rainfed conditions ("*maha*" season) in the dry zone which receives between 1 200 mm and 1 900 mm of rainfall annually covering two-thirds of the country.

The major constraints impacting on productivity of pulses were identified as limited use of high-yielding varieties and fertilizer, use of poor quality seed, poor adoption of recommended agronomic practices, poor use of inputs, high incidence of pest and diseases, high risk associated with rainfed farming and high cost of production inputs such as labour. Being the main responsible institute, the Field Crops Research and Development Institute (FCRDI) in the Department of Agriculture has developed high-yielding improved varieties and technologies in order to improve productivity of the pulse crops. The most important constraints limiting productivity were insects, pests and disease outbreaks in the field and storage pests. No resistant or highly tolerant varieties have been recommended and released against very serious stored pests (bruchids) in cowpeas and viruses in mungbeans.

Thailand

The area under pulse cultivation in Thailand has been declining because of lack of quality seed, unsuitable environment and competition with higher-income crops. Major pulses grown in the country are soybeans, mungbeans and peanuts. But the cropped area under pulses is declining because of inadequate supply of quality seed, increasing exposure to unfavourable growing environment and lack of competitive edge over other alternate crops. These constraints, however, should not get in the way of realizing a whole range of unique benefits to be derived from cultivation and consumption of pulses. They are full of essential nutrients for people and animals, in addition, they have a short production period that allows inclusion cropping systems leading to improvement of soil properties and sustainability of intensive agriculture.

Many types of food processing industries established in the country serve as the basis for expanding the market and driving the demand for pulses which will incentivize efforts for increasing domestic supply of pulses through both horizontal and vertical expansion (enhancing productivity). Other measures are development of national standards in seed production systems, value added product development and strengthening research and development on pulses. Finally farmers should be involved in the knowledge dissemination process. These processes should be applied to enhance pulse production.

III. Concept Note and Programme

Regional Consultation on
"Promotion of Pulses for the Multiple Benefits in Asia"
29-30 June 2015, Bangkok, Thailand

CONCEPT NOTE

Introduction

Pulses have a unique nutritional profile rich in high quality protein. Being the principal source of dietary protein, they are also called the meat of the poor in many developing countries. Pulses contain 22–24 percent protein, which is almost twice the content of protein in wheat and three times that in rice. In addition, pulses are an excellent source of essential amino acids, fatty acids, mineral and vitamins. They also contain several anti-nutrients believed to play a role in energy regulation. Pulses are also relatively low in energy density and a good source of digestible protein. Their carbohydrates are slowly digested, which allows some of the lowest glycemic index (GI) among carbohydrate-containing foods. In most developing countries, pulses play a fundamental role as a low-fat, high-fibre source of protein, an essential component of traditional food baskets.

Pulses are a regular part of the diets of millions of people, consumed by both vegetarian and non-vegetarian segments of population in various forms. Over 60 percent of the total utilization of pulses is for human consumption. But the importance of pulses in human diets varies from region to region and country to country, with a general trend of higher consumption in lower income nations. The share of food use in total utilization of pulses in the developing countries is over 75 percent, compared with 25 percent in the developed countries.

Pulses contribute about 10 percent of the daily protein intake and 5 percent of energy intake and hence are of particular importance for food security in low income countries, where the major sources of proteins are non-animal products. In addition, pulses also contain significant amounts of other essential nutrients like calcium, iron and lysine. Pulses are locally adapted and can be grown by farmers for their own nutrition as well as for sale, which is important to improve food security. They are highly accepted crops which keep well in storage.

Pulses also play an important role in improving soil health, long-term fertility and sustainability of the cropping patterns. They meet up to 80 percent of their nitrogen requirement by biological nitrogen fixation from air and leave behind substantial amounts of residual nitrogen and organic matter for subsequent crops.

Inclusion of pulse crops in the cropping system improves the organic carbon content of the soil. Pulses can be grown under a wide range of soil and climatic conditions. They play important roles in crop rotation, mixed and inter-cropping, maintaining soil fertility through nitrogen fixation, release of soil-bound phosphorous, and thus contribute significantly to sustainability of the farming systems.

Pulses, such as dry peas, lupins and beans are also used as feedstuff. Some 25 percent of the total use of pulses goes for feeding animals, namely pigs and poultry. Complementing animal feed with improved varieties of pulses has been shown to significantly improve animal nutrition too, yielding better livestock, which in turn supports food security.

Despite having superior nutritional quality over cereals and being well adapted under local conditions, the cropped area under pulse crops and their productivity in this region have been slowing down lessening food and nutrition security of millions of smallholder and other farming communities. In many countries these crops are still surviving in subsistence farming thanks solely to the initiatives of poor farmers. There is a real danger that if this trend continues, production of pulses may become extinct in future.

This set the stage for FAO RAP to hold a regional consultation to help member countries share knowledge of their respective countries in these fields in order to promote these crops in a sustainable manner.

Objective

The proposed Regional Consultation is planned to apprise member countries on the current status of pulse R&D and outreach programmes, input delivery systems, capacity building, socio-economic impact, value chains including processing and marketing, climate change adaptation, and a whole range of other factors responsible for low productivity, production and under-utilization of pulses with the ultimate goal of improving food and nutrition security of smallholder farmers and poor consumers by increasing pulse production, productivity and farmers incomes.

Specific objectives

- To assess the current status of pulse sector development, identify issues responsible for low productivity and future opportunities for its development in Asia.
- To exchange and share knowledge, experience, encountered problems, and available technologies in order to learn from each others' experience and lessons.
- To identify constraints and gaps limiting the further development of pulses in Asia, including access to technology, delivery of support services, value chain including processing and marketing in the context of food and nutrition security.
- To identify priority action, relevant policy options and recommendations for promotion of pulses in Asia.

Expected outputs

- Country status on pulse production, lessons learnt, opportunities and future plans documented and shared.
- Knowledge shared and experiences learnt on pulse production and utilization technology and other associated interventions with greater attention to policy, research and outreach programmes, utilization, nutritional value, support services, marketing and value chain, including processing and marketing, capacity building on pulses for its multiple benefit in Asian countries.
- Priority action, relevant policy options and recommendations to promote indentified and agreed pulses.
- A comprehensive report reflecting outcomes of the consultation to be published and distributed.

Participants

A total of 15 to 20 countries in the region (two participants from each country) and five pulse experts from the region and five representatives from FAO, and co-organizer (s) will be invited to attend this consultation. The proposed countries are: Bangladesh, Bhutan, Cambodia, Lao PDR, Republic of Korea, Japan, China, India, Indonesia, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand and Viet Nam.

Time and Venue

29-30th June 2015, Bangkok, Thailand

Regional Consultation on the Promotion of Pulses for the Multiple Benefits in Asia 29-30 June 2015, Bangkok, Thailand	
Day 1 (29 June 2015) Monday	
Time	**Draft Programme**
08.00–09.00	Registration – FAO RAP
Opening Session	
09.00–10.00	***Opening session***
	• **Opening Address** – Mr Hiroyuki Konuma, Assistant Director General/ Regional Representative, FAO Regional Office for Asia and the Pacific (10 minutes) • **Keynote Address:** Professor M.S. Swaminathan (30 minutes) • **Meeting objectives, programme and introduction of participants –** Mr Subash Dasgupta, FAO-RAP (10 minutes) • **Group photo** (10 minutes)
10.00–10.30	*Tea Break*
Technical Session	
10.30–12.45	**Presentation 1: Mainstreaming pulses into national food security policy** by Shiv Kumar Agrawal, ICARDA **Presentation 2: Importance of Pulses as a source of nutrition in Asian Region** by Mr Jagdish Singh, IIPR **Presentation 3: Productivity Enhancement through genetic improvement of pulse varieties in Asia** by Rajeev Varshney, ICRISAT **Presentation 4: Impact of climate changes in pulse development in Asia** by Mr P.S. Basu, IIPR **Presentation 5: Research Development and Outreach Activities for Enhancing Pulses Production in Asia** by Dr Pooran M. Gaur, ICRISAT **Presentation 6: Importance of value chain approach in developing pulse industry in Asia** by Ms Rosa Rolle, FAO-RAP
12.45–13.00	**Discussion**
13.00–14.00	*Lunch*
Country presentation on the status of pulse production, lessons learnt, and opportunities *(timing 15 minutes for each presentation and 10 minutes for questions at the end of the 7 country presentations)*	
14.00–16.20	Myanmar, Bhutan, Cambodia, Nepal, Pakistan, Thailand, Sri Lanka and Viet Nam

16.20–16.30	*Tea break*
16.30–18.50	Bangladesh, Republic of Korea, India, Indonesia, Islamic Republic of Iran and Lao PDR
19.00–21.00	*Reception*
Day 2 (30 June 2015) Tuesday	
09.00–12.30	**Working Group 1: Policy, strategy and governance in pulse development and identify policy options, priorities and recommendations –** Facilitator: Dr Ashutosh Sarker (Dr S.K. Singh-Rapporteur) **Working Group 2. Research, extension and outreach programmes in pulse and identify priority actions and recommendations** – Facilitator: Dr Pooran M. Gaur (Dr AKM Mahbubul Alam-Rapporteur) **Working Group 3: Discussion focussed on value chain approaches in pulse development and utilization including marketing –** Facilitator: Ms Rosa Rolle (Dr Sartaj Khan-Rapporteur) **Working Group 4: Promotion of pulses as source of nutrition to improve nutritional status of undernourished population –** Facilitator: Mr Jagdish Singh (Dr Didik Harnowo-Rapporteur)
10.15–10.30	*Tea Break*
10.30–12.30	**Discussions 8 chapters working groups findings**
12.30–13.30	*Lunch*
13.30–15.00	**Presentations of working groups and discussions**
15.00–15.30	*Tea Break*
15.30–16.30	**Final discussion, conclusions and recommendations**
16.30–17.00	**Close of meeting**

IV. List of participants

Regional Consultation on "Promotion of Pulses for the Multiple Benefits in Asia" 29-30 June 2015, Bangkok, Thailand

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V. Summary of group discussions

Working group discussions were organized to shed light on the existing status in four areas of pulse research and development. The group discussion was organized in four sessions to facilitate maximum participation of all countries. The major issues raised and recommendations that emerged from the group discussion are presented here.

Working Group 1: Policy, strategy and governance in pulse development

1. Mobilize adequate government support and policy advocacy in support of policy formulation, institutional arrangements and R&D of pulses with a focus on strengthening the role of pulses in cropping systems aimed at enhancing food and nutritional security.
2. In view of the markets for pulses being thin and fragmented, undertake a range of measures for improving market functioning and supply chain of pulses, including provision of market intelligence and increasing support to market chain development and R&D on value-added products with a focus on building adequate storage, grading, milling, secondary processing facilities.
3. Taking into account the high vulnerability of pulses crops to both biotic (pests and diseases) and abiotic constraints (temperature extremes and aberrant rainfall driven by climate change), design and implement appropriate crop insurance schemes as a hedge against crop failures.
4. Improve the profitability of cultivation of pulse crops through provision of incentives to farmers, such as competitive price supports through government procurement programmes, low-interest credit, and provision of subsidies on pulse-specific inputs.
5. Undertake focused extension efforts for popularization and expansion of pulse cultivation – strengthening linkage between research and out-scaling, village-level quality seed production by farmers and farmers' association in addition to formal seed production, creating hubs for custom hiring of farm machineries by small and marginal farmer.
6. Where appropriate policies and capacities exist for protection of biosafety, confined testing and environmental release, consider undertaking research and commercialization of GMOs in pulses.
7. In efforts to sustain continued focus on pulses, ensure international funding support for pulse R&D and exchange of information and experience, establish regional, inter-country networks in research and development; conduct periodic meetings and interaction to secure support from FAO, UN bodies, CG Centers, and other development partners.
8. Educating/creating awareness among children in schools (add to school curriculum), farmers and extension personnel about the value of pulses (human, animal and soil health) and health benefits.
9. Information sharing on production, supply and demand.
10. Participation of different stakeholders in consultation meetings.

Working Group 2: Research extension and outreach programmes in pulses and identification of priorities and recommendations

1. Establish a Legume Asia Network (LAN) to facilitate sharing of germplasm/breeding materials, information and also to develop joint projects for funding.
2. Enhance funding of pulse research programmes; strengthen infrastructure and develop human resources and modernize research programmes with the use of genomic resources, bioinformatics and other modern tools.
3. Conduct research for development of labour-saving technologies (varieties suitable for machine harvesting, herbicide resistance); tools/machines to enhance mechanization; varieties and technologies for boosting resilience to climate change, enhanced nutritional quality attributes (protein, minerals, vitamins) and reduced anti-nutritional factors (phytate, RFOs, etc.).
4. Conduct farmer-participatory trials to promote adoption of improved cultivars and technologies, including integrated crop management (ICM) practices along with provision of input supplies. Develop and strengthen sustainable community-based seed production systems.
5. Empower extension personnel and farmers with knowledge.

Working Group 3: Value chains

Technology

1. Post-harvest technology (storage, milling).
2. ICT to facilitate access to information.
3. Mechanization.
4. Milling – small vs. large mills.

Organization of small farmers

1. Contract farming.
2. Farmer motivation.
3. Minimization of intermediately/middleman involvement.

Market Information

1. Different types of value chains in the region need to be studied.
2. Indigenous value chains.
3. Strengthening role.

Policy issues and the enabling environment

1. Minimum Support Price (MSP).

Working Group 4: Promote pulses as a source of nutrition to improve the nutritional status of the undernourished population

- Strengthen the focus of on-going international projects on pulses as source of nutrients and dietary diversification in several Asian countries that have nutrition outcomes as their impact indicators.

- Extend support through forging multi-sectoral coordination to create awareness about the unique nutritional profile of pulses and strengthening policy advocacy and capacity to undertake initiatives to enhance the contribution of pulses in daily protein and energy intake.
- Consider incorporating pulses as an essential ingredient in national food security programmes like mid-day meals etc.
- Provide support to research on quality breeding: biofortification, limiting antinutrients and increasing bioavailability.
- Release new varieties with enhanced nutritional profiles.
- Promote the value chains of pulses through value addition, production of ready-to-use products, branding and packaging.

Recent achievements in research and development of pulses in Bangladesh

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Abstract

Food legumes, including pulses, play an important role in rainfed agriculture and also are a source of protein supplement in Bangladeshi diets. Pulses grown in Bangladesh are grass peas, lentils, mungbeans, blackgrams and chickpeas. They occupy about 93 percent of the total pulse area and contribute 97 percent to the total production. Cowpeas, though a minor crop, are predominantly grown in the southern part where they are preferred. Among pulses, lathyrus occupies the largest area (37 percent) followed by lentils (23 percent), blackgram (7 percent), mungbeans (24 percent), felon (7 percent) and chickpeas (1 percent). The area under pulses was 384 000 ha and production was 298 000 tonnes in 2004/05. In 2013/14, the area rose to 780 000 ha and production to 824 000 tonnes (AIS, DAE).

To meet the chronic deficit of domestic production of pulses on average about 320 000 tonnes of pulses are imported every year during the past ten years to satisfy domestic demand. Among the imported pulses dry peas rank at the top, followed by lentils and chickpeas. A total of 56 varieties of pulses have been released and many of them are tolerant to major diseases. Cultivation packages and management options of major pests and diseases have been developed. Efforts were also made to disseminate these technologies through a pilot project which produced a remarkable impact. Some niches have been identified for increasing pulse production in Bangladesh. Major constraints to pulse cultivation in the country are botrytis gray mold (BGM) a disease of chickpeas, stemphylium blight and rust of lentils, mungbean yellow mosaic virus (MYMV) in mugbeans and blackgram, and pod borer in chickpeas.

Introduction

Pulses play a significant role in rainfed agriculture and in average Bangladeshi diets. Among the pulses grown in the country, lathyrus (*Lathyrus sativus* L.), lentils (*Lens culinaris* Medik), chickpeas (*Cicer aretinum* L.), blackgram (*Vigna mungo* L.), mungbeans (*Vigna radiata* (L.) Wilcz.) and peas (*Pisum sativum* L.) are the major ones. They occupy 93 percent of the total area under pulses and contribute more than 97 percent to total pulse production in the country. Other pulses grown in the country are pigeonpeas (*Cajanus cajan* (L.) Millsp.), cowpeas (*Vigna unguiculata* (L.) Walp.), faba beans (*Vicia faba* L.) and horse grams. Pulses are cultivated in three seasons a year in Bangladesh. Lentils, lathyrus, chickpeas, fieldpeas, cowpeas and faba beans are cultivated during rabi (winter) season (November–March). Blackgrams, mungbeans and horse grams are cultivated during kharif-II (rainy) season (August–December). Mungbeans are also grown during late rabi (January–April) in the southern districts and kharif-I season (March–June) in western districts. Pulses are traditionally cultivated under rainfed conditions without addition of much input. At present, mungbeans are cultivated using irrigation in kharif-I season in some areas of western districts.

Trends in pulse area, production and productivity

The area, production and yield of different pulse crops in Bangladesh exhibited a declining trend over the period 1985–2005. The total area under pulses dropped from 734 500 ha to 275 300 ha (37.5 percent) over the period 1985/90–2005/06 and production fell from 510 520 tonnes to 208 500 tonnes (41 percent) during this period. Crop-wise the area under lentils was reduced from 215 300 ha to 104 000 ha and production from 156 200 tonnes to 91 000 tonnes. Chickpea area sharply decreased from 103 200 ha to 10 700 ha and similar trend was evident in production also.

Grass pea area dropped from 232 000 ha to 98 600 ha and production from 167 200 tonnes to 88 570 tonnes. Blackgram area decreased from 68 900 ha to 23 900 ha and production from 48 200 tonnes to 19 500 tonnes. Mungbean area and production almost reduced to half, though its area has increased in kharif 1 season but it has not been reflected in the statistics. However, the yields of these pulses have increased steadily over this period.

The main reasons for declining pulses areas is crop competition in rabi season as well as yield instability of pulses due to biotic and abotic constraints. Cultivation of boro rice expanded to the areas under grass peas, chickpeas and field peas in the medium low land, while wheat, potato, maize and vegetables have taken over the lands of lentils, mungbeans and blackgrams. Pulses are not able to complete with these crops.

Both the area and production of pulses showed an increasing trend over the period 2007/08–2013/14. It was due to development of high-yielding, disease resistant and short-duration variety. Therefore, it is urgently necessary to augment the pulse production in the country not only to meet the demand of the increasing population but also to reduce imports to save hard earned foreign exchange.

Pulses in sustaining soil productivity

Legumes have played an important role in sustaining productivity of soils through the centuries. In Bangladesh, declining soil fertility is due to intensive use of lands without proper replenishment of plant nutrients especially where HYV cereals are being cultivated using unbalanced doses of mineral fertilizers with little or no organic recycling (Karim and Iqbal, 2001). The main processes of fertility decline in Bangladesh are depletion of soil organic matter, degradation of physical and chemical properties of soils (Karim and Iqbal, 2001), reduction in availability of major- and micronutrients and lowering of groundwater table (Miah *et al.*, 1993).

Legumes can add 20–60 kg residual N to the succeeding crop (Ahlawat and Srivastava, 1994). They trap atmospheric N through root nodules and add substantial amounts of protein-rich biomass on the soil surface. Inclusion of legumes in cropping systems helps meet in part the heavy N requirement of modern intensive cereal-based cropping systems as well as improving generally the physical and chemical properities of soil (Kumar Rao *et al.*, 1998). Legumes in rotation with cereals economize the use of nitrogenous fertilizers to the extent of 30–40 kg/ha (Ali, 1994, Chandra, 1998, Rego *et al.,* 1998). Ahlawat *et al.* (1998) reported that incorporation of mungbean stover in a rice – wheat – mungbean system improved physical properties of soil by lowering bulk density and enhancing hydraulic conductivity. This also improves soil microbial biomass and their activity which is vital for supporting long-term soil health and productivity. Growing of legumes helps to conserve this soil N and it is recycled to rice by incorporating the legumes.

So it is evident that inclusion of legumes in the system helps improve the soil's physical, chemical and biological properties which are mainly degraded in a cereal-based cropping system. Therefore legumes, in general, play a vital role in enhancing crop productivity.

Pulse-based farming systems

In Bangladesh pulses are grown in pulse – rice cropping systems. Lentils like other pulses contribute to food and feed resources and to sustainable crop production by improving soil health and breaking disease and pest cycles. Lentils are grown in rice/jute – fallow – lentil cropping systems in medium high lands and in jute – fallow – lentil cropping systems in medium low lands. Among the pulses, grass peas, lentils, chickpeas, field peas and cowpeas are mainly grown after the harvest of monsoon-rice during October–April. But in most cases, pulse cultivation (specifically lentils) after the monsoon-rice harvest is delayed and consequently the growing crop becomes vulnerable to higher infestation of diseases and insects pests, matures earlier resulting in lower yields.

New cropping patterns including mungbean and blackgram have been developed, such as Aus/jute – mungbean/blackgram – Rabi crops in place of Aus/jute – fallow – Rabi crops, mustard/lentil/vegetable – mungbean – rice/cotton for kharif-I. However, relay cropping of lentils in rice fields (zero tillage) can provide an effective solution. Relay cropping has been found to have 45 percent lower production costs and is more productive than sowing by tillage after the rice harvest, as it enables better and early establishment of lentil seedlings because of adequate availability of soil moisture.

Major achievements in pulse production

Research efforts on pulses during the early 1950s was limited to the collection and evaluation of local germplasm. It was intensified in 1961-1962 with the establishment of Pulses and Oilseed Division under the Directorate of Agriculture, Govt. of East Pakistan (Shaik and Rahman, 2001). A fresh start and more systematic approach in collection and evaluation began at the Bangladesh Agricultural Research Institute (BARI) and the Bangladesh Institute of Nuclear Agriculture (BINA) during the late seventies. Besides, country-wide agronomic trials, microbiological, pathological, entomological research and on-farm trials were initiated. Simultaneously constraints were identified. Based upon the constraints, appropriate research programmes were developed and continued. Some of the important research achievements made so far are discussed below.

Varietal improvement

- A total 56 varieties of different pulses, including lentils, chickpeas, blackgrams, grass peas, cowpeas and mungbeans and peas have been developed (32 by BARI and 20 by BINA and 4 by Bangabandhu Sheikh Mujibur Rahman Agricultural University-BSMARU).

Disease management

- Disease problems of major pulses were identified and yield loss due to some major diseases studied.
- Protection of lentil and chickpea from collar rot attack was developed by treating seeds with Vitavax 200 @ 2.5 g/kg seed.
- Treatment with Rovral 50 WP at 0.2 percent was found effective in controlling stemphylium blight of lentil when sprayed 3-4 times at 7-day intervals from the initiation of disease.
- Control measures for rust of lentils was developed by spraying Tilt 250 EC (0.1 percent) or Calixin MC (0.2 percent). The disease can also be avoided by early planting (1st week of November).
- Control of powdery mildew disease of blackgram was developed by 2-3 foliar spray of Tilt (0.1 percent). For Cercospora leaf spot in mungbeans, foliar spray of Bavistin 50 WP (0.1 percent).
- Yellow mosaic virus of mungbeans can be controlled by controlling its vector, white fly, by spraying systemic insecticides.

Insect management

- Insect problems of major pulses were surveyed and major pests identified.
- Relothrin 10 EC (10 ml/l water), Tafgar 40 EC (2.22 ml/l water) and Malatar 57 EC (2 ml/l water) were effective in reducing pod borer of chickpeas.
- Foliar spray with Ripcord 4 ml or Azodrin 2 ml/l or Lmidachloprid 0.5 ml/l water was effective in controlling insects pests of mungbeans (white fly, pod borer, thrips).
- Application of poison baits made with Monophos in the evening effectively controls cut worms of chickpeas.
- Malthion 57 EC (2 ml/l water) effectively controls aphids of lentils and lathyrus).
- Hand picking and destroying of 1st instar larvae of hairy caterpillar or by spot spray with Lebaycid or Sumithion 2 ml/l water, was effective in controlling hairy caterpillar in blackgram, cowpeas and mungbeans.

Storage

- Pulses grain stored in earthen containers sealed with cow dung, mud or gunny bags with polythene lining remained free from external infestation. A cover layer of sand over the stored grains in earthen containers also prevents infestation.
- Dried tobacco leaves mixed with stored pulses offered substantial protection against storage beetle. Before preservation seeds should be well dried (moisture <12 percent). Preservation should be done in an air tight container like gunny-bag with poly-lining, a plastic or metallic drum. Using phostoxin tablets (1 to 1.5 g) for every 100 kg seeds in an airtight container can keep the stored seed for about one year free from infestation.

Constraints to pulses production and challenges

Biotic constraints

Diseases and insect pests, including stored grain pests are the major biotic constraints to pulse production in Bangladesh.

Diseases: The important diseases of major pulses are:–

(i) **Chickpeas:** Out of 13 diseases recorded so far, four diseases, viz. botrytis gray mold (BGM), root rot and collar rot are the major ones. BGM and collar rot may cause up to 90 percent and 84 percent yield loss respectively. All the diseases are widespread over the chickpea growing zones, except that BGM infestation is less in the Barind tract.

(ii) **Lentils:** Out of 16 diseases recorded, stemphylium blight (causing up to 80 percent yield loss) and rust are the most serious ones. Collar rot and wilt may also cause yield loss to some extent. Their distribution is almost uniform throughout the country.

(iii) **Mungbeans and blackgrams:** Sixteen diseases in mungbeans and 21 in blackgrams have been recorded. Of these, yellow mosaic virus (causing 70–80 percent yield loss in mungbean) cercospora leaf spot, powdery mildew (42 percent loss in blackgrams) are the major ones in both the crops, Recently, sclerotinia blight has also appeared as a major disease. These diseases are evenly distributed throughout the growing zones.

(iv) **Lathyruss:** Out of 11 diseases recorded, downy and powdery mildews are the major ones. Downy mildew may cause up to 12 percent yield loss while powdery mildew may cause up to 23 percent loss. Both diseases are evenly distributed across areas where lathyrus is grown.

(v) **Insect pests:** Among the 30 insects recorded many are common pests for several pulses. Aphids are common for lentils, lathyrus and mungbeans. Pod borer (*Helicoverpa armigera*) is a major pest on chickpeas and blackgrams, and can cause up to 90 percent pod damage in chickpeas. *Diacrisia obliqua* (hairy-streak blue butterfly) is a major pest of blackgrams and mungbeans. *Euchrysops cnejus* (hairy-streak blue butterfly pod borer), *Monoleepta signata* and *Bemisia tabaci* (white fly) are the major pests of mungbeans and blackgrams. *Agrotis ypsilon* (cut worm) is a common and major pest of chickpeas, and it also attacks lentils and blackgrams. Thrips are also a major pest in mungbean that causes flower to drop. Infestation of these pests varies over space and time, depending on weather conditions.

(vi) **Storage pests:** Fungal and insect pest infestations are major constraints in storage which can damage the seed and cause loss of seed viability. A total of 15 fungal species were recorded from different pulses. Fungi like *Aspergillus, Penicillum* and *Rhizopus* spp. are more common in stored grain and increase in serverity with the increase of storage period. Pulse seeds are severely damaged by bruchids. Two species of this pest, *Callosobruchus chinenisis* and *C. maculatus* have been reported to infest all pulses, expect blackgrams, which are attacked only by *C. maculatus*.

Abiotic constraints

A range of climatic and soil factors limit the productivity of both winter and summer pulses grown in Bangladesh. Among these, drought, excess moisture, and adverse temperature and soil conditions are important.

Drought: The climatic conditions in Bangladesh are variable, particularly during the post-rainy (winter) season. In some years very little rainfall occurs during the winter season and the major legumes (lentils, lathyrus, chickpeas) that are grown on conserved soil moisture suffer from drought stress. Dried-out surface soil hampers proper germination and emergence, especially in case of late sown lentils and chickpeas. Consequently, optimum plant stand cannot be established and, as a result, yield is low. The crops can suffer from drought stress during vegetative as well as reproductive phases. This leads to abortion of flowers and young pods and prevents seed filling.

Excess soil moisture and humidity: In some years excessive rainfall can occur during the winter season and this can cause substantial yield loss. If it occurs at an early stage, it encourages excessive vegetative growth leading to lodging, and also encourages development of various leaf and root diseases. If rainfall occurs at the reproductive stage, it not only physically damages the flowers and developing pods/seeds, but also encourages foliar diseases, such as botrytis gray mold (BGM) in chickpeas, rust and stemphylium blight in lentils, downy mildew in lathyrus. Some of these diseases can also complete yield loss in these crops. High rainfall coupled with high humidity also encourages insect infestation. In some years when rainfall occurs at the time of crop maturity (April), it affects crop yields owing to pod-shedding, seed rotting and hampering of harvesting and threshing.

Temperature extremes: Low temperatures encountered during January-February especially towards the northern region of the country can affect vegetative growth and pod set of both cool and warm season legumes. A sudden rise in temperature in late February in some years severely reduces vegetative growth and pod formation of Rabi pulses, especially of late sown lentils and chickpeas.

Soil factors: Pulse crops have been traditionally grown in the Ganges floodplain soil, although chickpea cultivation is now increasing in the Barind tract. The soils of the Barind tract are mainly imperfectly to poorly drained, brown to grey, loamy to clayey soils. The surface soil is acidic. In soils of higher clay content, plough pan formation impedes root development of crops following rice.

Challenges

- Resurgence of new diseases and insects.
- Lack of related wild species as a resistance source of pest and disease.
- Drought or excess moisture.
- Salinity.
- High competition with Boro rice and Rabi crops.
- Sensitivity to microclimate.
- Delayed sowing; and
- Less productivity compared to other crops.

Current efforts for improving pulse productivity

In the National Agricultural Research System, BARI and BINA are engaged in research on grain legume drawing on a range of collaboration with international research centres like the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Center for Agricultural Research in the Dry Areas (ICARDA) and the World Vegetable Center. The main activities are to identify the constraints to pulses and initiate research accordingly; introduce and evaluate germplasm from exotic and local sources; establish linkage with international centers and undertake human capacity building through higher studies and training. The current efforts are as follows:

- Strengthening research for development of suitable high-yield technology package.
- Seed production of improved varieties through the Bangladesh Agricultural Development Corporation (BADC).
- Strengthening extension services through training and demonstration programmes to familiarize farmers with the latest production technology.

In the past, the government launched a special project on pulses called "Pilot Production Project on lentil, mungbean and blackgram" in 1996/97 which continued till 2002. The main objectives of this project were to extend improved varieties and production technologies of these crops among the farmers to increase their area and production. This project created an excellent impact on expanding new varieties and increasing yield of the targeted crops. The ministry of agriculture also completed another project on strengthening of pulses and oilseed research from 2005 to 2010 for the development of improved technologies.

A project titled "Introduction of short duration pulses into rice based cropping systems in western Bangladesh", supported by the Australian Centre for International Agricultural Research (ACIAR), started operations beginning January 2011 and is slated for completion in December 2015. The main objectives of this project are to identify short-duration lentil, field pea and mungbean varieties and appropriate technologies and to introduce them in the rice-based cropping systems in ten western districts of Bangladesh. BARI is the lead agency for conducting on-station and on-farm research and will provide technical support for up scaling of the technologies by DAE and NGOs. IRRI Bangladesh office is coordinating the project activities.

Pulses for conservation agriculture

Conservation agriculture (CA) systems are yet to be developed for cultivation of pulse crops in the intensive rice-based cropping systems (three rice crops in a year in addition to other cereals, legumes and/or oilseed crops) of Bangladesh. Normally lathyrus is cultivated by broadcast lathyrus seeds before B aman and also T aman rice harvest in medium low lands, clay loam and clay soil. In southern regions, cowpeas also are cultivated by broadcasting seed before the rice harvest. After the harvest of monsoon rice, it is often difficult to take advantage of the optimum sowing time for pulse crops to be grown as a sole crop because of the delay in harvesting rice and excessive soil moisture.

It was also identified that as a result of climatic change, frequently high temperatures prevail during the end of crop cycles. In these circumstances, relay cropping, a conservation technology, can be practiced that allows broadcasting seeds of pulses in the standing crop of monsoon rice 15–20 days before rice harvesting begins. Research conducted on-station as well as on farmers' fields showed that relay cropping of different Rabi pulses produces up to 64 percent higher yield than does the conventional tillage system because of timely sowing and the best use of residual soil moisture and also low cost technology.

Besides these, inclusion of pulses in cereal-based cropping patterns makes an important contribution to increasing food and feed production without damaging the environment. It also supports crop diversification and sustainable agricultural production by adding nitrogen to the soil and breaking cereal-based monoculture.

Pulses contribution to nutrition, employment and income generation, value chain development including processing and marketing

Pulses are not only a rich source of protein but also a good source of carbohydrates, vitamins, and minerals. The presence of different types of proteins and other smaller molecules, including alkaloids, isoflavins, polyphenols and a variety of oligosccharids make legumes seed unique in providing nutracuticals. Pulse protein is now looked upon as phospholipid and cholestorel lowering agents. They also contain significant amount of fibre that prevent constipation (Palande, 2010). Besides these, grain legumes are characterized by a relatively low glycemic index that is one half of white bread. Hence it is beneficial to incorporate legumes in the diet of people having diabetes (type 2) (Mehta *et al.*, 2005).

Although pulses have, in general, high nutritive values but they also contain some antinutritional factors, such as high beta-oxalyl-amino-alanine (BOAA) in lathyrus, trypsin inhibitors, polyphenolic compounds, tanins, phytic acid, flatulence factors and allergens (Liner, 1980). However, fortunately most of these antinutritional factors are heat liable and are destroyed on cooking or roasting (Williams *et al.*, 1994). Considering both positive and negative sides the nutritionists consider pulses as highly nutritious food and a substitute for animal protein.

Short-duration legume varieties play an important role in employment and income generation in rural communities. Especially in case of mungbean cultivation, women workers can take part in harvesting mungbeans. Integrated Farm Management Component (IFMC) works on empowerment of women, where women can focus on business activities and hold the cash after selling. Pulses are more susceptible than other crops to stored grain pests. As a result, farmers can't store their produce for long and hence they sell it immediately after harvest at low price. There is neither a definite marketing channel nor a government support price for pulses. Also high labour wages discourage the farmers from taking care of pulses.

The Integrated Farm Management Component is implemented by the Department of Agricultural Extension for marketing and value chain development. IFMC provides support to farmers selling in bulk and collectively by organizing farmers' group. Similar projects were also supported by the Danish International Development Agency (DANIDA). IFMC is building capacity among farmers (landless, marginal and small scale households) and organizing them to sell their produce to traders at higher levels of the value chain. IFMC is also building the capacity of DAE field staff to emphasize farming as a business and advise farmers' organizations on business planning, marketing and market linkage. In the National Agricultural Technology Project (NATP Phase 1), the Hortex Foundation developed Commodity Collection and Marketing Centre (CCMC) based on market linkage and improved smallholder farmers' access to market information through adoption of appropriate technologies and strengthening farmer-market linkages.

Strategy for meeting future challenges and opportunities

The production of pulses in the country has not increased commensurate with the population growth. The population of Bangladesh will cross 173 million by 2020 and 195.3 million by 2030 (estimated). As mentioned earlier, the current domestic demand for pulses is met by both local production (46 percent) and commercial imports (54 percent). If, however, the current rate of consumption of pulses remains unchanged, the requirement is estimated to be 13.1 percent higher in 2020 and 27.7 percent higher in 2030. This means the reliance on imports is set to increase in the absence of measures to stimulate further growth in productivity and production of pulses. Therefore, concerted efforts need to be directed at augmenting the production of pulses.

Opportunities for increasing pulses production

Pulses face tough competition with rice, maize and other high value crops. The present cropping intensity is 190 percent and the scope of expansion for pulses as a sole crop is very limited. Therefore, the strategy to expand pulse cultivation should be built on (1) increasing productivity by adopting improved varieties and cultural practices (vertical expansion) and (2) increasing the cultivation area by introducting new cropping patterns and utilization of fallow lands (horizontal expansion).

Vertical expansion

Fifty-six varieties have been released by BARI, BINA and BSMRAU, most of which are high yielding and tolerant to major stress factors. The recently released varieties of lentils are resistant to rust and tolerant to stemphylium blight, chickpea varieties are resistant to wilt, mungbean and blackgram varieties are tolerant to YMV and cercospora leaf spot, etc. At research stations the yields of these varieties are very high but in farmer's fields the yields are not that high. For example, seed yield of lentil varieties ranged from 2 000 to 2 200 kg/ha at research stations depending on variety. The results of on-farm trials conducted by OFRD showed an average yield of 1 350 kg/ha, whereas the national average yield of lentils is only 738 kg/ha which is about one third of the potential yield. This means the national yield gap of lentils is 45 percent compared with farmers' field demonstration yields. Similarly the yield gap of lathyrus is 44 percent, chickpeas 51 percent. Therefore, these varieties along with their production technologies should be extended to farmers to replace the low-yielding local cultivars. This will ultimately enhance productivity.

Horizontal expansion

Some potential niches for fitting pulses in to rice-based cropping systems are as follows:

i) Expansion of mungbeans in Kharif-I season: Mungbeans have been successfully introduced in the lentil/mustard/wheat – mungbean – T. aman rice cropping systems in western and northern districts like Jessore, Kustia, Pabna, Natore and Rajshahi. Still there is much scope to expand the coverage of these patterns to more areas in these districts. In northern districts like Rangpur, Dinajpur, Thakurgaon, Panchagarh, a large area can be brought under these patterns provided lime @ 2 t/ha and Born @ 1.5 kg/ha are applied in addition to other recommended doses of fertilizers.

ii) Expansion of blackgrams in Kharif-II season in Aus/jute – blackgram – rabi cropping patterns. One of the patterns in the highlands in western districts is Aus rice/jute-fallow-Rabi crops. This fallow period is about 80–90 days. In this fallow period short-duration blackgram varieties can be cultivated without disturbing the existing cropping pattern.

iii) Expansion of chickpeas in Barind, Sylhet and northern part of Barisal district. A large area remains fallow after harvest of T. aman rice in the Barind tract of Rajshahi district, Sylhet and northern part of Barisal district. Chickpeas can be sown in mid November after harvest of early aman rice before depletion of soil moisture in Barind tract and Sylhet. It can be planted in late November-mid December in the northern Upazilas of Barisal districts.

iv) Cowpeas and mungbeans should be extended in the southern districts. These crops are sporadically grown in the greater Chittagong, Noakhali, Bhola and Barisal districts. There is great scope to bring more lands under these crops with improved varieties and production practices.

However, extension of pulses is not an easy task. It must be an integrated approach like the one followed in the pilot project where seed supply was ensured by BADC, DAE organized farmers' training where demonstrations and research institutes provided technical support and training. Project activities were regularly monitored by project partners in the field.

Lentils and mungbeans intercrop with sugarcane: Lentils and mungbeasn are sporadically grown as intercrop with sugarcane in the high lands. There is about 40 000 ha land suitable for such intercrop in the sugarcane growing zones. If part of this area can be brought under these intercropping systems, a substantial amount of pulses can be added to the total production.

Future research on pulses should be target-oriented and top priority should be given to developing stress tolerant HYVs for traditional and potential areas with regional preference addressing the specific problems. Crop-wise varietal needs are as follows:

i) **Lentils:** Rust and stemphylium resistant high-yielding varieties, short-duration with wider adaptation (for traditional and non-traditional areas).

ii) **Chickpeas:** Botrytis Gray Mold (BGM)-resistant and tolerant to excess moisture with high yield potential.

iii) **Lathyrus:** High-yielding variety with wider adaptation.

iv) **Mungbeans and blackgrams:** Short-duration, high-yielding variety.

v) **Cowpeas:** YMV-resistant, salinity tolerant, high-yielding variety for the southern belt.

Disease and pest management research should be strengthened. New pathotypes and virulence of pests are emerging. These should be continuously monitored and management practices should be developed in addition to identification of resistant sources. New cropping patterns need to be developed involving pulses, especially rice-based (with short-duration aman rice varieties), low cost weed management techniques. Identification of potential areas and limiting factors for pulses and finding their solutions are also necessary.

Breeder's seed production needs to be intensified so that BADC and private seed companies can multiply the seed of new varieties to meet the demand. Finally, a special project like the pilot project may be taken up for research and development of technology for promotion of pulses in the country.

Reaching out to farmers and consumers

About 75 percent people in Bangladesh are involved in agriculture. The government of Bangladesh gives priority to ensuring fair prices for farmer's products. Connecting farmers to consumers via local, urban, regional and global markets can raise incomes, deliver food from surplus to deficit regions and stabilize food prices. The IFMC, being implemented by DAE, is focusing on marketing and value chain development and improving infrastructure and support services so as to unblock 'value chains' and increase market access. Smallholders can improve their livelihoods by reaching consumers beyond their local markets. IFMC supports smallholders in their efforts to organize and build capacity so that they can sell in different markets, and contribute to domestic health and nutrition. Besides these initiatives, DAE also provides support to farmers through small farmer groups, farmers marketing associations, co-operative marketing and contract farming and marketing. Some private companies contract directly with farmers to produce pulses to sell as a value added product.

Conclusion

Pulses are an important food legume that also improves soil fertility and contributes to the nutritional security of farmers. Pulse production in Bangladesh needs to increase 27 pecent by 2030 to keep pace with the growth of the population. Development of disease resistant and high-yielding varieties and the expansion of their cultivation can play a vital role in increasing production. Rabi pulses should be introduced as intercrop/mix crop/relay crop in the cropping system. Research should focus on developing disease resistant, short-duration and high-yielding varieties which are suitable for existing cropping patterns. For popularizing improved pulse varieties, production technology and technical support should be extended to farmers.

Recent achievement in research and development of pulses in Bhutan

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Abstract

Bhutan is a small landlocked country with an area of 38 394 km^2 and a population of 745 153 people. Agriculture is the economic backbone of the country. Traditionally, Bhutan has recognized nine food crops known as "dra-na-gu" for its food security. These are rice, maize, wheat, barley, buckwheat, millet, amaranth, mustard and pulses. Pulses or grain legumes have played a diverse role in the Bhutanese farming system and still continue to do so. However, compared with other major cereals, pulses have received less focus and attention from the government and the pulse producers. Consequently, not much progress has been made in research and development of pulses in the country. In order to achieve the country's food and nutritional security, it will be critical to: 1) create a national legume sub-programme, 2) strengthen research and development on pulses, 3) introduce legume promotional programmes as in other cereals, 4) develop human resources, 5) have systematic seed production programmes and 6) organize marketing support for pulses. Without these, it would be difficult to scale up pulse production in the country.

Introduction

Physical setting

The Kingdom of Bhutan is a small landlocked mountainous country located on the southern slopes of the Eastern Himalayas and surrounded by two giant countries – China in the north and India in the south. It has a total geographical area of 38 394 km^2 and a population of 745 153 people (NSB, 2014). The land rises from an elevation of about 200 meters above sea level in the south adjoining the Indian plains to over 7 550 meters in the north. Because of this, there are extreme variations in climate, agro-ecology, and biodiversity.

According to the Bhutan Land Cover Assessment 2010, only 2.93 percent of the country's total geographical area is cultivated agriculture land, of which 61.9 percent (69 670.79 ha) is dry land, 27.9 percent (31 361.23 ha) is wetland (irrigated paddy field) and 10.2 percent (11 524.19 ha) is horticultural land. The average cultivated agriculture landholding is about 3 acres (RNR statistics, 2012).

Agriculture in Bhutan

Agriculture is the economic backbone of the country. It contributes about 16 percent of GDP (NSB, 2014) and directly engages 56 percent of the total population for their livelihood (NLFS, 2013). The majority of Bhutanese farmers practice subsistence farming, but are slowly moving towards commercial or market-oriented production systems. The main cereal crops grown are rice, maize, wheat, barley, buckwheat and millets, but rice is by far the most important and preferred food crop. Farming in Bhutan is a challenge because of small land holding size and rugged topography with steep slopes on most agricultural land, making farm labour intensive and mechanization difficult. Owing to a wide range of agro-ecological zones, diverse agriculture production systems exist (see Table 1).

Table 1. Agro-ecological zones and the agriculture production system of Bhutan

Agro-ecological zone	Altitude range (masl)	Annual rainfall (mm)	Farming systems, major crops and agricultural produce
Alpine	3 600–4 600	<650	Semi-nomadic people, yak herding, dairy products, barley, buckwheat, mustard and vegetables.
Cool Temperate	2 600–3 600	650–850	Yaks, cattle, sheep & horses, dairy products, barley, wheat & potatoes on dryland, buckwheat & mustard under shifting cultivation.
Warm Temperate	1 800–2 600	650–850	Rice on irrigated land, double cropped with wheat and mustard, barley and potatoes on dryland, temperate fruit trees, vegetables, cattle for draft and manure, some machinery and fertilizers used.
Dry Temperate	1 200–1 800	850–1 200	Maize, rice, millet, pulses, fruit trees and vegetables, wild lemon grass, cattle, pigs and poultry.
Humid Subtropical	600–1 200	1 200–2 500	Irrigated rice rotated with mustard, wheat, pulses and vegetables, tropical fruit trees.
Wet Subtropical	150–600	2 500–5 500	As for the humid zones – irrigated rice rotated with mustard, wheat, pulses and vegetables, tropical fruit trees.

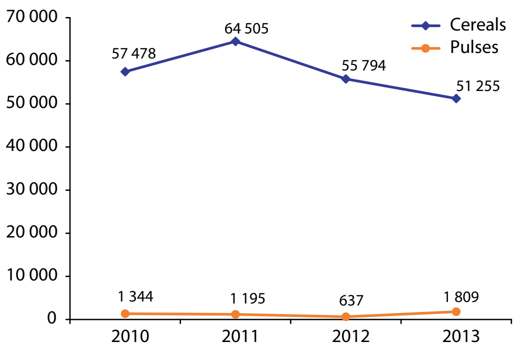
Source: MoA, 2002

Pulses and grain legumes in Bhutan

Traditionally, Bhutan has recognized nine food crops known as "*dra-na-gu*" for its food security. These are rice, maize, wheat, barley, buckwheat, millet, amaranth, mustard and pulses. Pulses or grain legumes have been and will continue to play diverse role in the Bhutanese farming systems, e.g. as food crops through direct consumption as grain, green pod and leaves thereby contributing towards food security and dietary diversity goals, as a cash crop through sale which helps reduce poverty and as fodder crop thereby contributing to livestock productivity and as a rotation crop. They are grown in diverse land use systems, but more than 75 percent of the national legumes or pulses are grown in dry lands (National Legumes Survey, 1999). While a survey in 1999 has recorded 16 species, the most widely grown pulse species in Bhutan are rajma beans (*Phaseolus vulgaris),* mungbeans/green grams *(Vigna radiata*), urd beans/blackgrams (*Vigna mungo*), lentils (*Lens esculenta*) and soybean (*Gycine max*).

Trends in pulse area, production and productivity

Generally, compared to major cereals (rice and maize), the contribution of the minor cereals to the food basket has declined due to increased consumption of rice and non-cereal items owing to enhanced purchasing power of consumers. In 2013, the total production of all pulses was 1 665 tonnes compared with rice 75 228 tonnes, maize 75 715 tonnes and wheat 4 286 tonnes (DoA, 2013). This huge production gap may be attributed to the area under cultivation (see Figure 1) and the yield, both of which are comparatively low for pulses. However, the average yield of about 0.8 tonne/ha is comparable with that of some Asian countries, e.g. 0.69 tonne/ha in India, 0.86 tonne/ha in Nepal and 0.88 tonne/ha in Bangladesh, but lags much behind that of 2.03 tonnes/ha obtained in China (Akibode and Maredia, 2011). The factors causing low productivity of pulses in Bhutan are: low or negligible use of external inputs (chemical fertilizers or farm yard manure), lack of suitable high-yielding varieties, poor soil nutrient and water management, inadequate plant protection measures, poor agronomic and husbandry management, cultivation in marginal areas with better land allocated to other cereals, lack of focus and priority from the government and limited research on pulses. Table 2 shows the major pulse producing *Dzongkhags* (Districts) in Bhutan. Pulses are largely produced in the east and the south which clearly correlates with maximum dry lands prevalent in these regions.



Source: DoA, 2010–2013

Figure 1. Trends in area cultivated across all pulses and cereals

Table 2. Major pulse producting districts (2011–2013)

Dzongkhag	Area (ha)	Production (tonnes)	Yield (t/ha)
Chhukha	131	89	0.682
Dagana	754	305	0.405
Mongar	694	923	1.329
S/Jongkhar	364	245	0.672
Samtse	475	161	0.339
Sarpang	279	109	0.392
Trashigang	593	511	0.862
Tsirang	571	238	0.417

Source: DoA, 2010–2013

Pulse and multiple cropping

Based on the most dominant food crops grown, three distinct farming systems are practiced in the country – the rice, maize and potato-based cropping systems. Rice-based farming system is exclusively practiced in the irrigated terraced wetlands while the maize and potato-based systems are primarily practiced in the dry lands which are largely located on steep slopes. Pulses or grain legumes are either intercropped with maize or mono cropped as a succeeding crop following crop rotation. The main legumes are rajma beans or kidney beans (*Phaseolus vulgaris*), soybeans (*Glycine max*), urd beans (*Vigna mungo*), peas (*Pisum sativum*), groundnuts (*Arachis hypogea*) and cowpeas (*Vigna unguiculata*). Unlike in maize, in rice-based systems, legume crops, largely urd beans, are planted along the terrace bunds following the paddy transplantation.

Major achievements in increasing pulse production and productivity

Pulses or grain legumes in Bhutan have not received adequate policy focus and attention from the government like other major cereal crops (rice, maize and wheat). Consequently, no major investment has been made in research and development of pulses in the country. For instance, the National Research Centres have developed and released about 40 varieties of fruits, 24 varieties of vegetables, 29 varieties of cereals, but only four varieties of legumes (Dorji *et al*., 2009). The development and release of these legume varieties have been possible due to institutional linkages developed between the Department of Agriculture, the Royal Government of Bhutan and AVRDC – the World Vegetable Centre.

Table 3. Agronomic traits of four legume varieties

Variety	Important characteristics
Limithang Mung 1 (KPS 2)	Plant height 40–45 cm; Yield 1.25–2.5 t/ha. A short and early maturing variety, recommended for altitudes <2 000 masl in rice and maize based cropping systems
Limithang Mung 2 (Barimung 2)	Plant height 35–40 cm; Yield 1.25–2.6 t/ha A short and early maturing variety, recommended for <2 000 masl in rice and maize based cropping system
Khangma Libi 1 (AGS 258)	Matures in about 140 days; Yield 400–600 kg per acre (monocrop) and 200–250 kg per acre (intercrop); suitable for 600–2 000 masl
Khangma Libi 2 (GC860 18-427-3)	Plant height 70–75 cm; Yield 1.5–2.0 t/ha (monocrop) and 1.0–1.25 t ha^{-1} (intercrop); short duration crop; recommended for 600–2 000 masl

Constraints in productivity enhancement and emerging challenges

Various biotic, abiotic and socio-economic constraints impede pulse production in Bhutan. Because of the lack of policy support, available resources and expertise in the field of pulses, considerable challenges lie ahead in addressing these constraints. The major biotic constraints on pulse production are various diseases, insects and weeds. Among diseases, foliar disease is the most commonly observed one in pulses (Tshewang, *n.d)*. Systematic research is needed on foliar disease and other diseases and their impacts on yield. The crop damage from insects has been reported to be minimal (Tshewang, *n.d.*), but for diseases, proper research is required to document their occurrences and impacts. Weeds, on the other hand, have been another obnoxious biotic constraint in pulses production. Because the majority of pulses are cultivated on rainfed dry lands, weeds such as purple nutsedge (*Cyperus rotundus* L.), bermuda grass (*Cynodon dactylon* (L.) Pers.), goat weed (*Ageratum conyziodes* L.) are commonly encountered (Tshewang, *n.d.*).

Most of the pulses in Bhutan, as is in other countries like India, are grown in marginal areas with low fertility and unpredictable environmental conditions (Gowda *et al*., 2013). Farmers apply limited efforts on soil fertility and water management and, as a result, pulse crops are exposed to both nutrient and water stress which drastically reduces crop production and productivity. The situation becomes more aggravated as the pulses are largely grown in drylands.

Pulses are considered as secondary crops both by the government and the farmers alike. Government has provided the main policy support to rice in achieving the country's food self-sufficiency, although pulses too have potential to contribute towards food and nutrition security. Similarly, farmers also give first priority to staple cereals because of the support provided by the government, including easy access to inputs and market. Furthermore, there are no high-yielding varieties and packages of best practices for pulses readily available to farmers and even marketing is limited to FCB auction yards only. Therefore, to encourage farmers to enhance pulse production, it is critical to address the above socio-economic constraints.

Pulse production in Bhutan is challenged by other factors, such as limited landholding coupled with loss to infrastructure development and natural disasters through land degradation, high production cost due to farm labour shortages and the limited scope for farm mechanization owing to mountain topography, human wildlife conflict and climate change.

Current efforts for improving pulse productivity

As noted in earlier sections, pulses have received very little policy support and investment from the government in terms of its Research and Development (R&D). Therefore, there has been very little incentive to enhance pulse production and productivity. Noting this, efforts have been made to revive pulse research particularly with the institution of three-year SAARC project on shuttle breeding since July 2009. The main collaborating countries are India, Bhutan and Nepal. The project is coordinated by the Indian Institute of Pulses Research in Kanpur under the aegis of Indian Council of Agricultural Research.

Bhutan has benefitted immensely in accessing the germplasm of different species from the collaborators and human capacity development through workshops and training courses. Several elite lines or varieties of mungbeans (11), urd beans (8), rajma beans (5), and lentils (3) have been received from the collaborators which are currently undergoing vigorous testing at different Research and Development Centres (RDCs). Table 3 shows the agronomic traits of different varieties of pulses received as part of SAARC shuttle breeding. Parallel to on-station testing, evaluation in farmers' fields will be carried out for those varieties that have shown promising results. If there is convincing performance in the farmers' fields, the varieties will be released by the releasing committee in the ministry for general use.

Table 4. Agronomic traits of pulse varieties received through SAARC shuttle breeding programme

Crop/Variety	Days to 50% flowering	No of pods/plant	Plant height (cm)	Grain yield (tonne/ha)
Lentils				
Maheshwar Bharati	74 a	137 a	43 a	0.66 a
Shital	73 a	117 a	42 a	0.57 a
Simal	74 a	169 a	39 a	0.77 a
Mungbeans				
Meha	34 ab	14 b	36.6 ab	0.41 ab
Samrat	33 ab	14 b	31.6 b	0.42 ab
HUM 1	40 bc	12 ab	32.6 ab	0.34 ab
HUM 12	33 ab	12 b	35.0 ab	0.44 ab
Pant Mung 5	33 ab	8.0 ab	24.6 b	0.36 ab
IPM-19	35 ac	8.0 ab	40.3 ab	0.46 ab
Saptari Local	34 ab	13 ab	34.6 ab	0.50 a
Prateksha	28 a	10 ab	36.6 ab	0.41ab
IPM 16	37 bc	7.0 a	52.0 a	0.50 a
HUM 16	42 c	8.0 ab	34.0 ab	0.31 bc
Limithang Mung 2	39 bc	8.0 ab	40.0 ab	0.41 ab

Table 4. *(continued)*

Crop/Variety	Days to 50% flowering	No of pods/plant	Plant height (cm)	Grain yield (tonne/ha)
Urd beans				
Uttara	45 a	25 ac	25 b	0.41 a
NDU-1	44 a	26 bc	30 ab	0.45 a
Pant U-40	27 b	13 c	34 ab	0.40 a
Pant U-31	40 a	40 b	39 ab	0.37 a
IPU-2002-1	32 b	40 b	36 ab	0.42 a
IPU-2002-2	38 a	38 ab	32 ab	0.39 a
BLG-0067-1	30 b	33 ab	42 ab	0.39 a
BLG-0068-2	25 b	35 ab	34 ab	0.39 a
Rajma beans				
Arun	33 bd	24 a	49 ab	0.38 a
HUR-15	36 a	21 a	58 a	0.50 a
PDR-14	35 ac	18 a	47 ac	0.50 a
Utkarsh	34 cd	16 a	41 bc	0.41 a
VL-125	32 b	16 a	34 c	0.52 a

Means indicated by different letter(s) within a column are statistically significant at P ≤0.05 by 95 percent confidence interval.

Source: RNRRDC Bajo, Annual Report (2010).

Suitability of pulse for conservation agriculture

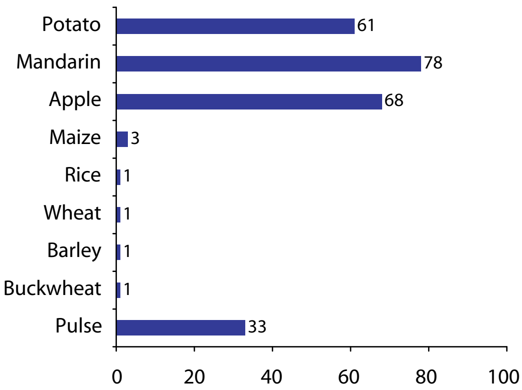
In the current 11th Five Year Plan (2013–2018), the goal of the Ministry of Agriculture and Forests (MoAF) is to achieve green economic growth, inclusive social development, poverty alleviation and climate smart sustainable management and utilization of natural resources. Clearly, the goal takes into account climate change as the Renewable Natural Resources (RNR) sector is going to be impacted the most by climate change and climate-induced disasters. In line with this, the RNR Sector Adaptation Plan of Action (RNR-SAPA) has been prepared highlighting the main interventions to mitigate and adapt to the impacts of climate change. One of the actions prioritized in the RNR-SAPA is the promotion of climate smart agriculture (CSA) and conservation agriculture (CA). Both CSA and CA share intercropping with legumes and crop rotation as the common crop management practices. Intercropping with pulses or legumes help to protect soil from extreme erosion, improves soil structure, enhances the soil fertility status (Powers, L.E. and McSorley, R., 1999). Similarly, through crop rotation with legumes and other crops, farmers can avoid or reduce the problem of soil-borne diseases and weeds. They can also manage water availability by sequencing crops that have different patterns and amount of water use (Loomis amd Conor, 1996).

There are other new frontiers and initiatives to enhance sustainable agriculture such as organic agriculture and sustainable land management, which has compatible or complementary principles with CSA and CA. In Bhutan, the majority of the farmers practice integrated farming systems and continue to use indigenous and traditional technologies, mainly using legumes in intercropping and crop rotation. This makes small Bhutanese farms more diverse and sustainable as it focuses on effective and efficient use of available resources. It avoids dependence on a single crop. A more diverse farm helps farmers meet their subsistence, social and cultural needs besides the *in-situ* conservation of agro-biodiversity resources (Katwal, 2010). A wide diversity of genetic resources at the farm level also ensures sustainability of a farm system (Reijntjes *et al*, 1996). Therefore, pulses have a very important place and role in the CSA, CA and other allied agricultural systems.

Socio-economics of pulse production

Pulse as a cash crop

The major grain crops, rice, maize, wheat, barley and buckwheat, are largely produced for home consumption with only about 1 percent of the production going into the market (Table 4). The most important agriculture products with a large proportion flowing into the market, especially in India and Bangladesh are mandarin, apple and potato (Figure 2). About 33 percent of the total pulse production is going into the market, earning more than Nu 26 million. In general, the country has a negative balance of trade on cereals, edible oils and horticultural commodities. For instance, in 2014, the country has imported about 2 779 tonnes of pulses worth Nu 149 million, while the export was 142 tonnes worth Nu 8 million (BTS, 2014). All these commodities are imported from India thereby contributing substantially to the shortage of Indian Rupees in the country. Therefore, there is a huge opportunity and potential to enhance agriculture production in the country including pulses or grain legumes.



Source: DoA, 2013

Figure 2. Proportion of disposable production sold

Table 5. Major produce sold and cash generated

Crop Type	Production (MT)	Qty Sold (MT)	Amount Earned (Nu Mil)
Potato	50 390	30 548	560
Mandarin	33 469	26 049	463
Apple	8 032	5 431.1	155.68
Maize	75 755	2 517	43
Rice	75 228	521	19
Wheat	4 286	38	1
Barley	2 009	26	0.9
Buckwheat	3 641	23	0.786
Pulse	***1 664***	***554***	***26.3***

Source: DoA, 2013

Future outlook for pulses in Bhutan

Strategies, policies and institutions

Although, the government acknowledges the important role of pulses in national food and nutritional security, there is no specific strategy or policy intervention towards pulse research and development in the country. As such, the focus of agriculture development in the past decades has been on major cereal and horticulture crops with very limited attention being given to minor cereals and pulses. Even in the current 11th FYP (2013–2018), there is no separate programme for the improvement of pulses in the country. Despite the fact that pulses or grain legumes are placed on a par with other major cereals under the overall National Field Crop Development Programme (Box 1), the focus still continues to be placed on rice, maize and wheat.

BOX 1

MoAF/01: National Field Crop Commodity Development Programme

Field crops include rice, maize, wheat, barley, millet, buckwheat, grain legumes and oil seeds which are the major food commodities and contribute significantly to food and nutrition security both at the household and national levels. Under the National Field Crop Commodity Development Programme, the following commodities will be taken up:

a. Rice development
b. Maize development
c. Other cereals development
d. Oil seeds and legumes

Therefore, to enable the ministry to achieve its targeted pulse production of 5 000 tonnes by the end of 11th FYP in 2018 and also to achieve its broader objective of food and nutritional security, there is a need to: 1) create a national legume sub-programme, 2) strengthen research and development, 3) introduce legume promotional programmes as in other cereals, 4) develop human resources, 5) build systematic seed production programmes and 6) organize marketing support for pulses.

Reaching out to farmers and consumers

Presently, there are three Regional Research and Development Centers (RDCs) in the country which are strategically located at Bajo, Wengkhar and Bhur. The RDC at Bajo located in the west central region leads and coordinates the National Field Crops programme; the RDC at Wengkhar, based in the east coordinates the national horticulture research programme while the RDC at Bhur has the responsibility to coordinate research and development programmes on sub-tropical crops. However, the research on pulses is being taken up by RDCs at Bajo and Bhur in collaboration with other regional and international organizations. More support is required to undertake research on varieties that are tolerant to biotic and abiotic stresses.

To assist these three RDCs in delivering improved technologies to the end users, a well-functioning extension system exists in all the twenty districts. But the extension-research linkage is currently weak and needs further strengthening for meaningful research engagement and services delivery. Farmers need improved and suitable varieties which are of short duration, high yielding and resistant to multiple pests and diseases. Such varieties can be promoted in a rice-based farming system, where most of the paddy fields are currently left fallow due to lack of suitable pulse varieties and other support measures.

Conclusion

Bhutan is an agrarian country with about 56 percent of the population engaged in agriculture for their livelihood. The mountainous topography limits the yield potential for most crops and increases the labour requirements as compared to other more favourable production environments, e.g. India. As a result, the production cost per unit produced is high, making Bhutanese products less competitive in regional and global markets. In fact, it is very difficult to compete even in the domestic market with cheap Indian imports, which further discourage farmers from producing more. Currently, most of the cereal requirements of the country, including pulses are met through imports which have resulted in a negative balance of trade and shortfall of Indian Rupees. As far as pulse production is concerned, there exists huge opportunity and potential. But this will require support and interventions from policy, research, extension and marketing. Without these collective measures, it will be difficult to scale up pulse production in the country and consequently achieve national food and nutritional security.

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The integrated technology on legume growing after rice in the rainfed lowland of Cambodia

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Abstract

The agriculture sector remains crucial for economic stability and growth in Cambodia. Rice is the main crop and staple food that also meets the basic needs of the majority of people and marginal farmers. Rice production relies heavily on the rainfed lowland ecosystem, which accounts for 86 percent of about 2 827 130 ha of rice production areas. The country has been self-sufficient in rice with a small amount of exportable surplus since 1995. Total rice production increased dramatically from 5.99 million tonnes (mt) in 2005 to 9.23 mt in 2014 with 3.02 mt surplus of milled rice equivalent to 4.71 mt of paddy rice.

Cultivation of other crops such as soybeans, mungbeans, peanuts, vegetables and rubber declined markedly since 1967, either because of loss of markets or because during the long period of civil war, most farmers reverted to subsistence rice production. Opportunities for crop diversification and increasing household income of rice-dependent farmers exist through growing legumes and vegetables in the early wet season and dry season, especially where supplementary irrigation can make up for deficits in stored soil moisture and rainfall. Upper and high fields with marginal water supply for rice can also be considered for crop diversification.

Legumes such mungbeans, soybeans and peanuts are suitable for growing on lowland paddy field after wet season rice or early wet season. The results of recent research conducted by the Cambodian Agricultural Research and Development Institute (CARDI) indicated that mungbeans and peanuts were the high-yielding potential crops suitable for growing on the sandy soil in the rainfed lowland areas after harvesting wet season rice. Four mungbean varieties have been released by CARDI since 2009 which are grown after harvesting wet season rice. These are *CMB1, CMB2, CMB3* and *CARDI's Chhey*. These are short-duration varieties requiring 50–55 days from planting to the first harvest with an average yield of 850 kg/ha. The yield can be as high as 1 900 kg/ha under proper crop management and the farmer can keep the seed for growing in next season.

Based on information obtaineds from interviewing 350 households, most farmers indicated interest in growing mungbeans after wet season rice using a new integrated technology package. Mungbean growing in sandy soil in the rainfed lowland areas following wet season rice can help farmers produce sufficient food for their household and increase cash income throughout the year, and it improves soil fertility through crop rotation (legume) and multicropping in paddy fields. Income from mungbeans grown in this system was shown to be 60 percent higher than the income from growing only a single rice crop (40 percent).

Introduction

The Kingdom of Cambodia, located at the centre of the Indochina peninsula, has a land area of about 181 035 km^2 and a population of 15 million (MAFF, 2014). More than half of its land is flat, and the Mekong river flows from North to South in the heart of the country. Agriculture is the mainstay of the Cambodian economy. The country is blessed with vast fertile land and the rich water resources of the Mekong river system. The agriculture sector employs around 84 percent of the total population with a high proportion of them being very poor (PDAFF, 2014). A significant number of the rural population lives below the poverty line, according to a government report that shows the proportion of poor people in rural areas of Cambodia decreased from 47 percent in 1994 to 35 percent in 2004 and 26 percent in 2010.

Recently, the Royal Government of Cambodia announced its policy of poverty alleviation and improving the living standards of all Cambodians, especially of rural farmers by improving agricultural production through crop diversification and the introduction of integrated farming systems. Agricultural production in Cambodia can be improved by diversification from traditional wet season lowland rice production to double cropped and rice-based production systems. However, this will require significant capacity building in essential agricultural information technology and extension support services to strengthen the knowledge and skills of farmers, conducting applied research and transfer of agricultural technologies through training, information sharing and creating public awareness.

In Cambodia, lowland areas are widespread throughout the country. They are suitable for rice production and are generally underutilized. Rice is the staple food crop which meets the basic needs for the majority of people and marginal farmers. Other crops grown are legumes, maize, cash crops, cassava and vegetables. Rice production relies heavily on the rainfed lowland ecosystem which accounts for 86 percent of approximately 2 827 130 ha of rice production areas (MAFF, 2014). It is recognized that rice productivity in a rainfed lowland system is dramatically affected by the amount of rainfall (Ouk *et al.*, 2001). Cambodia achieved self-sufficiency in rice with a small amount of exportable surplus in 1995 (MAFF, 1995–2015). Rice in Cambodia holds the potential to reduce food shortages among the rural poor.

However, the area cultivated by other crops such as soybeans, mungbeans, peanuts, vegetables and rubber declined remarkably since 1967, either because of loss of markets or because during the long period of civil war, most farmers reverted to subsistence rice production (Table 1). Opportunities for crop diversification and increased household income of rice-based farmers exist through growing legumes and vegetables in the early wet season and dry season especially where supplementary irrigation can make up for deficits in stored soil moisture and rainfall. Upper and high fields with marginal water supply for rice can also be considered for crop diversification. Based on Landsat imagery of 1993, 1.25 million ha (mha) of land is potentially available for crops other than rice, and another 2.3 mha of shrub lands may also have potential (FAO, 1996). When compared with 0.30 mha currently under cultivation of legume and vegetable crops, this assessment indicates a 10 to 30-fold increase of potential area for growing legumes and other horticulture crops. Security considerations have until recently hindered productive utilization of these areas. Now with the easing of those concerns, growing population pressure and market access factors are likely to be key drivers of the expansion of legume production as they were in northern and northeast Thailand in 1960s and 1970s (Chiang Mai Uni., 1993).

In July 2010, the Royal Government of Cambodia approved a policy paper on “the Promotion of Paddy Production and Rice Export”. This paper aims to promote agriculture development at a new pace and in a new scale that broadens and strengthens the foundation of economic growth, while accelerating poverty reduction and improving people’s livelihoods. The purpose of this document

Table 1. Production of major crops in Cambodia (area: 000 ha, production: 000 tonnes)

Crops		1967	1980	1992	2000	2002	2004	2007	2009	2012	2014
Rice grain	Area	2 513	1 440	1 685	2 318	2 113	2 374	2 567	2 674	2 980	3 055
	Prod.	2 456	1 717	2 221	4 026	3 822	4 170	6 727	7 585	9 290	9 234
	Yield	0.98	1.19	1.35	2.11	1.91	1.98	2.62	2.84	3.117	3.052
Maize	Area	117	101	50	71.5	80.5	91.2	107.8	221.3	215.4	218.2
	Prod.	150	101	60	156.9	148.9	256.7	377.0	924.0	950.9	916.8
Cassava	Area	2	17	16	16.3	19.6	22.8	96.5	160.3	337.8	521.5
	Prod.	23	152	150	147.8	122.0	362.1	2 182	3 497	7 614	11 567
Mungbean	Area	47	36	28	24.9	39.8	39.1	85.0	49.6	62.7	54.0
	Prod.	25	10	14	15.1	23.9	45.3	59.9	44.6	74.67	
Soybean	Area	8	4	16	33.3	33.4	84.9	74.1	96.4	70.97	80.0
	Prod.	7	3	40	28.1	38.7	110.3	98.3	137.3	120.2	
Peanut	Area	–	–	–	10.4	13.8	19.2	17.0	16.5	18.13	19.0
	Prod.	–	–	–	7.5	9.7	21.5	23.8	21.8	30.37	
Vegetables	Area	43	48	25	33.7	34.4	32.6	42.0	50.3	54.15	52.0
	Prod.	430	106	162	195.9	163.2	179.1	223.1	322.7	411.4	

is to increase paddy production and rice exports. The Royal Government expects that the success of the "***Policy Paper on the Promotion of Paddy Production and Rice Export***" will give a strong political message that encourages and paves the way for the promotion of other agricultural products such as soybeans, mungbeans, rubber, cashew nuts, cassava, maize, peanuts and vegetables, not to mention other agricultural sub-sectors such as aquaculture. All of this is embedded in the long-term, vision of the Royal Government for economic development.

Legumes such mungbeans, soybeans and peanuts are suitable crops for growing on lowland paddy field after wet season rice or early wet season. The results of recent research done by CARDI indicate that mungbeans and peanuts are high-yielding potential crops suitable for growing on sandy soil in the rainfed lowland areas after harvesting wet season rice. Moreover, they have a unique nutritional profile rich in high quality protein; the principal source of dietary protein. They are also called the meat of the poor in many developing countries.

Climate condition

Cambodia is in the humid tropics and experiences annual alternating high and low pressure systems which move seasonally over the central Asian land mass. The climate is characterized by a cool dry season from November to January, a hot dry season from February to April and wet season from May to November. The annual mean temperature is 28°C and the mean annual precipitation is 1.44 meters, with considerable variation from year to year. In general, the climate and topography are conducive to cultivation of both tropical and temperate crops, depending on the location within the country. However, the dry season is long and pronounced spanning from November to May with little or no rainfall. The dry period is characterized by a high vapor-transpiration. Crops grown during the dryer months (January–May) usually require supplementary irrigation.

In March and April the climate is very hot and dry throughout the whole country. Scarcity of water limits crop production and relatively few crops are grown in this period. Short-duration crops are usually grown depending on the availability of water. The major crops that are grown in subsistence gardens in this period include water convolvulus, cucumber, and yard long bean. Surplus produce is sold through the local markets.

In the rainfed areas, high lands and surfaces are sometimes available to grow other crops. The characteristics of these areas are the same as those of the bank tops. However, water management during the dry season is critical in this area. The practice of cultivating a home garden is not as widespread in Cambodia as it is in other countries in the region (PRASAC, 1997). The brown hydromorphic soils in Battambang province are also very important areas for non-rice crop production (Vang *et al.*, 2003). Other lowland crops are also being cultivated in the upland rice fields in the northeast province of Cambodia. In Kratie, intercropping rice with rows of corn, cucumber and peanuts is common among Cambodian farmers (Javier, 1996).

The climate condition in 2014, especially rainfall, is considered to have been more favourable for crop production in the country, except for some areas of the following provinces which faced some problems of slight mid-season drought occurring in Siem Reap, Svay Rieng, Kampong Speu and Kandal provinces; and slight end-season drought occurring in Kampong Cham, Kampong Speu, Takeo, Kampot, Kampong Thom and Prey Veng province.

Project objectives

Field demonstrations on integrated technology for growing mungbeans on sandy soil after wet season rice, including land preparation, planting techniques, application of recommended fertilizer rates, crop management and the released new variety were conducted from 2009 to 2014 in the rainfed lowland areas following wet season rice in three provinces (Kampong Thom, Kampot, and Takeo).

The objective of this study was to promote growing upland crops in rainfed lowland areas, improving the livelihood of farmers and increasing their income through growing mungbeans after harvesting wet season rice. It also focused on improving soil fertility through crop rotation (legumes) in paddy fields to help farmers produce sufficient food for their household and increase cash income through the sale of surplus food.

Generally, after harvesting the wet season rice in December, the Cambodian farmer usually leaves the paddy fields fallow because of the shortage of water and a number of other constraints to growing a second crop. The results of recent research conducted by CARDI indicate that mungbeans and peanuts are the high-yielding potential crops suitable for growing on the sandy soil in the rainfed lowland areas after harvesting the wet season rice. However, soybeans are also a high-yielding potential crop suitable for growing on upland rainfed lowland areas.

Since 2009, CARDI released four mungbean varieties – CMB1, CMB2, CMB3 and CARDI's Chhey – that can be grown after harvesting the wet season rice. These are short-duration varieties with growth duration ranging from 50 to 55 days with an average yield of 850 kg/ha. The yield can be as high as 1 900 kg/ha with application of recommended crop management practices, and the farmer can keep the seed for growing in next season. In addition, farmers can benefit from the higher market prices of mungbeans that prevail during the harvesting time.

Results

As is evident from Figure 1, the application of CARDI's technology package produced grain yield of mungbeans at 561 kg/ha averaged over 23 sites. However, there is potential to increase the yield level to 1 062 kg/ha if farmers apply good management practices. The grain yield obtained in the trial was nearly double what farmers harvested (275 kg/ha) with their traditional practices and varieties (Figure 1). Economic analysis revealed that the gross income received from CARDI's technology package was 2.93 million Riel/ha, while the gross income received from farmers' practice with farmers variety treatment was only 1.07 million Riel/ha (Figure 1). Apart from field demonstrations, the programme conducted one famers' field day attended by 53 participants. Based on information obtained from interviewing 350 farmers, it became apparent that most farmers were interested in growing mungbean variety CMB3 after wet season rice using CARDI's technology package.

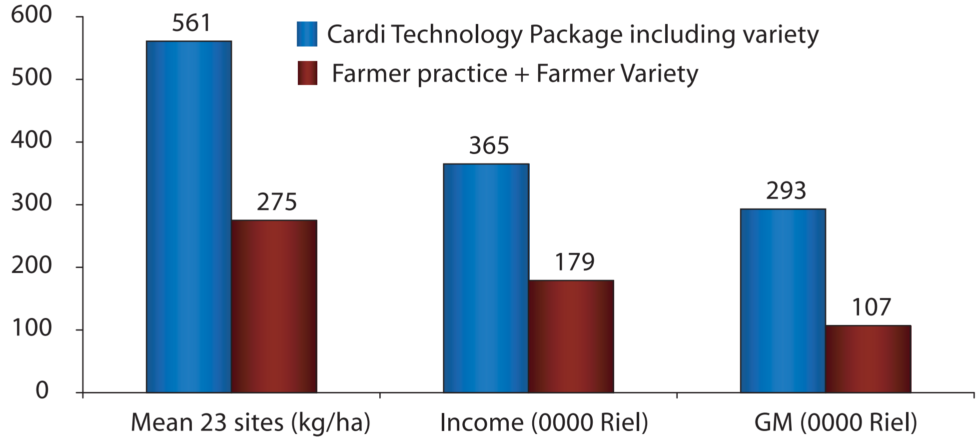

Figure 1. Mungbean yield (tonne/ha) and gross margin of CARDI's technology package and farmer's practices

Conclusion and recommendations

The results of field demonstration showed that with the application of CARDI's technology package, farmers obtained an average 561 kg/ha grain yield of mungbeans. However, with proper crop management practices yield increased up to 1 062 kg/ha. The average grain yield was nearly double compared with only 275 kg/ha obtained using farmers' traditional practices. Similarly, gross income also doubled to 2.93 million Riels/ha with the use of CARDI's technology compared with 1.07 million Riels/ha obtained using traditional practices only.

Apart from field demonstrations, farmer field schools were conducted on land preparation, planting techniques, recommended fertilizer rates, water and pest management, and post-harvest technology in the target areas attended by 760 participants. Besides, a farmers' field day was organized. Based on information obtained from interviewing 350 households, it was evident that most farmers were interested in growing mungbeans after wet season rice using new integrated technology package. Moreover, mungbean growing on the sandy soil in the rainfed lowland areas after harvested wet season rice can help farmers produce sufficient food for their household and increase cash income year round and improve soil fertility through crop rotation (legumes) and multicropping in paddy field.

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Recent achievement in research and development of pulses in China

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Abstract

China has vast territory with diverse ecological conditions where more than 20 pulse species are grown. Rotation, intercropping and mixed cropping involving pulses are the normal cropping systems. China became a member of the WTO in 2001, which affected the production status of pulses with sharp increases in production of green pod and a slight reduction in dry grain production of pulses. The research and extension system for pulse crops production chain have shifted their efforts to the newly emerged demands for research, breeding, production and consumption of pulses.

Introduction

China has vast territory, diverse ecological conditions and a great variety of pulse species. The main pulse crops grown in the country are: soybeans (*Glycine max* (L.) Merill), groundnuts (*Arachis hypogaea* L.), broad beans (*Vicia faba* L.), peas (*Pisum sativum* L.), chickpeas (*Cicer arielinum* L.), lentils (*Lens culinaris* Medik), common beans (*Phaseolus vulgaris* L.), adzuki beans (*Vigna angularis* (Willd) Ohwi & Ohashi), mungbeans (*Vigna radiata* wilczek), cowpeas (*Vigna unguiculta* L. Walp. spp. *unguiculata*), multiflora beans (*Phaseolus multiflorus* Willd), lima beans (*Phaseolus Lunatus* L.), hyacinth beans (*Lablab purpureus* (L.) Sweet), rice beans (*Vigna umbellata* (Thumb.) Ohwi and Ohashi), winged beans (*Psophocarpus tetragonolobus* (L.) DC.), pigeon peas (*Cajanus Cajan* L.) Millsp.), velvet beans (*Mucuna pruriens* (L.) DC. var. *Utilis* (Wall. ex Wight) Baker ex Burck), lupine (*Lupinus* L.), etc. In China, peanuts are not included in pulses or food legumes, but in oil crops.

Soybeans originated in China, mungbeans and adzuki beans partially originated in China, faba beans and peas were cultivated for longer than 2 000 years; Common beans, cowpeas, chickpeas and lentils were cultivated for hundreds of years. Pulses play an important role in cropping system in China for traditional and sustainable agriculture since ancient times. Pulses are also the key components in dietary protein, vitamin B, and diversified recipes in ordinary food dishes. This traditional preparation ensured the basic health of Chinese people.

Trends in pulse area, production and productivity

Production of pulses in China

The status of pulse production in China averaged over 2004–2013 is shown in Table 1.

Table 1. Cropped area, production and yield of pulses in China averaged over 2004–2013*

Pulses	Planting area (000 ha)	Production (000 tonnes)	Yield (kg/ha)
Soybeans	8 549.61	14 682.05	1 723.66
Peanuts	4 437.15	14 890.52	3 354.26
Faba beans (dry)	937.90	1 648.60	1 757.99
Peas (dry)	913.27	1 098.75	1 204.05
Peas (green)	1 163.71	9 243.39	7 995.70
Chickpeas	2.61	9.48	3 643.79
Lentils	66.85	138.00	2 074.25
Common beans (dry)	982.33	1 450.59	1 472.48
Common beans (green)	572.42	13 606.30	23 618.58
Adzuki beans**	175.99	24.22	1 376
Mungbeans**	652.06	77.17	1 183

* Cited from reference 1. ** Cited from reference 2.

Currently, China is one of the biggest producers of pulses in the world. The contribution of China in the global output of pulses is shown in Table 2. Except soybeans and peas, other pulses listed in Table 2 yielded higher than the world average levels.

Table 2. Share of China in the global production of pulses, 2013*

Pulses	% of the world total output	Rank	% of the world average yield
Soybeans	4.33	4	71.12
Peanuts	37.28	1	203.95
Broad beans (dry)	39.67	1	103.97
Peas (dry)	10.54	3	73.90
Peas (green)	60.08	1	106.35
Chickpeas	0.09	22	418.92
Lentils	3.47	7	208.03
Common beans (dry)	4.55	5	141.55
Common beans (green)	75.10	1	192.24
Mungbeans	–	–	–
Adzuki beans	–	–	–

* Calculated with the data from reference 1.

Pulses are favourites in the daily life of the Chinese people and were important in the history of crop production in China. Since 2001, the import of pulse grains from USA, Brazil, Argentina and Canada was increasing year by year. Pulse grain production is declining gradually and the proportion of vegetable pulse production sharply increased during the past 15 years (Table 3). Because of the short crop duration and high market value, peas and common beans became dominant in vegetable pulse production in China. Vegetable soybeans and faba beans are following the same trend as peas and common beans.

Table 3. Harvest area of pea and common bean in China (ha) since 1999*

Year	Pea (dry)	Pea (green)	Common bean (dry)	Common bean (green)
1999	830 000	660 000	1 158 500	325 000
2000	840 000	730 000	1 200 000	370 000
2001	942 000	770 000	1 330 000	425 000
2002	950 000	820 000	1 434 500	455 000
2003	940 000	880 000	1 313 800	474 000
2004	878 000	920,000	1 148 000	500 000
2005	1 000 000	1 040 000	1 220 000	525 000
2006	900 000	1 050 000	950 000	550 000
2007	981 000	1 150 000	987 000	565 000
2008	925 000	1 170 000	1 000 000	587 300
2009	875 000	1 200 000	900 000	575 400
2010	871 300	1 250 000	907 000	594 000
2011	872 400	1 295 000	937 530	593 820
2012	925 000	1 300 000	848 720	616 890
2013	905 000	1 300 000	925 000	628 700

* Cited from reference 1.

Distribution of pulses in China

Pulse crops can be found in all provinces, autonomous regions and suburban regions of big cities in China, but most pulses are distributed unevenly (Table 4).

Table 4. Distribution of pulses in China*

Pulses	Regions	Top five producing provinces, or autonomous regions
Soybeans	Northeast, Yellow-Huai-Hai Rivers Valleys, South China	Heilongjiang, Henan, Aihui, Shandong, Inner Mongolia
Peanuts	East, Northeast, Southeast	Shandong, Jilin, Henan, Hebei, Guangdong
Faba beans	Southwest, Northwest, Southeast, North	Yunnan, Sichuan, Jiangsu, Qinghai, Hebei
Peas	Southwest, Northwest, East, Northeast	Sichuan, Yunnan, Gansu, Hebei, Jiangsu
Chickpeas	Northwest, Southwest	Xinjiang, Gansu, Ningxia, Shaanxi, Yunnan
Lentils	Northwest, Southwest	Gansu, Yunnan, Xinjiang, Shanxi, Shaanxi
Common beans	Southwest, Northwest, Northeast	Heilongjiang, Guizhou, Inner Mongolia, Shandong, Sichuan
Mungbeans	Southwest, Northeast, South	Jilin, Hebei, Henan, Shandong, Anhui
Adzuki beans	Northeast, East	Heilongjian, Tianjin, Hebei, Beijing, Shandong

* Cited from reference 3 with editing.

Pulse-based farming system dynamics

Soybeans

Rotation

In China soybeans are grown in rotation mostly with maize, sorghum, millet, wheat, potato. Cereals are the best crops for rotating with soybeans.

Intercropping and mixed-cropping

Soybeans are also grown as an intercrop with maize in eastern provinces such as Shandong, which produces higher total production per unit area than monocropping of soybeans or maize.

Faba beans and peas

Rotation

Faba beans and peas are preferred crops for rotation with rice, cotton, maize, sweet potato, tobacco in winter-sown areas; they are rotated with wheat, barley, canola, peas, vetch and lucerne in spring-sown areas of China.

Intercropping and mixed-cropping

Faba beans and peas are often intercropped with with wheat, canola, potato; they are also planted in rows between fruit trees, tee trees and mulberry trees for vegetable production.

Chickpeas and lentils

Rotation

Chickpeas and lentils are rotated with wheat, sorghum, cotton in spring-sown areas; and with sugarcane and rice in winter-sown areas.

Intercropping and mixed-cropping

Chickpeas and lentils are grown as intercrop and mixed crop with barley, wheat, sorghum, peas, flax, canola, saffron.

Common beans

Rotation

Common beans are a good rotating crops with wheat, maize in maize and wheat production areas like Heilongjiang province and Shanxi province.

Intercropping and mixed cropping

Common beans are intercropped with maize, cotton and potato; it is also planted in rows between fruit trees and timber trees, for fallow land utilization.

Mungbeans and adzuki beans

Rotation

Mungbeans and adzuki beans are good rotating crops with wheat in wheat production areas, such as Hebei province, Shandong province and Henan province.

Intercropping and mixed-cropping

Mungbeans and adzuki beans are intercropped with maize, sorghum, cotton, sweet potato, sesame, millet; they are also planted in rows between fruit trees and timber trees, for fallow land utilization.

Major achievements in increasing pulse production and productivity

Research on pulse crops in China is mainly conducted by the Chinese Academy of Agricultural Sciences (CAAS), provincial agricultural academies, prefecture-level institutes and agricultural universities. Recently, some enterprises have invested in pulse breeding. The crop germplasm was collected and conserved in the Institute of Crop Sciences of CAAS, some provincial agricultural academies and a few universities.

Pulse crop breeding

In the past 50 years, China released more than 2 300 improved pulse varieties. The varieties of major pulses were replaced several times. Up to 2014, 2 064 soybean varieties were approved by MoA or provincial governments for release. At present, improved varieties occupy 90 percent of the total area under soybean cultivation in China. The varieties were replaced five to seven times in the northeast, four to six times in the Yellow-Huai-Hai Rivers Valleys and three to five times in the south. Since 1949, significant advances have also been achieved in the breeding of mungbeans, broad beans, peas, common beans and other pulses. The varieties of pulse crops released in China are shown in Table 5.

Table 5. A list of elite varieties of pulse crops in China*

Pulses	Varieties
Soybeans	Heihe 3, Heihe 43, Keshan 1, Xiaojinhuang 1, Mancangjin, Dongnong 4, Suinong 14, Heinong 26, Hefeng 25, Hefeng 55, Jilin 3, Jilin 20, Jiyu 47, Tiefeng 18, Fengshouhuang, Yuejin 5, Youbian 30, Ludou 4, Zhonghuang 13, Nandou 12
Broad beans	Yundou 324, yundou 147, Fengdou 6, Fengdou 10, Chenghu 14, Chenghu 15, Chenghu 16, Tongcan 5, Tongcan(xian) 6, Chonglicandou, Qinghai 9, Qinghai 10, Qinghai 12, Qinghai 13, Qinghai 14, Lincan 4, Lincan 5
Peas	Zhongwan 4, Zhongwan 6, Airuan 1, Kewan 1, Kewan 2, Suwan 1, Caoyuan 276, Caoyuan 224, Qinxuan 1, Baofeng 3, Caoyuan 12, Yunwan 4, Yunwan 10, Chengwan 7, Chengwan 8, Shijiadacaiwan 1, Caoyuan 31, Taizhong 11, Tiancui 761
Chickpeas	Muying 1, Keying 1, A-1, 88-1
Lentils	Dingxuan 1, Ningbian 1, Qindou 9, Xiangfenxiaobiandou, Binxianbiandou, Qingyangbiandou, Lijiangbiandou, Tongxinbiandou, Dingbianbiandou
Common beans	Xiaobaiyundou, Zaolvdidou, Pinyun 2, Zihuayundou, Changnaihuayundou, Ziyuanyundou, Dahongyundou, Shenhongyundou, Xiaohongyundou, Zhunaihuayundou, Huangyundou, Honghuayundou, Longyundou 4, Longyundou 5, Naihuayundou, Ayun 1, Ayun 2, Suyundou 1
Cowpeas	Zhongjiang 1, Zhongjiang 2, Yujiang 1, Lijiangdou, Zaozhuangjiangdou, Tai'anbaijiangdou
Adzuki beans	Jihongxiaodou 2, Jihongxiaodou 4, Jihong 9218, Jibaohongxiaodou 2, Bao 876—16, Zhonghong 2, Baohong 947, Baihong 2, Baihong 3, Jihong 6, Jingnong 5, Jingnong 8, Liaoxiaodou 1, Jinlinghongdou, Ehongxiaodou 1
Mungbeans	Zhonglv 1, Zhonglv 2, Zhonglv 4, Jilv 2, Jilv 9239, Jilv 7, Jilv 9, Baolv 942, Nenlv 1, lvfeng 5, Bailv 5, Bailv 6, Dayinggelv 935, Jilv 2, Weilv 1, Weilv 4, Elv 2, Yulv 2

* Cited from reference 5 with editing.

Germplasm studies

China has a long history of agriculture and is one of the largest centres of origin for crop diversity. It holds rich genetic resources for pulse crops. Till now, more than 74 thousand accessions of pulses genetic resources have been collected (Table 6).

Table 6. Accession numbers of pulses in China

Pulses	Number	Pulses	Number
Soybeans	23 587	Beans	448
Peanuts	20 287	Lima beans	44
Broad beans	4 957	Multiflora beans	134
Peas	5 067	Pigeonpeas	140
Lentils	1 176	Sword beans	17
Cowpeas	2 055	Winged beans	52
Azuki beans	4 893	Mungbeans	5 739
Rice beans	1 554	Hyacinth beans	68
Velvet beans	57	Chickpeas	322
Blackgrams	2	Total	74 599

Apart from collection and conservation of pulse germplasm, Chinese scientists evaluated various characters such as agronomic traits, quality, pest resistance, and stress tolerance of the germplasm. The National Databank of Crop Germplasm Resources, a useful tool for the evaluation and study of pulse germplam, has been established.

Crop management optimization

Pulse-based cropping systems for monocropping, intercropping and mixed cropping have been optimized during the past ten years, supported by the China Agriculture Research System (CARS). Optimized packages for soybean, faba bean, pea, common bean, mungbean, adzuki bean production in their major production areas in China are available.

Constraints in productivity enhancement and emerging challenges

Export and import trade of pulses in China re-statued their production

Crops are important items in international trade for China, and pulses played major roles in the trade of agricultural products. The import and export of some pulses and their products in 2012 is shown in Table 7. China exported faba beans and adzuki beans to Japan, European countries and, Southeast Asian countries. The imported soybeans were mainly from the USA, Brazil and Argentina.

Imported dry soybeans and dry peas dominated the market, which greatly reduced the income of smallholder producers of dry soybeans and dry peas. This obviously reduced sowing area of soybean and peas for dry grain production in China.

Table 7. China's international trade in some pulses and their products in 2012 (FAO, 2012)

Pulses	Import		Export		Net export	
	Amount (tonnes)	Value (000$)	Amount (tonnes)	Value (000$)	Amount (tonnes)	Value (000$)
Soybeans	60 765 498	36 454 951	330 782	284 094	-60 434 716	-36 170 857
Peanuts	25 420	33 395	103 699	206 010	77 679	172 615
Faba beans	–	–	–	–	–	–
Peas (dry)	689 347	301 384	1 053	2 044	-688 294	-299 304
Peas (green)	5 926	4 262	16 274	29 237	10 348	24 975
Chickpeas	537	509	36	45	-501	-464
Lentils	1 132	1 210	14 051	11 303	12 919	10 093
Common beans (dry)	80 407	65 334	944 106	968 568	863 699	903 234
Common beans (green)	134	143	1 703	1 315	1 569	1 172
Adzuki beans	–	–	–	–	–	–
Mungbeans	–	–	–	–	–	–

Climate change reduced pea and faba bean production in winter-sown areas

Since 2005, because of climate change rainfall in the main production areas of faba beans and peas, such as the provinces of Yunnan and Sichuan, significantly decreased during the cropping period affecting the winter-sown areas. As a result, the cropped area and productivity of faba beans and peas decreased sharply. In areas like Wenshan prefecture in Yunnan province, dry pea production declined to 30 percent from the original area in 2005.

Strong competition with maize has sharply reduced sowing area for soybeans, mungbeans and adzuki beans

Since hot season pulses like soybeans, mungbeans, adzuki beans and cowpeas, are grown in the same season as cereals, the C4 maize has dominant competitiveness over hot season pulses. This resulted in a sharp reduction of soybean, mungbean, adzuki bean and cowpea sowing areas in their traditional production provinces.

Current efforts for improving pulse productivity

Shift production of soybeans, peas, common beans and faba beans for dry grain to green pods

Green pod production holds the potential for increasing income of smallholder farmers because of its higher market price than that of dry grain soybeans, peas, common beans and faba beans, as well as shorter crop duration for green pod production. Frmers tend to switch to green pod production in traditional soybean, pea, common bean and faba bean growing areas. So, the breeding and research efforts shifted to developing varieties suitable for green pod production of soybeans, peas, common beans and faba beans.

Explore new areas for green pod production of peas and faba beans

Global warming has opened opportunities for winter cultivation of peas and faba beans in traditional spring-sown areas for green pod production. Since 2009, CAAS screened 4 000 accessions each of pea and faba bean germplasm from vast geographical origins globally. Strong tolerant accessions or winter hardy accessions were selected for breeding programmes of peas and faba beans.

Develop new areas of chickpeas in drought areas of winter sowing regions

As global warming has led to winter drought in the major dry pea production provinces, Yunnan and Sichuan, dry pea production declined remarkably. Improved pulses were introduced into these areas three years ago by CAAS and YAAS cooperative programme. The preliminary results showed a promising future for chickpea production in the above provinces.

Suitability of pulse for conservation agriculture

Traditional crop rotation, intercropping, and mixed cropping systems including pulses proved suitable for conservation agriculture in China. Pulses produce nitrogen fixation nodules, which can be self-sufficient for N supply and also serve as N fertilizer providers for their companion crops in the cropping systems.

Contributions of pulses to nutrition, employment and income generation, and value chain development

Soybeans

Soybeans are one of the major plant protein sources in the Chinese diet. In the daily life of Chinese people, tofu, soybean sprouts, soybean milk, soy sauce, fresh or frozen soybean pods are popular non-staple foods. Soybean oil is the main plant-derived edible oil in the country, second only to palm oil. In recent years, the consumption of soybean products increased dramatically and a large amount of soybeans and soybean products were imported. At present, China is the biggest buyer of soybeans in the world with over 60 percent market share of the global soybean export market.

Peanuts

Peanuts are used for production of edible oil, for favourite snack foods and nuts. Peanuts are also used as important components in the preparation of various kinds of cakes, sweets, soups, and traditional local foods in China.

Other pulses

The food made from the other pulses are favorites of Chinese people. The main types of this kind of food are as follows:

Staple food: grinding to flour, mixing with wheat or maize flour to make various staple foods; or adding to rice or maize to cook rice meal or gruel. Sometimes the pulses are used solely to make food.

Non-staple food: mungbeans, broad beans and peas can be used to make starch noodles; green peas, green faba beans, green chickpeas are high quality vegetables for cooking dishes; mungbeans sprouts and lentil sprouts, fresh pods of some pulses are popular vegetables in China too.

The tonic and medicinal value of some pulses

According to traditional Chinese medicine, balanced nutrition is the basis of health. Pulse crops with different nutritional and chemical compositions are highly regarded as healthy food. Some of them are used as tonics or even medicine. Table 8 shows the tonic and medicinal values of some pulse crops according to traditional Chinese medicine.

Table 8. The tonic and medicinal value of some pulse crops according to traditional Chinese medicine*

Pulses	Tonic and medicinal values
Adzuki beans	Curing oedema, parotitis, milk excretion obstacle and some gynecological diseases.
Soybeans	Preventing coronary heart disease, hypertension, atherosclerosis, colon cancer, and climacteric syndrome.
Black soybeans	Curing eczama, neurodermatiris and vitiligo when using crudely on the skin.
Mungbeans	The mungbean gruel is a good cure for heat stroke. Mungbeans can also be used in promoting urine, alleviating swelling, etc.
Broad beans	Curing arteriosclerosis, oedema, chronic nephritis; Resisting senescence.
Pea	Curing cholera, beriberi, diabetes, swelling, etc.

* Cited from reference 4 with editing.

Strategy for meeting the future opportunity and challenges

Research on genetic resource development for specific traits of economic interest

While developing pulse genetic resources, researchers are primarily interested in such traits as drought tolerance, heat tolerance, and winter hardiness. CAAS and provincial research groups on pulses should strengthen their efforts to meet the future needs of breeding programmes.

Breeding for abiotic tolerance and for green pod production

The demand for new varieties that are tolerant to drought and heat, with winter hardiness and suitable for green pod production ranks top among the priorities in pulse breeding programmes. CAAS and provincial breeding teams on pulses should concentrate their efforts on meeting the future needs of smallholder farmers.

Reaching out to farmers and consumers

National platform for release of new varieties has been established by MOA, China

The national platform for release of new varieties bred by CAAS and provincial breeding teams has been established by MoA, China in 2014 to meet the needs of pulse varieties for smallholder farmers, large farmers and seed companies. Smallholder farmers, big farms and seed companies in China, can visit the government website for detailed information.

China Agriculture Research System (CARS) established by MoA, China

China Agriculture Research System (CARS) established by MoA in 2008 includes CARS-soybean system, CARS-peanut system, and CARS-food legume system. The CARS system provided stable funding each year that enabled national research scientists working with specific crops to efficiently coordinate ongoing research on breeding, crop management, plant protection, food processing, production chain economy development. It also allowed effective and smooth transfers of research results to farmers, consumers and other actors in commodity value chains.

Conclusion

The demand for pulse crops is projected to grow significantly along with rising living standards of the people and increasing awareness about consumption of healthy food. Since China became a member of the WTO in 2001, the import of soybeans and peas from the USA, Canada, Brazil and Argentina was increasing rapidly which depressed the market price of dry pulses. This has resulted in driving down the returns in domestic production of dry grain of pulses and has decreased of the sown area and total production. At the same time, the increasing trend of Chinese consumers to eat traditional food based on vegetable pulses, as well as growing appreciation of the health benefits of vegetable pulses has led to a sharp increase in vegetable pulse production in China. This also benefits the cropping systems by reducing crop duration as pulses are grown for consumption as vegetables.

In future pulse-based cropping systems that include dry pulse production will likely to remain static or decline and the vegetable pulse production is likely to increase rapidly. Therefore, breeding research on genetic resources and genetic studies in China will be oriented towards supporting vegetable pulse production and will be strengthened at national and provincial levels.

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Pulses in India: current status and way forward

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Introduction

Pulses are the irreplaceable source of dietary proteins in vegetarian diets of the developing countries. The protein content of grain legumes (16–48 percent) is double that of wheat and three times that of rice (Rodino *et al.*, 2011). This makes a diet of pulses complemented with cereals as one of the best solutions to protein-calorie malnutrition. Besides proteins, these are also an important source of the 15 essential minerals required by man (Wang *et al.*, 2003). Due to their diverse uses as atmospheric nitrogen fixing agents, green manure and cover crops, catch crops in short season cropping windows, breakfast grains and ingredients of specialty diets, pulses are an important subject of agricultural, environmental and biotechnological research (Singh and Pratap, 2015).

In India, over a dozen pulse crops including chickpeas, pigeonpeas, cowpeas, mungbeans, urdbeans, lentils, French beans, horse grams, field peas, moth beans, lathyrus, etc. are grown in one or the other part of the country. However, the most important pulse crops grown in the country are chickpeas (41 percent), pigeonpeas (15 percent), urdbeans (10 percent), mungbeans (9 percent), cowpeas (7 percent) lentils (5 percent) and field peas (5 percent).

During the last few years the production of pulses in the country has witnessed an upward trend and it has consistently remained above 18 million tonnes (mt) since 2010. The latest production figure of 19.27 mt for the year 2013-2014 has been an all-time record high. This appears to be a revolutionary moment for the country towards achieving self-sufficiency in pulse production which has been a long pending demand. The scenario was entirely different during the first decade of this century when the total production of pulses stagnated hovering at around 14–15 mt. The deficit was to the tune of 4–5 mt which was mainly filled by imports from other countries. However, the accomplishment of the last few years and tremendous opportunities available for vertical and horizontal expansion of pulses brighten the prospects for moving rapidly towards achieving self-sufficiency in pulses.

The nutritional value of pulses is quite high as compared with most of the cereals. The pulse protein is low in sulphur-containing amino acids but rich in lysine, an amino acid that is deficient in many cereals. Therefore, when pulses are added in cereal-based vegetarian diets, their nutritive quality comes on a par with animal proteins. Pulses are also good sources of the B-group vitamins apart from riboflavin. Although pulses are devoid of vitamin C, a large amount of ascorbic acid is formed during their germination. During the sprouting process, vitamins, minerals and protein increase substantially, with a corresponding decrease in calories and carbohydrate content, which leads to an improvement in nutritive value and digestibility of the pulses. The ascorbic acid or vitamin C content rises from negligible levels in the seed to 12 mg per 100 g, 18 hours after germination. Riboflavin and niacin content also increase significantly. Sprouted pulses are, therefore, an important food for protection against scurvy. All these changes are brought about by the enzymes that become active during germination (Singh and Singh, 1992). Finally, the digestion of pulses and the absorption of their principal nutrients are practically complete in the gut for people without gastrointestinal disorders. Despite so many advantages, only small quantities of well-cooked pulses should be included in the diets of patients. Pulses are also a good source of fibre. Evidently, those pulses that are consumed with the seed coat on, such as mungbeans, lentils, chickpeas, etc. are much higher in dietary fibre than those that have been dehulled before consumption.

Statistics on pulse cultivation

India has been a world leader in production as well as consumption of pulses. During 2012-2013, the total pulse production in India was 18.34 mt (up by 7.3 percent over the previous year) which further increased by another 5.07 percent in 2013-2014 with a production of 19.27 mt. This positive trend in production has been sustained over the last four years. After 2000-2001, the area under pulses grew significantly at 1.17 percent annually, although it was not significant in the preceding three decades between 1970 and 2000. Similarly, the growth in production as well as productivity between 2000 and 2012 was also positive and higher than that of the preceding three decades.

Remarkably, the growth rate in pulse production (2.61 percent) during this decade has been even higher than the growth rate of rice (1.59 percent), wheat (1.89 percent) and all cereals together (1.88 percent). Among pulse crops, the annual growth rate in production was highest in chickpeas (5.89 percent) followed by pigeonpeas (2.61 percent). A number of factors contributed to a significant rise in production in these crops including the concerted efforts of researchers, involvement of various government agencies, policy makers and the pulses growers, and the benefit of favourable environmental conditions. More than 550 improved varieties in different pulses, availability of their quality seed, improved pulse production and protection technologies, active government involvement and policy support fuelled an upward growth in pulse production in India. Chickpeas contributed the most in increased production, which witnessed a record production of 9.93 mt during 2013-2014.

Import-export status

Notwithstanding the impressive growth of pulse production in the country, import has also shown a positive trend over the years while exports remained almost stagnant. With a growth rate of 9.09 percent for the import of pulses between 1981 and 2012, the growth in terms of value of imports was 16.26 percent. But it has slowed down to 12.16 percent after 2000-2001. This downward trend was due to an increase in the production of pulses in the country as well as an imposition of a ban on the export of pulses from India since 27 June 2006, except for the export of commercially important *kabuli* chickpeas and 10 000 tonnes of organic pulses and lentils. Owing to these factors, the growth in export of pulses was observed to be negative (-2.41 percent) for the period 2000/01–2011/12. The ban on the export of pulses was further extended by a year till March 2014 to enhance the domestic supply. Furthermore, customs duty on the import of pulses had also been reduced to zero with effect from 8 June 2006 and it was extended up to 31 March 2014. These interventions significantly boosted per capita availability of pulses between 2000 and 2012 with an annual growth rate of 2.10 percent.

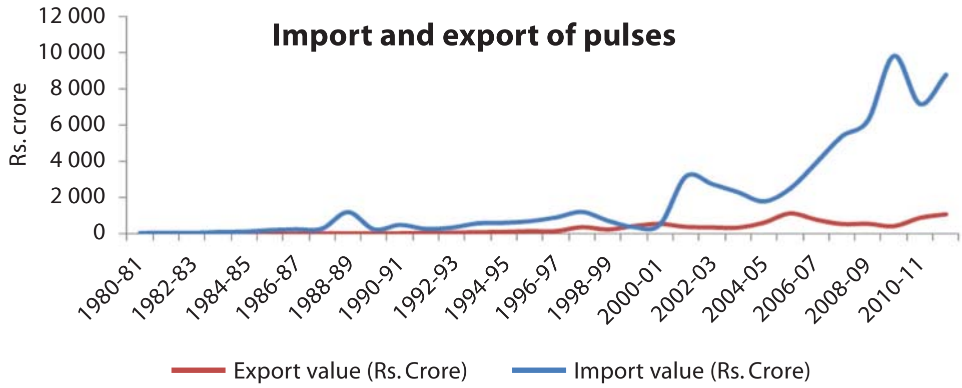

Figure 1. Import and export of pulses in India

Geographical shift

The Indo-Gangetic Plains (IGP) of northern India used to be the major pulse basket of the country till the 1970s, followed by a decline of pulse cultivation over the last three decades. The area was largely replaced by wheat, rice and maize because of increased availability of irrigation facilities. However, this reduction in area under pulses in IGP was compensated by an increase in central and southern parts of India. Over the past two decades (1991–2010) Andhra Pradesh emerged as the leader in total pulse production with an average increase in the yield of chickpeas and pigeonpeas, two major pulses, by about 81–100 percent. Consequently, the total pulse area in central and southern India increased from 11.34 million hectares (mha) to 15.01 mha during the last three decades. The short duration chickpea varieties developed by ICAR-NARS-ICRISAT collaboration played a key role in expanding the area and productivity of chickpeas in southern India. Similarly, the area of lentils increased significantly in Madhya Pradesh, and pigeonpeas in Andhra Pradesh and Karnataka. Development and adoption of appropriate varieties led to increased area, production and yield of lentils in Jharkhand and Rajasthan. Similarly, the cropped area under mungbeans and urdbeans showed an upward trend in north India which almost doubled along with a significant increase in productivity.

During the XI Plan period alone, production and productivity of total pulses increased significantly in Jharkhand, Gujarat and Andhra Pradesh. In chickpeas, there was a positive growth in area, production and productivity in Andhra Pradesh, Gujarat, and Maharashtra. Production of pigeon peas rose by about 0.253 million tonnes (mt) in Karnataka, 0.126 mt in Gujarat and 0.113 mt in Andhra Pradesh. Similarly, the area under pigeonpeas increased significantly by 113 000 ha in Karnataka, and 74 000 ha in Andhra Pradesh. The development of short-duration varieties ushered in expansion of summer season cultivation of mungbeans in the rice-wheat cropping system in north India. Similarly, Uttar Pradesh recorded a significant expansion of the area under peas by 117 000 ha and production by 180 000 tonnes.

Constraints to increasing pulse production

The area under pulse cultivation in the country is estimated to be about 25-26 mha and the realized productivity is less than 1 tonne/ha. The shortfall in pulses has been attributed to a number of factors. The major factors being ever-increasing population, geographical shift, abrupt climatic changes, complex disease-pest syndrome, socio-economic conditions of the farmers and fewer market opportunities (Singh and Pratap, 2014). Since major pulses are largely cultivated in rainfed and monsoon-dependent areas where soil moisture is the critical factor determining the productivity, the production trends keep fluctuating every year depending upon rainfall. The major constraints to realizing the potential yield of pulses include biotic and abiotic stresses prevalent in the pulse-growing areas besides socio-economic factors. Among biotic stresses, fusarium wilt coupled with root rot complex is probably the most widespread disease causing substantial losses of chickpeas. While fusarium wilt, sterility mosaic and phytophthora blight cause substantial losses in pigeon peas, yellow mosaic, cercospora leaf spot and powdery mildew are considered as the most important diseases in both mungbeans and urdbeans. In lentils, the rust, powdery mildew and wilt cause considerable damage. Among key insect-pests, gram pod borer (*Helicoverpa armigera*) in chickpeas and pigeon peas, pod fly in pigeon peas, whitefly, jassids and thrips in dry beans cause severe damage to the respective crops. Weeds also cause substantial loss to pulses. Recently, nematodes have emerged as a potential threat to the successful cultivation of pulses in many areas.

Among abiotic stresses, drought and high temperature at the terminal stage, cold as well as a sudden drop in temperature coupled with fog during the reproductive phase and salinity/alkalinity throughout the crop period inflict major yield losses and instability in production. All these stresses make pulse crops less productive with unstable performance in one or the other way.

Factors responsible for the revolution in pulse production

Besides soil and climatic factors, the non-availability of quality seeds in adequate quantity was one of the major constraints in pulses production in India till now. Seed replacement rate was also very low (5 to 10 percent) and recurrent unfavourable weather conditions and gaps in technological know-how further added to the constraints in pulse production. Realizing this, with technological back up and interventions of the National Agricultural Research System and the well planned financial support of the Planning Commission and Ministry of Agriculture, Govt. of India, several programmes viz., National food security Mission–Pulses, Accelerated Pulses Production Programme (A3P), *Rashtriya Krishi Vikas Yojna* (RKVY), 60 000 Pulses Villages, etc. were launched during the XI Plan period to boost pulse production with an objective to add 2 million tonnes of pulse grains to the current production in the country. Situation-specific, cost effective and system-based technological know-how and a package of practices in pulses were disseminated among the farmers through farmers' participatory research and extension (FPRE), on-farm demonstrations, frontline demonstrations, and skill-based training to bridge the gap between potential and realized yield in pulses. Inclusion and adoption of improved varieties of different pulse crops under different farming systems also helped increase productivity per unit area. The policy initiatives such as increasing the minimum support price by the government encouraged farmers to take up pulse cultivation as a profitable venture. The breeder seed production was doubled which ensured availability of quality seed of pulses in sufficient quantities. The seed supply model has been practically successful and it led to one important step forward towards this transformation. All these efforts together have undoubtedly resulted in yielding encouraging results and enhancing pulse production in the country. Besides the above factors, moderate to good monsoons and effective farm-oriented government policy support have also had their share in this success.

Technology initiatives

An aggressive research and development approach has been adopted in pulses in the country during the last three decades. A large number of region-specific and widely adapted high yielding varieties of pulses with tolerance to biotic and abiotic stresses have been developed in the past 30 years. Intensification of pulse-based cropping systems and development of modern production and protection techniques have led to a better technical know-how on increasing the productivity of pulses. The whole genome sequencing of pigeon peas and chickpeas has widened the scope of targeting loci controlling complex traits such as stress tolerance and yield and nutritional quality improvement paving the way for development of varieties with desired attributes. Transgenic development against pod borer in chickpeas and pigeonpeas is underway. At the same time, efficient extension models like pulse-seed-village have been implemented for dissemination of pulse-based technologies for farmers to make pulse cultivation in the country productive and remunerative.

The other major technologies to bridge yield gaps include availability of quality seeds of high yielding and input responsive varieties of different pulse crops, identification of suitable pre- and post-emergence herbicide molecules for effective control of weeds, suitable micro-irrigation systems, modern agronomic practices viz., raised bed planting, ridge sowing, optimum utilization of nutrients and interculture practices, use of farm machinery and equipment for efficient farm operations and reducing drudgery, and state-of-art food processing and post-harvest handling units of farm produce. Development of bio-intensive eco-friendly IPM modules to effectively manage major insect pests and diseases have had complimentary effects in the form of effective control of pests as well as saving the environment.

Several new research initiatives have also been taken up viz., development of new plant types for different agro-climatic situations, exploitation of heterosis in pigeonpeas through development of cytoplasmic male sterility-based hybrids, transgenic development in chickpeas and pigeon peas for managing *Helicoverpa* pod borer, marker-assisted selection for introgression of resistance genes and characterization of biotic and abiotic stresses that are expected to have tremendous impacts on improving productivity of pulses in the country.

The way ahead

The requirement of pulses has been projected to reach 32 million tonnes by 2050 taking into account the estimated growth of the population to 1.69 billion by 2050 and the availability of proteins in diets from some other sources such as milk products. Reaching this goal requires annual production of pulses to grow at 2.2 percent against the current growth rate of 3.5 percent. This target seems to be well within reach despite myriad looming challenges such as climate change-driven distribution of rainfall and temperatures, decreasing water and land resources, etc. A tangible step in this direction will be increasing the average productivity of pulses above 1 200 kg/ha and bringing an additional area of about 3.5 mha area under pulse cultivation. Reducing post-harvest losses to the tune of 10–15 percent from current losses will also add another 1 mt of pulse grains to our kitty.

Vertical expansion of pulses in the country through yield enhancement can be achieved by development of input-responsive and climate-resilient varieties of pulses, varieties with multiple resistances to diseases and insect pests, short-duration varieties that fit well in different cropping systems and increasing the harvest index. Similarly, development of new plant types for different agro-climatic situations, and development of photo-thermo insensitive cultivars in crops like mungbeans and urdbeans will help expand the areas of these crops in the non-traditional areas of the country. This will also help develop varieties which could perform equally well over different seasons and locations.

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Recent achievement in research and development of pulses in Indonesia

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Abstract

Pulses, a group of food legumes, hold considerable potential for development in Indonesia. The high nutritional value of pulses as a cheaper source of vegetable protein can make them ideal for people who can't afford animal protein. Few pulses can be used as a substitute for soybeans in making several processed food products, so they can potentially reduce the domestic soybean demand which is increasing every year. Pulse crops are also useful for increasing soil fertility because they can fix nitrogen from the air thus reducing the requirement for synthetic nitrogenous fertilizers. Pulses are usually cultivated as minor priority crops on marginal land during the late dry season on wet land or the late rainy season on upland.

Research and development on pulses is still limited. The constraints to pulse development trace their origin to agro-ecological factors, production systems, farmers' socio-economic conditions, product development, and marketing. Breeding research on pulse in Indonesia is focused on developing and releasing new varieties with high yield potential for various sub-optimal agroecologies, early maturity, and resistance to pests and diseases. Research on mungbeans attracts priority over other pulses. Because pulses are not considered as staple foods, serious attention and efforts are needed to raise the status of pulses in Indonesia which is now considered neglected crop.

Opportunities to improve productivity and production of pulses lie in modernizing breeding programmes to develop and release new varieties, organizing quality seed production, implementation of the full recommended technology packages, and their rapid dissemination to farmers. Post-harvest research especially on the development of pulse-based food products remains central to driving the market demand or pulses. The development of potential areas for expanding pulse cultivation should be directed to provinces with the most favourable agro-ecological conditions, such as Bali, East Nusa Tenggara, Yogyakarta, West Java, Central Java, East Java, and South Kalimantan.

Introduction

Feeding a growing world population is critical to maintaining food and nutrition security, including eradicating hunger in some parts of the developing and underdeveloped world. It means not only carbohydrates need to be supplied sufficiently, but the diets must also contain lipid and protein for a healthy and productive life.

In Indonesia, soybeans are the source of vegetable protein for most people in the form of processed foods – 'tempe' and 'taucho' (fermented soybeans), 'tahu' (tofu), and 'kecap' (soysauce) – which are very popular. Because of shortages in domestic grain production of soybeans, arround 1.2 million tonnes of soybeans are imported per year. The government is now emphasizing increasing soybean production to meet self-sufficiency by 2017.

Pulses are also popular in the country for many other uses, such as vegetable and processed food. Indonesian farmers grow a wide range of pulse crops, such as pigeonpeas (*Cajapus cajan*), jack beans (*Canavalia ensiformis*), lablab (*Lablab purpureus*), velvet beans (*Mucuna pruriens*), winged beans (*Psopocarpus tetragonolubus*), bambara groundnuts (*Vigna subterranea*), kidney beans (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), dry peas (*Pisum* spp.), and mungbeans (V*igna radiata*) (Van der Measen and Somaatmaja, 1992).

In general, pulses can be used for food, feed and raw material for industrial products. Besides, these crops play an important role in improving soil health, maintaining long-term fertility and sustainability of cropping patterns. Like other leguminous crops, they meet up to 80 percent of their nitrogen requirement by biological nitrogen fixation, and leave behind substantial amounts of residual nitrogen and organic matter for subsequent crops. Also, inclusion of pulse crops in cropping systems improves the organic carbon content of the soil.

In terms of nutrition, pulses provide protein, complex carbohydrates, and several vitamins and minerals. Like other plant-based foods, pulses contain no cholesterol and little fat or sodium. Pulses also provide iron, magnesium, phosphorus, zinc and other minerals, which play a variety of roles in maintaining good health (Sutanto and Saneto, 1994; Damardjati and Widowati, 1985). In Indonesia, pulses are normally consumed as traditional foods, such as vegetables (young pods, dry grain, sprouts), snacks, and side dishes. The consumption of pulses is far below that of soybeans. Moreover, farmers almost never grow pulses in specific land/area in monoculture system. This is because of the government policy which has categorized pulses as minor crops. However, based on nutrition content and its role as a protein source for the population, we believe that in the near future the government will give higher priority towards the significant development of these minor crops.

Trends in pulse area, production, and productivity

Among the various pulses grown in the country, mungbeans (*Vigna radiata*) occupy the largest area. During the last seven years, the cropped area and grain production of pulses showed a decreasing trend. The area declined to 182 075 ha in 2013 from 306 207 ha in 2007. During this period, no significant change in productivity of pulses was observed with 1.109 tonnes/ha in 2013 as against 1.053 tonnes/ha in 2007 (CBS, 2014). The second largest area of pulses was under cowpeas (*Vigna unguiculata*) which covered 14 000 ha with productivity of 0.6 tonne/ha, followed by pigeonpeas (*Cajanus cajan*) with 6 500 ha area and productivity of 0.55 tonne/ha (Manurung, 2002). Mungbeans are cultivated mainly in six provinces, i.e. East Java, Central Java, West Nusa Tenggara, South Sulawesi, West Java and East Nusa Tenggara. The area under mungbeans varies widely among provinces. In 2013, Central Java accounted for the largest area (57 941 ha), followed by East Java (48 845 ha) and West Nusa Tenggara (19 374 ha). The contribution of these three provinces to total production of mungbeans in Indonesia was 31.4 percent, 28.2 percent, and 10.8 percent, respectively (CBS, 2014). Consumption of mungbeans projected for the period 2015–2025 is shown in Table 1.

Table 1. Projected consumption of mungbeans based on predicted annual per capita consumption and population in Indonesia over 2015

Year	Per capita consumption (kg/year)	Predicted population growth (%)	Predicted population (000)	Total consumption (000 tonnes)
2015	1.31	1.46	254 548	335
2016	1.32	1.52	258 413	342
2017	1.33	1.57	262 476	350
2018	1.34	1.63	266 747	359
2019	1.35	1.68	271 233	367
2020	1.36	1.74	275 941	376
2021	1.37	1.79	280 882	386
2022	1.38	1.85	286 065	396
2023	1.39	1.90	291 499	406
2024	1.40	1.95	297 194	417
2025	1.41	2.01	303 164	429

Source: Directorate General of Food Crops (2013).

Area under other pulse crops is not well documented. Manurung (2002) reported that some other pulses are grown in several provinces (Table 2).

Table 2. Harvested area, productivity, and production of pulses in Indonesia in 1999

Pulses	Province	Harvested area (ha)	Productivity (tonne/ha)	Production (tonnes)
Cowpeas	Central Java	1 000.0	0.60	600.0
	Yogyakarta	4 378.0	0.56	2 451.9
	East Java	332.8	0.77	256.3
	Bali	5 528.0	0.70	3 869.6
	South Kalimantan	514.0	0.80	432.8
	East Nusa Tenggara	2 130.8	0.60	1 278.5
Pigeonpeas	Central Java	3 500.0	0.68	2 380.0
	Yogyakarta	1 444.0	0.43	620.9
	East Nusa Tenggara	1 420.5	0.54	416.0
Bambara groundnuts	West Java	327.0	0.84	274.7

Source: Manurung (2002).

Pulse-based farming system dynamics

Pulse-based cropping patterns vary depending on the land type, such as the paddy field and dry land. In the paddy fields, pulses, especially mungbean, are usually sown after paddy/rice in the dry season. In dry land, pulses are usually sown during late rainy season after upland rice or after maize or soybean. The cropping pattern is upland rice – maize – pulses or upland rice – soybean – pulses. This sequencing of pulses in cropping patterns often exposes the growing pulse crop to drought owing to scarcity of water and the crop becomes prone to pest attacks, mainly thrip (pest) or powdery mildew (disease).

Mungbeans are the major pulse in Indonesia and have become an important component in the cropping pattern, because the crop is sown at the end of the cropping pattern. Furthermore, the crops must have characteristics of early maturity, resistance to pests and diseases, and tolerance to drought. Especially for mungbeans planted in an area where labour is scarce, the characteristic of simultaneous harvesting is very important. Pulses which are climbing in growth habit, such as sword beans, lima beans, winged beans and velvet beans are grown in the household garden for vegetable or animal feed.

Major achievements in increasing pulse production and productivity

The most important technology for increasing crop yield is the use of high quality seed of improved variety. This is because a new improved variety is easier to be adopted by farmers than other technology components. The Indonesian Legumes and Tuber Crops Research Institute (ILETRI) conducts breeding programmes and other research to continuously improve the yield potential and other traits of mungbeans. Table 3 lists new improved varieties of mungbeans released as of 2014.

Few pulses other than mungbeans received meaningful breeding and related research attention. However, at least until 1998, eight new varieties of cowpeas were released in the country (Table 4). In 1987, one variety of pigeonpeas (Mega) were released, which were introduced from Australia. Its yield potential was 1.2 tonnes/ha of dry seed, the crop duration 95 days, 100 seed weight 9 to 10 g, and protein content 20 percent.

The agronomic research was concerned with development of crop management technology for increasing productivity and production of mungbeans especially in dry land areas. The general recomendation is: minimum land preparation, plant population 250 000 plants/ha, planting distance 40 cm × 20 cm (2 plants/hill), Urea 25 kg/ha, SP 36–45 kg/ha, and KCl 45 kg/ha. Research for increasing pulse production has also been done by the Directorate of Legume and Tuber Crops, Directorate General of Food Crop by producing pulses in several potential provinces. The extent of pulse cultivation between 2003 and 2011 is shown in Table 5.

Table 3. Mungbean varieties released during 1988–2014

Variety	Year	Productivity (tonne/ha)	Crop duration (day)	100 seed weight (g)	Seed colour	Remark
Parkit	1988	1.35	56	6.7	Glossy green	Tolerant to powdey mildew
Camar	1988	1.35	56	6.7	Glossy green	Tolerant to powdery mildew
Nuri	1993	1.60	58–85	3.6	Glossy green	Tolerant to leaf spot, rust
Sampeong	2003	1.0–1.8	70–75	2.5–3.0	Glossy green	Moderate tolerant to poldery mildew, leaf spot
Kutilang	2004	1.13–1.96	60–67	6.0–7.0	Green	Tolerant to poldery mildew
Vima 1	2008	1.38–1.76	57	6.3	Green	Tolerant to poldery mildew
Vima 2	2014	1.18	56	6.6	Glossy green	Moderate tolerant to soil borne diseases
Vima 3	2014	1.18	60	5.9	Dull green	Tolerant to thrip

Source: ILETRI (2012).

Table 4. Cowpea varieties released until 1998

Variety and year released	Yield potential (tonne/ha)	Crop duration (day)	100 seed weight (g)	Seed color
KT-1 (1989)	1.5	77	12-13	Light brown
KT-2 (1991)	1.5	77	12-13	Brown
KT-3 (1991)	1.4	70	12–15	Greyish brown
KT-4 (1992)	1.6	60	13–15	Brown
KT-5 (1992)	1.6	60	13–15	Red
KT-6 (1998)	1.9	65	11-12	Greyish brown
KT-7 (1998)	2.2	67	10-11	Red
KT-8 (1998)	1.8	68	8-9	Red
KT-9 (1998)	2.2	69	12-13	Dark red

Source: ILETRI (2014).

Table 5. Provinces for the development of pulses

Year	Pulse	Province	Area (ha)
2003	Kidney beans	East Nusa Tenggara	500
2003	Cowpeas	South Kalimantan	500
2010	Jack beans	Lampung	5
2010	Jack beans	West Java	10
2010	Jack beans	Banten	5
2011	Jack beans	Lampung	5
2011	Jack beans	West Java	15
2011	Jack beans	Banten	10
2011	Jack beans	Central Java	20
2011	Jack beans	Yogyakarta	5
2011	Jack beans	East Java	10
Total			1 085

Source: Directorate of Legumes and Tubers (2012).

Constraints in productivity enhancement and emerging challenges

The yield gap (the difference between potential yield and yield realized at farmers' level) in mungbeans is relatively high ranging from 0.8 tonne/ha to 1.5 tonnes/ha. Low average productivity of pulses at the farmer level was due to several factors:

(a) recommended technology package is not fully implemented;

(b) farmers use uncertified seed;

(c) pulses are mostly grown as minor crops because of competition in land uses with other crops; and,

(d) farmers perceive little impact from their efforts to enhance the productivity of pulses.

Some problems in the development of pulses are:

(a) research on identification of these crops is still limited;

(b) production, quality, and farming efficiency are low because pulses are considered minor crops;

(c) limited capital and accessibility of farmers to resources and technology; and,

(d) no market development for pulses because farmers grow these crops only for their own consumption.

Current efforts for improving pulse productivity

Genetic improvement of pulses, in general, is limited by the availability of germplasm. Exploration of germplasms is, therefore, needed mainly for collecting local and wild varieties to enrich the gene sources for traits dealing with biotic and abiotic stresses tolerance. For these purposes, breeding programmes should be focused on the development of new varieties having high yield potential, early maturity, biotic and abiotic stress tolerance. In addition, more attention should be given to functional food, anti nutrient, toxic compound and feedstuff in these crops.

In order to improve production and productivity of pulses in the country, efforts are now focused on the following:

(a) crop improvement activity especially for mungbeans to accelerate the release of new varieties with high productivity, resistance to major pest and diseases, and adaptation to suboptimal land;

(b) research on production technology for various agro-ecological conditions; and,

(c) dissemination of pulses through field demonstrations and farmers' field days, as well as demonstrations of various pulse-based manufactured food products.

Strategy for meeting the future opportunities and challenges

The government policy on future development of pulses is paramount to increasing pulse productivity and production in the country. The opportunities and challenges in developing pulses should be reflected in government's policy making for expansion and improvement of cultivation of pulses in the country. These are as follows:

Opportunities:

(a) Substitution material for soybeans;

(b) the requirements of raw material for industrial purposes keep increasing;

(c) pulses have advantages as functional food because they are rich in protein, vitamins, and some minerals for a more healthy life;

(d) pulses have various derivative products which are useful for food and feed; and,

(e) there is still a high yield gap in pulses that can be bridged to increase production.

Challenges:

(a) Subsistence and speculative nature of pulse cropping;
(b) profit is not the main target for farmers;
(c) minimal use of production input;
(d) land is limited and less fertile;
(e) low capital ownership (poor farmers);
(f) commodity market is not yet formed;
(g) pulses are not considered as staple foods; and,
(h) pulses are neglected crops.

Based on the above opportunities and challenges, the following should be key elements in formulating the strategy for long-term development of pulses in the country:

1. maximizing land use by increasing cropping index and utilizing unused land;
2. dissemination of production technology to increase productivity and also processing; technology to develop pulse-base food products;

3. introducing and promoting the consumption of pulse-based food products in the country;
4. development of markets for pulses; and,
5. improvement of seed production to expand the use of quality seed by farmers.

Surveys for the development of pulses have already been conducted. Areas (districts and provinces) which are suitable and have potential for the development of pulses in Indonesia are shown in Table 6.

Table 6. Provinces and districts suitable for developing pulses

Pulses	Province	District
Mungbeans[1]	Central Java	Demak, Grobogan, Pati, Rembang, Kebumen, Kudus, Blora, Brebes
	East Java	Sumenep, Sampang,Tuban, Bojonegoro, Lamongan, Gresik, Banyuwangi, Bangkalan
	South Sulawesi	Gowa, Wajo, Jeneponto, Bone
	West Nusa Tenggara	Sumbawa, Dompu, Sumbawa Barat
	West Java	Cirebon, Garut, Sumedang, Karawang, Majalengka
	East Nusa Tenggara	Sikka, Belu, Manggarai, Timor Tengah Selatan, Kupang
Cowpeas[2]	Central Java	Wonogiri, Klaten, Boyolali, Pemalang, Batang
	Yogyakarta	Gunung Kidul, Kulon Progo
	East Java	Lumajang, Pacitan, Bangkalan, Ponorogo, Probolinggo
	Bali	Karangasem
	East Nusa Tenggara	Ngada
	South Kalimantan	Hulu Sungai Utara, Hulu Sungai Selatan
Pigeonpeas[2]	Central Java	Wonogiri
	Yogyakarta	Gunung Kidul
	East Nusa Tenggara	Ngada
Bambara goundnuts[2]	Weat Java	Sumedang, Bogor, Bandung, Sukabumi

Source: [1] CBS (2012); [2] Manurung (2002)

Contribution to nutrition, employment and income generation, and value chain development, including processing and marketing

Legumes, including pulses play an important role in the Indonesian diet as an excellent source of protein. The contribution of legumes to daily protein intake was about 9 percent, ranking third after rice and fish. In comparison with animal protein sources, such as fish and meats, legumes are relatively inexpensive. Among all legumes, soybeans have the highest protein content, ranging from 30 to 45 percent, while pulses, such as mungbeans, cowpeas, pigeonpeas and jack beans contain moderate amounts of protein (22–30 percent) as presented in Table 7. The protein quality of legumes is not as good as that of animal products due to limited content of sulphur-containing amino acids (methionine and cystine) and tryptophan (Iqbal *et al.*, 2006). However, they are rich in lysine, which is usually limited in cereals.

Therefore, a diet combining legumes and cereals can properly supplement the limited essential amino acids in both commodities. The protein digestibility is also poor due to the presence of anti nutritional factors, such as trypsin inhibitors and phytic acid that may bind protein to form complex undigestible compounds. This affects the protein availability and absorption in the gastrointestinal tract. However, the activities of these anti-nutritional factors can be normally reduced during processing, particularly through soaking and cooking/boiling. Legumes are also rich sources of fats, carbohydrate, vitamins and minerals (Table 7).

Table 7. Nutrition composition of selected legumes per 100 g

Composition	Soybeans (*Glycine max* L. Merr)	Mungbeans (*Vigna radiata* L.)	Cowpeas (*Vigna unguiculata* L.)	Pigeon peas (*Cajanus cajan* L.)	Red kidney beans (*Phaseolus vulgaris* L.)	Jack beans (*Canavalia ensiformis* L.)
Enery (kcal)	335	345	339.1	336	336	389
Moisture (g)	8	10	10	9.6	12.0	–
Protein (g)	38.0	22.2	22.0	22.4	23.1	30.36
Fat (g)	18.0	1.2	1.4	1.7	1.7	2.9
Carbohydrate (g)	31.3	62.9	59.1	51.2	62.7	54
Fiber (g)[a]	3.8	4.4	4.5	5.5	–	–
Ash (g)[a]	5.1	3.3	3.3	3.7	4.2	–
Calsium (mg)	227	125	77	125	80	153
Phosphor (mg)	585	320	449	275	410	298
Iron (mg)	8	6.7	6.5	4	5.8	10.1
Vitamin A (SI)	110	157	30	150	30	–
Vitamin B_1 (mg)	1.07	0.6	0.92	0.48	0.64	8.5
Vitamin C (mg)	–	6	2	5	–	–
Folat (µg)[a]	250	490	545	343	310	–

Source: [a] Augustin and Klein (1989); Directorate of Nutrition (1981).

Groundnuts have the highest fat content, up to 50 percent, followed by soybeans and lupins. Meanwhile, pulses contain very low fat and fairly high starch, thus belong to starchy legumes. This shows the great potential of pulses as a source of energy supply. Vitamins, such as vitamin A, E, K, and B, particularly thiamin, riboflavin, niacin, and folate are considerably high in legumes as well as minerals, such as calcium, phosphor and iron. Pulses, particularly mungbeans, cowpeas, pigeonpeas are rich sources of folates which are essential for preventing megaloblastic anemia and neural tube defects, particularly in new-born babies (Bower, 1996 *in* Ginting and Arcot, 2004).

Pulses are known to have low glycemic indexes (GI) that is <50 (Rizkalla *et al.*, 2002). GI refers to the blood glucose raising potential of carbohydrate foods, which is low if the value is <55. This is essentially needed for diabetic and obese patients to control or maintain normal blood glucose levels. High amylose and fiber content as well as the presence of natural enzyme inhibitors, such as a-amylase and a-glucosidase in legumes make the carbohydrate slow to digest, thus effectively lowering the GI (Sievenpiper *et al.*, 2009).

Other functional ingredients are high dietary fiber in legumes (average 36.5 percent) and resistant starch, particularly in pulses (average 24.7 percent) (Ofuya and Akhidue, 2005), which have hypocholesterolaemic effects (Anderson and Major, 2002). This prevents cardiovascular disease and prebiotic potential that promote large bowel health and prevent colorectal cancer (Fuentez-Zaragoza *et al.,* 2010). Bioactive components, such as isoflavones, phenolic compounds, flavanoids, tannins are responsible for legume antioxidant capacities (Xu and Chang, 2007). Some pulses, such as lentils, red kidney beans and black beans as well as black-seeded soybeans showed considerably high total phenolic content, while it is approximately 2 to 3-fold lower in yellow-seeded soybeans, chickpeas and yellow peas. The health benefits of each functional component in legumes are summarized in Table 8.

Table 8. Functional components of legumes and their health-promoting benefits

Component	Health benefit	Reference
Low Glycemic Index (GI) Carbohydrate	Control or maintain the blood sugar normal	Rizkalla *et al.*, 2002 Sievenpiper *et al.*, 2009
Dietary fiber	Prebiotic potential, promote the large bowel health and prevent colorectal cancer, hypoglycemic and hypocholesterolaemic effects	Anderson and Major, 2002
Resistant starch	Hypocholesterolaemic effects, prevent cardiovascular disease, prebiotic potential, hypoglycemic effects,	Fuentez-Zaragoza *et al.*, 2010; Niba, 2002
Phenolics, isoflavones, flavanoids, tannins	Antioxidant activities for disease prevention, particularly degenerative diseases, anti aging, and anti cancer	Xu and Chang, 2007

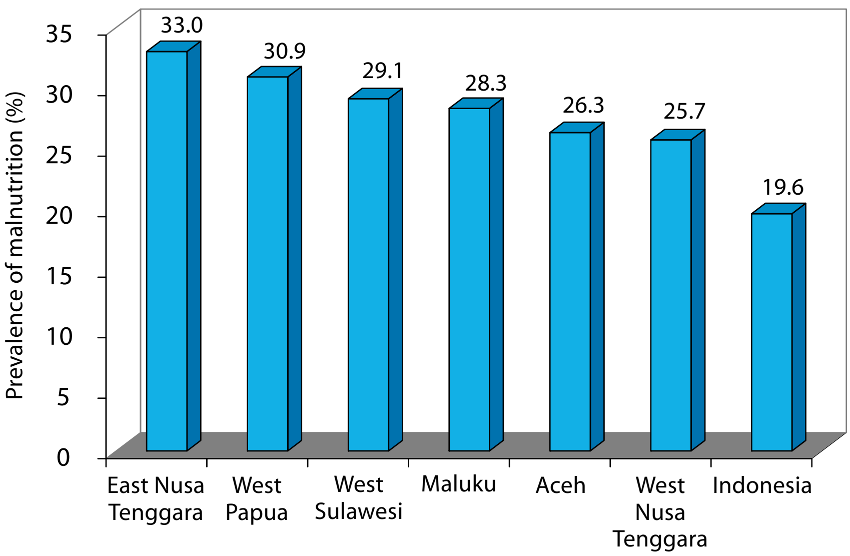
In Asia, Japan and Indonesia have the highest consumption of soybeans, while India leads in consumption of pulses such as chickpeas, pigeon peas, blackgrams and mungbeans. The status of consumption of other pulses is not well documented in national statistics. That might be due to insignificant area under cutivation and limited consumption. FAOSTAT (2013) reported the consumption of pulses in Indonesia as low as 0.09 kg/capita/year.

Pulses are normally consumed as traditional foods, such as vegetables (young pods, dry grain, sprouts), snacks, and side dishes. These limited food products may contribute to a decrease in consumption of pulses as they are less interesting and less practical in preparation. Therefore, efforts should be focused on developing more acceptable products both for household consumption and industrial purposes. In relation to importing a large amount of soybeans, particularly for tempe and tofu ingredients, selected pulses can be used as a substitute for soybeans in particular products, such as tempe, tofu, soymilk, and soy sauce to some extent, depending upon the product and kind of pulses. Cowpeas can substitute 100 percent of soybeans in tempe and 20 percent in tofu preparation (white-seeded cowpeas), while it can substitute only 30 percent for pigeonpea tempe (Haliza *et al.*, 2007). However, pigeonpeas as well as cowpeas and lab lab beans can be used 100 percent as ingredients of sweet soy sauce (Antarliana *et al.*, 1997). Jack beans have also potential as a substitute for soybeans in tempe (50 percent) and tofu preparation (IAARD, 2014). A number of studies also reported the potential use of pulses as ingredients in different kinds of food both using dry grain or flour. Table 9 presents existing or traditional food products derived from pulses in Indonesia and promising newly developed products in order to broaden the utilization of pulses.

Processing of pulses into different kinds of food products using simple techniques is expected to enhance household consumption and subsequently increase its nutritional status. This is essential, particularly in the dry areas where pulses can be potentially grown and further developed using improved varieties and proper cultivation practices. East and West Nusa Tenggara provinces which belong to such areas, currently show a high prevalence of malnutrition (Figure 2), and therefore need to be considered for pulse development in Indonesia. Pulses can be introduced in other areas with high malnutrition prevalence, such as West Papua, Maluku, and West Sulawesi in order to improve their nutritional status. In particular for Papua and West Papua areas where the main staple food is sweet potato, the consumption of legumes and pulses is essentially needed to balance their nutrient intake which is mainly based on a carbohydrate diet.

Table 9. Existing food products derived from selected pulses and promising developed products.

Pulses	Common or traditional products	Promising developed products
Mungbeans	• Seed: porridge, snack fillers, milk, drinks, sprouts • Starch: vermicelli (transparent noodle) • Flour: weaning food, snacks	• Seed: tempe, fermented milk (kefir and yoghurt with high antioxidant activity), cake and ice cream blends • Flour: protein isolate/concentrate, cakes, cookies, breads, composite flour with cassava or sweet potato flours to increase the protein content, such as instant *tiwul* • Sprouts: flour, milk/drinks
Cowpeas	• Young pod: vegetable • Seed: vegetable, dish, snacks (deep-fried)	• Seed: tempe (100%), tofu (20%), soy sauce (100%) • Flour: protein isolate/concentrate, composite flour, cakes, cookies
Pigeonpeas	• Young pod: vegetable • Seed: vegetable, dish	• Seed: tempe (30%), soy sauce (100%) • Flour: composite flour, cakes, cookies
Jack beans	• Young pod: vegetable • Seed: vegetable, dish, snacks	• Seed: tempe (50%), tofu (20%), milk, soy sauce (100%), animal and fish feeds • Flour: protein isolate/concentrate, composite flour, cakes, cookies
Lab-lab beans	• Young pod: vegetable • Seed: vegetable, dish	• Seed: tempe (100%), tofu (20%), soy sauce (100%) • Flour: protein isolate/concentrate, composite flour, cakes, cookies



Source: Ministry of Health (2015).

Figure 2. Prevalence of malnutrition in selected Indonesian provinces (2013)

In addition to nutritional aspects, processing of pulses in the potential areas would also give opportunity to run a small business of pulse products, particularly for women and their families or neighbours as labourers. These products can be sold at school and government office canteens, local markets, bus terminals, etc. or in collaboration with the local government authorities pulses-based snacks can be provided for their internal meetings or events made by these women processors. The government of Indonesia has established the President Instruction No. 29 in 2009 concerning the acceleration of local-based food diversification which would be in accordance with this pulse product development.

Therefore, socialization and promotion of the health benefits of pulses and their varied food products as well as extension and training on the preparation methods need to be conducted under the coordination of the local government. However, the availability of pulses as raw ingredients should be guaranteed through continuous supply. Consequently, farmers would be encouraged to grow pulses and increase the production as the market is available.

Conclusion

Pulses are important for food, espcially as a protein source for most Indonesian people, as well as for raw material for manufacturing processed products. The average productivity of pulses at farmer level is still low due to (a) non-adoption of the full technology package, (b) widespread use of uncertified seed, and (c) strong competition with other crops for land use. Research and development of pulses is still limited because pulses are mostly cultivated on marginal land, categorized as minor crop and thus remain negelected.

The pace of pulse development can be accelerated by improving breeding strategies and the release of new varieties, organizing production of quality seed, facilitating adoption of the full recommended technology package, and conducting a well-targeted extension campaign to rapidly disseminate production technology to farmers. In this context, supportive government policy can provide a powerful boost to pulse production by according a higher priority to these crops and elevating their status in providing food and nutrition security of the Indonesian people. The ability of pulses to provide nutrient-rich grain as well as increase soil fertility should be considered and given research priority by respective stakeholders.

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The status of pulses development in Islamic Republic of Iran

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Abstract

In the Islamic Republic of Iran, among the major pulse crops chickpeas are grown on 550 000 ha and lentils on 120 000 ha land. Major chickpea (97 percent) and lentil (94 percent) areas are planted under rainfed conditions and are grown in rotation with cereals, mainly wheat and barley. Beans, faba beans and mungbeans are planted on about 150 000 ha under irrigated conditions in the Islamic Republic of Iran.

The major constraints influencing the productivity of chickpeas and lentils include poor agronomic practices, drought, heat, ascochyta blight, fusarium wilt and cold. The agronomic practices for chickpea and lentil cultivation, including date of sowing, seed rate, method of sowing, plant population, weed control, and method of harvesting have been researched and recommendations developed for different areas.

Improved chickpea varieties (Hashem, Arman, Azad, Adel, Saral and Sameen), lentil varieties (Gachsaran, Kimiya, Bilesevar) and bean varieties (Dorsa, Sadri, Pak and Shekofe) were released in last decade. Efforts are being made to transfer these recommendations to farm level with the help of extension specialists. Research on exploration of the possibility of winter planting of chickpeas and lentils in milder environments and entzari planting in harsh (severe cold) environments has yielded promising results. Transfer of these technologies to farmers is in progress and in some areas farmers are getting almost 50 percent or more productivity with the adoption of winter- or *entezari* sowing. Research in pulses is conducted by DARI (Dryland Agricultural Research Institute) and SPII (Seed and Plant Improvement Institute) in collaboration with other research organizations in the Islamic Republic of Iran and with international research centres such as ICARDA, ICRISAT and CIAT.

Introduction

The Islamic Republic of Iran is located in the world's desert belt and is considered an arid and semi-arid region. The annual precipitation is about 250 mm which is 1/3 of the average world precipitation. Though the total land area of the Islamic Republic of Iran is 165 million ha, only 18.7 million ha are used for crop production. Out of this cultivated area (Table 1) 6.4 million ha are cultivated under rainfed conditions, only 1.2 million ha of this area receive more than 400 mm of rainfall; the remaining rainfed areas receive less precipitation. All precipitation is received in the form of snow or rain during winter months and early spring from October to May. There is moisture stress in crop production which is further aggravated by thermal stresses caused by low (down to -30°C) as well as high temperature (>40°C).

Table 1. General land use in the Islamic Republic of Iran

	Land use	Area (million ha)
1	Total agricultural land	18.7
	1.1 Irrigated land	5.8
	1.2 Irrigated orchards	2.0
	1.3 Dryland	6.4
	1.4 Fallow	4.5
2	Unused but potentially productive land with water limitation	32.3
3	Forest and scattered woodland and mountains	12.4
4	Range, wasteland and mountains	90.0
5	Sand dunes, salt flats, others	11.6
	Total land	165

The entire cultivated area is devoted to the production of major crops such as wheat, barley, alfalfa, rice, chickpeas and lentils (Anonymous 2014). Wheat and barley occupy 66 percent of the total area (Table 2).

Table 2. Total area and production of major crops in the Islamic Republic of Iran (2012-2013)

Crops	Area (000 ha)		Percent	Production (000 tonnes)		Percent
	Total	Dryland		Total	Dryland	
Wheat	6 399	4 000	63	9 304	2 884	31
Barley	1 635	920	56	2 812	874	31
Food legume (Chickpeas and lentils)	630	607	96	275	252	92
Alfalfa	612	47	8	5 199	127	2
Rice	564	0	0	2 449	0	0

Yields of wheat, barley, chickpeas and lentils are low and variable which can be attributed to unfavourable and fluctuating environmental conditions. In years of severe drought, wheat yield goes down to 500 kg/ha or lower, and crop failures occur in certain areas.

Legumes are important in the sustainable production of food and feed in the Islamic Republic of Iran. They are important sources of good quality protein in the diets of people and are valuable as animal feed. Legumes also increase and sustain the productivity of the soil and in rotation with cereal reduce chances of build-up of diseases, insect pests and obnoxious weeds for the following cereal crops.

Pulse uses

Pulses produced in the Islamic Republic of Iran are mostly consumed within the country, usually production is more than sufficient to meet the country's demand (Sabaghpour, 2015b). The excess food legume production is exported to other countries. Food legumes are used in many dishes because of its higher protein content. Chickpeas are eaten as cooked seed with rice and cereal breads. A popular chickpea and bean dish is "abgosht". Another food in which kabuli type chickpeas and beans are used is "Aash". Desi type chickpeas mainly in form of split peas is used. It is eaten in "ghymeh khoreasht" a traditional delicacy eaten with rice. Desi type chickpeas are also used in the preparation of "cutlets". A popular lentil dish is "adas polo". It is a traditional delicacy eaten with rice. Lentils, beans, faba beans and mungbeans are used in "Aash."

Pulse area and yield in Islamic Republic of Iran

Pulses include chickpeas (*Cicer arietinum*), lentils (*lens culinaris*), dry beans (*phaseolus vulgaris*), mungbeans (*vigna radiata*), cowpeas (*vigna unguiculata*) and faba beans (*vicia faba*). These crops occupied 820 000 ha in 2013 which is 6.3 percent of the country's cultivated area (Anonymous 2014). Chickpeas, lentils and beans are grown on 550 000, 120 000 and 98 000 hectares respectively in the Islamic Republic of Iran (FAO, 2013). The Islamic Republic of Iran ranks fourth in the world by areas planted to chickpeas and eighth by areas under lentils. The majority of areas under chickpeas (97 percent) and lentils (94 percent) are planted under rainfed conditions and are grown in rotation with cereals, mainly wheat and barley. In the Islamic Republic of Iran, mean productivity of chickpeas is 536 kg/ha and that of lentils 608 kg/ha compared with the world average of 968 kg/ha for chickpeas, and 1 140 kg/ha for lentils. Average yield of chickpeas grown in rainfed areas is 39 percent that of the crop grown with irrigation. The corresponding figure for lentils is about 41 percent.

This highlights the critical role of moisture conservation in rainfed areas in improving the potential pulse yields in such areas. The major reason for low productivity of these crops in the Islamic Republic of Iran is terminal drought stress. Most of the farmers grow chickpeas and lentils in marginal areas in the spring season (Sabaghpour, 2015b). In the Islamic Republic of Iran, chickpea areas have decreased from 570 000 ha to 550 000 ha and lentil areas from 215 000 ha to 120 000 ha over the last decade. Notwithstanding dwindling rainfall and its uneven distribution, productivity (kg/ha) of pulses over the last decade has increased from 482 to 536 for chickpeas and from 463 to 608 for lentils (Sabaghpour, 2015b). Major production areas of beans, faba beans and mungbeans are equipped with irrigation in the Islamic Republic of Iran. Average productivity of bean in the Islamic Republic of Iran is 791 kg/ha compared with world average of 2 582 kg/ha (FAO, 2013).

Key constraints to pulse production

Drought stress

Drought is the common abiotic stress limiting chickpea production in different parts of the Islamic Republic of Iran. Chickpeas and lentils frequently suffer from drought stress towards the end of growing season after flowering, during pod setting and seed formation. Drought is accompanied by heat stress in rainfed conditions (Sabaghpour, 2004). Terminal drought stress reduces productivity of chickpeas considerably in spring planting compared with autumn and *entezari* sowing. Autumn and *entezari* planting have comparative advantage over spring planting because of water use efficiency and less vulnerability to terminal drought stress (Sabaghpour, 2002). Research on exploration of the possibility of autumn planting of chickpeas and lentils in milder environments and *entezari* planting in harsh (severe cold) environments has produced promising results. Transfer of these technologies to farmers is in progress and in some areas farmers are getting almost 50 percent or more productivity with adoption of winter or *entezari* sowing. Therefore, four chickpea varieties, such as Hashem (Sabaghpour *et al.,* 2005), Arman (Sabaghpour *et al.,* 2006a), Azad (Sabaghpour *et al.,* 2010), Adel (Sabaghpour 2015b) and two lentil varieties including Kimiya (Sabaghpour *et al.,* 2013) and Bilesevar (Sabaghpour, 2012) were released for planting in autumn in milder environments and *entezari* sowing in harsh (*severe* cold) environments.

Plants adapt to drought environments either through escape, avoidance, or tolerance mechanisms. Drought escape is a particularly important strategy of matching phonological development with the period of soil moisture availability to minimize the impact of drought stress on crop production in environments where the growing season is short and terminal drought stress predominates (Turner, 1986).

Drought escape is the most important success for breeders so far in comparison with other mechanisms. Farmers usually are not able to plant chickpeas in the beginning of March due to high moisture in field. Therefore, they often have to plant chickpeas at the end of March. Flowering in chickpeas starts in the beginning of May when rainfall stops in many years (Sabaghpour *et al.*, 2006b). But some farmers prefer to plant chickpeas in spring (March) due to weed problems. Major successes due to breeding have been achieved, in the selection for drought escape. A new drought tolerant chickpea variety "Sameen" has been released for planting in spring in cold areas of the Islamic Republic of Iran (Sabaghpour, 2015a).

Cold stress

Cold stress is one of the most important abiotic stresses in cooler regions of the world. About 40 percent of the chickpea crop of the Islamic Republic of Iran is sown in areas susceptible to cold stress (Sabaghpour, 2005). The yield of autumn-planted chickpeas is higher than that of spring-planted due to winter rainfall and higher water use efficiency (Sabaghpour, 2002). The lowest absolute minimum temperature in cold areas of the Islamic Republic of Iran often occurs in December, January and February. Absolute minimum temperatures range from -10ºC to -30ºC with snow covering different cold areas of the Islamic Republic of Iran. Because local chickpea and lentil varieties cannot tolerate cold stress, farmers resort to planting these crops in spring. A new improved chickpea variety (Saral) has been released for autumn planting in cold areas of the Islamic Republic of Iran.

Diseases

Ascochyta blight

Ascochyta blight (*Ascochyta rabiei* [Pass.] Labr.) is a major yield reducer of chickpeas in north (Glostan), northwest (Oroumieh), west (Kermanshah, Lorestan and Ilam) and southern parts of the Islamic Republic of Iran both in winter and spring planted chickpeas, however it is more severe in winter sown crop (Sabaghpour 2015b). The disease was reported in 1957 for the first time in the Islamic Republic of Iran (Nori and Shahriyari 1994). Occurrence and severity of this disease depend largely on the cultivar and weather condition in a given year. Ascochyta blight incidence was 100 percent in the epidemic years in farmers' fields on local varieties in the Mediterranean region of the Islamic Republic of Iran. A survey on aschochyta blight disease conducted in different areas in northwest of the Islamic Republic of Iran in 1998 showed 35 percent of chickpea fields had Ascochyta blight incidence in the range of 30 to 80 percent (Akem, 1998). Hashem (Sabaghpour *et al.*, 2005), Arman (Sabaghpour *et al.*, 2006a), Azad (Sabaghpour *et al.*, 2010), Adel (Sabaghpour 2015b) Chickpea varieties which are resistant to ascochyta blight with erect growth habit and high potential yield were released for cultivation in cold, moderate, semi-warm areas of the Islamic Republic of Iran in the last decade. Ascochyta blight is not important on lentils, beans and mungbeans in the Islamic Republic of Iran. Ascochyta blight and Botrytis are major yield reduces for faba beans.

Fusarium wilt

Fusarium wilt (*Fusarium oxysporum* Schlecht. emend. Snyd. & Hans.f.sp. ciceri [Padwick] Snyd. & Hans) is another important disease mainly in spring chickpeas in the northwest of the Islamic Republic of Iran. A survey conducted in 1998 on fusarium wilt disease (Akem, 1998) in north and northwest of the Islamic Republic of Iran showed that 19 percent of the chickpea fields have fusarium wilt incidence in the range of 5 to 60 percent. Fusarium wilt incidence in chickpeas was in the range of 1 to 7 percent in the north (Nasrollah nejad, 1998), 5 to 50 percent in the west in Kermanshah Province and 2 to 20 percent in the western provinces of Lorestan and Kurdestan and south of the Islamic Republic of Iran (Nori and Shahriyari 1994). A chickpea variety "Sameen", tolerant to fusarium wilt and drought stress, with large seed size and high yield potential, has been released for planting in cold areas in spring planting (Sabaghpour, 2015a).

Fusarium wilt is a major yield reducer of lentils. In Ardebil province (Bilehsavar), 50 percent of lentil fields had fusarium wilt in the range of 20 to 80 percent in 2002 (Sabaghpour, 2006). A lentil variety "Bilehsavar", tolerant to fusarium wilt, with large seed size and high potential yield, has been released for planting in moderately cold, moderate and semi warm areas of the Islamic Republic of Iran (Sabaghpour, 2012).

Rhizoctonia

Rhizoctonia solani kuehn is a major yield reducer in mungbeans. The disease was reported in 1967 for the first time in the Islamic Republic of Iran. *Rhizoctonia solani* incidence in mungbeans was in the range of 4 to 57 percent in the Karaj (Nori and Shahriyari, 1994).

Virus

Virus diseases are also among biotic stresses limiting bean, chickpea, faba bean, lentil and mungbean production in the Islamic Republic of Iran. In the west of the Islamic Republic of Iran, incidence of virus diseases in chickpea fields ranged between 9.5 percent and 48.9 percent. Yield losses were about 20 percent, mainly due to *Bean leaf roll virus, Chickpea chlorotic dwarf virus, Faba bean necrotic yellows virus* and *Beet western yellow virus*. Lentil fields surveyed didn't have as extensive disease occurrence as that of chickpea fields. Major virus diseases affecting lentils can be ranked in the following order based on their frequency of occurrence in the surveyed fields: *Pea enation mosic virus, Bean leaf roll virus, Faba bean nerotic yellows virus* and *Pea seed-borne mosic* virus (Sabaghpour, 2006). *Pea eantion mosaic* virus was found to occur in a high incidence only in the Qazvin-Abhar region (27 percent). Of the fields surveyed, 25 percent had higher than 25 percent infection and losses in such fields were likely to be significant (Makouk and Kumari, 2001). In surveys conducted in the west of the Islamic Republic of Iran (Kermanshah and Lorestan) the most frequently encountered virus was *Been leaf roll virus* (Makouk, 2002). Yield losses in mungbeans were mainly due to *Mosaic mungbean virus* and *Alfalfa mosaic virus* (Sadri and Ghaffari, 1988).

Insect pests

Pod borers are the most important insect pest that cause substantial yield losses in chickpeas in the Islamic Republic of Iran. Two species of pod borer *Helicoverpa armigera* and *Helicoverpa viriplaca* are found more frequently than other species of the pod borers, however the population of these insect species are not similar in different areas. Cutworms, Agrotis spp, are also important pests in chickpeas, lentils and mungbeans. But the pest has a less damaging effect on winter planting of chickpeas and lentils. Bruchids are another important pest which is found in the stored seeds of these food legumes. Leaf miner is another important pest for chickpeas (Sabaghpour, 2014). Acari Tetranychidae (*Tetraanychus uricae* Koch) and Aphid (*Aphis fabae*) Scop are most important pests for beans and faba beans in the Islamic Republic of Iran (Parsa and Bagheri, 2008).

Major yield reducing constraints of food legumes in the Islamic Republic of Iran

1. Poor crop management practices result in soil moisture loss during field preparation, low plant density, late sowing, poor weed control in chickpea and lentil fields.
2. Chickpea local varieties planted in spring in moderate and in Mediterranean climates are susceptible to ascochyta blight.
3. The chickpea and lentil local varieties sown by farmers are susceptible to fusarium wilt.
4. The mungbean local varieties are susceptible to shattering.
5. Farmers are not able to plant chickpeas and lentils in winter or autumn due to cold damage in cold regions in the provinces of Kurdestan, Hamedan, East and West Azarbyjan, Zanjan and Khorasan.

6. Manual harvesting cost of local varieties is higher as these are prostrate in growth habit and farmers could not harvest chickpeas, lentils, beans and mung beans by combine.
7. Lack of varieties which have resistance to pod borer and leaf miner.
8. Lack of varieties which have resistance to viruses.
9. Lack of varieties which are tolerant to heat stress and soil salinity.
10. Weeds in chickpeas are generally controlled manually rather than by herbicides. Hand weeding is expensive. Moreover, the price of selective herbicide for broad leaves is higher than herbicides for narrow leaves.
11. Lack of varieties which have resistance to Cutworms.
12. Lack of varieties which have resistance Bruchids.
13. Lack of varieties which have resistance to Acari Tetranychidae.
14. Lack of varieties which have resistance to Aphid.
15. Lack of varieties which have resistance to Botrytis.

Strategies for increasing yields

Chickpea, lentil and mung bean productivity is low in the Islamic Republic of Iran. To increase seed yield of these crops, the following strategies have been recommended for transfer to farmers. These have been developed and standardized by the pulse research programmes of the country.

1. Minimum tillage should be done for preparing chickpea and lentil fields which will minimize soil moisture loss during field preparation.
2. Optimum date of sowing recommended for different regions and seasons should be followed:

The results of the experiment showed that chickpeas planted in autumn produced 71 percent higher yields than the crop planted in spring in Kermanshah. Improved chickpea varieties such as Hashem, Arman, Azad, Adel which have resistance or tolerance to aschochyta blight and improved lentil varieties such as Gachsaran, Kimiya and Bilesevar should be planted in the moderate and Mediterranean climate and semi-warm area in autumn. For cold areas, *entezari* planting (December) in winter may be done for theses varieties or improved chickpea varieties (Sameen) planted in spring. Mungbeans are planted in spring and summer. To obtain optimum yield in both seasons planting should be done early. In summer it should be done soon after harvesting cereals.

1. Optimum plant population should be used for local and improved varieties.
2. Optimum quantities of suitable fertilizer recommended for each variety and areas may be used.
3. Improved chickpea varieties such as Hashem, Arman, Azad, Adel all have erect growth habit and are suitable for mechanical harvesting.

Strategy for future research

1. Identify varieties with wide adaptability.
2. Develop varieties that have resistance to biotic stresses such as ascochyta blight, botrytis, fusarium wilt, viruses, pod borer, acari Tetranychidae, aphid, bruchids, cutworms and leaf miner.
3. Develop varieties which have tolerance to abiotic stress such as cold, heat, drought and salinity.

4. Develop varieties which have high yield and are bold seeded.
5. Develop varieties which have erect growth habit for mechanical harvest.
6. Conduct research on biological control of insect pests such as pod borer, cutworms, leaf miner, acari tetranychidae, aphid, bruchids and leaf miner.
7. Identify effective rhizobia and rhizobial inoculation technique.
8. Identify physiological aspects of yield variation under different environmental conditions, which might be helpful for agronomic manipulations.
9. Following the two-year food legume virus diseases survey in the Islamic Republic of Iran, it is recommended that a long term research plan be developed in order to eventually manage the spread of virus diseases in legumes to minimize the losses caused by them, and more importantly to stabilize yields in the regions where virus epidemics are likely to occur.

Strategies for improving agricultural productivity in dry land areas

1. Consolidate land holdings to make better use of agricultural machinery.
2. Formulate suitable policies and strategies for the use of lands with more than an 8 percent slope.
3. Government purchase of new harvesting combines and new seeding drills to replace the old ones.
4. Train drivers of the combines in adjusting the harvester to avoid shattering in wheat and barley.
5. Undertake proactive measures to transfer research results to extension workers and farmers.
6. Invite farmers to Agricultural Research Centers and expose them to the research work being carried out to solve the problems they face. There should be close interaction between farmers and extension agents.
7. Provide farmers with new facilities such as the internet to access the latest developments/ technologies for improving agricultural production.
8. Promote farmer's participation in the agricultural scientific meetings, congresses, etc.
9. Ensure farmers receive the same price in government procurement programme for food legumes from domestic markets as the price paid for importing pulses.
10. Encourage farmers to organize in cooperatives.
11. Organize in-country training for farmers and study visits abroad.
12. Provide farmers with meteorological data for making judicious use of agricultural input.
13. Supply agricultural inputs (water, seed, fertilizer, pesticides) to farmers at prices as low as possible.
14. Undertake measures to provide dry land farmers with long range climate forecasts.
15. Promote suitable research strategies for conservation of soils and other resources.

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Recent achievement in research and development of pulses in Lao PDR

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Abstract

Pulses, also called grain legumes, are crops that are harvested solely for the dry seed. In Lao PDR, soybeans and peanuts are also included in the category of pulses. Mungbeans, cowpeas, soybeans and peanuts are the most common grain legumes grown in Lao PDR. The country's total agricultural area is 3 513 234 ha, and the share of cropped area of pulses in total agricltural area is very small with only 0.7 percent for peanuts, 0.25 percent for soybeans and 0.08 percent for mungbeans.

Qualitative malnutrition is chronic in Lao PDR, and particularly among children under five years of age stunting is common (up to 40 percent). Rice is mainly consumed as a source of carbohydrate, while proteins and micro-nutrients are missing in the daily food intake. Pulses are a primary source of vegetable protein, complex carbohydrates, and several vitamins and minerals and should be promoted in daily food consumption.

Farmers widely grow mungbeans on low-lying areas, mostly during the rainy season. Soybeans are grown in rainfed upland areas and irrigated lowland after harvesting rice. Peanuts are grown on sandy soil along the Mekong river bank and the banks of other major rivers. It is also grown, to some extent, in irrigated rice fields, most peanuts are grown in the dry season.

The trend of cropped area under pulses keeps changing depending upon market demand and competition with other crops for land use. Productivity remains below the potential yield because of low input usage, especially chemical fertilizers; limited availability of quality seed, poor familiarity with the variety of existing pulse types, and limited use of modern agronomic practices. The link between the producers and the export markets is weak due to the large number of ineffective intermediaries operating in the value chain. While there has been substantial growth in recent years, the current export market is underdeveloped. The major causes of limited export development are (i) inadequate market intelligence; (ii) inability to leverage scale efficiencies due to smaller size; and (iii) non-conducive business environment because of missing credit and insurance; and (iv) inconsistent policy interventions.

The interventions and enabling actions can holistically strengthen the pulses value chain to become more productive and stable, and provide year round transactions that supply domestic and international markets.

Introduction

Lao PDR is located in the centre of Indochina sharing borders with China to the north, Myanmar to northwest, Thailand to the west, Cambodia to the south and Viet Nam to the east. It has a total area of 236 800 square kilometres, with around 70 percent of the terrain being mountainous with maximum elevation of 2 820 meters in Xieng Khouang Province. The landscapes of northern Lao PDR and the regions adjacent to Viet Nam, in particular, are dominated by rough mountains. The Mekong river is the main geographical feature in the west and, in fact, forms a natural border with Thailand in some areas. The Mekong flows through nearly 1 900 kilometres of Lao territory and shapes much of the lifestyle of the people of Lao PDR. In the south, the Mekong reaches a breadth of 20 kilometres, creating an area with thousands of islands.

As mentioned in the Agricultural Development Strategy to 2020 and vision to 2030 of the Ministry of Agriculture and Forestry, the government has identified the agriculture and forestry sector as the priority for food security and commercial agriculture production and connected to poverty reduction in rural areas. Agriculture contributes 23.7 percent to national gross domestic product (GDP), industry 32.2 percent and service 44.1 percent (CIA.GOV, 2014). In mountainous and slopey areas of northern Lao PDR, rice is grown and yields are low. Some northern upland farmers focus on production of cash crops such as maize, soybeans, peanuts, cotton, sesame, and others. Commercial production of soybeans and peanuts is the potential income source for upland farmers. The commercial agriculture production in lowland areas focuses on large scale rice production in irrigated areas.

According to FAO, the term pulse is reserved for crops harvested solely for the dry seed. This excludes green beans and green peas, which are considered vegetable crops. Also excluded are crops that are mainly grown for oil extraction (soybeans and peanuts), and crops which are used exclusively for sowing (clovers, alfalfa). Therefore, several countries do not necessarily declassify the soybean and other leguminous crops as pulse crops. Pulse is often called grain legume, it is in the botanical family of Fabaceae (formerly known as the Leguminosae family) and is used for human food and animal feed.

Mungbeans, cowpeas, soybeans and peanuts are the most common grain legumes considered in Lao PDR. They are widely promoted for commercial production with limited success because they are mostly grown in home gardens for family consumption. Mungbeans, cowpeas soybeans, and peanuts are grown as commercial crops in areas well connected to markets. Crops belonging to Vigna genus are important in Lao PDR. Among them, *V. radiata* (mungbean) and *V. unguiculata* (cowpea) are widely cultivated crops. *V. umbellate* (rice bean) is a traditional food crop of Lao PDR.

Trends in pulse area, production and productivity

Cowpeas and rice beans are grown in small gardens for family home consumption, there are no statistic records on the overall area, production and productivity of these crops. Soybeans, mungbeans and peanuts are widely cultivated in large areas on a commercial scale as shown in Table 1. Total agricultural area is 3 513 234 ha for upland crop, of which 7 percent is occupied by upland crops, 30 percent by rice, 33 percent by other crops, 1 percent by fruit trees and 29 percent is natural grassland for animal grazing (Deparment of agriculture land management, MAF, 2012). Legumes constitute a negligible share of the total cultivated area: only 0.70 percent for peanuts, 0.25 percent for soybeans and 0.08 percent for mungbeans. The largest produciton area of peanuts is in Saravane (7 135 ha), Champasack (4 125 ha) and Xayaboury (3 640 ha), of soybeans is in Chamasack (4 375 ha), Houaphan (1 820 ha) and Oudomxay (1 610 ha), and the biggest producer of mungbeans is Champasack (1 285 ha).

Table 1. Area, production, and yield of peanuts, soybeans and mungbeans grown in Lao PDR

Crop	Parameter	2005	2006	2007	2008	2009	2010	2011	2012	2013
Peanuts	Area (ha)	16 650	18 385	15 865	19 376	19 577	23 570	32 780	21 620	24 595
	Production (tonne)	26 990	27 600	35 070	32 690	35 163	50 945	70 195	44 735	54 804
	Yield (tonne/ha)	1.62	1.50	2.21	1.69	1.80	2.16	2.14	2.07	2.23
Soybeans	Area (ha)	9 535	8 920	8 040	9 690	10 278	7 235	9 145	3 885	8 900
	Production (tonne)	11 100	11 950	10 455	13 515	19 425	11 435	13 820	6 360	13 905
	Yield (tonne/ha)	1.16	1.34	1.30	1.39	1.89	1.58	1.51	1.64	1.56
Mungbeans	Area (ha)	2 925	2 665	2 445	2 920	2 432	3 145	3 685	3 345	2 940
	Production (tonne)	3 707	3 480	2 465	3 890	3 686	4 465	4 790	4 325	3 365
	Yield (tonne/ha)	1.27	1.31	1.01	1.33	1.52	1.42	1.30	1.29	1.14

Source: Department of Agriculture (DOA), MAF

The trends of production area are changing year by year owing to several factors. The major factor of changing production is market demand setting price and competition with other crops for land use such as cassava, sugarcane and rubber tree. The productivity of peanuts, soybeans and mungbeans in Lao PDR is much lower than in other countries, so it is not exciting for farmers to grow more or invest in expansion.

Pulse-based farming system dynamics

There are two growing seasons in Lao PDR, namely rainy and dry seasons. The rainy season starts from May and ends in October and the dry season lasts from November to April (in some years raining starts from April). Farmers widely grow mungbeans on low land areas and mostly during the rainy season. As for the soybeans, farmers mostly grow soybeans in rainfed upland areas in the rainy season and in lowland areas such as irrigated paddy field after rice harvesting (from December to April). Peanuts are grown along the banks of Mekong and other big rivers in sandy soil and also in rice field with irrigated system, most of which is grown in the dry season. In lowland areas (irrigated rice fields), some farmers practice crop rotation rice-soybean and rice – mungbean but only in very small areas.

Major achievements in increasing pulse production and productivity

Increases in pulse production is achieved through promotion of short-duration pulse crops. A focused attention on Integrated Pest Management has also triggered interest and facilitated the increase of productivity and production of pulses. Better access to water through irrigation and access to quality seeds and credit for growers also are critical factors to the development of pulse production.

Constraints in productivity enhancement and emerging challenges

With regard to the trend above, yield and production of such crops are not contantly increased. They rather fluctuate because of some constraints on cropping. The constraints and challenges can be both technical and of marketing aspects, among them the following can be mentioned:

- inadequate availability of quality seeds of improved varieties;
- prone to pest and diseases and heavy yield losses;
- inadequate and imbalanced use of nutrients;
- pulses suffer heavily from soil moisture stress/drought;
- lack of mechanization;
- policy does not fully support pulse growers.

Some potential solutions to facing these challenges and for enhancing productivity exist, such as integrated nutrient management, i.e. use of sulphur, micronutrients, rhizobium culture, PSB, urea spray, IPM, weed management.

Introduction of short duration pulses into rice-based cropping systems is recommended but challenges remain for short-maturing pulse varieties between two rice crops, and for adaptability to stresses caused by variable weather conditions.

- Prospects for pulse crops in Lao PDR are constrained by their lower financial attractiveness to farmers relative to other crops, notably maize and rice.
- The case study conducted in Pek, Kham, Nonghet district, Xiengkhouang province, Lao PDR, showed that diffusion remains constrained by 1) the important initial financial investments required for establishment and by the limited access to bank credit (high interest rate and too short refund period) and 2) villagers' relative lack of experience and limited awareness and recognition of environmental degradation linked to tillage (most villagers do not understand the details of technical aspects (herbicides, equipment, etc.) adoptation is therefore constrained.

Current efforts for improving pulse productivity

Currently, the Agricultural Research Center (ARC) under the National Agriculture and Forestry Research Institute (NAFRI) of the Ministry of Agriculture and Forestry of Lao PDR is conducting research on legumes such as germplasm collection and breeding, improving cultivation tehnology and extension of legumes cultivation. Their collection includes 16 accessions of peanuts, 20 accessions of soybeans and 26 accessions of mungbeans, all materials are local and introduced variety. ARC has improved two new varieties for meduim maturity soybeans combined with high yields. The centre also introduced a new high yield variety from Thailand and Viet Nam for peanuts, soybeans and mungbeans which showed good adaptation to Lao weather conditions.

ARC has developed a breeding programme for high yield, early maturity varieties that show tolerance to biotic and abiotic stresses, and are adaptated to a large spectrum of weather conditions for peanuts, soybeans and mungbeans. ARC has promoted intercropping and crop rotation systems on farmer field plots including legumes (peanuts, soybeans and mungbeans) and major crops such as rice, miaze and cassava. Also, the ARC has introduced soil nutrient improvment practices by using pigeon peas as green manure.

ARC in coordination with ICRISAT impmelented Sustainable Management of Crop-based Production Systems for Raising Agricultural Productivity in Rainfed Asia (IFAD Grant Number: I-R-1363–ICRISAT Project). This project has conducted agro ecological analysis, introduced pulse cultivation in dry season irrigated field as crop rotation, introduced intercropping and the superior varieties of peanuts and pigeon peas. The project also supported capacity building of scientists at the Agriculture Research Center in Viet Nam and in India for pulse breeding and pulse seed production.

Suitability of pulse for conservation agriculture

Like many leguminous crops, pulses play a key role in crop rotation owing to their ability to fix atmospheric nitrogen. Pulses are considered good 'cover crops' and also one of the crucial elements of conservation agriculture.

Area, production and yield of pulses in Lao PDR vary across the country depending upon the temperature, rainfall and source of irrigation. Most of the pulse crops grown in the rainy season thrive in uplands as rainfed crops with rain water as the source of moisture. Post-rainy season pulses largely grow on conserved moisture with supplemental irrigation. Summer pulses are grown with supplemental irrigation. Higher soil fertility and high moisture fend off pulse cultivation.

Pulse's contribution to nutrition, employment and income generation, and value chain development including processing and marketing

Malnutrition is chronic in the Lao PDR, and prevalent particularly among children under 5 years of age resulting in stunting, which is common (up to 40 percent). Proteins and micro-nutrients are lacking in the daily diet intake. Pulses are primary sources of vegetable protein, complex carbohydrates, and several vitamins and minerals. Like other plant-based foods, they contain no cholesterol and little fat or sodium. Pulses also provide iron, magnesium, phosphorus, zinc and other minerals, which play a variety of roles in maintaining good health. Pulses contain 20 to 25 percent protein by weight, which is double the protein content of wheat and three times that of rice. While pulses are generally high in protein, and the digestibility of that protein is also high, they often are relatively poor in the essential amino acid methionine. Grains (which are deficient in lysine) are commonly consumed along with pulses to form a complete diet of protein.

Pulses have significant nutritional and health advantages for consumers. They are the most important dietary predictor of survival in older people of different ethnicities, and in most cases, legume consumption is highly correlated with a reduced mortality from coronary heart disease. Furthermore, pulses are especially high in amylose starch making them a good source of pre-biotic resistantstarch. For people with diabetes, consuming lentils, peas and beans helps control blood glucose management. Compared with some other carbohydrate sources, pulses have a lower glycemic index. Studies have also shown that consuming pulses can result in more stable blood glucose levels after meals.

Consuming pulses can help with weight management. For people trying to lose weight, pulses are high in fibre and protein, low in fat and moderate in calories. One cup of cooked lentils or dry peas contains about half of the daily fibre recommendation for adults. Foods higher in fibre content usually help people feel "full" or satiated at meal time.

Strategy to meet future opportunities and challenges

Enhancing capcity building on grain legume research such as:

- Develop human resources for legume breeding and crop managment (recently, ARC has two specialists on soybeans no specialist on mungbeans and peanuts). Human resources are key to improving productivity.
- Improve genetic resouces by germplasm collection (local and introduced material) and induced by crossing and mutation methodology.
- Improve facility for doing research such as field facility (irrigation system, dry house, seed storage etc.) and laboratory equipment used for analysing nutrition contained in grain legumes and molecular markers for plant breeding.
- Develop education tools (handbook, leaflet, videos etc.) on the advantage of grain legume consumption, new technologies on grain legume production and managment and post-harvest and processing of grain legume technology. These tools will be used for training of trainers (TOT), farmers and students at college.
- Conduct research on grain legume processing and marketing, it will be a way to motivate farmers to grow more grain legumes. At least they will know how to process legumes for their family to increase nutrition consumption.

- Lack of pulse value chains and lack of interest of private sector investors to invest in agribusiness value chains is one key constraint to promoting market-linked pulse production.
- Lack of biofertilizer production centres and bio-pesticide production centres are key constraints.

Reaching out to farmers and consumers

A set of constraints hamper the pulse value-chain development with regard to production, bulking and trading.

- **Production:** Productivity is below potential due to low input usage, especially chemical fertilizers; limited availability of seed and limited familiarity with the variety of existing pulse types, and limited usage of modern agronomic practices.
- **Aggregation and trading:** The link between the producers and the export markets is weak due to the large number of ineffective intermediaries operating in the value chain. The intermediaries have failed to acquire scale and operate in limited geographic areas. The fragmentation of intermediaries between the producer and consumer markets creates a lack of transparency in markets.
- **Export:** While there has been substantial growth in recent years, the current export market is underdeveloped. The major causes of limited export development are (i) inadequate market intelligence; (ii) inability to leverage scale efficiencies due to smaller size and (iii) non-conducive business environment due to missing credit and insurance; and (iv) inconsistent policy interventions.

Conclusion and recommendations

Core interventions and enabling actions can holistically strengthen the pulse value chain so that it becomes more productive and stable, and provide year-round transactions that supply domestic and international markets.

Increase inputs to improve productivity

Access to inputs is a key step in bridging the yield gap between current and potential production. Phosphates and other fertilizers should be supplied to farmers, along with knowledge on how to use them effectively. Seed multiplication should be increased to adequately supply the needs of exporters and domestic demand. Extension should incorporate the agronomy of pulses into the curriculum.

Enhance linkages between exporters and producers

Stronger linkages between exporters and smallholders will lead to a more efficient value chain where demand signals are clearly communicated to the producers, and where inputs are available to ensure proper production of pulses designated for export. Actions to enable consistent supply between producers and exporters may include: provision of region-specific input packages; development of new varieties appropriate for export; leverage of cooperatives to provide consistent input supply and off take.

Provide adequate markets to the exporters and farmers

Strengthen the export sector

Developing the export sector will drive foreign reserve earnings and will create a steady demand for pulses, thereby acting as a catalyst for the sector. Exporters should be supported through a business environment more conducive to investment and policies aimed at bolstering exporters' scale, knowledge base, as well as business development. However, realizing the potential of the pulse value chain cannot be done in isolation; it can only work if other components of the agriculture system are in place: extension, improved seed, and soil fertility measures.

In the end, growing pulses should be lucrative to farmers and competitive to growing other crops at farming system level. The additional advantages that growing pulses bring (short growing season, erosion control, soil improvement/nitrogen fixing) should be actively promoted to farmers to enhance uptake.

Recent achievement in research and development of pulses in Myanmar

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Introduction

In dry areas, pulse crops play an important role in food, feed and farming systems. A vast majority of people in the dry areas of the world are dependent on pulses for their nutritional requirements and food security. The residues of pulses are valuable animal feed and these legumes when grown in rotation with cereals provide sustainable cropping systems. The productivity of pulses in developing countries remains stagnant and per capita availability is far below of the WHO recommended 45 g/person/day. Improvement in the production of these crops through germplasm enhancement and crop management will, therefore, contribute substantially to improved human nutrition in the developing world. Moreover, consumption of nutritionally enhanced pulses will provide health security to the poorer section of society who cannot afford high-priced animal protein.

Pulses are the second important crop in Myanmar after rice and other cereals. They are grown on 4 534 000 hectares (21.2 percent of sown area under various crops) with an annual production of 5 974 363 tonnes (Myanmar Agriculture at a Galance, DAP MOAI, 2014). Myanmar accounts for 4.7 percent of the world area and 5.8 percent of the world production of pulses (FAOSTAT, 2010).

Pulses are grown throughout Myanmar but 92.0 percent of total pulses growing in the country are concentrated in Ayeyarwaddy, Magwe, Pegu, Mandalay, Sagaing and Yangon regions. The major pulse crops of the country are mungbeans, blackgrams, pigeon peas, chickpeas, soybeans, butter beans, kidney beans, cowpeas, lab lab beans, sultani and sultapya. More popular among these are mungbeans, blackgrams, pigeonpeas, chickpeas, soybeans and cowpeas. In general, pulses are mostly grown in two seasons: (i) monsoon season (May–July), and (ii) post-monsoon season (October–December). Mungbeans, pigeon peas and soybeans are grown in the monsoon season, while blackgrams, chickpeas, cowpeas are grown during post-monsoon season. And also mungbeans are grown in post-monsoon season after the harvest of rice in the lower part of Myanmar.

Pulses are consumed almost daily in most area of Myanmar, especially in dry-zone regions. Pulses are also becoming an important export crop and Myanmar exported 339 900 tonnes of mungbeans, 644 400 tonnes of blackgrams and 316 800 tonnes of other pulse crops (Myanmar Agriculture at a Galance, DAP MOAI, 2014).

During 2012-2013, Myanmar exported over 1.9 million tonnes (mt) of beans and pulses, with India as the major export destination followed by the United Arab Emirates, Thailand, Bangladesh and Japan. India is the largest consumer of beans and pulses in the world and is currently Myanmar's largest export market. India's growing population coupled with the thrust on increasing cereal and oilseed production and consumption has resulted in the country producing beans and pulses in quantities regularly falling short of meeting the domestic demand. Thus, India has to import approximately 3-4 mt of beans and pulses annually, and this number can be exceeded if domestic production suffers owing to unfavourable seasonal conditions. India purchases beans and pulses on an as-needed basis, commensurate with their demand. Leveraging its almost monopoly role in Myanmar's export trade of pulses, India is able to highly influence the commodity price as the country is heavily dependent on India's decisions to import (Aye, P.S., Htun, H.W. and P.M. Thaw, 2013).

Although India is both the largest producer and consumer of pulses in the world, it relies on imports of significant amounts of pulses to close the gap between domestic production and surging demand for consumption of pulses. During 2009-2010, India imported 3.5 mt of pulses from Australia, Canada, and Myanmar. Thus, India is the largest importer, producer and consumer of pulses. On the other hand, India is also the largest pulse processor, as pulse exporting countries like Myanmar, Canada and Australia do not have adequate pulse processing facilities (Gowda, C.L.L., Srinivasan, S., Gaur, P.M., and K.B. Saxena, 2013).

Area, production and yields of pulses in Myanmar

Myanmar ranks fifth in global production of pulses. As stated above, the country contributes 4.7 percent of the world area and 5.8 percent of the world production of pulses (FAOSTAT, 2010). The status of pulse production in Myanmar is shown in Table 1. Among the pulse crops, mungbeans dominates with over 28 percent of total pulse production followed by blackgrams (24.3 percent), pigeonpeas (14.0 percent), chickpeas (8.4 percent), soybeans (3.4 percent), cowpeas (6.0 percent) and other legumes (16.0 percent) (Table 2).

Table 1. Pulses sown area, yield and production in Myanmar (State/Region)

State/Region	Sown area (ha)	% of total area	Yield (tonne/ha)	Production (tonne)
Kachin	24 785.43	0.55	1.32	32 783.31
Kayah	20 376.11	0.45	0.93	19 040.54
Kayin	59 701.62	1.32	1.22	73 088.98
Chin	10 303.24	0.23	0.74	7 615.61
Mon	21 012.55	0.46	1.25	26 208.15
Rakhine	46 728.34	1.03	1.06	49 638.41
Shan	174 502.83	3.85	1.28	223 885.14
Sagaing	1 026 044.53	22.62	1.43	1 463 032.50
Bago	799 520.24	17.63	1.53	1 220 647.26
Magwe	845 079.76	18.63	1.31	1 105 026.59
Mandalay	665 048.99	14.66	1.17	780 914.06
Ayewaddy	672 140.49	14.82	1.32	885 828.35
Yangon	170 249.39	3.75	1.21	206 127.93
Taninthayi	203.64	0.0045	0.51	102.99
	4 535 697.16		1.16	5 274 979.24

Mungbeans cover about 1 260 361 ha, mainly grown in Magway Region (24.0 percent), Sagaing Region (16.2 percent), Bago Region (16.7 percent), Mandalay Region (11.6 percent) and Ayeyarwaddy Region (5.7 percent) with an average yield of 1.11 tonne/ha and total production of 1 402 892 tonnes. Blackgram is grown on 1 102 500 ha with a total production of 1 549 293 tonnes

Table 2. Sown area and production of pulses in Myanmar

Crop	Sown area (ha)	Yield (tonne/ha)	Production (tonne)
Mungbeans	1 260 361.13	1.11	1 402 892.67
Blackgrams	1 102 500.81	1.41	1 549 293.20
Pigeonpeas	638 965.99	1.30	833 482.99
Chickpeas	384 372.87	1.53	586 526.37
Soybeans	155 181.78	1.49	231 252.50
Cowpeas	279 916.59	1.25	349 795.98
Others	713 668.42	1.13	807 407.49
Total	4 534 967.61	1.32	5 973 130.55

and average yield of about 1.41 tonnes/ha. Its major production areas are located in Bago Region (44.0 percent), Ayeyarwaddy Region (41.0 percent), Sagaing Region (7.0 percent, Mandalay Region (2.9 percent) and Yangon Region (1.8 percent).

Pigeonpeas are mainly grown in Sagaing Region (35.0 percent), Magway Region (28.0 percent), Mandalay Region (29.0 percent) and Shan State (4.0 percent). The total area under the crop is about 638 965 ha with total production of 833 482 tonnes and average yield of about 1.3 tonnes/ha. Chickpeas are currently grown in 384 372 ha with a total production of 586 526 tonnes and the average yield of 1.53 tonnes/ha. The majority of this area is concentrated in the central dry zone which includes Sagaing (46.0 percent), Mandalay (26.0 percent) and Magway (24.0 percent) contributing 96 percent of the total chickpea production.

Soybeans (*Glycine max* L.), locally known as *peboke*, are currently grown on 155 181 ha with a total production of 231 252 tonnes and an average yield of 1.49 tonnes/ha. The majority of soybean growing areas are located in highlands of Shan State in rainy season and in delta area of lower Myanmar following the recession of floodwater. Cowpeas are mainly grown in the regions of Magway and Bago with an average yield of 1.25 tonnes/ha with total production is 349 795 tonnes from cropped area of about 279 916 ha.

Production and productivity of pulses has registered an upward trend from 2005-2006 to 2013-2014 (Table 3). The slight improvements are probably driven partly by the promotion of export markets and favourable prices in the local market and partly by the research and development efforts.

Table 3. Pulses sown area, yield and production in Myanmar

Year	Sown area (000 ha)	Harvested area (000 ha)	Yield (tonne/ha)	Production (000 tonnes)
1995/96	2 046	2 006	0.69	1 375
2000/01	2 934	2 873	0.79	2 263
2005/06	3 808	3 806	1.05	4 008
2009/10	4 383	4 382	1.25	5 486
2010/11	4 501	4 499	1.29	5 792
2011/12	4 417	4 416	1.23	5 410
2012/13	4 449	4 447	1.28	5 701
2013/14	4 534	4 533	1.30	5 902

Constraints to pulse production

Production constraints

Production of major pulses is constrained by both biotic and abiotic stresses. In mungbeans and blackgrams, mungbean yellow mosaic virus, root rot (*Rhizoctonia bataticola*), maruca (*Maruca testularis*), armyworm (*Spodoptera litura*), common hairy caterpillar, leaf roller are among the biotic stresses. Pod borer (*Helicoverpa armigera*) infestation occurs every year throughout the growing season.

Root diseases including collar rot (*Sclerotium rolfsii*) at seedling stage, fusarium wilt (*Fusarium oxysporum*) at either early or late growth stage, dry root rot (*Rhizoctonia bataticola*) at late growth stage are serious constraints in chickpea production in Myanmar. Similarly, pod borer, maruca, fusarium wilt, and sterility mosaic diseases are affecting pigeonpea production. Bean fly, hairy caterpillar, armyworm, green bugs and rust, downy mildew and bacterial pustules diseases are major pests and diseases in soybean production.

Among the pulses, mungbeans and pigeonpeas are grown under rainfed conditions in the central dry zone. Blackgrams, mungbeans, chickpeas, other peas and beans are grown after harvesting rice using residual soil moisture. Drought and high temperatures are major stresses in pulse production in Myanmar. Frequent heavy rain, off-season heavy rain and prolonged rains at some stages in the crop life cause heavy losses to pulse crops.

Socio-economic constraints

In Myanmar, emphasis on rice and maize cultivation has reduced the status of pulses in farmers' cropping systems to secondary crops or catch crops. Therefore, the use of inputs is limited because farmers give first priority to staple cereals. In addition, there is a lack of policy support and post-harvest innovations related to pulse crops. Availability of quality seed of improved varieties and other inputs is one of the major constraints in increasing the production of grain legumes.

Strategies to improve pulse productivity and production

There are a number of technological options available for increasing the productivity and production of pulses. These are use of short-duration and high-yielding varieties with resistance to diseases and pest, improved varieties with drought tolerance, adoption of good cultural practices (pest and diseases management, weed control methods) and introduction of new adapted crop varieties, new cropping patterns for fallow land area and supplies of quality seed and improved varieties for farmers. Moreover, on-farm research and development programmes can enhance participation of farmers and secure their cooperation in improving pulse productivity and production.

Varietal improvement and recommended varieties of major pulse crops in Myanmar

Developing new varieties which are better than the existing best ones in respect to yield or any other desirable traits has been the foremost objective of breeding programmes. A critical examination of current varietal improvement programmes has shown some improvement in yield over the local varieties and the yields are rather unstable. Productivity of pulses is severely constrained by various biotic and abiotic stresses. Among the constraints, drought is the most important and causes great losses and complete crop failures. Therefore varieties with built-in resistance or tolerance to biotic (pests and diseases) and abiotic stresses (heat and moisture deficit), must be developed in order to achieve stable yield.

Successful research undertaken by the Department of Agricultural Research, Myanmar has led to development of new breeding lines and varieties. Mungbean Yezin-6, Yezin-11, Yezin-14 and local varieties are widely grown and a majority of farmers prefer the recommended varieties for their traits to fit in the local areas. Yezin-6, moderate drought tolerant variety, is suitable for dry regions with a considerable yield. Yezin-11 and Yezin-14, highly resistant to yellow mosaic virus disease, could be grown in mungbean growing area in which most of the released green gram varieties are affected by yellow mosaic virus disease.

Among the recommended varieties of blackgrams, mostly grown are Yezin-2, Yezin-3, Yezin-6 and local varieties. Yezin-2 is medium-seeded, high-yielding with early maturity. Yezin-3 is a small-seeded, high-yielding variety while Yezin-6 is a large-seeded, high-yielding variety. Yezin-3 is recently modified by induced mutation using gamma radiation and released under the name "Pale Tun" which is large-seeded, early-maturing variety. Developing of photo-thermo insensitive with high-yielding blackgram varieties is in progress. Yezin-4 is a photo-thermo insensitive variety which is sown in monsoon season with a substantial yield. In addition, several Yezin-4 derived lines modified by induced mutation have been investigated.

Pigeonpea varieties like Monywa Shwedinga and local varieties such as Thahtaykan are mostly sown in these areas. Monywa Shwedinga is locally well adapted and moderately tolerant to drought. However, the variety is small-seeded and holds low potential for export.

DAR released five *desi* chickpea types (Yezin 1, Yezin 2, Yezin 4, Yezin 6 and Shwenilonegyi) and 3 *kabuli* chickpea types (Yezin 3, Yezin 5 and Yezin 8) which have good export quality, high yield potential and wide adaptation. All released varieties, except Shwenilonegi (national breeding line), are supplied by ICRISAT. Among them, Yezin 3, Yezin 4 and Yezin 8 are early maturing varieties and Yezin 6 is heat tolerant. Shwenilonegyi has attractive grains with high recovery of split grains (Than *et al.* 2007).

In cowpea research and development programmes, black-eyed cowpea varieties – Sinpelunphyu-2, Sinpelunphyu-3 and Sinpelunphyu-5 – have been released. Because of their characteristics of short-duration, larger seed size and higher yield compared with existing varieties, the potential for export looks promising. And also in soybean development programmes, local varieties as well as introduced breeding materials are also grown and selected to develop new varieties with desirable traits. DAR released seven varieties, Yezin 1, Yezin 2, Yezin 3, Yezin 4, Yezin 5, Yezin 6 and Yezin 11, which have high yield potential. Among them, Yezin 3 is early maturing and disseminated in Shan State. Yezin 6 and Yezin 11 are high yielding with wide adaptation, suitable for different cropping systems and widely distributed in Northern Shan State. In addition, promising varieties, Yezin 12 (KUSL 20004), Yezin 13 (SJ 4) and Yezin 14 (Srisamrong 1), which have good grain quality and high yield potential and suitable for Shan State are also under pre-release stage evaluation. These varieties produced more yields than did the local variety, they were also more tolerant to soybean rust in various areas. significant research was also conducted on agronomic trials. Intercropping with soybeans and upland rice was identified as better crop diversification.

Conclusion

The area, production and yield of pulses in Myanmar had increased from 2000 to 2014. However, a number of constraints, biotic and abiotic, remain that negatively impact on productivity of pulses in Myanmar. Therefore, efforts need to be focused on improving productivity and production of pulses through the use of improved varieties with resistance to diseases and pest and tolerance to other stresses, adoption of good cultural practices (pest and diseases management, weed control methods) and use of quality seed. This is important not only for farmers to increase their income, improve their food and nutritional security, but also for the country to earn foreign exchange through boosting export.

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Current status of pulses research and development in Nepal

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General background

Nepal has diverse climatic conditions and agro-ecological environments. Because of sharp differences in the altitude, the country possesses more than 300 agro-ecological niches making agricultural research and development a complex process. Nepal is divided into four major agro-climatic zones, the Terai (part of the Indo-Gangetic Plain to the south), the inner Terai, mid-hills and valleys, and high mountains (in the north). Soil texture varies from rich alluvial deposits in the Terai to course-textured gravel in the high mountains (Pandey *et al*., 1994). Grain legumes are grown across all the production environments ranging from 75 m to about 3 000 m above sea level. But the main production areas are concentrated in the Terai, inner terai, valleys and middle hills of Nepal.

Grain legumes are grown mainly as a rainfed crop (dependent on residual soil moisture) both in the terai and in the hills. Winter legumes such as lentils, chickpeas, and grasspeas are grown mainly in the rice-based system of the terai and inner terai. Warm season grain legumes such as soybeans, blackgrams, pigeon peas and horse grams which are produced in the maize-based system of the hills. In the higher mountainous regions, peas and phaseolus beans are the two most important summer legumes. Winter grain legume crops are grown dependent on residual soil moisture after the harvest of rice or seed broadcasted on standing rice about 7–15 days prior to rice harvest (relay cropping). Warm season grain legumes are grown during summer months (monsoon rain) in mono, mixed with maize/finger-millet or on paddy bund.

Area, production and productivity of pulses in Nepal

In Nepal, several types and species of pulses are grown. Lentils, blackgrams, soybeans, pigeonpeas, grasspeas, chickpeas, horse grams, mungbeans, cowpeas, groundnuts, and faba beans are commonly grown legumes crops in the country. Grain legumes occupy 334 323 ha agricultural land and produce a total of 319 770 tonnes (Table 1). In terms of area and production, pulses rank fourth after rice (*Oryza sativa* L.), maize (*Zea mays* L.), and wheat (*Triticum aestivum* L.). Winter legumes such as lentils, chickpeas, and grasspeas account for about 68 percent and warm season grain legumes such as soybeans, blackgrams, pigeonpeas and horse grams about 22 percent of the total area under legume crops. *Phaseolus* beans, mungbeans, cowpeas, rice beans, faba beans and field peas occupy only 10 percent.

In the last twelve years, area under pulse crops has increased only by about 9 percent. Production of pulses increased from 243 243 tonnes in 2000 to 356 743 tonnes in 2012. Percentage increment is by about 47 percent. This increase is mainly by augmentation of yield rather than through area expansion. Pulse productivity has increased by about 35 percent in 2012 in comparison with the base-year data.

Table 1. Area, production and productivity of grain legumes in Nepal (2012/13)

SN	Legumes	Area		Production (tonnes)	Yield (kg/ha)
		Ha	%		
1	Lentils	207 280	62	204 653	987
2	Blackground	26 746	8	19 186	717
3	Soybeans	23 403	7	25 582	1 093
4	Pigeonpeas	16 716	5	15 989	956
5	Grasspeas	10 030	3	12 791	1 275
6	Chickpeas	10 030	3	9 593	956
7	Horsegrams	6 686	2	3 198	478
8	Others (mungbeans, cowpeas, groundnuts, and faba beans)	33 432	10	28 779	861
	Total	**334 323**	**100**	**319 770**	**956**

Source: Ministry of Agriculture Development (2012/13)

Table 2. Changes to area, production and productivity of pulses in Nepal (2000–2012)

Year	Area (ha)	Production (tonnes)	Yield (kg/ha)	Percentage change in		
				Area	Production	Yield
2000/01	306 220	243 243	794	–	–	–
2001/02	307 111	250 400	815	0.29	2.94	2.64
2002/03	311 170	256 900	826	1.62	5.61	3.93
2003/04	316 010	265 360	840	3.20	9.09	5.71
2004/05	316 806	271 312	856	3.46	11.54	7.81
2005/06	313 561	267 449	853	2.40	9.95	7.38
2006/07	319 557	274 375	859	4.36	12.80	8.09
2007/08	320 431	269 776	842	4.64	10.91	5.99
2008/09	313 269	255 384	815	2.30	4.99	2.63
2009/10	319 471	262 357	821	4.33	7.86	3.38
2010/11	334 380	318 362	952	9.20	30.88	19.86
2011/12	334 323	319 770	956	9.18	31.46	20.41
2012/13	333 436	356 743	1 070	8.89	46.66	34.69

Research on pulse crops

Production gains in pulses are achieved through the development and deployment of improved varieties and production technologies. The National Grain Legume Research Program (NGRP) under the Nepal Agriculture Research Council (NARC) is mainly responsible for conducting research in pulse crops. Non-governmental organizations (NGOs) are also involved in grain legume R&D activities in Nepal. R&D activities of both public and civil society organizations are mainly concentrated on germplasm collection, exchange and varietal development and validation of crop management technologies in collaboration with international organizations (ICARDA, ICRISAT, AVRDC, ACIAR/CLIMA, IITA, BARI), the Department of Agriculture (DoA), NGOs, community-based organizations (CBOs) and seed companies. After confirmation of the agronomical and genetics superiority of the germplasm, the National Seed Board (NSB) releases the variety for commercial production. Usually source seed (breeder and foundations seeds) is produced by NARC research stations. Once the variety is released, the DoA is responsible to support CBOs, NGOs and private seed companies for seed multiplication.

A total of 53 varieties of grain legumes have been released, including 47 varieties developed by NARC and six varieties registered by private seed companies of China and India for general cultivation. For winter cultivation of food legumes, ten lentil and seven chickpea varieties have been recommended. Among the summer legumes, seven varieties of soybean, two varieties of pigeonpea, six varieties of cowpea, three varieties each of mungbean and pea, six varieties of groundnut, two varieties of common beans and one variety of blackgram have been released for general cultivation (Table 3).

Table 3. Pulses varieties released and registered in Nepal

SN	Pulses	Total release	Total registration	Grand total
1	Soybeans	7	–	7
2	Lentils	10	–	10
3	Chickpeas	7	–	7
4	Cowpeas	6	5	11
5	Pigeonpeas	2	–	2
6	Blackgrams	1	–	1
7	Mungbeans	3	–	3
8	Groundnuts	6	–	6
9	Common beans	2	1	3
10	Peas	3	–	3
	Total	**47**	**6**	**53**

Bio-fortified (iron, zinc, and selenium-rich cultivars) lentil cultivars have been identified and are being tested for release. Similarly, several genotypes of major pulses crops have been identified for tolerance to *stemphylium* blight and wilt-root rot complex diseases. Other promising technologies generated include application of botanical pesticides to control stored grain pests, weed management using herbicides, optimum sowing times, seed priming and seed rate for sole and mixed crops.

Pulses promotion and its impact

The DoA is mainly responsible for technology transfer activities of grain legumes. In recent years, NGOs are also heavily engaged in the dissemination of improved varieties and technologies at the farmers' level. Research stations are also conducting on-farm validation and dissemination activities on a limited scale. The improved technologies are disseminated through distribution of minikits, large plot demonstrations, training, field visits and community seed increase.

Lentils are the main pulse crop in Nepal (62 percent area and 64 percent production of the total legumes (MOAD 2013). It is recognized as one of the major agricultural produce among 12 goods with high export potential and medium socio-economic impacts by the Nepal Trade Integration Strategy (NTIS).

Though limited work on formal surveys for assessment of project impacts have been done in grain legumes, information collected through formal/informal channels, official records, farm visits, district reports, farmers interaction, NARDIF project/IFAD project completion reports, indicate improved pulse technologies have made considerable impact on crop diversification, cash income generation and increase in dietary intake thus improving the living standards of farmers (Gharti, 2014).

Input delivery systems

Inputs such as fertilizer, seeds, tools, pesticides, etc. are marketed through government-owned companies (Agricultural Input Company and National Seed Company), private enterprises and agro-vets (local input retailers). However, in pulses, external inputs are rarely used and these are grown under residual nutrients and water.

Constraints

The low level of funding for grain legume research is the main bottleneck hindering increased production and productivity in the country. This is mainly due to the fact that until now Nepal's R&D priorities have focused on assuring food supply for the increasing population. The wide gap between the attainable yields and those on farmers' fields are due to various biotic, abiotic and socio-economic factors. The major diseases are wilt root rot, Stemphylium blight in lentils, and mungbeans, yellow mosaic virus in blackgrams, soybeans and mungbeans, white mold in rajma and *Botrytis* gray mold in chickpeas. *Helicoverva* pod borer is the major production constraint in chickpea production. In storage, bruchids can cause severe losses. The major abiotic factors affecting winter crop production are soil moisture deficits (drought and high temperature during pod filling stage), micronutrient disorders (nutrient deficiency boron). Low adoption of improved packages of practices, inadequate extension services and promotional activities, lack of systematic seed production mechanisms, non-availability of inputs on time (seeds, fertilizers etc.), unavailability of suitable varieties for varied agro-ecological domains and technologies for all grain legumes crops, yield instability over years, high losses in storage, and other socio-economic constraints (Shrestha *et al.,* 2011).

Opportunities for grain legume research and development in Nepal

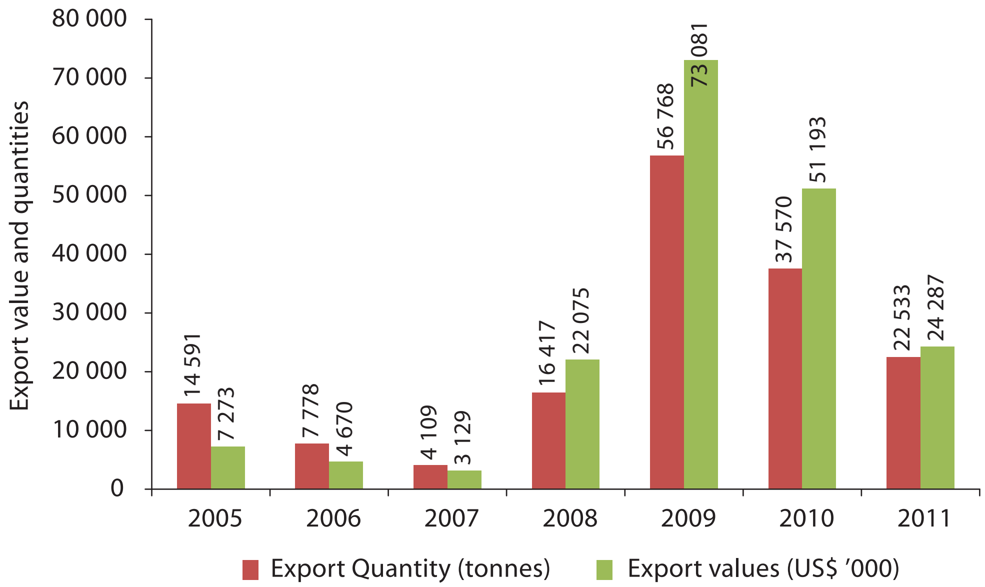
Grain legumes play an important role in Nepalese agriculture contributing towards food and nutritional security, nitrogen economy, crop intensification, diversification and sustainable farming systems (Gharti *et al.*, 2014). Pulses possess tremendous potential for alleviating poverty and malnutrition especially of subsistence producers and vegetarian consumers in Nepal. Seed is a good source of protein (18–22 percent), carbohydrate (52–70 percent), fat (4–10 percent), minerals (calcium, phosphorus, iron) and vitamins.

For a majority of the poor who cannot afford expensive animal protein, legumes can be important basis for their nutrition security. Most of the pulses have diverse utilization in the Nepalese diet. They are consumed as whole seed (boiled, roasted, parched, fried, steamed, and sprouted); *dal* (soup) or as flour. Tender leaves and twigs are used as green vegetable in various communities. Green pods of beans, peas and beans are used as green vegetables. Pulse seeds are usually digestible among other crops and most of the recipes prepared from pulses are widely used as in healthy diets. In spite of the fact that grain legumes are essential components of the Nepalese diet, their consumption is only 9 kg per capita per annum which is four times less than that recommended by FAO (Shrestha *et al.,* 2011). This shows the clear opportunity to expand area and increase productivity of pulse crops to meet the domestic demand of the country. Legumes are also grown for improving soil conditions. Green foliage can be used as green manure. Crop residues and by-products are also valuable as fodder, feed and firewood.

On the economic side, Nepalese farmers grow legumes for home consumption and marketing as well. In the mountains and hills, legumes are grown primarily for home consumption, while in the tarai and warmer valleys of the hills they are grown both for home consumption and for the market.

Large quantities of pulses are imported from India and other countries as domestic production falls short of meeting the growing demand. In 2009, pulses (excluding soybeans) export and import were valued at US$ 75 459 000 and US$ 29 184 000, respectively (FAO 2011).

Data on export quantities and values show very promising context for increasing pulse production and export. In 2005, Nepal exported 14 591 tonnes of pulses (mainly lentils) and earned US$ 7 273 and in 2011 the export quantity and values increased to 22 533 tonnes and US 24 287. Therefore, legumes can be extremely important for import substitution and export promotion in agriculture.



Source: TEPC (2011)

Figure 1. Pulses export values and quantity

Legume crops can be attractive commodities for Nepalese farmers to earn cash for better living conditions. The diverse climate and environmental conditions of Nepal offer opportunities to grow many species of food legumes and these crops fit well in the Nepalese cropping systems prevailing in most of the agro-ecological zones and can be grown in various seasons (winter, spring and summer seasons).

The cultivation of lentils is increasing because of the increasing preference for its internal consumption and potential for export. Nepalese lentils have great demand in the international market. Bangladesh, Singapore, Sri Lanka, Germany, Republic of Korea, UK, Indonesia are major export markets. Soybeans are identified as an industrial crop and important ingredient for the poultry industry.

Pulses can be promoted to adapt agriculture to climate change. Legumes usually can withstand moisture stress and they can be grown well in the areas with drier climate and low soil fertility. These crops can be grown in wasteland, terraces, bund and in agro-forestry systems. It has got multiple uses as food, fuel, fodder, soil fertility improvement and reduction of soil degradation in slopey land. Several species of legumes are short duration (60–70 days) crops which can be produced on residual soil moisture after rice, wheat and maize. Rice beans are one of the neglected and under-utilized summer grain legumes cultivated mainly in the hilly areas of the country as a mixed crop with maize with no additional inputs and care.

Lessons learned and recommendations

1. The Government of Nepal (GoN) should consider pulses as strategic high priority crop to realize the multiple benefits of pulses for food and nutrition security; environmental conservation; import substitution and export promotion. For this GoN should declare a 'pulses mission programme' in partnership with the CG centers and private entrepreneurs.
2. The National Pulses Breeding Programme should be strengthened by improving infrastructures and human resource capacity. Seed multiplication should be increased through community-based seed production and active participation of private seed companies.
3. Breeding should focus on developing varieties for higher yields, early maturity, pest and terminal drought and heat stress tolerance. Likewise, agronomic research should focus on IPM for the management of major pest and diseases of grain legumes and on cost-effective technologies such as conservation agriculture and small-scale mechanizations.
4. Breeding research should focus on screening and development of climate resilient varieties.
5. Studies should be undertaken to develop value chains for major pulses including soybeans.

Conclusion

Grain legumes have high potentiality to alleviate poverty and malnutrition of resource poor farmers. There are also opportunities for import substitution and export promotion by increasing area and productivity. However, the Government of Nepal still has not given due priority to grain legume research and development works. Pulses are considered secondary crops and almost no external inputs and agronomic practices are applied by farmers. Commercialization of high value legumes such as lentils, mungbeans, rajma (kidney beans) and peas can be achieved through coordinated efforts of public, private and farmers' cooperatives. In the initial stage, GoN may need to provide incentives to pulse producers, processors and traders to motivate them to engage in their businesses in a professional way. Access of farmers to quality seeds, fertilizers, irrigation, improved post-harvest management and marketing can be vital for increasing production and productivity.

Research to address the problems faced by value chain actors (farmers, traders, processors, exporters, consumers, input suppliers etc.) of the pulse subsector is equally important to promote commercial farming of grain legumes. Considering the diverse agro-climatic conditions and cropping systems prevalent in the country, we see tremendous scope to enhance pulse production in south Asia.

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Status of pulses in Pakistan

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Abstract

Four major pulse crops – chickpeas (*Cicer arietinum*), lentils (*Lens culinaris* Medik), mungbeans (*Vigna radiata*) and mashbean (*Vigna mungo*) – are commonly grown in Pakistan. Among these, chickpeas are the major winter food legume and mungbeans are the major summer legume. Chickpeas occupy 76 percent of the total pulses area with 73 percent contribution to the total production and mungbeans occupy 12 percent of total pulses area contributing 14 percent to the total pulses production. More than 80 percent of pulses are grown in Punjab and the rest of the area is spread in other provinces. Pulses are considered secondary to cereal crops and relegated to marginal soils as they are perceived to be low-yielding and less remunerative crops. As a result, the growth rate of production of pulses is lower than that of cereal crops. Per capita availability of pulses decreased from 8.11 kg/annum in 2005/06 to 4.64 kg/annum in 2012/13. The improvement in production of pulses was not enough and large quantities are imported to meet the ever increasing gap between the domestic production and requirements.

Production of pulses can be increased by adopting high-yielding varieties and production technology developed through coordinated research. The major output of the coordinated effort was the release of 27 varieties of chickpea, 11 of lentil, 15 of mungbean and 7 of mashbean for commercial cultivation. Development of chickpea varieties resistant to blight (*Ascochyta rabiei*) and release of short duration mung and mash bean varieties coupled with matching agro-technologies brought expansion in new niches and diversification in the existing cropping systems. There is great potential in central Punjab and Sindh to intercrop mungbeans with sugarcane. Similarly, short duration varieties of mungbeans can be successfully grown as catch crop in a rice-wheat cropping system to expand the area of cultivation and improve soil fertility. Development of high-yielding, early maturing and disease resistant genotypes along with a viable seed production and dissemination system will play major roles in pulse crop production in the future.

Introduction

Consumption of protein is essential to maintain the health and vigour of the people and pulses are the most important source of protein in Pakistan. They contain about 20–25 percent protein and can help in providing the essential nitrogenous constituents of the human food. The supply of meat is not keeping pace with the population growth and, therefore, the production of pulses should be increased. The agro-ecological conditions prevailing in the country are highly congenial for growing all different kinds of pulses. However, pulse production in the country is stagnant and is likely to disturb nutritional balance of the population especially of poor and weaker sections which cannot afford other expensive sources of proteins. The major supply of food legumes depends upon the production of chickpeas and mungbeans. Failure of these crops results in a pulse debacle in the country. One of the main reasons for stagnation in production of pulses in the country is inadequate investment resulting in non-adoption of the full package of improved production technology by the farmers. Pulses are grown under rainfed conditions on poor soils with low inputs, while higher productivity can be achieved through the use of improved varieties, bio-fertilizers and micronutrients. In irrigated areas, pulses cannot compete with cash crops and hence the area under pulses remained static with little change.

This phenomenon occurred in Sialkot area where cultivation of blackgrams and lentils has almost disappeared because of the installation of tubewells and farmers shifting to cash crops due to water availability. There is an urgent need to increase pulse production in the country to cope with the requirements. This is possible by either area expansion or realizing yield potential, while the scope of former is limited and an increase in area under pulses crops is only possible by incorporating pulse crops in rice-wheat cropping systems and in sugarcane fields. The latter can be achieved if a serious thought is given to the adoption of the full package of available improved production technologies. Unfortunately, farmers in rainfed areas are yet to adopt the practice of using high-input technology and this merits attention from policy makers as most farmers in rainfed areas are resource-deficient.

Trends in pulse area, production and productivity

The total area and production of pulse crops from 2007-2008 to 2013-2014 in Pakistan is presented in Table 1. Among these, chickpeas are the major winter food legume and mungbeans are the major summer legume. Chickpeas occupy 76 percent of the total pulse area with 73 percent contribution to the total production, whereas mungbeans occupy 12 percent of total pulse area

Table 1. Area, production and yield of major pulses in Pakistan

Year	Chickpeas			Lentils		
	Area (000 ha)	Production (000 tonnes)	Yield (kg/ha)	Area (000 ha)	Production (000 tonnes)	Yield (kg/ha)
2013-14	975	775	795	17.8	9.3	522
2012-13	992	751	757	19.3	10.8	559
2011-12	1 007	284	282	22.8	11.1	487
2010-11	1 054	496	471	26.1	13.3	510
2009-10	1 067	562	526	24.0	10.9	454
2008-09	1 081	741	685	30.9	30.9	466
2007-08	1 107	475	429	30.4	14.6	480
Year	Mungbeans			Mashbeans		
	Area (000 ha)	Production (000 tonnes)	Yield (kg/ha)	Area (000 ha)	Production (000 tonnes)	Yield (kg/ha)
2013-14	131	92.9	709	20.9	10.2	488
2012-13	135	90.0	666	23.2	108.0	469.8
2011-12	141	93.1	661	24.5	10.9	445
2010-11	137	76.2	555	24.5	11.3	461
2009-10	183	118.7	648	24.1	10.7	444
2008-09	246	157.4	716	27.6	13.6	493
2007-08	246	177.7	723	32.5	17.3	532

Source: Agricultural Statistics of Pakistan 2013-2014 contributing 14 percent to total pulse production. Mash and lentils each are cultivated on around 2–5 percent of the total pulse area and each of them contributes 2–5 percent to the total pulse production. More than 80 percent of pulses are grown in Punjab and the rest of the area is spread in an other three provinces.

Chickpeas are the major winter food legume grown on 73 percent of the total pulse area with 76 percent contribution to the total production (GOP 2012-2013). Two types of chickpeas are grown: *Desi,* which is thought to have originated first and produces small, brown-coloured seeds and *Kabuli,* which produces a larger, cream-coloured seed. Almost all the countries with high chickpea yields are producers of *Kabuli* and yet it is often more prone to climatic and disease stresses. But in Pakistan, *Kabuli* chickpeas occupy a small proportion of total chickpea cultivated area. Therefore, most of the chickpea production comes from *Desi* type. Chickpeas are well known for their ability to withstand moisture stress. The major supply of grain legumes depends upon the production of chickpeas and failure of this crop results in shortage of pulses in the country.

The area of chickpeas in the country remained stagnant with little fluctuation. However, the production profile revealed severe fluctuation highlighting the problem of instability (Figure 1). As >80 percent of the area of chickpea is grown as rainfed, the crop is highly sensitive to changes in weather conditions.

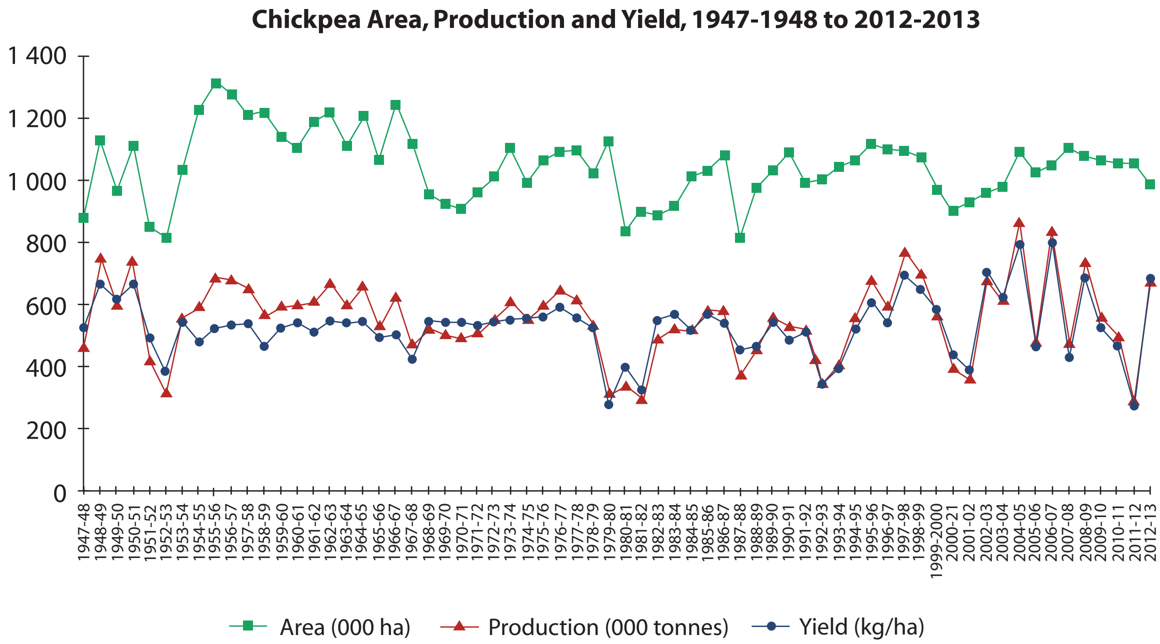

Figure 1. Trend in area, production and yield of chickpea

Lentils are the second major winter season pulse crop after chickpeas in Pakistan. Lentils represent only 5 percent of the total pulse production (GOP 2012-2013). During the last 65 years, the annual lentil production in the country remained around 30 thousand tonnes, which is stagnant and meets almost half of the total demand (Figure 2). The total area has decreased by 33 percent during this time. The achievement of the same total production from less area may be attributed to the use of relatively better varieties and crop management practices by farmers.

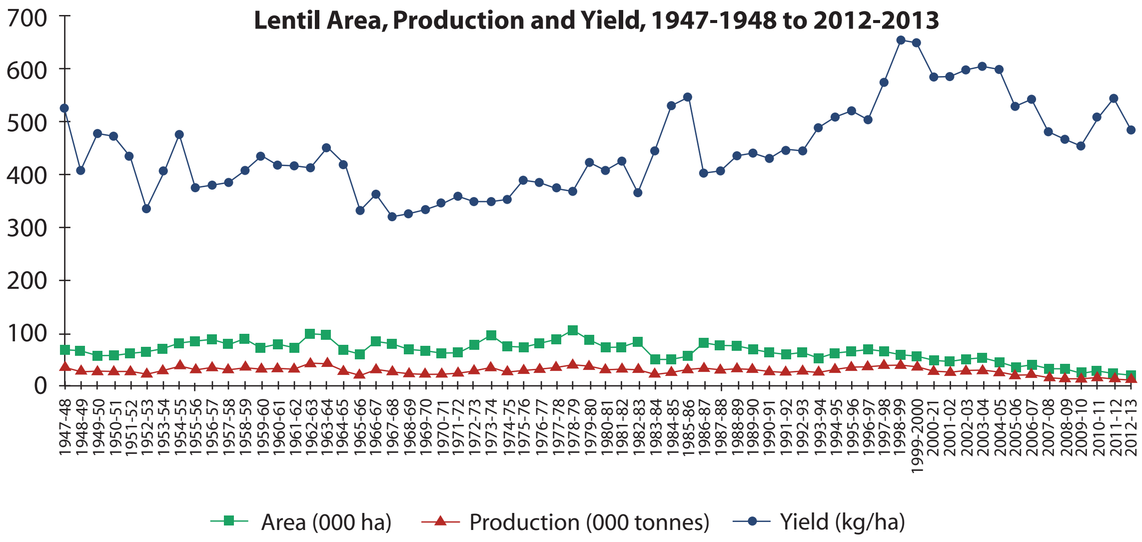

Figure 2. Trend in area, production and yield of lentil

Mungbeans are also grown during the spring season mainly in southern Punjab and Sindh province. Punjab is the major mungbean growing province that alone accounted for 88 percent in area and 85 percent of the total mungbean production in the country. It is also grown in different crop rotations; about 75 percent of cultivation follows mungbean–wheat crop rotation. The breeding improvement of mungbeans had been limited until 1970 due to the selection from land races which were of trailing types. Since the 1980s, research on this crop gained momentum as in other pulses. About ten improved varieties have been released for general cultivation in the country since 1985/86. With the development of short-duration and uniformly maturing varieties, mungbeans can be fitted in various cropping systems. Trends in the annual production of mung beans for the last 65 years are shown in Figure 3. Among the major constraints weeds, insect damage and lack of seed production are the most important ones. Research activities on mungbeans have been mainly focused on the development of high-yielding varieties with wider adaptability, resistance to diseases, such as mungbean yellow mosaic virus (MYMV) and *Cercospora* leaf spot (CLS), early maturity and insensitivity to photo period.

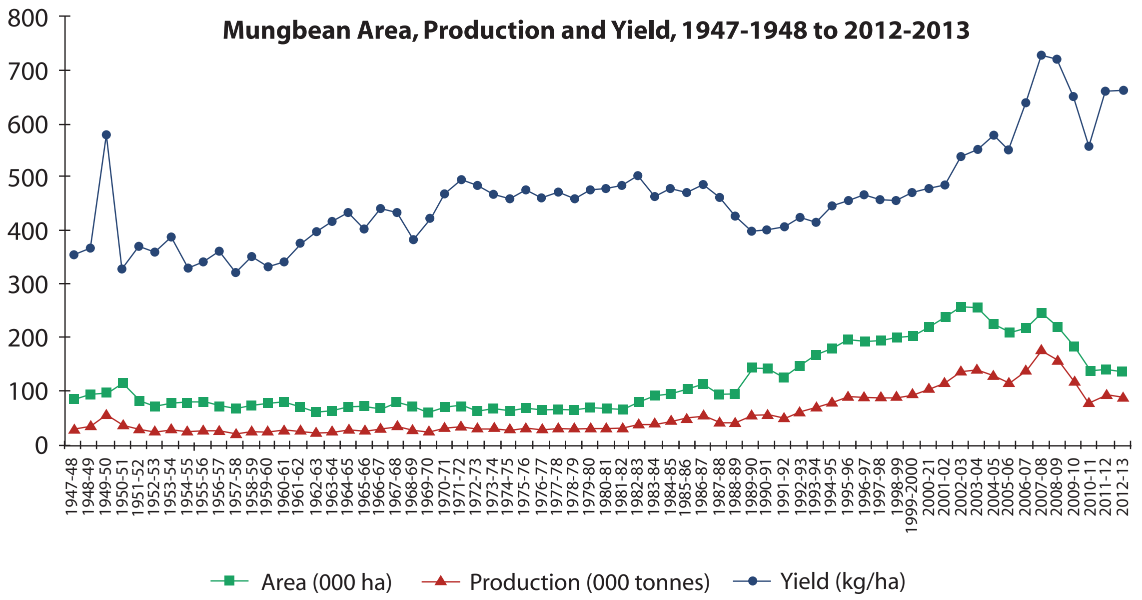

Figure 3. Trend in area, production and yield of mungbeans

Mash or backgrams occupy an important position in Pakistan's agriculture. They grow on marginal land where other crops perform poorly. Yield of mash is very low because mostly indigenous land races are cultivated and also because the crop is often grown on marginally fertile land with insufficient water. Trend in area, production and yield of mash are given in Figure 4. In Pakistan, mash is the least researched crop among pulses despite its high nutritive and economic value and as a result its area and production decreased continuously. The lack of suitable and high-yielding varieties and basic information about production technology are major inhibiting factors. Therefore, research on mash improvement should be focused on development of high-yielding varieties with resistance to diseases, particularly MYMV and CLS.

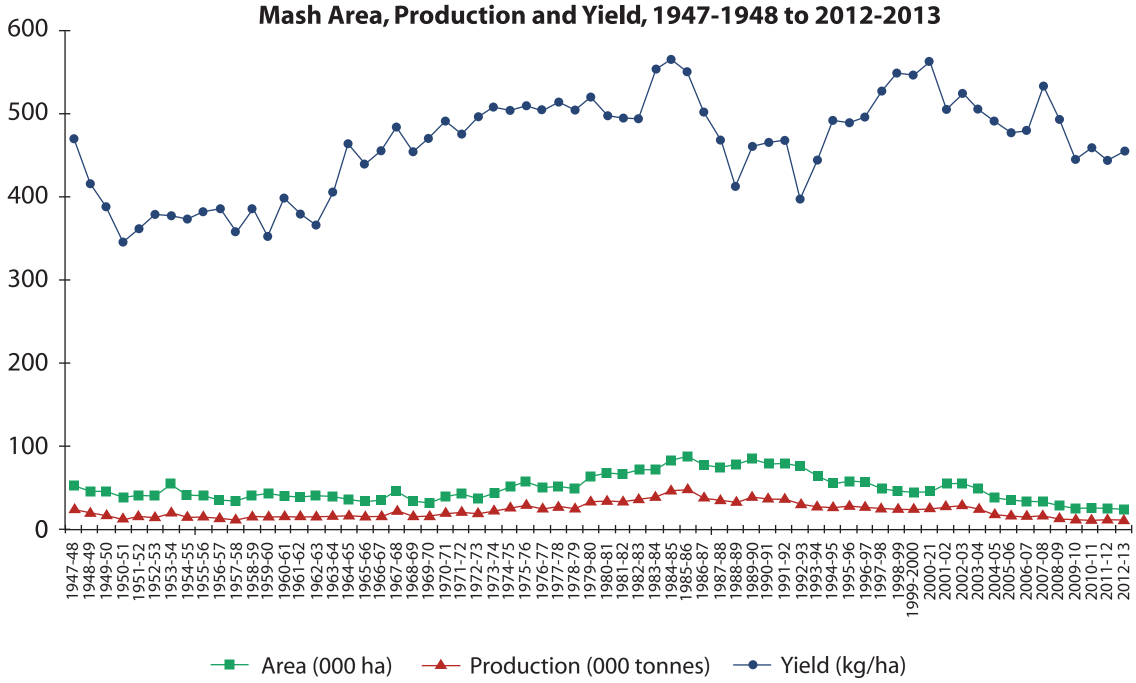

Figure 4. Trend in area, production and yield of mashbeans

Pulse-based farming systems dynamics

Major cropping patterns of pulses are chickpea-fallow-chickpea and mungbean-wheat-mungbean. In the system, chickpeas are cultivated as rainfed crop and mungbeans as irrigated. Chickpeas are being mono cropped in the Thal desert. It is a drought tolerant cash crop and thus is the major wealth for the people of Thal. The cost-benefit ratio of 1: 2.5 suggests that even in the present circumstances chickpea production is beneficial in this desert area. Adopting improved technology in chickpea production would further increase returns at the farm level (Nisar *et al.*, 2007).

The cereal–cereal crop rotations are predominant in most of the irrigated areas of Pakistan since decades. This situation warrants restructuring of chickpea production systems placing more emphasis on its vertical growth with the use of irrigation and better inputs besides introduction of input responsive short-duration varieties. This will enable fitting chickpeas in the cropping systems of irrigated areas so as to compete with other cash crops. This will also help diversify the cropping systems of irrigated areas with inclusion of legumes. *Kabuli* chickpeas have potential to grow in irrigated areas. Economic analysis of chickpea production in the rainfed area of Thal is presented in Table 2.

Table 2. Economic analysis of chickpea production under rainfed conditions of Thal

Input	Unit	With traditional farmers' practices	Improved variety and practices
		Amount (Pak Rupee)	
Cost of ploughing	Rs./ha	1 200	1 500
Cost of sowing	Rs./ha	1 200	1 200
Seed rate	kg/ha	50	75
Cost of seed	Rs./ha	4 000	6 000
Weeding cost	Rs./ha	2 000	5 000
Harvesting cost	Rs./ha	4 000	4 000
Threshing cost	Rs./ha	3 000	3 000
Managerial cost	Rs./ha	5 000	5 000
Total cost of production	Rs./ha	20 400	25 700
Output			
Grain yield	kg/ha	1 750	3 750
Dry stalk yield	kg/ha	1 000	2 000
Returns from grain yield	Rs./ha	113 750	243 000
Returns from dry stalk yield	Rs./ha	6 250	12 500
Returns analysis			
Gross benefit	Rs./ha	120 000	255 500
Net benefit	Rs./ha	99 600	229 800

1 US$ = 102 Pak Rupees

Although mungbeans are grown in different crop rotations, about 75 percent of cultivation follows mungbean–wheat crop rotation. With the development of short-duration and uniform maturing varieties, mungbeans can be fitted in various cropping systems. There is great potential in central Punjab and Sindh to intercrop mungbeans with sugarcane. Similarly, short duration varieties of mungbeans can be introduced as a catch crop in rice-wheat cropping systems to expand the area of cultivation and improve soil fertility. A large area of 0.5 mha (million hectares) in the medium to high rainfall region of Potohar remains fallow after wheat where mungbeans can be grown as part of double cropping in wheat-fallow areas to increase overall production in the country. This area is double the current area under cultivation of mungbeans in the country which indicates its high potential for increasing total production. Studies suggested that wheat growth and development and yield formation differ significantly when followed after mungbeans as compared with fallow. Net monetary benefits of Rs.5 820 per hectare could be obtained by sowing mungbeans in wheat-based cropping system (Asim *et al.,* 2006). Preliminary comparative economics of various cropping patterns in Punjab is presented in Table 3. It showed that the cropping pattern involving pulses provide more economic benefit to farmers.

The total area under lentils decreased by 33 percent, the Potohar region contributes more than 35 percent of the total production of the country. The area of lentils can be expanded by intercropping the crop in September-sown sugarcane. The total area under sugarcane is approximately 1 million hectares out of which one-fourth is autumn planted. This autumn planted sugarcane has great potential for intercropping of lentils and Kabuli chickpeas. This crop not only increases the output per unit area but also can provide mid-season income which eases the burden on the already depleted income of the farmers and can provide them with an option for better input management for the remaining sugarcane growing season. Production of lentils can be increased from 0.4 tonne/ha to 1.5 tonnes/ha with the adoption of improved varieties and management practices. Economic analysis of lentil production in rainfed areas is given in Table 4.

Table 3. Economics of various cropping patterns in Punjab (amounts in Rs./ha)

Cropping Patterns	Districts	Total cost of production	Total income	Net benefit
Rice – Wheat	Gujranwala, Sheikhupura, Sialkot, Narowal, Mandi Bahudin	136 648	406 472	269 824
Rice – Wheat – Mungbeans	-do-	166 408	510 632	344 224
Fallow – wheat	Rawalpindi, Attock, Chakwal, Jehlum	32 240	53 568	21 328
Mungbeans – wheat	-do-	69 440	163 380	93 940
Masoor – Mungbeans	-do-	68 200	247 008	178 808
Wheat – Mashbeans	-do-	69 440	191 000	122 016
Chickpea – Mungbeans	Bhakkar, Layyah (irrigated area)	63 240	243 040	159 960
Chickpeas (Kabuli) – Mungbeans	-do-	75 144	327 360	252 216
Wheat – Mungbeans	-do-	79 360	243 040	163 680
Wheat – Cotton	-do-	166 160	523 280	357 120
Chickpeas – Cotton	-do-	151 280	523 280	372 000

Table 4. Economic analysis of lentil production in Pothwar region

Inputs	Unit	Farmers' practices	Improved variety and practices
Land Preparation	Rs./ha	8 432	8 432
Sowing/Planting	Rs./ha	1 488	1 488
Seed for Sowing	Rs./ha	1 500	5 952
Fertilizer	Rs./ha	0	11 160
Weedicide/Labor Cost	Rs./ha	0	4 960
Harvesting (Manual)	Rs./ha	14 880	14 880
Threshing (By Thresher)	Rs./ha	6 944	6 944
Total Expenditure (Rs.)	Rs./ha	33 244	53 816
Total Produce (kg)	kg/ha	600	1 500
Total Benefit (produce × market Price*)	Rs./ha	54 000	135 000
Net Benefit (Rs.)	Rs./ha	20 756	81 184

In view of the potential role of legumes in contributing to cropping system sustainability in the country through their ameliorative effects on soil health (in terms of additions of fixed N and soil organic matter) without having to sacrifice major crops like wheat and rice, strong efforts are needed to introduce legumes where soil organic matter is generally declining and more rational N cycling is needed. Availability of short-duration mung and mash varieties coupled with matching agro-technologies has tremendous potential for expansion in new niches and diversification in the existing cropping systems as shown in Table 5.

Table 5. Possible new niches for pulses

Cropping Pattern	Possible niches	Suitable varieties of pulse crops
Rice – wheat – Mungbeans	Gujranwala, Sheikhupura, Sialkot, Narowal, Mandi Bahudin, Larkana, Shikarpur, Jacobabad	NM-11
Wheat – mungbeans	Pothwar Region	NCM-13, NM-11
Spring sugarcane + mungbeans	Punjab and Upper Sindh	NM-11, NM-06
Autumn sugarcane + lentils or chickpeas (Kabuli)	Punjab and lower Sindh	Lentil (Markaz-09, Punjab Masoor-09) Chickpea (Noor- 09, Noor- 2013)

Constraints to pulses production

Pulse production faces problems, such as use of rainfed marginal lands, susceptibility to pest and disease attack, weather aberrations, lack of genetic breakthrough and diversion of pulse areas to more remunerative crops with availability of irrigation water. The wide gap between the attainable yield potentials and farmers' yield is due to various biotic, abiotic and socio-economic factors. Biotic factors are diseases, insects and weeds. The major diseases and pests of pulse crops are presented in Table 6. The weeds are another serious constraint to increased production. Pulses are generally poor competitors to weeds because of slow growth rates and limited leaf area development at early stages of crop growth and establishment. In storage, bruchids can cause severe losses.

Table 6. Important biotic and abiotic stresses identified in major pulse crops of Pakistan

Crop	Stresses	
	Biotic	Abiotic
Chickpeas	**Diseases:** Ascochyta blight (*Ascochyta rabiei*), Fusarium wilt (*Fusariumoxy sporum f. sp. ciceris*), Dry root rot (*Rhizoctonia vataticola*), Rust (*Uronyces ciceris-arietini*), Powdery mildew (Leveillula taurica), Alternaria blight (*Alternaria sp.*), **Insect Pest:** Pod borer (*Helicoverpa armigera*), Semilooper (*Autographa nigrisigna*), **Weeds:** Chickpea is sensitive to weed competition during seedlings and early vegetative growth stages.	Low temperature, terminal drought, salt stress, frost damage, nutrient deficiency, salinity and sodicity
Lentils	**Diseases:** Ascochyta blight (*Ascochyta rabiei*), Rust (*Uromyces viciae-fabae*), Vascular wilt (*Fusarium oxysporum f. sp. Lentis*) Botrytis graymold (*Botrytis cinerea*), *Sclerotinia* stem rot (*Sclerotinia sclerotiorum*), Collar rot (*Sclerotinia rolfsii*) **Weeds:** Slow growth habit allows fast growing weeds to smother the lentil crop resulting in 10–80 percent yield reduction.	Cold and drought (high lands), drought (low lands), frost damage, nutrient deficiency, salinity and sodicity
Mungbeans	Diseases: Leaf spot (*Cercospora canescens*), Anthracnose (*Colletotrichum lindenuthianum*), Yellow Mosaic virus, Web blight, *Choanephora* pod rot, Bacterial blight, Hollow blight and Seedling blight. Insects Pests: Root knot nematode, Hairy caterpillar, White flies, Tobacco caterpillar (*Sopodoptra litura*), Army worm, Sucking insect pests.	Excessive soil moisture, nutrient deficiency, salinity and sodicity
Mashs		Excessive soil moisture, nutrient deficiency, salinity and sodicity

The major abiotic factors affecting winter crop production are cold stress at flowering stage, soil moisture deficits (drought and high temperature during pod filling stage) and micronutrient disorders. In Kharif crops temperature stress and terminal drought are major abiotic factors. Socio-economic constraints include low adoption of improved packages of practices, inadequate extension services and promotional activities, lack of systematic seed production mechanisms, non-availability of inputs on time (seeds, fertilizers etc.), unavailability of suitable varieties for varied agro-ecological domains, yield instability over years and high losses in storage. Post-emergence chemical weed control and no mechanization for combine harvesting are other researchable factors.

Trends in production and consumption

Domestic production of all pulse crops needs to be increased to meet the demand of the country. Chickpea production increased from 474 600 tonnes in 2007-2008 to 975 000 tonnes in 2012-2013. On the other hand for the same period, production of lentils, mungbeans and mashbeans decreased with time (Table 1). As a result, per capita availability of pulses has decreased from 8.11 kg/annum in 2005-2006 to 4.64 kg/annum in 2012-2013 (Agriculture Statistic 2012-2013). Consumption of pulses is relatively high during the summer season, Ramadan, Eid, Moharram and other local festive seasons, various pulse varieties are consumed according to regional preferences.

Import and export of pulses

To keep pulse prices in the domestic market stable, Pakistan imports large quantities of pulses to meet the ever increasing gap between domestic production and requirements (Rani *et al.,* 2014). The improvement in production was not enough to meet the increased requirement of pulses in the country. Import of pulses for the last seven years has increased (Table 7). Domestic production of pulses needs to be increased by adopting improved production technology.

Table 7. Import and export of pulses

Year	Import		Export	
	Qty (000 tonnes)	Value ($ million)	Qty (000 tonnes)	Value ($ million)
2006-07	520.9	245.0	19.2	0.008
2007-08	336.0	202.0	4.1	0.002
2008-09	379.8	236.0	–	–
2009-10	445.0	262.0	–	–
2010-11	637.4	344.77	–	–
2011-12	672.5	388.10	–	–
2012-13	472.6	315.00	–	–

Agriculture Statistics of Pakistan, 2012-2013

The shortfall in the domestic production of *Kabuli* chickpeas, lentils and mash increased the import of these pulses. There is a considerable yield gap between the potential and national average yields of all pulses crops (Table 8).

Table 8. Yield gap of major pulse crops

Crop	National av. yield (kg/ha)	Potential yield* (kg/ha)	Yield gap (kg/ha)
Chickpeas	600	1 500	900
Lentils	600	1 500	900
Mungbeans	525	1 500	975
Mashbeans	500	2 000	1 000

* Farmers' yield with optimum management practices.

Projected demand of pulses

The demand for pulses has been projected at 1.23 million tonnes by the year 2020 and 2.01 million tonnes by 2050 (Zubair 2011). The future demand as indicated in Table 9 will continuously grow with increased population.

Table 9. Projected demand of pulses with population growth by 2050 in Pakistan

Year	Population* (million)	Demand** (million tonne)
2010	174	1.04
2020	205	1.23
2030	242	1.45
2040	285	1.71
2050	336	2.01

* Population growth rate 1.8%.
** Per capita consumption 6.0 kg/annum.

Research achievements

The support of the National Coordinated Research Programme (NCRP) on pulses benefited the country in terms of germplasm acquisition, variety development, and capacity building of scientists, new technologies, and knowledge sharing and strengthening of the National Agricultural Research System (NARS). The activity has significantly contributed to monetary returns to the country. *Ascochyta* blight, the deadly disease of chickpeas did not appear in epidemic after 1984 due to release of resistant cultivars. Remarkable impact was noted in mungbeans wherein its area increased 3-4 times due to development of short duration, bold-seeded disease resistant varieties. Mungbeans were included into irrigated systems in the districts of Bhakkar, Mianwali and Layyah, where they occupy more than 80 percent of mungbean cropped area. It all happened thanks to the release of improved cultivars. Some valuables of lentils and mash were evolved but the impact was masked by displacement of these crops from their traditional areas, resulting in a drastic decrease in cultivated area in last two decades. Germplasm of major pulse crops acquired from indigenous and exotic sources was evaluated and shared with provinces as shown in Table 10. The major output of coordinated efforts was the release of improved varieties through the NARS. Twenty-seven varieties of chickpeas, 11 of lentils, 15 of mungbeans and 7 of mashbeasn were released for commercial cultivation. Chickpea varieties tolerant and resistant to *Ascochyta* blight include Balkasar, Venhar and Dasht, Parbat, respectively.

Table 10. Germplasm, acquisition, evaluation and distribution

Crop	Accession acquired, evaluated at NARC	Accession distributed to provincial units	Segregating generations shared with provinces	Elite lines tested
Chickpeas	8 600	2 300	250	392
Lentils	4 300	253	35	343
Mungs	3 650	160	136	372
Mashs	1 500	135	–	315

Crop management

Weed management through the use of post-emergence herbicides: The work to find post-emergence herbicides for pulses was started in 2004/05 in collaboration with the private sector. Eighteen different herbicides used over the years and the following two were found safe for mungbeans and mash only. Both weedicides showed no phyto-toxicity in mungbeans and mash. The application of these herbicides increased yields by 50 percent in mungbeans and mash. It is expected that these findings will revolutionize mungbean and mash production in the country. Research work is in progress for chickpeas and lentils. A pre-emergence application of Pendimethalin herbicide can successfully be used to control weeds in lentils and chickpeas. Initial findings show that the herbicide with 'Haloxyfop-R-Methyl' is safe for lentils and chickpeas which is also a remarkable breakthrough at least in controlling the narrow-leaf or grassy weeds. The complete detail of both herbicides is given below:

For narrow leaf weeds	For broad leaf weeds
a. Active: Haloxyfop-R-Methyl	a. Active Lactofen
b. Group: Aryloxypropionate	b. Group Diphenyl ether
c. Formulation: 10.8 EC	c. Formulation 24 EC
d. Mechanism of Action: Absorbed by foliage and roots	d. Mechanism of Action: Absorbed by Foliage and roots
e. Method of Application: Foliar Spray @1 000 ml/ha	e. Method of Application: Foliar Spray @750 ml/ha

Mechanized harvesting and threshing of mungbeans: To harvest and thresh mungbeans using combining harvester, chemical desiccant (Gramixon) was applied for drying the crop to ensure uniform crop maturity.

Opportunities for increasing pulses production

- Availability of certified seed of pulse crops to farmers;
- Induction of pulse crops in irrigated areas with the development of high input responsive varieties;
- Introduction of lentils and blackgrams in high lands of Balochistan, Khyber Pakhtunkhwa, reverine areas of the districts of Bhakkar, Layyah, Muzaffargarh and Dera Ghazi Khan which are suitable for the cultivation of these crops;
- Mungbeans have great potential to be intercropped in spring-sown sugarcane in central Punjab and Sindh. Similarly, short duration varieties of mungbeans can be introduced as catch crop in rice-wheat cropping systems to expand the area of cultivation and improve soil fertility;

- Introduction of mungbean in wheat-fallow cropping systems under rainfed conditions of Potohar;
- Inoculation of seeds with *Rhizobium* bacteria helps in better nitrogen fixation and improves yields.

Future thrust

- Acquisition, evaluation and distribution of germplasm;
- Development of cold, drought and disease resistant varieties;
- Strengthening breeding programme on Kabuli chickpeas to develop the plant ideotype with erect branches, bold seed, blight resistance and high yield;
- Exploring new areas for lentil cultivation, e.g. highlands of Balochistan and north of the country;
- Mechanization of lentil harvesting;
- Development of photo-insensitive varieties of mungbeans with uniform maturity for the promotion of spring cultivation;
- Development of early maturing varieties of mungbeans for introduction in rice-wheat cropping system;
- Exploring new areas (relatively fertile) for mash cultivation in view of its continuously declining area;
- Use of post emergence herbicides for weed control;
- Establishment of a viable seed production and dissemination system;
- Demonstration of biological nitrogen fixation (BNF) and micro-nutrient management technology for sustainable crop production;
- Dissemination of production technology for pulse intercropping in sugarcane and other crops.

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Recent achievement in research and development of pulses in Republic of Korea

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Introduction

Beginning in the 1960s, economic growth in the Republic of Korea started to sparkle, predominantly developing and focusing on agricultural crops and light manufacturing sectors such as flour mills, breweries, and textile factories. With its gross domestic product (GDP) per capita of $155 (current US$) in 1961, approximately half of the Republic of Korea's GDP was generated from agriculture, and subsequently, the government established the first National Economic Development Plan for food self-sufficiency as one of the national priority (RDA, 2012). For efficient management of the agricultural cooperatives (Agricultural Cooperative Bank, National Agricultural Cooperative Federation and Village level cooperatives) that were set up during late 1950s, the Korean government consolidated the two Agricultural Cooperatives and newly established the National Agricultural Cooperative Federation (Choi, 2006) in 1961. Great efforts were made to achieve self-sufficiency through the introduction of the Green Revolution.

The Korea Green Revolution was initiated by the research centre of Rural Development Administration (RDA), which was established in 1962. Agricultural technologies developed through sustained investment in agricultural research and development between the 1960s and 1970s were disseminated to farmers through focused extension efforts (Kim *et al.*, 2010). This had an impact on rice production, which had reached 100 percent self-sufficiency in the late 1970s through expanding the cultivation of high-yielding rice varieties, "Tongil" and Tongil-type, and rice became the staple food crop (RDA, 2012).

Despite considerable progress achieved in the development of agriculture in the Republic of Korea, the development of pulse crops started off slowly as they were considered less important than staple crops such as rice, even though 100 percent pulse self-sufficiency was achieved back in 1965 (Processing and Utilization of legumes, 2000). Pulse crops in the Republic of Korea have traditionally been recognized as a valuable food source owing to their use in a wide array of Korean dishes, including fermented soybean paste stew (Doenjang Chigae), adzuki bean porridge (Pakjuk), and mungbean pancake (Nokdu Jeon). In 1970s, Korean farmers stated to look for other ways to make money with their produced pulse crops instead of pursuing self-sufficiency farming. However, the production of mungbean and adzuki bean started decreasing over 1971–1980 because of low levels of income generated from pulses compared with other crops. In contrast, the demand of soybean grew substantially from 1975 to 1985, resulting in a fast-track breeding programme for development of soybean cultivars. The modernized soybean breeding began from as early as 1960 at the Crop Experiment Station in Suwon, but a full-scale breeding programme was implemented in the early 1970s that accelerated cultivar development. The progress in breeding systems and techniques of other pulses such as adzuki beans, mungbeans, cowpeas, common beans and peas started slowly in the 1980s. From 1981 to 1991, field experiments were conducted for the improvement of genetic diversity among pulse cultivars and for the selection of the right herbicide and right application dose. These efforts resulted in rapid increases in production of adzuki beans and mungbeans after treatment with benomyl at a concentration of 1 000 that helped reduce the occurrence of brown blotch, powdery mildew, downy mildew diseases during 1986 and 1987.

Considering the nutritional and health aspects, Koreans started to pay attention to pulse crops where the development of new varieties started gaining momemtum and led to increasing their yields. Many new pulse varieties have been developed since the early 1990s including Danbaegkong for soybeans, Seonhwanogdu for mungbeans, Kumsil-pat for adzuki beans, Jangchae for cowpeas, Hwanghyeob 1 for common beans, and Sachulwandu for peas.

Keeping in perspective the increase in demand for consumption of pulses fuelled by growth of the population, estimated at 50.2 million in 2013 up from 25.0 million in 1960, research focus was mainly directed at enhancing legume productivity to increase production as well as improve crop quality for human wellbeing. As technology advances, tremendous progress has been made in recent years. Therefore, this report highlights the recent achievement in research and development of pulses in the Republic of Korea.

Trends in pulse area, production and productivity

The Republic of Korea is one of the important pulse producing countries in Asia. The most edible pulses grown in the Republic of Korea are soybeans, adzuki beans, mung beans, cowpeas, common beans, and peas (Table 1). About 89 percent of the total pulse production in Korea comes from soybeans. It is grown on a range of land types from the plain lands (31 percent) to the middle mountains (43 percent), and from the mountains to the mountainous regions (26 percent). The cropped area remained fairly constant across all pulse crops from 1971 to 1989 for soybeans, 1971 to 1987 for adzuki beans, 1971 to 1988 for mungbeans, and 1971 to 1987 for other pulses (Figure 1).

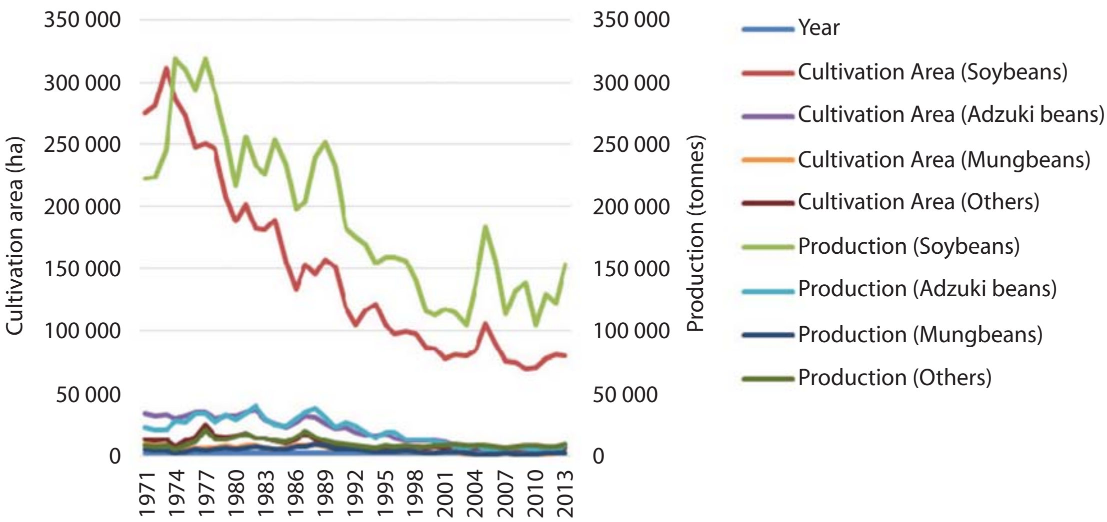

Figure 1. Area, production and yield of soybeans, adzuki beans, mungbeans, cowpeas, common beans, peas, and total pulses of the Republic of Korea from 1971 to 2013

This was followed by a steadily decreasing trend that persisted till 2013. To note, mungbeans and adzuki beans gained popularity in 1981 and 1982, resulting in a short-term increase. During the last 30 years, continuous reduction of yield and production was observed; however, extensive breeding efforts to improve the yield led to higher production from less land depending on specific use. For example, even though the area of soybean cultivation decreased from 188 431 ha in 1980 to 85 270 ha in 2004, the improved varieties such as Hwangkeumkong, Taekwangkong, Daewonkong, and Daepungkong for tofu and soy sauce allowed soybean yields to increase (Figure 2).

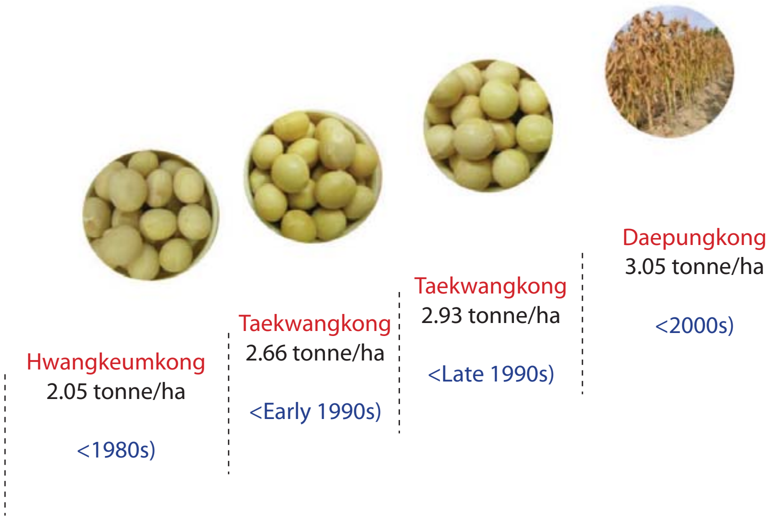

Figure 2. Yield increase in soybeans from 1980s to 2000s by new varieties

In general, among the pulses, soybeans occupy the largest area, and produce the highest yield and production in the Republic of Korea. Adzuki beans rank second and mungbeans third in production of pulses in the country. The national production has been highly concentrated in the provinces of Youngnam, Honam, and Chungcheong for soybeans, Jeonnam, Chungbuk, and Gyeonggi for mungbeans, and Gangwon, Gyeongbuk, Chungbuk for adzuki beans. Since low temperature prevents germination for cowpeas and common beans, they are usually grown in middle and southern Republic of Korea at different planting dates depending on the regions. In contrast, peas are generally planted in November usually in the southern part of the Republic of Korea because of its ability to adapt well to the cold and a light freeze.

Pulse-based farming systems dynamics

Even before the 1980s, cereal and legume intercropping has been practiced in the Republic of Korea as nitrogen-fixing improves soil quality that ultimately increases yields. In the past, intercropping of field crops with barley, wheat, vegetables, tobacco, medicinal crops, potatoes, and legumes was common to increase self-sufficiency in food. As barley is the second most important cereal crop, barley-pulse crop intercropping systems have been extensively practiced since the 1970s including barley + soybean/adzuki bean (57.6 percent) and potato + soybean/adzuki bean (2.3 percent) (Table 1). The evidence of the advantages of intercropping systems led to more combinations of crops having been developed in the 1980s, diversifying the past pulse-based cropping systems. In the 1980s, the combinations of barley + soybean/adzuki bean accounted for 40.1 percent, potato + soybean/adzuki bean 0.5 percent, tobacco – soybean/adzuki bean 13.4 percent and vegetable – soybean/adzuki bean 3.7 percent of pulse-based cropping systems (Table 1).

Table 1. Pulse-based cropping system in 1970s and 1980s

Cropping system	1970s (%)	1980s (%)
Barley – Soybean/Adzuki bean	57.6	40.1
Potato – Soybean/Adzuki bean	2.3	0.5
Tobacco – Soybean/Adzuki bean	–	13.4
Vegetable – Soybean/Adzuki bean	–	3.7

In the Republic of Korea, soybean-based intercropping has been mostly practiced because soybeans enrich the soil in nitrogen, and phosphorous and potassium uptake increase in intercropping compared with monocropping. When soybean is planted as sole crop, the optimum time for planting date is from early May to mid-May (Table 2); however, double-cropping soybeans and barley are planted in the latter half of June, which has been widely practiced as it reduces the incidence of disease effectively.

Table 2. Comparison of intercropping and monocropping

Type of cultivation	Area	Planting time	Harvesting time
Soybean monocropping	Northern and middle Korea	Early to middle May	Early October
Barley + double cropping soybean	Northern and middle Korea, and southern Korea	Early to late June	Early October

Major achievements in increasing pulse production and productivity

There has been a significant achievement in breeding that contributed to increasing pulse production since the 1990s. In the past, breeding successes were limited to a few productive cultivars because of a deficit in knowledge and technology (Table 3). Based on purposes, different varieties have been developed. Soybeans have been used in various forms in the Republic of Korea including soy pastes, soybean sprouts, soybeans for cooking with rice, vegetable soybeans, and others. The most popular soybean foods are derived from soy pastes and soybean sprouts and a majority of varieties that have been developed focused particularly on those two characteristics (Table 4).

Table 3. Number of improved pulses developed by programme during different times

Classification		Before 1960	1961–1970	1971–1980	1981–1990	1991–2000	2001–2007	After 2008	Total
Soybeans	NICS	7	4	7	17	50	44	31	160
	Gyeonggi	–	–	–	–	–	–	6	6
	Gangwon	–	–	–	–	–	3	1	4
	Gyeongbuk	–	–	–	–	–		2	2
	SNU	–	–	–	–	–	1	2	3
	KNU	–	–	–	–	–	4	4	8
	YU	–	–	–	–	–	2	–	2
	GNU	–	–	–	–	–	4	4	8
	KARI	–	–	–	–	–	1	3	4
	Total	7	4	7	17	50	59	53	197
Adzuki beans		–	–	–	2	2	3	8	15
Mungbeans		–	–	1	1	5	4	6	17
Peas		–	–	–	–	3	5	–	8
Common beans		–	–	–	–	1	4	–	5
Cow peas		–	–	–	1	–	–	3	4

NICS – National Institute of Crop Science, SNU – Seoul National University, KNU – Kyungpook National University, YU – Yeungnam University, GNU – Gyeongsang National University, KARI – Korea Atomic Research Institute

Table 4. Number of improved soybean varieties developed for different uses

Purpose	NICS and extension centers	NICS	Extension center	University	Research institute	Total
Soy paste	62	12	9	2	–	85
Sprout	36	8	–	14	–	58
Cooking with rice	17	5	3	5	4	34
Vegetable	14	5	–	–	–	19
Other	–	1	–	–	–	1
Total	129	31	12	21	4	197

Extensive breeding efforts were focused on increasing the yield potential of other pulses, resulting in the development of higher yielding cultivars such as Jangan Nokdu and Kyeongseon Nokdu for mungbean (Table 5), and Kyungwon-pat, Yungum-pat, Saegil-pat, and Kumsil-pat (Table 6).

Table 5. List of the popular mungbean varieties with their production

Cultivar	Stem length (cm)	Date of maturity	1 000 grain weight (g)	Resistance				Production (kg/10a)
				lodging	virus	brown leaf spot	powdery mildew	
Jangan Nokdu	55	Aug. 13	50	Strong	Strong	Middle	Strong	143
Kyeongseon Nokdu	74	Aug. 26	49	Middle to strong	Middle to strong	Strong	Strong	174

Table 6. Characteristics of adzuki bean varieties grown in the Republic of Korea

Cultivar	Flowering date	Maturity date	Stem length (cm)	Seed coat color	100 grain weight (g)	Production (kg/10a)
Kyungwon-pat	Aug. 12	Sept. 28	59	Red	13.4	141
Yungum-pat	Aug. 10	Oct. 4	63	Light green	12.0	190
Saegil-pat	Aug. 12	Oct. 9	55	Light auburn	16.5	172
Kumsil-pat	Aug. 1	Sept. 7	41	Brown	9.3	215

About 4 238 ha of adzuki beans were harvested with a production of 4 561 tonnes and yield of 1 076 kg/ha in 2010. Self-sufficiency in adzuki beans reached 60 percent before 1990s, but dropped significantly to 18.2 percent in 2010. Mungbeans, the third important crop followed by soybeans and adzuki beans, had an average production of 4 200 tonnes over 1991–2000. Because of asynchronous flowering of mungbeans, production was significantly low and caused problems in harvesting. However, a new mungbean cultivar, "Dahyeon", has been developed recently that has synchronous pod maturity and higher yield.

Most of the cultivars for cowpeas, common beans, and peas had been developed in the early 2000s for different purposes such as seed variety, vegetable variety, and edible-pod variety (Table 7).

Table 7. List of improved cultivars of cowpeas, common beans, and peas

Name of pulse	Purpose	Cultivar
Cowpeas	Seed	Seowon-dongbu (1986) and Yeonbun (2010)
	Vegetable	Jangchae (2010)
Common beans	Seed	Gangnangkong 1 (1993) and Seondu (2001)
	Vegetable	Hwanghyeob 1 (2005), Hwanghyeob 2 (2005), and Nokhyeob (2005)
Peas	Edible-pod	Sachulwandu (1995), Daehyeobwandu (1997), Olwandu (1998), Dacheongwandu (2002), Cheongmiwandu (2003), Sanghyeobwandu (2004), and Daehyeobwandu 2 (2006)

Constraints to enhancing productivity and emerging challenges

The major constraints to productivity are 1) limited size of land holdings, 2) condition of land, 3) unfavourable weather conditions, and 4) management. Soybeans hold the largest area for cultivation; however, according to RDA, the per capita area of cultivated land is less than 1 ha in 2005 and 0.1 ha in 2010 (Table 8), accounting for approximately 80.3 percent and 71.9 percent of the total soybean area, respectively, where mechanization in farming has been a constraint.

Table 8. Percentage of soybeans produced by the different farm sizes

Year	<0.1 ha	0.1-0.3 ha	0.3-0.5 ha	0.5-0.7 ha	0.7-1.0 ha	>1.0 ha	Number of farms
2005	80.3	13.6	3.8	1	0.6	0.6	630
2010	71.9	18.9	5.2	1	0.9	1.3	445

Pulse crops, considered as poor-income crops, are grown mostly in the middle to high mountainous regions of the Republic of Korea because these areas are unfavourable for growing most other crops. Serious drawbacks to mountainous farming are soil erosion, fertilizer application, and shortage of water. Usually, pulses are planted around May-June and are harvested in September-October, but lack of irrigation causes the crops to be affected by drought that reduces grain yield and subsequently results in low income.

Geographically, the Republic of Korea lies in a temperate climate zone which is not an optimal area for pulse cultivation. The insufficient rain occurring in May and June retards initial growth in the plant's life cycle including germination. However, the rainy season starts in the Republic of Korea in mid-July which increases lodging and disease infestation. Finally, even though pulse crops have considerable commercial value and can make a contribution to income, other crops, such as corn, sweet potatoes, potatoes and horticulture crops are considered a better source of boosting household income. Consequently, pulse cultivation faces major challenges of mechanization and irrigation. Implementation of irrigation schemes with proper drainage should be undertaken to combat drought stress in May to June and water stress during the rainy season in July. The government should invest more resources in accelerating mechanization because it alleviates major constraints on productivity and helps increase the farm income in cultivation of pulse crops. For example, labour time required for soybeans has been much higher compared with the labour time required for rice (Table 9). In rice cultivation, the staple crop in the Republic of Korea, faster mechanization has helped reduce the labour intensity.

Table 9. Required labour time on an hourly basis for soybeans and rice per 10 acre

Crop	1970	1980	1990	2000	2010
Rice	128	93	60	21	16
Soybean	123	96	80	48	26

Current efforts on improving productivity of pulse crops and increasing their suitability for conservation agriculture

In the Republic of Korea, systematic efforts through several programmes are in place to enhance pulse productivity such as the promotion project of the specialized farmers, the farm machine bank project and the generalization project of agricultural land use. They aim at reducing the farming costs through the expansion of farming areas, mechanization systematization and modernization of the facilities in the aspects of production of upland crop products including pulse crops.

The field improvement project has been launched in order to improve productivity of crops and to improve the condition of fields for production by upgrading infrastructure. Not only does the project include the field condition, but also water irrigation systems, construction of farm road, and readjustment of field. Until 2005, a total of $1.68 billion had been invested for improvement of 69 000 ha of field. Moreover, the Korean government has promoted a project to expand farmer's income sources by implementing different programmes, such as expansion of exchanges between urban and rural areas, establishment of industrial complexes of rural areas, promotion of farm produce processing businesses, development of green tourism villages and development of tradition in villages.

The conservation agriculture of pulse crops focuses on maximizing their biological N fixation because of the utility of intercropping systems among pulses including soybeans, adzuki beans, mungbeans, cowpeas, common beans, and peas. In fact, intercropping, in general, provided higher and more stable incomes from 1997 to 2006 (Table 10).

Table 10. Types of intercropping system associated with income (1997–2006)

Type of intercropping system	Average income	Maximum income	Minimum income
Monocropping	768	1 138	369
Barley + soybean	1 018	1 399	527
Rye + soybean	1 042	1 415	640
Cabbage + soybean	1 398	1 666	1 131
Potato + soybean	1 125	1 587	756

Contribution of pulses to nutrition, employment and income generation and value chain development including processing and marketing

Pulses provide a range of essential nutrients that are high in protein and carbohydrate (Table 11). In contrast to aduzki beans and mungbeans, soybeans contribute enormously to oil production in the Republic of Korea as edible cooking oil consisting of polyunsaturated fats, especially linoleic acid (omega-6).

Table 11. Nutrition facts in some of the pulse crops

Type	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrate
Soybeans	416	39.7	20	30.2
Adzuki beans	314	21	0.7	54.1
Mungbeans	331	25.59	0.7	53.6

The contribution of labour in pulse production has been low due to urbanization and the industry movement from primary to secondary and tertiary. Currently, adzuki beans and peas are becoming valuable economic crops and thus they have income-generating capacity (Table 12).

Table 12. Income generated from adzuki beans and peas

Type	Cropping system	Yield (kg/10 acre)	Income
Adzuki beans	Monocropping	122	1 164
	With barley	147	1 440
	With garlic	139	1 353
	With pea	116	1 102
Peas	–	1 178	854

The current model of processing and marketing of pulse crops begins from farmers who produce seeds. These are then distributed either to industry or consumer or agriculture cooperatives (Figure 3). A large amount of seeds are collected by industry such as CJ or PulMooWon, where pulse crops are processed into paste, sauce, or other end uses. However, domestic production of pulses in the Republic of Korea meets only 10 percent of consumer demand for pulses and the remainding 90 percent of the demand is met by imports.

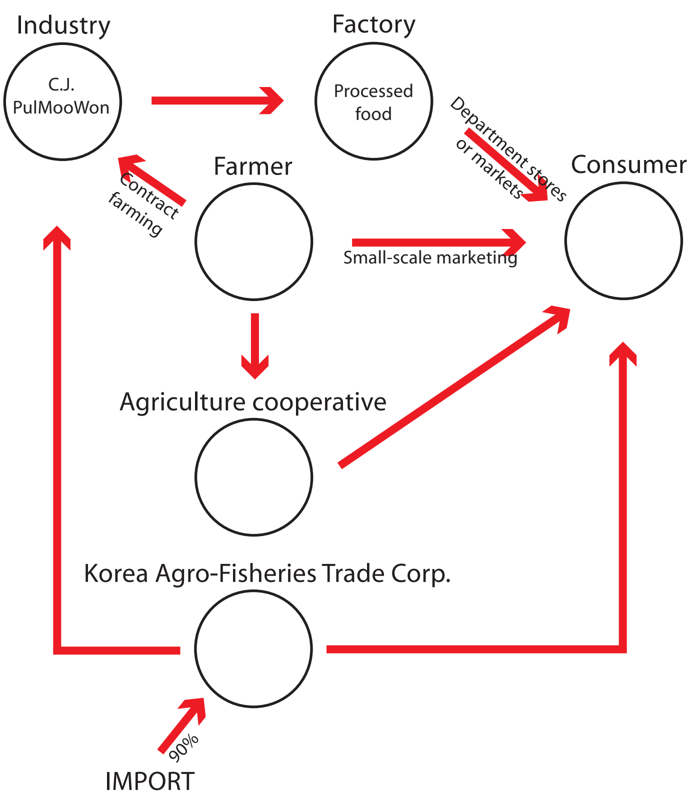

Figure 3. Current model of pulse processing and marketing

Even though soybean is the major pulse crop, the Republic of Korea is the one of the major importers of soybeans in Asia and its import has been steadily increasing over the years. In order to activate the pulse crop industry, the brand management promotion programme is suggested. By fostering the brand product from CJ or PulMooWon, it is possible to reduce the distribution costs and increase the productivity.

Strategy for meeting future opportunities and challenges and reaching out to farmers and consumers

The Republic of Korea government nowadays is putting great efforts into meeting the future challenges of pulses, particularly the negative impact of global warming. Through overseas agriculture, elite cultivars and good quality seeds can be developed and yield increased for meeting the challenges. More opportunities will be driven as industrial agriculture based on large-scale cultivation has become a dominant feature of farming in the Republic of Korea. Consequently, industrial companies are the ones who will be reaching out to farmers and consumers individually.

Conclusion

As the total demand for pulse crops increases, researchers are currently working on the development of varieties to improve food quality in the Republic of Korea. There has been much research associated with identification of important agronomic QTLs in soybeans. Significant progress has been made by institutes and universities in molecular marker development because they have great potential in improving breeding efficiency. In fact, with the advent of next generation sequencing (NGS) technologies, the Republic of Korea has recently released the whole genome sequence of mungbeans and adzuki beans that will be very useful in breeding programmes of pulse crops. However, a combination of marketing and scientific approaches will still be inadequate to achieving 100 percent self-sufficiency in soybeans, mungbeans, adzuki beans, cowpeas, common beans, and peas in the foreseeable future. This demands that efforts remain focused on steady development of agricultural research and administration policies to support the production of pulse crops in the Republic of Korea.

Improving productivity and production of pulse crops in Sri Lanka

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Abstract

Pulses such as mungbeans, cowpeas, soybeans and blackgrams play a prominent role in the cropping systems of dry and intermediate zones in Sri Lanka owing to their wide ecological adaptability. More than 85 percent of pulse crops are grown under rainfed conditions ("*maha*" season) in the dry zone which receives between 1 200 mm and 1 900 mm of rainfall annually covering two-thirds of the country.

The major constraints impacting on the productivity of pulses were identified as limited use of high-yielding varieties and fertilizer, use of poor quality seed, poor adoption of recommended agronomic practices, poor use of inputs, high incidence of pest and diseases, high risk associated with rainfed farming and high cost of production inputs such as labour. Being the main responsible institute, the Field Crops Research and Development Institute (FCRDI) in the Department of Agriculture has developed high-yielding improved varieties and technologies in order to improve productivity of the pulse crops. The most important constraints limiting productivity were insects, pests and disease outbreaks in the field, and storage pests. No resistant or highly tolerant varieties have been recommended and released against the very serious stored pest (bruchids) in cowpeas and viruses in mungbeans. Challenges and approaches for achieving self-sufficiency in pulse production have been described.

Introduction

Sri Lanka is an island with a land area of 65 525 km^2 and located between 5° 54' and 9° 52' north latitude and 79° 39' and 81° 53' east longitude. The island has a maximum length of about 435 km and its maximum width is nearly 225 km. The climatic pattern of the country is determined by the generation of monsoonal wind patterns in the surrounding oceans. Rainfall is monsoonal, convectional and depressional and 55 percent of island rainfall comes from the monsoons. The mean annual rainfall ranges between 900 and 6 000 mm. The country is divided into three broad climatic zones: wet zone, dry zone and intermediate zone on the basis of the rainfall and its distribution. The mountains and the southwestern part of the country, known as the "wet zone", receives annual rainfall of 2 500 mm. Most of the southeastern, eastern, and northern parts of the country comprise the "dry zone", which receives between 1 200 and 1 900 mm of rainfall annually covering two-thirds of the country. Most of the rainfall in these areas occurs from October to January and during the rest of the year there is very little precipitation.

The rainfall distribution in the country shows a bi-modal pattern with two growing seasons; a relatively wet season "Maha", from October to February and a comparatively dry season "Yala", from March to September. More than 85 percent of pulse crops are grown under rainfed conditions and mostly as a mono crop and mixed cropping by smallholder farmers. At the onset of monsoon rains, pulses are planted with one or two other crops, usually maize, finger-millet (*Eleusine coracana*), mustard (*Brassica nigra*) and vegetables under a mixed cropping system.

The agriculture sector of the country produces mainly rice, coconut and grains largely for domestic consumption and occasionally for export. The tea and rubber industry is mainly focused on export rather than domestic use. Of the total agricultural land of 2.9 million ha (mha), 65 percent (1.9 mha) is cultivated with agricultural crops. Paddy occupies 26 percent of the agricultural land. Coconut, tea and rubber together account for 21 percent and 41 percent of lands are occupied by home gardens. The remainder (12 percent) is accounted for all other crops; other field crops, horticultural crops and other export crops (Central Bank Reports). Subsistence farming exists in rural communities, where rice, yams, pulses and vegetables are grown extensively.

Pulse crops grown in the country

According to the literature, grain legumes can be classified into those containing low and high edible lipids. The latter is categorized as oilseeds and the former is generally harvested as dried pulses. The major pulse crops grown in the country are shown in Table 1. The oilseed legumes, groundnuts and soybeans are most widely grown as commercial crops for their oil content. Soybeans, introduced to Sri Lanka in order to provide an additional source of protein for the consumer, are categorized as an oil crop.

Lentils, mungbeans, cowpeas, soybeans and blackgrams are the pulses commonly consumed by the Sri Lankans. Although lentils are an important staple in the local diet, it is not domestically produced and the entire requirement is met by sizeable commercial imports. In addition, *Kollu (Macrotyloma uniflorum* (Lam.) is one of the underutilized pulse crops grown in negligible land area in the dry upland cropping systems.

Pulse crops are mostly grown in the dry and intermediate zones in Sri Lanka because of their wide ecological adaptability. Many of those crops are cultivated either as mono crop or in mixed crop with cereals such as maize. In addition, these crops especially mungbeans and cowpeas are cultivated as a sandwich crop between the two seasons in paddy fields (Dharmasena *et al.,* 1999). This helps increase farmers' incomes as well as enhance soil fertility by adding nitrogen to the soil. The choice of pulses as an important component of the cropping pattern in Sri Lanka has been based on nutritional and economic considerations.

The low per capita protein intake in the country with a predominantly cereal-based diet necessitates the cultivation of pulses to supplement the diet with high percentage of plant protein. The average yield of pulses remains at a very low level. In Sri Lanka, pulses are cultivated mainly in marginal lands under low fertility with minimum inputs resulting in low productivity (Table 2). Major pulse growing areas in Sri Lanka are shown in Table 3.

Table 1. Important pulse crops grown in Sri Lanka

Crop	Scientific name	Common name
Mungbeans	*Vigna radiata* var. radiata (L.) R. Wilczek	*Mung*
Cowpeas	*Vigna unguiculata* (L.) Walp.	Cowpea
Soybeans	*Glycine max* (L.) Merr.	*Soya bonchi*
Blackgrams	*Vigna mungo* (L) Hepper	Udu

Table 2. Potential and average yield of the pulses in Sri Lanka

Crop	Potential yield (tonne/ha)	Average yield over 2000–2013 (tonne/ha)
Mungbeans	1.8	0.81-1.27
Cowpeas	1.5	1.32-1.34
Soybeans	2.0	1.69-2.42
Blackgrams	1.5	0.75-1.14

Table 3. Pulse growing areas in Sri Lanka

Crop	District
Mungbeans	Moneragala, Hambantota, Kurunegala, Ratnapura
Cowpeas	Ampara, Moneragala, Anuradhapura, Kurunegala, Puttlam
Soybeans	Anuradhapura and Mahaweli-H (North Central Province)
Blackgrams	Anuradhapura, Vauniya

Source: Agstat DOA, Sri Lanka

Productivity of pulses over the period 2000–2013 is shown in Table 4.

Mungbeans

Mungbeans (*Vigna radiata* var. radiata (L.) R. Wilczek) are an important pulse crop in the traditional farming systems in the dry and intermediate agro-ecological zones of Sri Lanka. Agriculturists and nutritionists have been trying to promote the crop to generate employment, improve household income, diversification of farming systems for sustainable agricultural production and reducing malnutrition among children and adults (Perera *et al.,* 2012). Twenty percent of children under five years and 30 percent of the mothers are suffering from the protein malnutrition due to poor consumption of animal protein in rural areas of the country. Hence pulses, especially mungbeans, could be used as cheap source of protein in the areas.

They are grown in uplands as well as in lowlands as a catch crop with or without supplementary irrigation. Despite having the potential of being self-sufficient in the mungbeans, the country still imports 33 percent of its requirement. In 2013, it produced about 14 130 tonnes of mungbeans with an average yield of 1.27 tonne/ha (SEPC). However, under favourable conditions available varieties could have a realizable yield potential of about >2 tonne/ha.

Cowpeas

Cowpeas (*Vigna ungiculata* L. Walp) are the second most important pulse crop grown in Sri Lanka. It has been traditionally grown in the subsistence farming system in the dry and intermediate zones. Cowpeas are grown both in *maha* and *yala* seasons, it is a hardy crop well adapted to relatively dry environment due to its tolerance to drought (Dharmasena *et al.,* 1999). It is well-suited for intercropping with maize, millet and sorghum because of its ability to tolerate shade. Cowpeas are grown in both *maha* and *yala* season with *maha* accounting for 70 percent of the total production (Perera *et al.,* 2012). The country is almost self-sufficient in cowpeas with annual production standing at 15 416 tonnes and an average yield of 1.32 tonnes/ha (Table 4).

Table 4. Productivity (tonne/ha) of major pulses in Sri Lanka

Year	Mungbean	Cowpea	Soybean	Blackgram
2000	0.81	0.93	0.93	0.81
2001	0.88	0.93	0.96	0.81
2002	0.92	0.88	0.95	0.78
2003	0.88	0.93	1.16	0.83
2004	0.91	0.94	1.46	1.04
2005	0.93	0.98	1.62	1.11
2006	0.91	0.95	1.69	1.09
2007	0.97	1.02	1.68	1.04
2008	0.95	0.98	2.42	1.14
2009	1.08	1.18	2.29	0.90
2010	1.14	1.07	1.30	1.02
2011	1.16	1.12	1.56	0.67
2012	1.23	1.34	1.10	0.93
2013	1.27	1.32	1.69	0.82

Soybeans

Soybeans (*Glycine max* (L.) Merrill) are one of the most important legumes because of their nutrient content and potential for industrial processing. They can be promoted by increasing the demand for processed food. Demand is rising with expansion of the poultry industry. Soybeans are a seasonal crop mainly grown in *yala* season occupying 80–90 percent of the total area under pulses. National production was 13 316 tonnes in 2013 with an average yield of 1.69 tonnes/ha (Table 5). Average yield of soybeans observed during the recent past was quite stable, while the extent and production have declined especially owing to low market prices for the product.

Blackgrams

Blackgrams (*Vigna mungo* (L.) Hepper) are one of the important pulse crops in rainfed farming systems in the dry and intermediate zones. It can also be grown under low moisture and fertility conditions. About 80 percent of the crop is cultivated during *maha* season as rainfed and the remainder is grown in *yala* season in paddy fields with supplementary irrigation (19). The total production of blackgrams in 2013 was about 9 172 tonnes with an average yield of 0.82 tonne/ha (Table 5).

Table 5. Utilization pattern of pulse crops

Crop	Form of utilization	Preferred characters
Mungbeans	Boiled mature grains, on special occasions boiled with rice, flour use as animal and human feed, dhal use as curry, roasted dry grains	Large seeds with shiny dark green seeds preferred, less boiling time, low/no hard seeds
Cowpeas	Boiled mature grains, roasted dry grains, use as a curry, green cowpea seeds used as a fresh vegetable/curry	Cream/red colour large seeds, less boiling time
Soybeans	Milled dry grains into flour used for animal and human feed, preparing ice cream and snacks	Large seeds with cream in colour
Black grams	Milled dry grains into flour use for preparing different foods such as *Papad, Thosai, Vadei* etc.	Large seeds, easiness to remove seed coat, suitability for *papad* and food preparation

Source: SEPC, DoA, Sri Lanka

Importance of pulse crops

Smallholder farmers use pulses for household needs as well as for generating income by producing valuable and diverse products, such as grains, flour *etc.* Pulses are often fitted into underutilized niches that helps increase total food production within farming systems (5) and also to secure food supplies in the rural community. Pulses are superior sources of lysine, and increase the biological value of the combined protein while low lysine content is the limiting constraint in cereal-dominated diets relative to human amino acid balance. Pulses exhibit low glycemic index thus reducing the risk of obesity and diabetes (Foster-Powell *et al.,* 2002) and are also shown to improve iron status in Mexican school children (Haas *et al.,* 2010). Pulses help to reduce fertilizer cost by fixing nitrogen in soils providing benefits also to the subsequent crops.

Yield gap between potential and average yield

The pulse yields obtained by the farmers are much lower than the potential yields (Table 3). The main reasons for the low yields are the limited use of high-yielding varieties and fertilizer, use of poor quality seed, poor adoption of recommended agronomic practices, poor use of inputs, high incidence of pest and diseases, high risk associated with rainfed farming and high cost of farm resources such as labour.

Constraints to pulse crops production

Constraints to pulse crop cultivation can be broadly categorized as biotic, abiotic and socio-economic. Pulses are mainly cultivated during *maha* season under rainfed conditions. Poor drainage and waterlogging during the rainy season causes heavy yield losses owing to low plant stand and high incidence of fungal diseases. Further, these crops are cultivated by resource-poor farmers with low or no use of inputs. Most significant socio-economic constraints are the use of poor quality seeds, poor crop management, poor marketing facilities and high labour wages. A considerable amount of pulses are imported at lower price. Consumer preference is more biased towards red lentil and yellow lentils which are imported to Sri Lanka to meet the national requirement. Post-harvest handling and value addition of pulses is very poor in Sri Lanka. More than 90 percent of the products are being consumed directly. Cost of cultivation is much higher than the net income.

Present status of pulse crops in the country

Major pulse growing areas

Dry and Intermediate zones are the major pulse growing zones in Sri Lanka. Table 4 shows the main pulse growing districts in the country.

Trends in pulse production

The extent of cultivation of pulse crops depends mainly on the farm gate price and climatic conditions. Pulses produce marginal/low yields when grown under moisture stress and low soil fertility conditions (Perera *et al.,* 2012). If there is favourable weather condition with good rainfall, farmers always go for paddy cultivation. The trend in cropped area under pulses and production for the period of 2000–2013 is shown in Figures 3 and 4. Production of all the pulses fluctuated during the period of 2000–2013. In general, area and production in mungbeans, cowpeas and soybeans showed an increase in 2013.

The area and production of mungbeans declined from 2004 to 2009 followed by a sharp increase in production till 2013. Yield of mungbeans increased from 0.81 tonnes/ha to 1.27 tonnes/ha

(Table 5). Yield increase was mainly due to government intervention in increasing the production of pulse crops and use of quality seed. The farm gate price of mungbeans (Rs./kg) rose from 37.94 to 158.30. The Department of Agriculture under the Ministry of Agriculture launched a strong programme on third season mungbean cultivation as a catch crop between the two seasons in paddy fields by using the residual moisture or one or two supplementary irrigation systems to increase mungbean production.

Cowpea production dramatically increased over the period 2005–2013. In 2013, the harvested area and production of cowpeas was 11 701 ha and 15 415 tonnes respectively with the average yield of 1.32 tonnes/ha (Table 4). As shown in Table 5, productivity of the crop increased from 0.93 tonnes/ha to 1.32 tonnes/ha during the period 2000–2013. Because of its short duration, cowpeas are also cultivated as a catch crop between the two seasons in paddy fields.

Trends in pulse consumption and imports

The large gap between supply and demand for pulses caused increases in market prices of pulses over the years. According to the 2009 Agstat figures, 77 percent of the local requirement is met by imports as against 23 percent by local production. The lack of an assured market is a key factor in the poor performance of the pulse crops. Unlike rice, there is no stable price for the crops. Therefore, farmers often receive low prices during the harvest season. Erratic and uneven rainfall, poor use of inputs, marketing and government policies are the other important factors involved in rainfed pulses.

Compared to the locally produced pulses, consumption of lentils is higher due mainly to food habits of Sri Lankans (Sri Lanka Customs Reports). Though lentils are not produced in Sri Lanka, it is very popular dish among the children and adults in the country mainly consumed as a curry with coconut milk. Second consumer preference is for mungbeans followed by cowpeas and blackgrams.

Pulses produced in the country are consumed in various ways. The most popular method of using pulses in the country is boiled, roasted, milled dhal and flour of mature grains. Processing of pulses into dhal is performed at domestic level in rural areas using mainly traditional methods. The pattern of pulse utilization is summarized in Table 5.

Mungbeans play a very important role in the food security of lower income groups of the country. Though sprouted mungbeans are a good source of foliate, which is essential to synthesize and repair DNA for numerous body functions, it is not popular among consumers. And also its high lysine content makes it a good complementary food for rice-based diets. It has been shown that mungbeans help substantially increase body iron content of anemic school children (AVRDC, 1997 and 1998).

Cowpeas are also used as a green manure crop, a nitrogen fixing crop or for soil erosion control. Researchers found that 25 percent of nitrogen requirement of maize could be cut down by incorporating vegetable cowpea residues in the soil before planting maize (Annual Reports, FCRDI).

Soybeans are mainly used as textured vegetable protein (TVP) among Sri Lankans and popularized especially in the group belonging to the rural and estate sector. It is a prominent feature that soybean consumers in all sectors belong to the lowest income groups. Soybean flour mixed with cereals and mungbeans are used to prepare infant feed. Blackgrams are used for making different food items mixed with other cereals and pulses.

Research achievements

Review of past research, conclusions drawn from research over the past decades on the pulse crops are summarized below:

Varietal development

The Field Crops Research and Development Institute (FCRDI) in DoA is the main organization responsible for developing high-yielding varieties and technologies in order to improve the productivity of pulse crops. A number of improved varieties of pulse crops have been developed using conventional breeding techniques like selection and backcross methods. Limited availability of improved varieties with commercially preferred market traits (suitability for mechnical harvesting) and management practices also leads to low productivity of the pulse crops. Productivity constraints of insects, pests and diseases in the field and storage conditions are perceived as being very important. So far no resistant/high tolerant varieties are recommended and released for the very serious stored pest (*bruchids*) in cowpeas.

The crop varieties recommended and released by the variety Releasing Committee in the Department of Agriculture (DOA) are described in Table 6. The commercial production of certified seeds is done by the Seed and Planting Material Divisions of the DOA for distributing among the growers.

Table 6. Recommended pulse crops varieties with major traits

Crop	Varieties	Major traits
Greengrams	MI 06	Early matured, Light green seed coat, Large seeds, average yield 1.8 t/ha
	MI 05	Early matured, Dark green seed coat, Large seeds, average yield 1.5 t/ha
	Ari	Early matured, Dark green seed coat, Average yield 1.7 t/ha
Cowpeas	Dhawala	Early matured, White seed coat, Average yield 1.5 t/ha
	Waruni	Early matured, Reddish brown seed coat, Average yield 1.5 t/ha, Tolerance to collar rot diseases
	MI 35	Medium matured, attractive cream seed coat, Average yield 1.4 t/ha
	Bombay	Late matured, speckled grey brown seed coat, Average yield 1.5 t/ha
	MICP 01	Days to maturity 60–65 days, determinate growth pattern, cream seed coat, 100 seed weight 11-12 g, Average yield 2.0 t/ha
	ANKCP 01	Days to maturity 60–66 days, pale brown seed coat, Average yield 1.5 t/ha, suitable for 3rd season cultivation
Soybeans	Pb 01	Medium matured, Cream seed coat, average yield -2.5 t/ha, highly adaptable
	PM 13	Medium matured, Cream seed coat, average yield 2.5 t/ha.
	MISB 01	Medium matured, Cream seed coat, 1 000 seed weight 120 g, average yield -3.0 t/ha, highly adaptable
Black grams	MI 01	Late matured (85–90 days), average yield -1.5 t/ha, Black seed coat with dull luster
	Anuradha	Early matured (65–70 days), dwarf plant structure, average yield -1.5 -2.0 t/ha, Black seed coat with dull luster

Source: Variety Released Committee Report, DOA, Sri Lanka

Production technology

Depending on the agro-climatic conditions, pulse crops are grown as monocrop, intercrop, mixed crop, and catch crop. They are sown by line or broadcasting. Mungbeans, Cowpeas and soybeans are predominently sown by line while blackgrams are sown by broadcasting. Seed sowing by seeders has just started. It is reported that about 25–30 percent losses in pulses are caused by weeds. Major weeds affecting the crops are *Cyperus rotundus* and *Cynadon ductylon*.

Nutrient management

In general, pulses are grown on marginal lands with low management and inputs. A series of experiments conducted at FCRDI had led to recommendations of management practices for pulse crops as shown in Table 7.

Table 7. Fertilizer recommendation for the pulse crops

Crop	Fertilizer recommendation
Mungbeans Cowpeas Blackgrams	*Basal application* Urea – 30 kg/ha, Conc. Super Phosphate – 100 kg/ha; Muriate of Potash – 75 kg/ha, *Top dressing (at flowering)* Urea – 30 kg/ha
Soybeans	*Basal application* Urea – 50 kg/ha, Conc. Super Phosphate – 100 kg/ha; Muriate of Potash – 75 kg/ha, *Top dressing (at flowering)* Urea – 50 kg/ha

Source: Annual Reports, FCRDI, DOA, Sri Lanka

Water management

Crop water requirement for cultivated pulses in Sri Lanka has been calculated under the dry zone conditions (Table 8). Research done at FCRDI showed that yield could be subtantially increased by supplementary irrigation at critical stages of the crop growth (Annual Reports, FCRDI).

Table 8. Crop water requirement and planting time for pulse crops

Crop	Crop Duration (days)	Water requirement (mm)		Planting time	
		Yala	Maha	Yala	Maha
Soybeans	105	710	390	1 April	1 October
Greengrams	75	460	245	15 April	15 November
Cowpeas	90	770	370	15 April	15 November
Other pulses	90	560	300	15 April	15 November

Source: Annual Reports, FCRDI, DoA, Sri Lanka (1)

Crop protection

The disease Ascochyta blight caused by *Ascochyta Spp*. was identified for the first time in Sri Lanka. None of the recommended varieties showed resistance/high tolerance to the disease.

Suitability of pulses for conservation agriculture

More than one million hectares of land in the dryzone that falls under the rainfed upland category, comprising one fifth of the total land of Sri Lanka have been severely degraded due to continuous cultivation. Experiments conducted at the Field Crops Research and Development Institute reported that soil fertility depletes under continuos cultivation on uplands and addition of inorganic fertilizer does not give substantial crop returns unless it is combined with organic matter (FCRDI, 2003). Initially pulses were inter-cropped with maize and soybeans, and blackgrams gave better results regardless of different maize populations. Mixed blackgrams and sorghum plantings gave the highest return when sorghum was planted on one side and blackgram on the other side of the same ridge (FCRDI, 2003). Further it was observed that the advantages of intercropping manioc with mungbeans and cowpeas was also in promising in intensive systems. Under rainfed conditions, intercropping maize with soybeans was found more profitable than mono cropping.

It was found that short-aged varieties of blackgrams, cowpeas and mungbeans were successful, when cultivated after rice with residual moisture under well-drained and moderately well drained conditions. It was reported that mungbeans could be broadcasted 3-4 days prior to harvesting rice or on the rice stubble after harvesting without land preparation and weedicide was applied just after seeding. Thereafter the crop was maintained with two manual weedings under no fertilizer and irrigation (FCRDI, 2003). The system would be more profitable if row seeding with one irrigation is practiced. Inclusion of pulses mainly short-aged crops such as mungbeans (<60 days) and cowpeas (65–70 days) in a rice-based system increased the productivity besides improving the soil fertility. Researchers at FCRDI reported that 25 percent of the total N requirement could be cut down when vegetable cowpeas are grown and incorporated into the soil prior to maize crop (Annual Reports, FCRDI). Conservation farming has shown advantages over existing farming systems. DoA lanched a strong programme to popularize pulses specially mungbeans and cowpeas in rice-based cropping systems where ample land is left fallow during the *yala* season as well as in between two rice crops as a sandwich crop.

Initiatives for promotion of pigeonpea and chickpea cultivation

In 1988, several pigeonpea lines were tested under Sri Lanka-ICRISAT-ADB pigeonpea project, for the adptabiltiy to the local conditions. Among those lines, one variety was released as *Prasada* (ICPL 2) for cultivation in Sri Lanka (Variety Release Committee Reports). However, pigeonpea cultivation was not a success story due to poor adaptability, less consumer preference and inadequate proccessing methods as well as high incidence of *Maruca* pest damage.

Thousands of chickpea germplasm received from ICRISAT were screened and few were identified as promising lines. But seed size (smaller) was not acceptable by the farmers and the consumers. The whole chickpea requirement is imported.

Ongoing research programmes and activities

Plant breeding and crop improvement

i) Hybridization and selction programmes of mungbeans, cowpeas, soybeans and blackgrams are continuing with the objective of developing high-yielding, early or late maturing, large-seeded varieties with high consumer preference which are tolerant to major diseases and pests such as collar rot and pod borer (Table 6).
ii) Germplasm evaluation trials of mungbeans, cowpeas, soybeans and blackgrams are going on to introduce new varieties and to select suitable parents for a hybridization programme.

Plant protection

Availability of resistant varieties against major insect pests is a big help to pulse growing farmers who are not adopting pest control measures. Collar-rot incited by *Sclerotium rolfsii* is one of the most important diseases of cowpeas. It reduces crop yield over 40–50 percent. Collar-rot is a soil borne disease and *S.rolfsii* has been found to persist in soil or infected debris for several years. Therefore, the experiment is being conducted to identify long-term management practices for the management of the collar-rot pathogen. So far no bruchid resistant cowpea variety was identified. Identification of resistant/high tolerant pulse crop lines for major pests and diseases is continuing.

Government intervention in enhancing pulse crop production

Local production of pulses was encouraged during the period of 1970–1977 by imposing a ban on imports resulting in short supply and unprecedented price increases . As a result, cropped area and production went up. All pulses were heavily protected until 1991. More emphasis was given to crop diversification programmes with the reclamation of new lands for cultivation under a major river basin development project (*Mahaweli* Development Project). Although agricultural extension staff tried to persuade farmers to diversify their cropping systems, they did not succeed owing to various constraints, mainly low market assurance. While imposing different tariffs, Sri Lanka is signatory to many regional agreements such as Indo-Lanka, Pakistan-Sri Lanka, SAPTA or BIMSTEC (Perera *et al.*, 2012).

According to the Department of National Planning of Sri Lanka, the government places high priority on modernization of agricultural practices, improvement of productivity and competitiveness in marketing in both domestic and international markets, while enhancing value addition and product diversification (Perera *et al.,* 2012).

The government's agriculture policies aim at realizing multiple goals: (i) achieving food security of people, (ii) ensuring higher and sustainable income for farmers, (iii) ensuring remunerative prices for agriculture products, (iv) uninterrupted access to competitive markets, (v) farm mechanization, (vi) expanding the area under cultivation, (vii) reducing waste in storage, (viii) ensuring environmental conservation, (ix) introducing efficient farm management techniques and (x) expanding use of high-yielding varieties and efficient water management.

The Ministry of Agriculture together with the Department of Agriculture has launched a massive national campaign to increase the productivity and production of pulses. Increased attention is given to making available quality pulse seed to the farmers.

Future forecast and research direction

According to the ten year work plan of the DoA, pulses are categorized into priority groups on the basis of their demand (6). Mungbeans and soybeans are categorized under the first priority while cowpeas and blackgrams are under the second priority group. Productivity improvement is the main strategy in order to enhance the contribution of pulses to the national economy because of virtually non-existent opportunities for horizontal expansion. This strategy is based on strengthening research, extension, training, seed production and seed certification programmes (Table 9). Research activities for the improvement of pulses have been undertaken to achieve the objectives as mentioned in Table 10.

Table 9. Targeted pulse productivity for achieving self-sufficiency

Crop	Present national average (tonne/ha)	Yield achieved in 2014 (tonne/ha)	Targeted realizable yield (tonne/ha)	
			2018	2025
Mungbeans	1.1	2.5	2.8	3.0
Cowpeas	1.2	1.5	2.5	3.0
Soybeans	1.7	3.5	4.0	4.5
Blackgrams	0.9	2.2	2.5	3.0

For this purpose, more germplasm such as the International Pulse Nurseries should be introduced from AVRDC, ICARDA etc. Therefore, collaboration among the relevant agencies should be strengthened.

Table 10. Main objectives set for the breeding research programs of the pulse crops

Crop	Objectives of breeding programme
Mungbeans	Development of improved mungbean varieties with the following characters: • Resistance/high tolerance to pests (pod borer, bean fly and buchids); • Resistance/high tolerance to diseases (MYMV, PM, CLS); • High-yielding (Target 2.8 tonnes/ha by 2018 and; 3 tonnes/ha by 2020); • Short duration/long duration/drought tolerance; • Improved grain quality; • Less/no hard seed; • Bold seed (1 000 seed weight >65 g); • Attractive appearance (dark green in colour); • Synchronized maturity; • Suitability for mechanical harvesting; • Suitability for processing into *dhal*.
Cowpeas	Development of improved varieties with the following characters: • High-yielding: (3 tonnes/ha under irrigated and >2.0 tonnes/ha under rainfed conditions by 2018); • Improved quality of seed; – Boiling time; – Seed size, shape and colour (cream, brown, maroon); – Texture; – Protein content; – Maturity (early (60 days) /medium (75 days)/late (>75); • Determinate/Indeterminate growth habit; • Resistance/tolerance to major pests and diseases (collar rot, pod borer and bruchids).
Soybeans	Development of improved soybean varieties with the following characters: • Yield (4 tonnes/ha under irrigated and 3 tonnes/ha under rainfed by 2018) • Early maturing (<85 days); • Determinate growth pattern; • Tolerance to shattering; • Tolerance to lodging; • High N-fixing ability; • Improved quality characteristics; – Large seeds (>12 g/100 seed) with cream-colored seed coat; – Seed longevity (>3 months); – High protein content (>40 %) – Pest and diseases tolerance – Tolerance to purple seed stain disease – Tolerance to pod sucking bugs
Blackgrams	Development of improved varieties with the following characters: • High yielding (2.5 tonnes/ha); • Short-duration/medium duration/drought tolerance; • Pest and disease resistance; • Suitability for making processed food, e.g. papad.

Source: Research Programs, FCRDI, Mahailluppallama, Sri Lanka

Strategies to improve pulse productivity and production

Increasing pulse productivity and production is the team work of policy makers, planners, researchers, seed producers, extentionists and the farmers. The group should work together in order to increase production, reduce the cost of production, increase the quality of products and to have policy support for assured market prices and organized marketing channels. *St*rategies for increasing productivity and production of pulses could be broadly grouped into the following categories:

Technology transfer

1) Adoption of existing improved varieties and technologies for bridging up the yield gap.
2) Strengthening extension services to effectively disseminate technology package to farmers.
3) Provision of life-saving irrigation at critical growth stages.
4) Expansion of potential areas under pulses.

Technology development

1) Develop short-duration high yielding varieties.

   It aims at developing short-duration (<60 days) varieties that can escape terminal drought and fit into the third season cultivation as a catch crop between the two seasons in paddy fields. The variety should have characters of synchronized maturity that are suitable for mechanical harvesting, specially mungbeans and cowpeas.
2) Develop varieties with drought tolerance.

   Mungbeans, cowpeas and blackgrams are mainly grown under rainfed conditions and developing drought tolerant varieties is the long-term solution to increasing productivity of pulses.
3) Develop varieties suitable for crop diversification.

   It calls for development of short-duration (<60 days) varieties of mungbeans and cowpeas suitable for third season cultivation (a catch crop in between two paddy crops). These varieties should have a characteristics of harvesting >85% of the total harvest at the first pick.
4) Develop varieties/technologies to improve resistance/tolerance to major pest and diseases, e.g. viruses in mungbeans; storage pest in mungbeans and cowpeas.
5) Application of micronutrients and growth hormones.

   Study done by Wani *et al.,* (2012) indicated that the application of small quantities (0.5 to 2 kg/ha) of micronutrients such as boron, sulphur, zinc and magnesium has resulted in 40–120 percent yield increase. Research needs to be done in local conditions to study the effect of application of micronutrients on the pulse crops.
6) Increase value added products such as ready to eat or snack foods and introduce small-scale dhal processing machines.

Support services

1) Increase availability of quality seeds and strengthen input delivery system at farmer level.

   Pulses are mainly grown by resource poor farmers using poor quality seeds despite availability of a considerable number of improved varieties. Private seed companies are not interested to produce pulse seeds owing to its low profit margin. Therefore, farmer societies should be strengthened to produce quality seed of the improved varieties. Using quality seed alone can lead to increasing the yield by 400–700 kg/ha (verbal communication with agriculture extension workers).

2) Support assured marketing price and organized marketing channels. Steps should also be taken to ensure guaranteed market prices and develop marketing channels that curtail the role of middlemen and bring growers and buyers into direct contact.

Capacity building

1) It is very important to train the research staff especially in specific fields such as novel techniques in plant breeding, plant protection, preparation of value added products and use of machineries in the pulse cultivation.

Conclusion

Food security and protein nutrition especially for the rural population is a very important issue in Sri Lanka. Pulse crops serve as a cheap vegetable protein source for people who cannot afford more expensive animal protein. Erratic and uneven rainfall, use of poor quality seeds, poor crop management, poor use of inputs, no assured market and high labour wages have been identified as the most significant constraints to pulse crops production. As a result, significant quantities of pulses are imported at lower prices spending foreign exchange. Increasing pulse productivity and production is the team work of policy makers, planners, researchers, seed producers, extentionists and the farmers. The group should work together in order to increase production, reduce the cost of production, increase the quality of products and to have policy support for assured market prices and organized marketing channels. In view of the diversity of constraints associated with pulse crops, more assistance from international research institutes is required support the R&D programme in the future. And, also information and germplasm sharing should be given a higher priority in a regional collaborative programmes.

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Recent achievement in research and development of pulses in Thailand

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Abstract

The area under pulses in Thailand has been declining because of a lack of quality seed, unsuitable environment and competition with higher-income crops. Major pulses grown in the country are soybeans, mungbeans and peanuts. They are a cheap protein source for humans and animals which local farmers have realized and used as cooking seed and in producing processed food for a long time. Progressive plant breeding programmes contributed to increasing average yields of pulses nationally and valuable nutrient content in seed promoted by a variety of food processing industries. However, the country continues to rely on large-scale commercial imports of pulses to meet the rising domestic demand. Therefore, to increase pulse production and productivity, concerted efforts need to be focused on developing national standard seed production systems, research and development on high-yielding varieties with better seed nutritional profiles, and enhancing the role of farmers in participatory research and technology development.

Introduction

Thailand is an agricultural country with rice, cassava and sugarcane as important economic crops. However, pulses are also important as food security crops under government policies because they are a cheap protein source available in rural areas. These crops also play an important role in improving soil fertility and sustainability of cropping patterns. Major pulses grown in the country are mungbeans, soybeans and peanuts. These crops can adapt to a wide range of environments, therefore, they are grown throughout the country. However, production area and productivity of these pulses have shown a decreasing trend because of many factors, while demand in the country continues to rise, especially in the last five years. Recent research and development of pulses in Thailand aims to maintain the production area and increase productivity and quality.

Trends in pulse area, production and productivity

Cropped area planted with mungbeans, soybeans and peanuts tended to decline over time. In 2010, the area under mungbeans was 136 640 ha which produced 98 000 tonnes with an average yield of 738 kg/ha. The planting area and production increased in 2011 and then declined since 2012 onwards. Average yield dramatically decreased from 2011 to 2013 and then again rose to nearly the same level as in 2014 (Table 1). Mungbeans can be planted round the year in all parts of the country. The main growing areas are located in the north – Phetchabun, Sukhothai, Nakhon Sawan, and Kumphaeng Phet, followed by central areas, mainly in Lop Buri, Saraburi, Chai Nat and Ang Thong, and then north-eastern areas – Nakhon Ratchasima, Khon Kaen, Loei and Udon Thani. As the demand expanded, the productivity was not enough, therefore, Thailand needs to import mungbeans, for example, in the year 2011 about 24 313 tonnes worth US$ 13.3 million were imported. However, Thailand exports to the USA, Sri Lanka, Malaysia and Singapore a variety of mungbean processed products, such as noodles, flour, threshed mungbeans and canned sprouts. The value of annual exports over the period 2008–2013 was about US$ 14.7–40.19 million.

The declining trend in area and productivity of mungbeans was due to unsuitable environment and competition with high value crops such as cassava and sugarcane.

Table 1. Mungbean production during 2010–2014

Year	Cropped area (ha)	Yield (1 000 tonne)	Yield (tonne/ha)	Import (000 tonne)
2010	136 640	98	738	
2011	152 160	104	681	24
2012	146 560	103	706	
2013	138 880	99	719	
2014	135 840	99	731	

The area under soybeans in 2010 was 92 320 ha with a total production of 152 000 tonnes and an average yield of 1 694 tonnes/ha. This was followed by a decline of both cropped area and production with only 30 240 ha remaining under soybeans and production hitting a low of 52 000 tonnes in 2014. Average yield fell slightly in 2011/2012, it recovered and increased to 1 713 tonnes/ha in 2013 and 1 738 tonnes/ha in 2014 (Table 2). Soybean cropped areas are located mainly in the north and northeastern parts of the country.

Table 2. Soybean production during 2010–2014

Year	Planting area (ha)	Production (000 tonnes)	Average yield (tonne/ha)	Import (000 tonnes)
2010	92 320	152	1 694	1 819
2011	60 320	96	1 644	1 994
2012	39 520	64	1 631	2 112
2013	31 360	53	1 713	1 679
2014	30 240	52	1 738	2 020

Soybeans are sown in the rainy season and in the dry (summer) season mostly under irrigation. Like mungbeans, area and productivity decreased because of competition with high-income crops, such as cassava, maize and sugarcane. Other factors such as high production costs and limited supply of quality seed of good varieties also played a role in this decline. Domestic production meets only 2.38 percent of the demand and the remaining 97.62 percent of the soybeans consumed in the country are imported. However, Thailand exports soybeans, to Asian countries. The outstanding quality of our product is freedom from GMOs. In 2015, Thailand expects the demand to be 2.15 million tonnes of soybeans with 2.38 percent coming from in-country production and the remaining 97.62 percent from imports.

Peanuts are pulses that can grow round the year. They are grown mostly by smallholder farmers, with the average growing area of 0.16-0.48 ha throughout the country. The areas under peanuts are mostly located in the north followed by northeast, the south and central areas. Following the same trend as observed in mungbeans and soybeans, planting area and productivity of peanuts decreased over time. In 2009, planting area and total production were 32 838 ha and 51 586 tonnes, respectively and in 2013 they decreased to 28 258 ha and 45 920 tonnes, respectively. Average yield was 1 581 kg/ha from 2009 to 2012 and then increased to 1 619 and 1 625 kg/ha in 2013 and 2014 respectively because of increased availability of new varieties.

Table 3. Peanut production during 2010–2014

Year	Planting area (ha)	Production (000 tonnes)	Average yield (kg/ha)
2009	32 838	51 586	1 581
2010	30 835	48 839	1 581
2011	30 179	47 840	1 588
2012	29 483	47 680	1 619
2013	28 258	45 920	1 625

Pulse-based farming systems dynamics

As rice is the major crop in Thailand, pulses are grown mostly in the paddy field after harvesting rice, which is in the dry season (December to March or April). This is in the irrigated areas. There has also been pulse cropping in the upland, which is mainly rainfed areas and a sole crop system.

Mungbeans are grown after rice in the paddy but not on a large scale because of the risk of exposure of the crop to low temperature in winter, therefore it can be grown as late as in February. The second season is early rainy during May and July, which is in the paddy fields and before rice or other major crops. The risk of this cropping is uncertain rainfall and dry spells. This covers about 10 percent of mungbean growing areas. The third is in the late rainy season in the uplands (August–September), covering 80 percent of growing area. This is mainly grown after harvesting maize and is rainfed.

Soybean cropping systems are mostly rice-soybean covering 80 percent of growing area in dry season cropping (December–April) due to sufficient water supply (but less water is used than in the dry season rice). The other 20 percent is grown in the uplands as a sole crop. The production problems are uncertain rainfall and dry spells leading to insect pest attacks. However the latter system benefits farmers to have soybean seed themselves for dry season production.

Peanuts can also be grown in the paddy fields with or without irrigation. This needs to grow in areas with shallow groundwater levels after harvesting rice. The crop should be sown in November-December and harvested in February–April. With irrigation in the paddy fields, peanuts are grown in December-January and harvested in April-May. Peanuts are also grown in the uplands as a sole crop in the early rainy (April–May) and late rainy seasons (July–August).

Major achievements in increasing pulse production and productivity

1. High performance varietal improvement: high yielding, drought tolerance, pests tolerance, high nutrition for value added purpose.
2. Research and development for precision agriculture: decreasing cost of production and still providing high yields.

3. Soil improvement for better physical and chemical properties.
4. Enhancement of farmer's knowledge and access to useful information.
5. Development of standard seed production systems for pulses to solve the problem of availability of quality seed.
6. Improvement of water supply sources on farms.
7. Introduction of crop diversity in production systems to prevent from disease and insect pest outbreaks.

Constraints in productivity enhancement and emerging challenges

The following are the limiting factors in production of pulses in Thailand:

1. Low yield due to inadequate supply of quality seeds of good varieties, low fertility of soil, drought, insect pests and disease, and inappropriate location-specific use of technology.
2. High production cost due to high cost of manual labour in planting, crop management and harvesting, high rate of seed used, and high costs of production inputs.
3. Low quality of products, especially for peanuts, which tend to be contaminated with aflatoxin because of improper postharvest procedures.
4. Dynamics of production area and productivity as affected by the environment, area and farm price.
5. Free trade for agricultural products, e.g., WTO, AFTA and AEC, can decrease productivity as production cost in Thailand is higher.
6. High average age of farmers (53 years), affecting supply of quality labour.
7. Climate change (uncertain rainfall pattern, high and very low air temperature), decreasing pulse productivity and harm to human health.

Current efforts for improving pulse productivity

1. The government has a policy to maintain the planting area of the pulses and increase productivity. The Department of Agriculture produces and supplies foundation seeds or extension seeds to Department of Agricultural Extension or Cooperatives Promotion Department or farmer groups to produce registration seed for sale to farmers.
2. The government has a policy to reduce off-season rice area and instead to promote growing pulses, especially soybeans and mungbeans after the main season rice harvest. In addition, pulses are also promoted for crop rotation with sugarcane to break insect and disease accumulation and to improve soil health. This is because pulses have a short production period, require less water or moisture and the demand in the country is still high.
3. There is a collaboration project among private and government sectors to promote soybean production in the country, i.e. machinery, soymilk industry, sugarcane factory, Department of Agriculture and Cooperatives Promotion Department.

Suitability of pulse for conservation agriculture

1. Pulse is a low cost protein source for humans and animals. Different kinds of pulses are grown for a long time in specific areas such as soybeans in the north of Thailand (a way of living crop).
2. Pulse improves soil chemical and physical properties and leaves essential nutrients in the soil for the following crops.

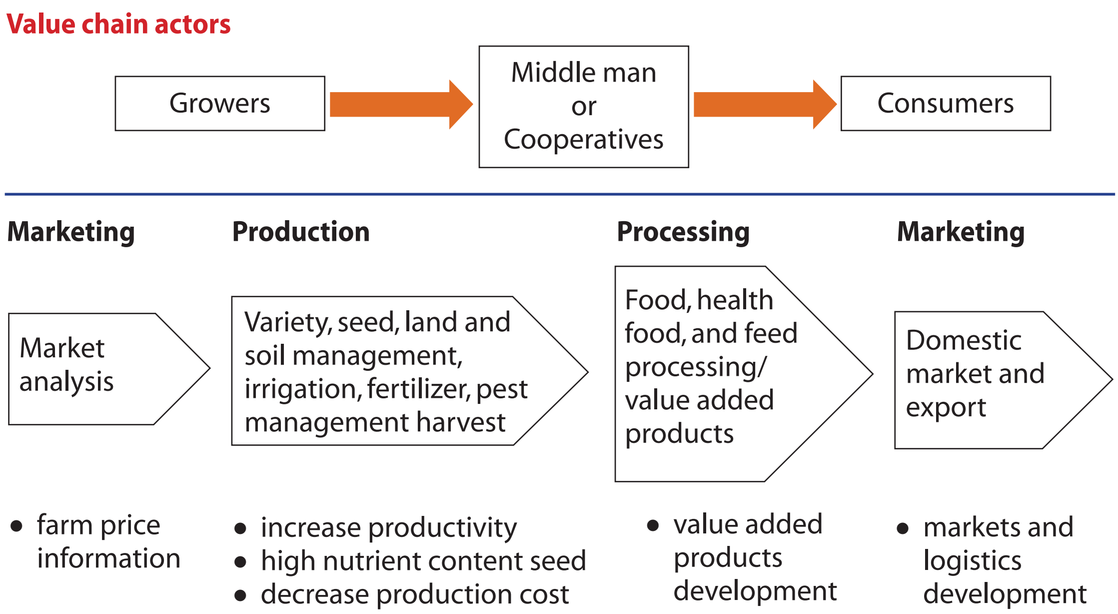
3. Short production period, so suitable for introducing to rice-based farming system or another major crop.
4. Breaking insect pest and disease life cycles in main crops when used in crop rotation.
5. Provision of supplementary income for farmers.

Pulse's contribution to nutrition, employment and income generation, and value chain development, including processing and marketing

Soybeans, mungbeans and peanuts are widely used in food and feed processing. Soybean seed is composed of about 36 percent protein (can substitute animal protein in food), 20 percent oil (63 percent is polyunsaturated amino acids, containing lecithin of 5 percent) and 30 percent carbohydrate. There are also vitamin A, B1, B2, B3, B5, B6, B9, C, E, K, calcium, magnesium, phosphorus, potassium, and isoflavones. Soy flour and soymilk are processed as primary products.

Mungbean seed is mainly composed of protein (63 percent), carbohydrate (22 percent) and oil (1.5 percent). It also has vitamin B1, B2, iron, calcium and phosphorus, which are essential for health. Peanut seed contains oil (48 percent, oleic, linoleic and arachidic acids), protein (25 percent and carbohydrate (21 percent). It has vitamin B1, B3, B6, B9, C, calcium, magnesium, phosphorus and potassium.

Food processing industries in the country use all three types of pulse for food, snacks, health food and feed in the country in large, medium and small-scale production and export the products. Apart from these, there are the OTOP (One Tumbon One Product) products developed on a community scale. These enterprises increase rural employment and income. Value chain development of pulses in Thailand is shown in the following diagram:



Strategy for meeting future opportunities and challenges

1. Promote the national standard in seed production industry and build farmers' capacity in seed production and trade locally.
2. Promote research and development on pulses breeding, climate-smart production technology to increase yield and improve adaptation to changing climate conditions and value added pulse products.

3. Develop and introduce medium- and small-sized machinery in pulse production.
4. Popularize farming and farm-based enterprise development among the new generation of youth.

Outreach to farmers and consumers

1. Dissemination of knowledge, provision of training, organizing workshop and farm visits to promote awareness about the importance of pulse crops in management of soil fertility and improvement of sustainability in agriculture.
2. Promote value added food processing in community or small and medium enterprises (SME).
3. Promote and develop health food or other competitive products from pulses.
4. Encourage young people to realize the nutrition value of pulses.

Conclusion

Major pulses grown in Thailand are soybeans, mungbeans and peanuts. But the cropped area under pulses is declining because of inadequate supply of quality seed, increasing exposure to unfavourable growing environments and lack of competitive edge over other alternate crops. These constraints, however, should not get in the way of realizing the whole range of unique benefits to be derived from the cultivation and consumption of pulses. They are full of essential nutrients for human and animals, in addition, they have short production periods that allows inclusion cropping systems leading to improvement of soil properties and sustainability of intensive agriculture.

Many types of food processing industries established in the country serve as the basis for expanding the market and driving the demand for pulses which will incentivize efforts to increase the domestic supply of pulses through both horizontal and vertical expansion (enhancing productivity). Other measures are development of national standards in seed production systems, value added product development and strengthening research and development on pulses. Finally, farmers should be involved in the knowledge dissemination process. These processes should be applied to enhance pulse production.

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Research, development and outreach activities for enhancing pulse production in Asia

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Abstract

A sustainable increase in the production of pulses can be achieved in Asia by making enhanced investments and efforts in research, development and outreach activities on pulses. Further improved cultivars and production technologies need to be developed for enhancing productivity and the opportunity to expand the area planted with pulses. Development and outreach activities with already available improved cultivars and technologies offer opportunities for increasing both area and productivity of pulses in Asia. Additional area can be brought under pulses by promoting their cultivation in rice-fallows and in intercropping, sequential cropping and other cropping systems. Wide yield gaps exist between the realized and potential yield of pulses due to lack of adequate adoption of improved varieties and crop management practices. Concerted efforts are needed on knowledge empowerment of farmers and extension personnel on improved varieties and production technologies and quality seed of new varieties and other needed inputs must be ensured. Policy support favouring sustainable intensification of cropping systems with pulses, crop insurance for pulses, credit and input supplies for farmers and marketing of pulses are needed to encourage farmers to cultivate pulses. Mechanization of pulses would play an important role in making pulse cultivation more profitable and attractive to farmers, particularly young farmers.

Introduction

Crop diversification with pulses as a component of intercrop, crop rotation or relay crop is identified as one of the strategies to achieve sustainable enhancement in agricultural productivity. Pulses restore soil fertility through biological nitrogen fixation, by breaking pest, disease and weed cycles and by extending protective land cover. Pulses are widely adapted to a broad range of environmental and cropping sequence niches which can be better exploited in an effective crop diversification programme and which can then lead to substantive economic and environmental benefits. Pulses make vital contributions to the human diet by providing protein and micronutrients and complementing cereals for amino acid profiles.

The need to enhance food production to meet the demand of increasing populations in Asian countries placed higher emphasis on production of cereals compared with grain legumes. As a result, the area under legumes declined substantially in several countries, particularly in South Asia. There are challenges in sustaining the productivity of cropping systems in cereal mono-cropped areas and, thus, the emphasis is now increasing on bringing back pulses in the cropping systems.

There has been substantial progress in the development of improved cultivars of pulses in recent years. These cultivars have higher yield potential, greater tolerance to insect-pests and diseases and better grain quality. There are success stories of substantially enhancing area and productivity of grain legumes in some countries/regions (e.g. chickpeas in Myanmar and Southern India). Cultivars are now available which are more resilient to the impacts of climate change and provide greater potential of expanding the area of legumes in new niches and cropping systems. Another landmark achievement in pulse improvement is the development of commercial hybrids in pigeonpeas that give 25 to 40 percent higher yields than the open pollinated varieties. The advances in genomics of pulses have been remarkable and breeders can now have enhanced precision and efficiency of breeding programmes by integrating genomic approaches.

There is still much to be done in developing further improved cultivars and production technologies and enhancing adoption of available improved cultivars and production technologies. This article describes potential areas of research, development and outreach activities that can lead to sustainable increases in pulse production.

Development of further improved cultivars and production technologies

Restructuring plant type for higher productivity

Restructuring of plant architecture has played a key role in enhancing the yield potential of several crops, including wheat and rice. There is a need to bring a drastic change to existing types of plant pulses to realize a breakthrough in productivity. The plants should be physiologically efficient to allow more solar light interception and have proper partitioning of photosynthates. We may need different plant types for rainfed and irrigated conditions. Pulses have long been grown on marginal soils under rainfed conditions with minimum inputs. The available cultivars, which have been developed taking into account these harsh growing conditions, do not respond favourably to high input conditions (application of fertilizer and irrigations). High input conditions, particularly in deep black soils (vertisols) or heavy textured soils, may stimulate excessive vegetative growth leading to poor pod set, lodging, reduced harvest index, reduced grain yield and poor seed quality. Thus, we need varieties which are responsive to inputs, have high input use efficiency, resist excessive vegetative growth and lodging and have high biomass coupled with high harvest index.

Machine harvestable varieties

Mechanization would play a key role in modernization of pulse production in India. Mechanization contributes to timeliness of operations, reduces cost of production and improves resource use efficiency. Farmers need pulse varieties which can be directly harvested by combine harvesters. The current varieties of most of the pulses are not suited to mechanical harvesting because the plant height is not adequate and the branches are close to ground due to semi-spreading growth habit. Thus, there is a need to develop varieties with semi-erect to erect growth habit and minimum 20 cm ground clearance for their suitability to mechanical harvesting.

Herbicide tolerance

Manual weeding, currently being used in pulse for removal of seasonal weeds, is becoming expensive and in some cases is uneconomical due to rising labour costs. There is a need to develop post-emergence herbicide tolerant varieties so that herbicides can be used effectively for weed management. Weed management by herbicides will not only be economical but also facilitate no-till methods, which help preserve topsoil. This will further help in horizontal expansion of pulses like, urad beans, lentils and chickpeas in rice-fallows or cereal-pulse cropping systems.

Climate smart varieties

The expected impacts of climate change include temperature extremities (frost, cold, heat), erratic and unpredictable rainfall patterns (more intense rainfall events and less light rainfall events) and more frequent floods and droughts. Thus, there is a need to develop climate smart varieties which are resilient (better recovery after stress) to climate change. Enhanced drought tolerance is required in all the pulses. Heat tolerance would be important for post-rainy season pulses, such as chickpeas and lentils. It will also be important for rainy season pulses, mungbeans and urdbeans for their cultivation in spring/summer. Waterlogging tolerance would be required in rainy season pulses, such as pigeon peas, mungbeans and urdbeans. The frequent waterlogging in some areas also increases soil salinity and the available cultivars of major pulses are sensitive to soil salinity, thus there is a need to develop salinity tolerant cultivars. With continuous rains during harvest, pre-harvest sprouting in mungbeans and urdbeans often occurs, thus efforts should be made to develop cultivars tolerant to pre-harvest sprouting. Climate change could also affect occurrence of insect-pests and diseases. Severity of some of these biotic stresses may increase, such as dry root rot and collar rot in chickpeas and lentils, and new insect-pests and diseases may emerge. Thus, tolerance to these stresses must be an integral activity in the development of climate smart varieties. Furthermore, strong forecasting and forewarning modules are necessary to predict the incidence of these pests well in advance.

Hybrids in pigeonpeas

Pigeonpeas are the only pulse crop where development of commercial hybrids has been possible. This is because pigeon peas are an often cross-pollinated crop. A few cytoplasmic-nuclear male-sterility (CMS) based hybrids have been released in India, which have demonstrated 30–40 percent yield advantage in farmers' fields in some pockets of the country. There is a need to diversify the sources of CMS systems and incorporate resistance to key diseases and insect-pests in the parental lines. Hybrids should be developed in different maturity groups to cater to the needs of different geographic regions and the cropping systems.

Reduced maturity duration

Sustainable intensification of cropping systems is the key to enhancing agricultural production where there is little scope of bringing additional area under cultivation. Early maturing varieties will help in bringing pulses in non-traditional seasons or between two cereal crops as a catch crop. Vast rice-fallow areas (~14 million ha) available in South Asia (India, Bangladesh, Nepal) offer opportunities to expand the area of post-rainy season pulses, such as chickpeas and lentils. As the sowing is delayed due to late harvest of rice, early/extra-early varieties are needed to escape end-of-season stresses in rice-fallows.

Enhanced phosphorus acquisition efficiency (PAE)

Phosphorus (P) is vital to plant function but is a finite resource in nature. There is a continuous rise in costs of P fertilizers in India as most of the P fertilizers are imported. However, a lot of P is available in fixed forms in soil which can be made available to pulse crops if varieties with enhanced phosphorus acquisition efficiency (PAE) and responsive to phosphorus solubilising bacteria (PSB) are developed. Research is required to develop reliable screening techniques for PAE, identify genotypes with greater PAE and unravel mechanisms that contribute to PAE. Integration of genomic approaches would help in introgressing PAE in available high yielding cultivars.

Exploitation of wild species and transgenics for insect resistance

Pod borer continues to be a major and challenging insect-pest of pulses. It has not been possible to develop varieties with high levels of resistance to pod borer due to the non-availability of sources with high levels of resistance in the germplasm of cultivated species. Higher levels of resistance have been observed in some wild species and efforts should be made to exploit these wild species in improving pod borer resistance. Greater chances for development of pod borer resistant cultivars exist through application of transgenic technology. Concerted efforts are needed on using different transgenes and promoter options for developing transgenic events and their evaluations for effectiveness and bio-safety.

Protein enhancement and bio-fortification

Pulses are a good source of protein, carbohydrates, dietary fibre, minerals (Fe, Zn, Ca and Mg) and other important nutrients that are essential for human health and development. There is for scope further improvement in the nutritional quality of pulses. Protein content of present day cultivars is usually in the range of 18–22 percent whereas much larger variability (14–32 percent) exists in the germplasm which could potentially be exploited to develop high protein (≥25 percent) varieties. Similarly, wide variation has been observed for iron and zinc contents in the germplasm, which can be exploited to develop high iron and zinc varieties. It is important to develop nutritionally enhanced varieties as consumers would get a higher amount of protein and other nutrients from the same amount of pulses consumed.

Refinement of agronomic practices for crop establishment in rainfed-rice fallows

One of the constraints in growing pulses in rainfed rice-fallows is crop establishment. Current field preparation methods lead to losses of moisture. Thus, sowing of pulses in rice-fallows has to be done with minimum or zero tillage. The soil type and soil texture may vary from one location to another location and, thus, may have different agronomic requirements for optimum crop establishment. The agronomic practices need to be standardized including seed priming and seed treatment with fungicides/insecticides, application of rhizobium inoculant, and sowing method (relay cropping, seed dibbling and sowing with zero till seed drill).

Modernization of pulses breeding programmes

The application of novel methods and tools in breeding programmes is needed to improve efficiency and effectiveness so that higher genetic gains can be achieved and the time required for development of a variety can be reduced. Breeding programmes should have access to controled environment facilities (green houses, growth chambers) for rapid generation advancement of breeding materials and phenotyping platforms for high throughput screening of genetic materials and use of electronic field books and data management systems for increasing efficiency. There has been rapid progress in development of low cost genotyping platforms and genomic resources in the recent years. We now have the draft genome sequence available for most of the pulses. Integrated breeding involving genomic approaches needs to be used for higher precision and efficiency of breeding programmes. Pulses breeding programmes should be able to develop varieties in the shortest possible time as per need of farmers, consumers and the industries.

Development and outreach activities with available improved cultivars and technologies

Promotion of pulses cultivation in rice-fallows

Vast areas of rice-fallows (~14 million ha), available in South Asia (India, Bangladesh and Nepal, offer opportunities to expand the area (2.0 to 3.0 mha) of post-rainy season pulses, such as chickpeas, and lentils. A holistic farming system approach would be required for cultivation of pulses in the rainfed rice-fallows. This includes promoting (1) cultivation of early maturing paddy in the rainy season, so that the fields are vacated early for timely sowing of pulses, (2) cultivation of pulse varieties suitable for rice-fallows (early growth vigor, early to extra-early maturity, and tolerance to reproductive stage heat stress), (3) suitable agronomic practices (seed priming, sowing under zero or minimum tillage condition) for ensuring optimum plant population in rainfed rice-fallows, and (4) integrated crop management practices (nutrients, weeds, insect-pests, diseases, etc.).

Bringing additional area under pulses through intercropping and sequential cropping

Ample scope exists for promotion of pulses in intercropping and sequential cropping. Short-duration pigeon pea varieties are now available which can mature in 120–130 days and allow sowing of a post rainy season crop, such as wheat. There are several niches for intercropping of pulses with cereals and other crops which can be exploited for enhancing areas with pulses, maximizing profitability and increasing cropping system sustainability.

Knowledge empowerment of stakeholders

There has been a slow adoption of improved varieties and production technologies of pulses by farmers in several states. Many farmers are still growing decades old varieties and making little or no investment in crop management. In some cases, this is simply because the farmers do not have adequate information about the improved varieties and production technologies. Increased adoption of improved cultivars and production technologies are very much needed to enhance the yield of pulses. Thus, concerted efforts are needed on knowledge empowerment of farmers and extension personnel. This can be achieved by organizing training programmes and various awareness activities through field days/farmers' fairs and electronic and print media. Special efforts should be made to encourage participation of women farmers. In some cases, it can be achieved through organizing training programmes and field days exclusively for women farmers. Farmer participatory trials/demonstrations are very helpful in convincing farmers of the benefit of improved cultivars and technologies. Distribution of small seed samples (2–5 kg) to a large number of farmers would help in the rapid spread of new varieties.

Expanding pigeon pea hybrid production

Hybrids have been developed in pigeon peas, which offer huge potential for enhancing pigeonpea yield, which has remained almost stagnant around 700 kg/ha during the past five decades. Some commercial pigeonpea hybrids, such as ICPH 2671 and ICPH 2740 are already available in India. A large number of demonstrations on farmers' fields were conducted in several states of India in which the hybrids gave 25 to 40 percent higher yield than the open pollinated varieties (OPVs). Concerted efforts are needed on production of hybrid seed and promotion of hybrid pigeonpea cultivation in India, Nepal and Myanmar.

Improving access of farmers to seed

One of the major bottlenecks in spread of new varieties is the inadequate availability of quality seed for farmers at the local level and at the right time. Several old varieties are still in the seed chain. There is a need for enhancing seed availability of new varieties. In addition to public seed corporations, seed societies and private companies should be involved in seed production.

Integrated nutrient management

Proper nutrient management based on soil analysis is important for maximizing productivity of pulses. Farmers generally provide only major nutrients like phosphorus (P), and in some cases Potash (K). The secondary nutrients, such as sulphur (S) and the micronutrients, such as zinc (Zn), boron (B) and molybdenum (Mo) are ignored. Widespread deficiencies have been observed for these secondary nutrients and micronutrients in pulse growing areas. The experiments conducted suggested that applications of each of these nutrients can increase pulse yields in the range of 10 to 25 percent depending on the extent of deficiency. Thus, there is a need for developing a soil map for availability of nutrients for each state to recommend applications of nutrients accordingly. It is also important to ensure availability of the fertilizers/micronutrients for farmers at the local level and at the right time.

Promoting ridge and furrow method of planting in rainy season pulses

Waterlogging causes severe damage to rainy season pulses, such as pigeonpeas, mungbeans and urdbeans. Experiments have shown that ridge and furrow method of planting can avoid waterlogging of the crops and the diseases associated with waterlogging (e.g. phytophthora blight in pigeonpeas). A large number of demonstrations should be conducted on ridge and furrow method of planting in rainy season pulses. The tractor driven ridge makers should be available to farmers on custom hiring.

Promotion of micro-irrigation

Pulses are largely grown under rainfed conditions and moisture stress leads to a reduction in productivity. Sub-optimal moisture in the soil at the time of sowing leads to poor germination and plant stand. High emphasis should be given to water conservation so that the pulses receive required number of irrigations. Water saving irrigation methods, such as sprinkler and drip irrigation should be promoted.

Integrated pest management

Pod borer causes heavy yield losses in pulses (chickpeas, pigeonpeas) if not managed. Similarly, thrips in spring/summer in mungbeans; and aphids in lentils cause huge crop losses. There is a need to promote integrated pest management (IPM) approaches for managing these insect-pests. An effective pest surveillance mechanism should be put in place at district/block level and region specific advisories should be given to farmers to assist in pest management.

Enhancing mechanization of pulse cultivation

Increasing mechanization is important for making the cultivation of pulses more profitable and attractive to farmers. One of the keys to success for production of cereals has been mechanization of farm operations. Now, the cultivation of wheat and rice is mostly mechanized. Even farmers with smallholdings can afford mechanization because of the availability of farm implements on custom hiring. Mechanization would play a key role in modernization of agriculture due to its benefits of improved labour efficiency and productivity, efficient use of expensive farm inputs, reduction of human drudgery and timeliness of operations. Line sowing by seed drills or ridge maker-come-planters should be promoted in the states where farmers are still using seed broad casting for sowing. Harvesting by combine harvesters should be promoted for the crops where suitable varieties are available. Machine harvestable chickpea varieties have recently been released in India. Cultivation of these varieties needs to be promoted.

Policy support

Procurement of pulses at minimum support prices, market intelligence research, input supplies, promotion of micro-irrigation, increased and sustained investment in technology development and dissemination, farm mechanization and, value addition are the areas where immediate attention needs to be paid. Investment in the storage sector needs to be enhanced to ensure quality seed supply. Farmers can be encouraged to store seeds of pulses or grains in such stores on a payment basis. Credit facilities for farmers can be extended on the basis of seed/grain stored in such places.

Asian network for research, development and outreach activities on pulses

There is a need to enhance greater cooperation among Asian countries for research, development and outreach activities on pulses. The Asian Grain Legumes Network (AGLN) was established in 1986 by ICRISAT in partnership with 11 Asian countries. The AGLN focused on the three ICRISAT-mandate legumes (chickpeas, pigeonpeas and groundnuts) and facilitated and coordinated collaborative research activities on these crops to generate appropriate technologies by more effectively using existing staff and facilities in member countries. Later in 1992, the AGLN and the Cooperative Cereals Research Network (CCRN) were merged to form the Cereals and Legumes Asia Network (CLAN). The CLAN is also coordinated by ICRISAT and includes all five ICRISAT-mandate crops (sorghum, pearl millet, chickpeas, pigeonpeas and groundnuts). The CLAN received funding support from the Asian Development Bank up to 1999. Because of a lack of funding support, there have been very limited activities in CLAN during the past 15 years. There is a need to have an active network similar to AGLN to enhance cooperation among Asian countries for development and exchange of technologies on pulses.

Impact of climate changes on pulse development in Asia

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Abstract

More than 50 percent of the pulses in the world are grown in south and southeast Asian countries. The productivity of all rainfed crops because of their dependence on rain is increasingly threatened by high temperatures and drought caused by climate change. The majority of the pulse growing countries like India, Pakistan, Bangladesh, Nepal, Bhutan, Myanmar, Viet Nam, Cambodia and Thailand are particularly vulnerable to the impacts of climate change due to their strategic geographical locations in the mid-north latitude nearer to the equator where maximum threshold temperature for tolerance of pulses has already reached 35°C. A further rise in temperature, as is evident now, will adversely affect the productivity of pulses in these areas.

Increased CO_2 levels in the atmosphere is not beneficial for pulses grown under stressed environments. Both drought and heat are recurrent phenomena in south and southeastern countries. Gene mining for stress tolerance from diverse germplasm collections, including wild species will remain the great strength for evolving newer varieties tolerant to multiple abiotic stresses. Strategies have been made to develop climate resilient varieties based upon screening of a large number of germplasms available worldwide. Early flowering, short duration, faster biomass accumulation, deep root system, high water-use efficiency and high root proliferation before the onset of terminal drought and heat have been found to be the best strategy to escape abiotic stresses. The reproductive component of the pulses is very sensitive to high temperature. A number of genotypes have been identified as tolerant to heat stress based on reproductive stage tolerance, including fertile pollens and pod formation.

The mechanisms of heat and drought tolerance in pulses have been deciphered. Drought-specific genes, Dreb 1A, Dreb 1B and Osmotin, are being used for developing drought-tolerant chickpeas and pigeonpeas. Drought-specific signal molecules ABA and its role in drought tolerance have been characterized. Identification of linked quantitative trait loci (QTLs) for root and high yield and marker-assisted selection (MAS) opened new horizons in the field of drought research. Rapid advancements in genomics provide an opportunity for molecular mapping of QTL controlling heat tolerance and using marker-assisted breeding for development of heat tolerant varieties with suitable agronomic background and desired seed traits. Molecular markers will be soon available for major heat tolerance QTL in some legumes which will further facilitate breeding for heat and drought tolerance. The latitudinal difference is very important in considering the productivity of pulses in Southeast Asian countries in the perspective of global climate change and accordingly strategies have to be made towards development of pulse varieties.

Introduction

Global climate change is driven by the rise in temperature caused primarily by anthropogenic activities, including indiscriminate burning of fossil fuels, which leads to increases in the CO_2 level in the atmosphere along with other greenhouse gases trapping the infrared radiation (heat) received from sun. This phenomenon is known as the greenhouse effect and is the primary cause of global warming. The rise in temperature is likely to threaten food security of South Asian countries, including India, as these parts of the world are geographically located in areas that have been declared as most vulnerable to climate change. India, Pakistan, Bangladesh, Nepal, Bhutan, Myanmar and other Southeast Asian countries are producing about 50 percent of total world pulses.

Climate change projections indicate that agricultural productivity in Indonesia, the Philippines, Thailand and Viet Nam may decrease from 2020 onwards. Asian countries like India, Pakistan, Bangladesh, Myanmar, Bhutan, Nepal, China, Lao PDR, Sri Lanka, Viet Nam and Cambodia grow pulses and consume them in different forms. These are the countries that suffer from malnutrition to a great extent and pulses remain one of the important dietary components for cheap protein. Among these countries, India is both the largest producer and consumers of pulses. The major pulses grown in India and Southeast Asian countries include chickpeas, pigeonpeas, greengrams, blackgrams, lentils, soybeans, field peas as major pulses, whereas cowpeas, horse grams, faba beans, kidney beans, rice beans and Adjuki beans are minor pulses. Among those pulses, chickpeas, pigeonpeas, lentils, cowpeas, horse grams have better tolerance to drought compared with greengrams, blackgrams and field peas.

Asian pulses are highly vulnerable to climate change because they are grown under rainfed conditions in high temperature zones due to their proximity to equator. These countries are densely populated and the majority of the pulse growers are poor and have marginal land holdings.

Drought and high temperature both have become recurrent events during the present climate change scenario. Agriculture is the foremost victim of climate change as the productivity of important food crops is largely dependent upon the availability of water. Rainfed pulses are expected to suffer with severe water crisis owing to delayed monsoons, uneven distribution or the complete failure of rains. Rainfed agriculture is particularly vulnerable as rainfed crops are predominantly dependent upon rainfall and failure or scanty rain often leads to very poor productivity. As rainfed crops, vulnerability of pulses to climate change is higher and more severe because heat stress during the reproductive phase is often combined with terminal drought. Thus, reduction in yields is often more pronounced and the damaging effects of both stresses are far more severe than their individual effects.

A parallel increase in CO_2 gas and temperature has been observed during the past two decades. An average surface temperature may increase by 5ºC with doubling of CO_2 concentration in the atmosphere. The rate of increase of CO_2 is about 2 µmol mol^{-1} per year and is expected to reach up to 670 µmol mol^{-1} by the end of this century. It is projected that if carbon emissions are not regulated globally, the atmospheric CO_2 level may become almost double (670 µmol mol^{-1}) from the present level of 380 µmol mol^{-1} by the end of this century, consequently, temperature is to rise between 3.5 and 5ºC. As is evident, the rise in the global temperature would influence the hydrological cycles due to change in the land and sea surface temperature, deviation of monsoons, erratic, scanty or often heavy rainfall changing the pattern of rainfall distribution and accelerating melting of polar ice causing a rise in the water level of the sea leading to an increase in the salinity of the long stretched coastal agricultural field. The most vulnerable areas are the arid, semi-arid, and dry sub-humid regions where pulses are grown. In lower latitudes, even small amounts of warming will tend to decrease yields.

In many parts of South and Southeast Asia, pulses are already being cultivated near their maximum temperature tolerance 35–40ºC. Under rainfed conditions, vulnerabilities are still high and even moderate warming of 1ºC will reduce yields of pulses significantly. However, possible yield increases and precipitation have been predicted in regions of northern latitude where crops are usually grown under cool temperate conditions. Crop yields benefit from higher latitudes through longer growing seasons (IPCC, 2007).

Agricultural crops under mid-latitudes (north) may suffer from heat stress because of an increase in temperature above average and dryer summers with reduced yields as the net predicted result. The regions falling under north-mid latitude covering are already experiencing high summer temperatures often exceeding 35ºC. Most of the agricultural crops have a maximum temperature tolerance limit of 35ºC, beyond which anthesis and particularly reproduction process is adversely affected. Particularly, C_3 crops including pulses have a temperature tolerance limit for optimum physiological function within the range of 30–35ºC. Even Vigna groups of pulses green grams and blackgrams grown during summer are often exposed to high temperatures beyond 40–42ºC, which has overall detrimental effects on grain yield. The negative effects of high temperature is usually compensated for by irrigation lowering the canopy temperature, however, availability of water for pulses is very difficult in rainfed growing areas.

Temperature tolerance limit of pulses and genetic diversity

Genetic diversity has been exploited for development of cold tolerant varieties of pulses within the sub-optimal temperature range within 0–14ºC. However, temperature below 5ºC for longer period often becomes lethal for pulses. Foliage growth usually ceases or reduces in most of the winter pulses such as chickpeas, and lentils growing at low temperature range 6–15ºC. Most varieties of pulses are well adapted to optimum temperature range falling between 15 to 35ºC but can have the ability to tolerate up to a maximum limit of 45ºC, though with significant reduction of photosynthesis, chlorophyll content, decreased foliage growth and inducing massive pollen sterility with progressive increases in the temperature beyond 35ºC.

A temperature rise up to 42–45ºC even for a short period may induce forced maturity, leaf senescence, pollen sterility and causes failure of anthesis. Grain filling is adversely affected in young pods that recently set seeds exposed to high temperature above 42ºC and as a result further seed development abruptly terminates and such impaired seeds never restore to their normal conditions even when temperature becomes favourable afterwards. These immature seeds usually do not imbibe during water soaking and remain hardy. Most of the research efforts for improving heat tolerance in pulses are based upon exploitation of genetic diversity of heat tolerance withinthe temperature range between 36ºC and 45ºC.

Temperatures above 45ºC is considered to be lethal for most of the pulses as it causes irreversible physiological changes at cellular level, aggregation of macromolecules, massive destruction of the photosynthesis process leading to complete inhibition and no fertilization takes place at this extreme temperature. Perhaps no cultivar of pulses is reported to have tolerance beyond 45ºC. Genetic diversity rarely exists in such high temperatures except for some wild relatives that might possess tolerance a few degrees above the maximum tolerance level of 45ºC.

Occurrence of genetic diversity in pulses within the optimal temperature range 15–35ºC is very high indicating that irrespective of the origin of the pulses (temperate, sub-temperate, tropical, sub-tropical), the probability of adaptation is very high within the optimal temperature zone.

Dew precipitation for sustaining growth in cool-season pulses

Observations recorded over the last two to three decades in pulse growing areas of northern India revealed an astonishing fact about low dew precipitation. The dew precipitation in fact is gradually vanishing during winter as a result of high night temperature. Normal dew during December and January may contribute the equivalent of about 150 mm of rainfall which is considered to be quite adequate for rainfed pulses. The patterns of maximum and minimum temperatures also showed an unusual trend. There is an asymmetric increase in the temperature reflected in the steady increase of night time minimums compared with day-time maximums. This caused narrowing down the differences between day and night temperature and average temperature increased significantly and unfavourably affecting grain filling that usually takes place during relatively low temperature at night. The simultaneous increase in average temperature is expected to hasten the maturity and shorten the crop duration. Cool-season legumes will be subjected to severe atmospheric drought and may likely to require supplemental irrigation if present trends continues. Climate change may alter both distribution and frequency of rainfall and may likely increase the number of heavy rainfall and decrease the number of rainy days. Rise in mean surface temperature is likely to cause a 70 percent decline in summer rainfall by 2050. Scanty rainfall in some areas may lead to increased demand for irrigation water because of evaporative losses affecting rates of decomposition of organic matters and release of nutrients and decline of soil fertility. About 2.5 billion people in South Asia are likely to be affected by water scarcity by 2050 (UNDP 2006).

Rising temperature, changing precipitation and more extreme weather events lead to low water availability impacting hydrological cycles of evaporation and precipitation. This will drastically affect agriculture production in a region where over 60 percent of the agriculture is rainfed, such as in India. On the other hand, climate change can also increase the occurrence of floods. Southern Asia's increased temperatures resulted in diminished precipitation. Increased temperatures may cause longer-lasting droughts. Large areas in South Asia are currently experiencing water deficits. Changing patterns in the monsoon are a threat to agriculture, food security, and the overall economy. The onset of the summer monsoon in India is getting delayed and disturbed. This affects crop cycles and cultivation in rainfed areas.

Will pulses be benefitted by CO_2 rise in the atmosphere?

Crop response to high CO_2 in the atmosphere varies among crop species. It is generally believed that CO_2 fertilization may improve photosynthesis in crop species. However, increased photosynthesis under higher CO_2 concentrations has been often observed under optimum temperature and light if the plant is not experiencing any stresses. For the majority of the pulses grown in rainfed conditions, water stress is a recurrent phenomenon and pulses may not benefit from increased CO_2 levels due to the combined effects of terminal drought and heat stress during the reproductive phase. In countries geographically located in northern mid-latitudes, such as India, Pakistan, Bangladesh, Myanmar and other Southeast Asian countries, the day-time temperature is already exceeding 35ºC during the reproductive phase and further temperature rises due to global warming may be likely to reduce yield to a considerable extent. High temperatures above 35ºC often combined with low soil moisture result in reduced grain yield in most of the regions closer to the tropics. On the contrary, pulses grown in northern latitudes where temperate climate prevails, temperature rises along with CO_2 may be beneficial for the pulses as the threshold tolerance limit of 35ºC–40ºC has not yet been crossed.

Nitrogen fixation ability of pulses at higher temperature

Another important issue related to climate change-induced temperature rise is a reduction in the biological nitrogen fixation (BNF) by legumes. N-fixation is very sensitive to high temperature and almost ceases beyond 35ºC. Nodule growth is adversely affected during podding stages coinciding with high temperatures. It has been reported that the occurrence of nodule formation and BNF is adversely affected beyond 35ºC, therefore, a lack of nitrogen in the leaves may lead to decreased protein content and also may likely enhance starch content in the seeds. Because pulses are efficient carbon sinks, high CO_2 and temperatures are likely to increase the content of starch and decrease that of protein in pulses. About 60 percent carbon and nitrogen reserve in leaf and stems in cool-season pulses support grain filling through post-anthesis remobilization under normal conditions. The proportion of carbon gain in seeds will be more over nitrogen due to low BNF activities resulting in reduced protein content in pulse grains.

There will be an overall decrease in the remobilization efficiency due to high night temperature. Leaf nitrogen content drastically declines at high temperature >37ºC. Nodulation and nitrogen fixation almost terminate at high temperature and the crop is subjected to nitrogen starvation, if nitrogen fertilizer is not added. Exogenous application may prove beneficial to improve yield under heat stress.

Abiotic stresses as influenced by climate change

Drought and heat stresses are major concerns influenced by climate change. Both these stresses are often superimposed on each other and reduce yield by more than 40 percent in pulses. These stresses a affect wide range of physiological processes and alter plant-water relationships (Summerfield *et al.,* 1984). Heat stress above 35ºC often causes irreversible damage to growth and development (Wahid *et al*. 2007). Cool-season legumes optimally function between the temperature range 15–35ºC, biomass growth and particularly reproduction are partially or completely arrested beyond 40ºC, though duration of exposure to high temperature has a profound effect on these physiological processes (Ali *et al.,* 2009 and Basu, 2010).

Grain legumes are ranked in the following order: mung beans > pigeonpeas > urd beans > chickpeas > lentils > rajmashs > fieldpeas for their tolerance to heat stress. Stategies have to be made to develop heat and drought tolerant varieties of pulses with improved yield for warmer climates based upon specific physiological attributes such as early flowering, short duration, vigorous root system and large seed size with quick biomass accumulation. In general, all pulses are highly sensitive to salinity and waterlogging. Frost and waterlogging are highly damaging for pigeonpeas. In fact, temperature extremes both higher and lower are more detrimental to pigeon peas in terms of flower drop. While, chickpeas, lentils and fieldpeas are more adapted to low temperature. Sensitivity of pulses to abiotic stresses is shown in Table 1.

Table 1. Sensitivity of different pulses to abiotic stresses

Crop	Climatic conditions	Sensitivity to abiotic stresses
Pigeonpeas Chickpeas Lentils	• Tropics to sub-tropics between 30ºN and 30ºS latitude • Rainfall 600–1 000 mm • Temperature 15–30ºC	Sensitive to water logging and temperature extremities both temperature below 7ºC and above 40ºC (pigeonpea) All these pulses, e.g. pigeonpea, chickpea and lentil have moderate to high level of drought tolerance with deep tap root, high water use efficiency (WUE) and osmotic adjustment (chickpea, pigeonpea, lentil) Estimated yield loss 40–60% (drought and heat combined)
Greengrams Blackgrams, Field peas, Rajmash	• Warm temperate and sub-tropical regions monsoon tropics; • Rainfall 600–1 000 mm • Temperature 20–40ºC	Moderate tolerance to drought Photoperiod sensitive/quantitative short day Low WUE ans photosynthetic rates Less drymatter and recover slowly after drought Deeper roots, short flowering & maturity Faster stomatal closure during drought Reduced growth & leaf expansion during drought Estimated yield reduction 20–45% due to high temp >40ºC

Response of different pulses to climate change

The reproductive parts and grain filling process are extremely sensitive to chilling and high temperature. The combined effect of heat and drought is more detrimental than the effects of drought and heat alone, as a result the productivity further goes down (Basu *et al.,* 2009). Pigeon peas, in particular, are highly sensitive to temperature fluctuations, causing massive flower drop, forced drying and bending of apical leaves when subjected to cold stress (<5ºC) (Basu *et al.,* 2009).

In greengrams, temperatures above 42ºC during summer causes seed hardening owing to incomplete sink development. Field peas are better adapted to low temperature than other winter pulses like lentils and chickpeas showing retarded growth below 7ºC. Daytime maximums beyond 40ºC during the reproductive phase in winter pulses results in complete failure of anthesis, pod setting and induces hardening of seeds. The failure of anthesis at high temperature is primarily caused by poor pollen germination, stigma receptivity, pollen load on stigma and ovule viability above 35ºC (Basu *et al*., 2009). Field peas are even more sensitive to high temperatures than chickpeas and lentils. A reduction in pollen germination occurs above 38ºC.

Physiological changes associated with abiotic stresses

Pulses are particularly sensitive to heat stress at the bloom stage; only a few days of exposure to high temperatures (30–35ºC) can cause heavy yield losses through flower drop or pod abortion (Siddique *et al.,*1999). Low biomass and forced maturity are the manifestation of high temperature in pulse crops. Biomass decreases significantly under short and warm winters, less dew precipitation, and high night temperature. The late flowering chickpea genotypes with low biomass often encounter sudden high temperature during anthesis. Short-duration varieties growing in central and southern zones of India do not encounter such contrasting temperatures. Short-duration bold-seeded chickpea genotypes, e.g. ICC 4958, Phule G5 bred for warmer southern zones of India have high biomass and deep root systems compared with the medium to late maturing chickpea genotypes KWR 108, C235 and Pant G114 bred in the northern plains of India (Basu *et al*., 2014). The deeper root system supports water extraction from deep soils to meet water requirements of high evapotranspiration demand under warm climates of South India while shallow rooting genotypes of northern India are equipped for faster and efficient water absorption from top soil layers saturated with dew precipitation (Basu *et al.,* 2007).

Seed size reduces with the majority of chickpea genotypes having reduced, shrivelled or deformed grains at high temperatures exceeding 35ºC. Critical temperature causing damage of reproductive organs was found to range between 35ºC and 40ºC, however, sensitivity varies among genotypes. Pollen germination in other crops has been reported to have higher vulnerability at high temperatures, and the degree of pollen tube growth is reduced significantly (Kakani *et al.,* 2005). Pollen germination in pepper is drastically reduced when grown at 38ºC compared with 25ºC (Kafizadeh *et al*., 2008). Brief exposure of chickpeas to high temperatures during seed filling accelerates senescence, diminishes seed set and weight and reduces yield (Siddique *et al.,*1999).

In pulses, remobilization of pre-anthesis reserve carbohydrates and nitrogen in leaves and stems contribute significantly towards grain filling. Therefore, biomass is the main factor determining grain yield in the majority of the pulses grown during winter season. Under climate change, a sudden rise in the temperature beyond 35ºC causes increased respiration rates and unusually high degradation of stored starch in the chloroplasts. The reduced or incomplete grain development could be partly due to an inadequate supply of carbon and nitrogen from leaves or by a decrease in the activity of sucrose synthase, the key enzyme for grain development.

Effect of high temperatures on physiological traits

Prolonged exposure to warm environment may likely deactivate the photoperiodic receptors causing a reduction of phenotypic plasticity and induction of early flowering, senescence and forced maturity, accelerated pollen sterility and eventual reduction of yield. High temperature is one of the factors causing enhanced crop respiration and transpiration rates along with reduced photosynthesis, as a result, loss of water and carbon is more accelerated than carbon gain through photosynthesis affecting overall biomass accumulation. There will be obvious effects of altered carbon metabolism on photosynthate partitioning to grain. Temperature rise in lower latitude regions accelerates the rate of respiration leading to sub-optimal growth. Higher daytime temperature accelerates plant maturity and results in reduced grain filling, while higher night temperatures increase yield losses due to higher rate of respiration. Extreme high and low temperatures cause physical injuries to crop plants and damage the grain. Injuries are inflicted by high temperatures on the exposed area of plants, scorching leaves and dehydrating the plant. Young seedlings dehydrate quickly when soil temperature rises. Episodic heat waves can reduce yields, particularly when they occur during sensitive developing stages, such as the reproductive phase which increases sterility. Higher levels of ozone in the lower atmosphere (troposphere) also limits crop growth.

Cellular membrane stability decreases at high temperature in cowpeas (Ismail and Hall, 1999). Exposure of (chickpeas and pigeon peas) to 35ºC for 24 hours reduced the membrane stability, but genetic differences in membrane stability is evident (Srinivasan *et al.*, 1996). Chlorophyll fluorescence (maximum quantum yield of PSII-Fv/Fm) indicates inhibition of thylakoid stability/ photochemical efficiency under heat stress in pigeon peas and chickpeas (Srinivasan *et al.* 1996). In common beans, high temperatures can affect nitrogen fixation and plasma membrane integrity (Shonnard and Gepts, 1994). In temperate legumes high heat stress affects structure and function of nodules whereas, it affects nitrogen fixation efficiency in tropical legumes (Bordeleau and Prévost, 1994). Even under moderate day/night temperatures (30/20ºC; in *Phaseolus vulgaris*) rapid degeneration of nodules occurs affecting the nitrogen fixing efficiency of the plant (Graham, 1979). The studies indicate that high temperatures affect root/shoot growth and cause damage to fruits/pods. Further, leaf senescence and abscission are increased under high temperature. In cowpeas, under warmer temperatures leaf area index increased and leaf death occurred sooner (Littleton *et al.,* 1979). Under heat stress conditions in legumes the amount of root mass produced is reduced, fewer lateral roots are observed and the roots produced are thin and unbranched (Bordeleau and Prévost, 1994). High soil temperature (38ºC) in groundnuts reduces dry matter accumulation and seed mass coupled with decreased flower production. The fluorescence images of heat sensitive chickpea genotype ICC 10685 showed complete inhibition of photosynthesis at 43ºC, while heat tolerant genotype ICCV 92944 showed reduced photosynthesis but leaf remained photosynthetically active even at 43ºC. Similarly, the heat tolerant chickpea genotype ICCV 92944 showed the lowest membrane injury when subjected to high temperature and sensitive line ICC 10685 had the maximum injury.

Particularly, male reproductive organs development is more prone to high temperature damage compared to the female (Monterroso and Wien 1990). A reduction in number of flowers borne (Laurie and Stewart 1993) and the duration of flowering and pod filling (van Rheenen, 1997) was observed in chickpeas under high temperature. The heat stress causes reduction in pod set by reducing pollen viability and pollen production per flower (Devasirvatham *et al.*, 2012) in chickpeas. The pollen of heat tolerant chickpea genotype (ICCV 92944) was viable at 35/20ºC (41 percent fertile) and at 40/25ºC (13 percent fertbile), whereas the pollen of heat sensitive genotype (ICC 5912) was completely sterile at 35/20ºC with no *in vitro* germination. However, the stigma of the sensitive genotype (ICC 5912) remained receptive at 35/20ºC and non-stressed pollen

(27/16ºC) germinated on it during reciprocal crossing. These data indicate that pollen grains were more sensitive to high temperature than the stigma in chickpeas.

Both anthers and pollen showed more structural abnormalities under stress such as changes in anther locule number, anther epidermis wall thickening and pollen sterility, rather than function (e.g. *in vivo* pollen tube growth). The critical temperature for pod set was ≥37ºC in heat tolerant chickpea genotypes (ICC 1205 and ICC 15614) and ≥33ºC for heat sensitive chickpea genotypes (ICC 4567 and ICC 10685). In mungbeans, high temperature increases flower shedding (Sinha, 1977) and pollen sterility and dehiscence of anthers in cowpeas (Hall, 1992,). Heat stress affects flower initiation, flowering, pollen formation, fertilization and pod set/development in common beans (Shonnard and Gepts, 1994) and pea (Guilioni *et al*., 1997). High night temperatures affect pod and seed set in common beans, lima beans and cowpeas (Shonnard and Gepts, 1994).

Development of climate resilient varieties in pulses

Precision phenotyping and multilocation field trials at hot spots across different agro-ecological zones

Screening of pigeon pea germplasm showed wide variability in osmotic adjustment (OA) ranging between 0.2 and 1.6 MPa or even higher, 5.0 MPa for wild pigeonpeas. A number of varieties have been identified showing high osmotic adjustment under drought. These are VKS11/24-1, TGT-501, Bennur local, JKM-7, BDN 2008-12, VKS11/24-2, RVK-275, AL-1855, ICP-13673, AL-201, GRG-2009-1, ICP-84031, MAL-13, BSMR-853, Bahar, GRG-815, BDN 708. These genotypes are well adapted to drought condition. A large number of genotypes from diverse genetic resources of pulses have been identified as tolerant to multiple stresses. Among these, wild progenitors of various pulses were found to possess very high levels of tolerance to drought and heat or both combined. Combined tolerance to heat and drought has been identified in wild accessions of pigeonpeas *Cajanas scarabaeoides* Wild accession ICP 15671 had very high osmotic adjustment with pod setting ability at 40ºC

A majority of the blackgram and greengram genotypes are lacking osmotic adjustment and thus remain sensitive to drought. Few blackgram and greengram lines showed osmotic adjustment to the maximum extent up to 0.4 MPa. These genotypes are PKG-U03, STY 280-1, GP-15, PGRU 95016, IPU-90-32, IPU-06-12, UH-85-5, UH-85-13, PLU-110 of blackgram, and Ganga 8, HUM-1, ML 5 of greengram. Very little or lack of osmotic adjustment ability causes less tolerance to drought in blackgram and greengram and thus require irrigation. The wild relatives of pulses are the potential sources for gene mining for heat and drought tolerance due to the following reasons.

- Wild and extant varieties could have traits tolerant to high temperature/elevated CO_2.
- They might have been discarded in the past because of low yield potential.
- They can be used as parents for breeding of varieties tolerant to climate change.
- There is need for revisiting gene banks with a view to searching for unique traits required for climate change.
- Indigenous knowledge and farmers' wisdom has immense value.

Short-duration drought-tolerant cultivars: *Answer to reduced duration due to climate change*

Strategies to address climate change impacts

- Develop cultivars tolerant to heat, salinity, flood and drought stresses;
- Modify crop ,water and pest management practices;

Table 2. Some promising varieties of pulses tolerant to high temperature

Crop	Variety	Duration (day)
Pigeonpeas	T-21	176
Groundnuts	Vemana	105–110
Soybeans	JS-90-41	87–98
Chickpeas	JG-14	90–100

- Adopt resource-conserving technologies.
- Diversification of cropping.
- Better weather forecasting.

Heat stress management

Screening for heat tolerance and identification and development of heat tolerant genotypes

Delayed sowing synchronizing the reproductive phase of the crop with occurrence of higher temperatures (≥35°C) was proposed for screening chickpea genotypes for tolerance to heat (Gaur *et al.,* 2007). A screening of 180 genotypes at Patancheru, and Kanpur India during 2007/08 revealed large genotypic variation with significant variations for heat tolerance index (HTI) in chickpeas (Krishnamurthy *et al.,* 2011). The genotypes that showed high heat tolerance over best known heat tolerant line ICCV 92944 included ICCV 07104, ICCV 07105, ICCV 07110 and ICCV 07115. Experiments conducted at ICARDA in collaboration with its NARS partners of India have identified heat tolerant faba bean, chickpea and lentil genotypes. Similarly, testing in Sudan with full irrigation facilities identified FLIP87-59C, also resistant to drought, as a heat-tolerant genotype. In lentils, ICARDA is targeting genotypes with rapid ground cover, early phenology, a prolonged flowering and podding period leading to increased dry matter production, more pods, high harvest index, efficient water use and large seeds to adapt to heat stress.

Most of the progress in breeding for terminal heat escape has been made in development of short-duration varieties such as Precoz, Idleb 3, Bakaria, BARI M4, BARI M5 and BARI M6 without compromising yield level. In lentil, evaluation of germplasm under delayed planting with and without irrigation resulted in presumptive identification of genotypes tolerant to heat (ILL 3597, Sel #33108, 33109, 33110 and 33113) and drought (ILL1878, ILL 6002, ILL 759 and ILL 6465). Three heat tolerant genotypes of lentil, IG4258, FLIP2009-55L and IG2507 were identified through delayed planting that exposed the crop reproductive phase to high temperature >37°C under irrigated conditions. (Kumar *et al.,* 2014).

In chickpeas, development of recombinant inbred lines (RILs) is in progress at ICRISAT for mapping of quantitative loci (QTL) controlling heat tolerance. The phenotypic and genotypic data available on the reference set are being used for association mapping (Thudi *et al.,* 2014).

In mungbeans, extra early maturing genotypes (IPM 205-7 and IPM 409-4), which mature in 46–48 days, have been developed at the Indian Institute of Pulses Research (Pratap *et al*. 2013). These genotypes when grown during summer will save two irrigation and one insecticide spray and better suited to growing at high temperatures.

A high degree of pollen sterility was observed in pigeon peas at temperatures exceeding 38°C. Similarly frost and low temperature cause significant damage to the standing field crop of pigeon peas. One hundred fifty minicore collections of pigeon peas, 85 medium and long duration lines and 35 early duration lines were tested at different hot spots (Ludhiana, Kanpur, Badnapur, Khargone and Gulbarga) under NICRA project of India. Phenotyping for high temperature tolerance was developed based upon variable fluorescence and imaging. These tolerant genotypes were WRP-1, JKM-7; ICP-8700; JKM-189; MAL-13; ICP-995; BSMR-736; and NDA-1. Some promising wild derivatives of *C Scaraboeides* were identified which flowered and set pods at 40/20ºC max/min temp and low soil moisture. Therefore, combined tolerance such as foliar resistance based upon variable fluorescence and reproductive tolerance, e.g. pollen viability and in-situ germination proved essential criteria for selection.

Wild accessions of *Vigna* are maintained in the gene bank of IIPR, India. Photo-insensitive and thermo-tolerant greengram genotypes setting pods at 43/25ºC max/min temperature and 11 and 16 h daylength have been identified. These are IPM 02-3; MH 3-18: Ganga 8; TARM 1; ML 1257; Copergaon; HUM 1. Vigna accessions were evaluated and characterized based on 37 morpho-physiological traits. Two extra early greengram genotypes IPM 409-4 (INGR 11044) and IPM 205-7 (INGR 11043) have been developed. These genotypes are useful for summer cultivation and ideal for intercropping in crops like sugarcane that can avoid terminal heat stress; due to early harvesting they can save 1-2 irrigations and also save 1 insecticide spray.

Photoperiodic response, a high yield stabilizing factor or stress

Pulses are considered to be highly sensitive to photothermoperiods. Sensitivity to photo- and thermoperiods is the major factor responsible for high genotype × environment (G × E) interaction, and yield instability of major pulses across different environments. Therefore, development of photo-and thermo-insensitive genotypes had been the primary requirement to address climate risk. The severity of these stresses is unpredictable in field experiments, so multilocation field trials are increasingly supplemented with controlled-environment testing and physiological screening. Blackgrams, greengrams and pigeon peas are known to be thermo- and photosensitive crops. They are grown in areas where day length varies from 11 to 14 h and large differences in temperature are experienced, largely due to variations in altitude and latitude.

Field studies have been conducted in pigeonpeas with different maturity durations (extra-early, early, medium and long durations) in Kenya to determine the effect of photoperiod and temperature on flowering. It has been found that the extra-short duration genotype 'ICPL 90011' was the least responsive to variation in photoperiod, while the two long-duration genotypes 'ICEAP 00040' and 'T 7' were the most sensitive to photoperiod. In chickpeas , ICCV 960029 and ICCV 960030 have been identified as photothermoinsensitive. Generally, chickpea varieties originated from south and central zones of India are relatively photothermoinsensitive contrary to those originated from the north.

Sources of heat tolerance

Sources of heat tolerance have been identified in some legumes by exposing the crop to high temperatures at reproductive phase. Efforts are being made to understand mechanisms and genetics of heat tolerance. The extensive screening of germplasm for heat tolerance across chickpea germplasm indicates large genetic variation in heat tolerance (Krishnamurthy *et al.,* 2011) that can be used in the breeding programmes for development of heat tolerant varieties. Several thermo-tolerant chickpea lines, e.g. ICC 1205, ICC 15614, ICC 8950 have also been identified. A heat tolerant chickpea variety JG 14 has been released for late sown condition in India and Myanmar (Gaur *et al.,* 2010, 2014). Improving reproductive stage tolerance through selection and short-duration varieties escaping terminal heat and drought should be the primary goal to develop climate resilient pulses.

Under ICAR, India sponsored the programme National Initiative on Climate Resilient Agriculture (NICRA), ACIAR and DAC funded projects, a large number of pulse genotypes were identified based upon multilocation trials and controlled environments showing tolerance to drought, heat, water-logging, frost and insensitive to photo-thermoperiods. For example, drought tolerant chickpeas identified are RSG 888, PG5, BGD 72, Vijay, PG 96006, ICC 4958, Tyson, Katila, K 850 (Basu *et al.,* 2007; Jha *et al.,* 2013).

Similarly, thermotolerant and photoinsensitive genotypes in blackgrams, e.g. PGRU 95016, IPU 99-89, IPU 94-1, IPU 99-79, BGP-247; thermotolerant genotypes in greengrams e.g. IPM 02-3, IPM 02-10 and PM-5 were identified and photo-and thermo-insensitive lines in wild *Vigna* species included *V. glabrescens* (IC 251372), *V. umbellata* (IC251442) (Pratap *et al.,* 2014).

Some wild accessions of pigeonpeas (*C. Scaraboeides)* showed combined tolerance to drought and heat. Sources of drought resistance in pigeonpeas were explored in wild species *C. Sericious, C. Scarabaeoides and C. Aquitifolius* based *on* osmotic adjustment. Some of these wild sps showed very high osmotic adjustment (OA) up to 2.5 MPa. Out of fifty pigeonpea genotypes from ICRISAT evaluated at Ludhiana, Kanpur, Khargone, Badnapur and Gulberga, the lines, namely BDN 2008-1, Bennur Local, ICP1156, BDN-2008-12, TJT501, GRG2009, ICP995, ICP4575 and ICP14832 appeared superior at pod filling stage under rainfed conditions likewise, ICP1126, JKM7, JKM189 and ICP4575 appeared better in rainfed at Badnapur.

Drought stress management in pulses

Pulses, in general, consume very little water compared with cereals and vegetables. However, if heat tolerant pulses are developed, the water requirement of these genotype has been estimated to be about 5-6 times higher to attain the same amount of biomass as under normal temperature. Each 1°C increase in the average temperature will require 20–25 percent more water and nitrogen to meet the crop demand for water and nitrogen. A concept has emerged that suggests that elevated CO_2 may improve water use efficiency (WUE) in grain legumes. Climate change-driven high carbon gain per unit availability of water enables faster dry matter accumulation, hence WUE of all cool-season pulses may dramatically increase. However, benefits of high WUE cannot be derived due to shortening of crop duration and adverse effects of high temperature that induces pollen sterility.

Biomass has been found to be the most sensitive to water stress. Leaf expansion is affected even under mild water stress with a leaf water potential declined to ≤1.2 MPa. The biomass showed a linear relationship with yield under rainfed indicating source (leaves and stems) are the major limiting factor for low yield. Field screening for drought tolerance is largely based upon drought susceptibility index. The genotypes which showed low yield relative to its rainfed counterpart, had higher drought susceptibility index (DSI). The lower the DSI, the greater was the drought tolerance of the line. The line-source sprinkler technique was used to compare moisture responses of a range of chickpea lines grown on receding soil moisture which showed a linear response of both aerial biomass and grain yield to moisture applied (Johansen *et al*., 1994).

Matching phenology and early biomass accumulation, dehydration postponement, root characteristics, osmotic adjustment, lethal leaf water potential, membrane stability, proline accumulation, water use efficiency are some of the potential traits identified for selecting drought tolerant lines in pulses. The phenology to the water supply with early biomass and setting of reproductive organs before onset of terminal drought is largely considered a drought escape mechanism. In environments in which terminal drought is likely, selection for shorter time to flowering has been highly successful (Subbarao *et al*., 1991).

The postponement of drought by reducing water loss by reducing transpiration or by reduction in the stomatal density and an increase in the leaf reflectance through production of glandular hairs in chickpeas are considered to be adaptive traits through which leaves reduce water loss and intercepted non-photosynthetic radiation.

Anatomical differences in pod wall imparts tolerance to drought in blackgrams. Waxy cuticle above the epidermis along with high density tall pod wall hairs prevent moisture loss and the pod wall remains photosynthetically active under drought. Pod wall photosynthesis is independent of plant water status.

A wide genetic variability among root characters such as density and depth, total root biomass has been reported in pulses. Kashiwagi *et al*., (2005) have identified lines of chickpeas with increased drought tolerance through increased root biomass.

The degree of osmotic adjustment (OA) has also been shown to be correlated with yield under dry land conditions in pulses. Osmotic adjustment (OA) has been shown to maintain stomatal conductance and photosynthesis at low leaf water potential, delay leaf senescence, reduce flower abortion and improve root growth and water extraction from the soil (Basu *et al.,* 2007). Intra and interspecies difference in osmotic adjustment and its range in grain legumes are given in Table 3. From the table it is clear that among pulses chickpeas, pigeonpeas and peanuts are tolerant to drought as compared to others. A significant genotypic variation in osmotic adjustment was observed in chickpeas (Basu *et al.,* 2007) and pigeonpeas (Subbarao *et al.,* 2000), greengram and blackgrams and this trait is being used for drought tolerance.

Table 3. Range of osmotic adjustment in grain legumes

Species (Pulses)	Range osmotic adjustment (M Pa) in leaves	Degree of dehydration postpontment	Species (cereals/ vegetables)	Range in osmotic adjustment (M Pa)	Degree of dehydration postpontment
Groundnuts	0.2 to 1.6	Very high	Sorghum	0.8 to 1.7	Very high
Pigeonpeas	0.1 to 1.3	High	Wheat	0.2 to 1.5	High
Soybeans	0.3 to 1.0	High	Barley	0.2 to 0.5	Moderate
Chickpeas	0.0 to 1.3	High	Maize	0.1 to 0.4	Moderate
Lentils	0.0 to 0.6	Moderate	Potato	0.0 to 0.25	Low/sensitive
Greengrams	0.3 to 0.4	Moderate	Lupin	0.1 to 0.5	Moderate
Blackgrams	to 0.5	Moderate	Fieldpea	0.0 to 0.4	Moderate
Cowpeas	0.0 to 0.4	Moderate	Faba bean	0.0 to 0.2	Low/sensitive
			Lathyrus	0.0 to 0.1	Low/sensitive

Table 4. Lethal leaf water potential for a range of grain legumes

Species	Crop	Lethal water potential (M Pa)	Dehydration tolerance	Important osmolytes that accumulate in plants during drought and salinity
Pigeonpeas	Legume	-7.0 to -8.2	Very high	Sucrose, Sorbitol, Pinitol, Mannitol, Glycerol, other polyols, Arabinitol, Proline, Betaine, Glutamate, Asparate, Glycine, Choline, Putrescine, Oxalate, Malate
Groundnuts	Legume	-3.4 to -8.2	Very high	
Soybeans	Legume	-5.0	High	
Mungbeans	Legume	-1.9	Moderate	
Cowpeas	Legume	-1.8	Moderate	
Sorghums	Cereal	-3.0	High	
Wheat	Cereal	0 to -2.0	Moderate	

The lethal leaf water potentials in a range of grain legumes are given in the Table 4. The lethal leaf water potential, i.e. the lowest water potential experienced by the last viable leaf, was a key measure of dehydration tolerance. this shows that soybeans have more dehydration tolerance than others.The ability of cells to continue metabolism at low leaf water status is termed dehydration tolerance. Membrane disorder is often measured as leakage of solutes from the cell. Electrolyte leakage measured by conductivity meter has been used as a screening technique for heat and dehydration tolerance. Accumulation of proline in cell in response to water deficit is another mechanism protecting protein structures as cell dehydrate, and as an organic nitrogen source.

Significant genetic variation was observed in water use efficiency WUE among the chickpea genotypes. Kashiwagi *et al.,* 2006) reported highly significant relationship between Δ^{13} C and transpiration efficiency (TE) in chickpeas. The method can be applied to large scale screening of pulses for higher water-use efficiency with less time and more precisely. Indian chickpea cultivars e.g. RSG-143-1 and Vijay have been identified to have high water-use efficiency. WUE can be regarded as a very potential physiological trait for crop improvement. Chickpea lines ICC4958 and FLIP87-59C and faba bean line ILB938 have demonstrated good drought tolerance parameters in different experiments (Stoddard. *et al*., 2006). Thus increased WUE may have tremendous impact on crop growth and grain yield under drought. Water use efficiency in terms of gaseous exchange of plant is represented by the following formula.

WUE = Photosynthesis/Transpiration = Photosynthesis/Stomatal conductance

There is a clear relationship between the amount of water transpired and yield across a diverse range of crop species. Water and soil resource being limited, the only options for increasing biomass production in pulse is to increase the water use efficiency (WUE) i.e. more biomass per unit of water. Passioura (1977) defined that grain yield is the simple function of transpiration, water use efficiency and harvest index (HI)

Yield = Transpiration X WUE X HI: Where, WUE = Water-use efficiency; HI = Harvest index

Improving drought tolerance in pulses

Physiological traits imparting tolerance to drought form the basis of selection of drought tolerance in pulses. Pulses require very less water as compared to other crops, therefore pulses are well adapted to water-limiting environment. Extensive attempts had been made for the past several decades to improve drought tolerance in pulses for further minimizing water requirement under rainfed situation. Drought tolerance rating or sensitivity of pulses are as follows: lathyrus> horsegrams>cowpeas>pigeonpeas>chickpeas>lentils>greengrams>blackgrams>fieldpeas> rajmash. Among pulses, drought tolerance levels are very high in pigeonpeas allowing the crop to grow more in dry situations as lethal leaf water potential is very high (Table 4).) The lethal water potential is defined as the water status of the leaf at the point where the plant cannot survive any longer. Comparative studies showed that turgor loss in pulses occurs at much lower leaf water potential than wheat and potato indicating the high tolerance of pulses to drought.

Two wild accessions of *Vigna* were identified as photo-thermo insensitive (Pratap *et al.,* 2014). These include one accession each of *V. glabrescens* (IC 251372) and *V. umbellata* (IC 251442) based upon viable pollen and normal pollen tube formation, podding and seed set at high temp up to 44ºC and low temp. up to 4.4ºC. Distant Hybridization Programme for climate resilience in mungbeans was initiated. Photothermoinsensitive & thermotolerance genotype in blackgram PGRU 95016 has been identified which is characterized by flowering at both 10 and 16 h photoperiod; flowered at both 25/15 and 36/20ºC max/min temp regimes and has the ability of pollen germination at 43ºC.

Table 5. Some pigeon pea genotypes/cultivars tolerant to abiotic stresses

Abiotic stress		Cultivars/genotypes	Tolerance mechanism	References
Moisture stress	Water-logging	ICPL 84023 (early) Asha (medium)	Lenticel development, more root biomass and adventitious roots	Sarode *et al.* (2007)
	Drought	LRG 30, ICPL 85063, ICPL 332 (medium)	High RWC, pod/plant and HI, osmotic adjustment	Reddy (2001)
Temperature stress	Low temperature	IPA7-2, Bahar, MAL 19 (Late)	Ability to flower and pod setting at low temperature	Choudhary (2007); Singh *et al.* (1997); Singh and Singh (2010)
Mineral stress	Salinity	C 11, ICPL 227, WRP 1, GS1, TS3 (medium), UPAS 120 and ICPL 151 (early)	Reduced translocation of Na and Cl from root to shoot	Chauhan (1987); Promila and Kumar (1982); Subbarao *et al.* (1991); Asraf (1994); and Karajol and Naik (2011)
	Aluminium toxicity	IPA7-10 and T7 (late), 67 B and GT 101E (early)	Aluminium exclusion	Choudhary *et al.* (2011)

Based on multilocation evaluation at Vamban (Tamilnadu) and Durgapura (Rajasthan) in India, the 12 promising genotypes identified in greengram (IPM 02-16, IPM 9901-10, IPM 409-4, IPM 02-3, PDM 139, IPM 02-1, IPM 2-14, IPM 9-43-K, PDM 288, EC 470096, IPM 2K14-9, IPM 2K14-5) which have been confirmed to be tolerant to heat and drought. Based upon sucrose synthase activity and protein profiling, a few promising greengram lines were identified as heat tolerant which are presently under field trial across diverse agroclimatic zones. These genotypes are PDM 139 (Samrat), IPM-02-1, PDM 288, IPM-05-3-21, ML-1257.

Cold stress and frost tolerance

For frost tolerance, an efficient controlled-environment procedure involves exposing hardened pot-grown plants to sub-zero temperatures. Faba beans Cote d'Or and BPL4628 as well as lentil ILL5865 have demonstrated good freezing tolerance in such tests (Stoddard *et al.*, 2006). Low temperature leads to conversion of intracellular water into ice and consequently shrinking of cells and wilting and death of plants. Pigeonpea genotypes IPAC76, IPAC77, IPAC78, IPAC80, IPAC85, IPAC114, IPAC127, IPAC245 CP246, Amar, IPA16F showed less flower and pod drop in peak winter compared to other long duration pigeonpeas. Five germplasm lines exhibited less damage to frost in a low lying areas. Visual observations on flowering and pod development indicated that IPAC234 and IPAC114 have better recovery.

Chilling-tolerance tests are more commonly conducted in the field and lentil line ILL1878 as well as derivatives of interspecific crosses between chickpeas and its wild relatives have repeatedly shown good results. The timing of chilling is particularly important as temperatures which are not lethal to the plant can greatly disrupt fertilization of flowers (Stoddard *et al*., 2006).

Tolerance to waterlogging

Flooding situations may arise due to heavy rains in some of the areas under the present climate change scenario. Pulses are very sensitive to flooding. Water logging affects plant growth by reducing the oxygen diffusion rate between soil and atmosphere and by changing physical and chemical properties of the soil. Pigeonpeas [*Cajanus cajan* (L.) Millsp.] are a waterlogging-sensitive legume crop. Water logging tolerance can be evaluated using paired hydroponic systems, one oxygenated and the other de-oxygenated. The development of lysigenous cavities or aerenchyma in roots, common in warm-season legumes, is reported in peas and lentils but is not well established in chickpeas or faba beans. The antioxidant enzyme activities in two pigeonpea genotypes viz., ICPL-84023 (waterlogging resistant) and MAL-18 (waterlogging susceptible) were compared. Waterlogging treatment significantly increased hydrogen peroxide accumulation and lipid peroxidation, which indicated the extent of oxidative injury posed by stress conditions. Enzyme activities of peroxidase (POX), catalase (CAT), ascorbate peroxidase (APX), superoxide dismutase (SOD) and polyphenol oxidase (PPO) increased in pigeon pea roots as a consequence of waterlogged conditions, and all the enzyme activities were significantly higher in waterlogged resistant line ICPL-84023 than in sensitive line MAL-18. Higher antioxidant potential in ICPL-84023 as evidenced by enhanced POX, CAT, APX, SOD and PPO activities increased capacity for reactive oxygen species (ROS) scavenging and indicated a relationship between water logging resistance and antioxidant defense system in pigeonpeas (Bansal and Srivastava, 2012). Five pigeonpea lines, namely NA1, IPAC 79, IPAC 42, IPAC 76, LRG30 showed relative tolerance against water logging in the initial growth stage as compared to sensitive genotype ICPL7035.

Salinity tolerance

Haryana, Gujarat and some of the coastal belt of India are highly affected with salinity and the problem will be further aggravated in the present climate scenario. Salinity response can be determined using hydroponic methods with a sand or gravel substrate and rapid, efficient scoring is based on leaf symptoms. Many lines of chickpeas, faba beans and lentils have shown good salinity tolerance. Karnal chana CSG 88101 has been identified as a salt-tolerant chickpea variety suitable for moderate saline and alkaline areas (Dua, 1998). Soil salinity affects pigeon pea plants through osmotic stress and interference with uptake of mineral nutrients. It has been suggested that development of greengram genotypes with drought and salinity tolerance, which can retain large number of flowers with productive pods during high temperature (>40^oC) are prerequiste to increase greengram production in India (Singh and Singh, 2011). Salt tolerance of Pigeonpeas (*Cajanus cajan* (L.) Millsp) was assessed in local pigeonpea, ICPL-151 and ICPL-850014. The tolerant accession, ICPL-151 accumulated significantly lower shoot and root Na+and shoot Cl^-. The better performance of ICPL-151 under saline conditions seems apparently due to accumulation of less Na+ and more K+ and K/Na ratio and higher concentration of proline, free amino acids and soluble sugars than the other two accessions (Waheed *et al.,* 2006).

Molecular characterization

Molecular marker analysis was done in 58 genotypes of *Vigna* including 50 wild accessions and four standard check cultivars each of greengrams and blackgrams.These genotypes were subjected to SSR screening using already reported 87 primer pairs from *Phaseolus*, adzuki bean, mungbean and urdbean background. Till now, 52 SSRs have been screened for diversity analysis in all 58 accessions among which 40 were found polymorphic while 12 were found monomorphic Prebreeding was initiated on the basis of information generated (Pratap *et al.,* unpublished).

Drought specific genes, Dreb 1A, Dreb 1B and Osmotin are being used for developing drought tolerant chickpeas and pigeonpeas. Drought Specific signal molecules ABA and its role in drought tolerance have been characterized. Identification of linked QTL's for root and high yield (MAS) opened new hope in the field of drought research. Rapid advancements in genomics provide an opportunity for molecular mapping of quantitative trait loci (QTL) controlling heat tolerance and using marker-assisted breeding for development of heat tolerant varieties with suitable agronomic background and desired seed traits. Molecular markers will be soon available for major heat tolerance QTL in some legumes which will further facilitate breeding for heat and drought tolerance.

Conclusion

Pulses are largely drought tolerant crops and are well adapted to rainfed situations requiring little conserved soil moisture to sustain and produce reasonably good yields. However, inadequate rainfall under water-limited rainfed areas often threaten pulses, which leads to substantial loss of grain yield. The drought tolerance characters of pulses are well characterized and genotypic variability of the drought tolerant morpho-physiological traits have been established. Root-based traits are being used to improve drought tolerance in major pulse crops. However, yield stability of pulses requires less genotype × environment interaction and wider adaptability across the environment. The physiological trait such as water use efficiency is considered to be the most important to contribute to grain yield and biomass under drought conditions. A large pool of pulse germplasm is available which needs to be evaluated for drought tolerance and high water-use efficiency.

Rapid screening for water-use efficiency in a large number of germplasm is now possible using the carbon isotope discrimination technique. In addition to physiological and breeding approaches to enhancing yield, efficient agronomic practices need to be evolved to minimize the irrigation water and conserve soil moisture to increase the water productivity. Phenotypic plasticity, i.e. adjusting flowering time (daylength and temperature) is one of the best strategies for adaptation of pulses in diverse climates. This needs to be properly exploited to develop many short-duration varieties. To improve pulse productivity in the present scenario, gene mining for tolerance to abiotic stresses, restructuring plant types for climatically vulnerable regions (Singh, 1997), changing cropping patterns, efficient nutrient and water management, seed bank for alternate legume crops, watershed management, microirrigation facilities are some of the better options to address climate change. Studies on physiological mechanisms and genetics of heat tolerance and identification of molecular markers and candidate genes for heat tolerance are in progress and would help in developing more efficient breeding strategies for heat tolerance in grain legumes. In the background of climate change, irrigated pulses are also affected adversely and yield loss is projected. Chilling temperature, frost, water-logging and salinity are increasingly becoming hidden threats which need to be addressed immediately.

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Importance of pulses as a source of nutrition in Asian Region

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Abstract

Pulses represent one of the most important food categories that have been extensively used as staple foods as well as part of healthy, balanced diet to meet basic protein and energy needs. Pulses have a unique nutritional profile – low-fat source of digestible protein, (typically containing about twice the amount of protein found in whole grain cereals like wheat, oats, barley and rice), dietary fibre (containing both soluble and insoluble fibres), complex carbohydrates, resistant starch and low glycemic index and a number essential vitamins and minerals such as iron, potassium, magnesium, zinc and selenium.

Pulse carbohydrates are slowly digested which allows some of the lowest Glycemic Index (GI) among carbohydrate-containing foods. Pulse GI typically ranges from about 29 to 48 (using glucose as the standard). The relatively slow digestibility and hence low GI of pulses has been attributed to several constituents, including carbohydrate composition, protein content and protein-starch matrix, and antinutrient factors such as enzyme inhibitors (e.g. amylase inhibitor, trypsin inhibitor), phytates, lectins, saponins, and tannins. Pulses are also particularly abundant in B vitamins including vitamin B9 (folate), thiamin and niacin. In addition to contributing to a healthy balanced diet, pulses contain a number of bioactive substances, including enzyme inhibitors lectins, saponins, phytates, oligosaccharides, and phenolic compounds which make them particularly helpful in the fight against some non-communicable diseases often associated with diet transitions and rising incomes.

Enzyme inhibitors can diminish protein digestibility, and lectins can reduce nutrient absorption, but both have little effect after cooking. Phytic acid can diminish mineral bioavailability. Some phenolic compounds can reduce protein digestibility and mineral bioavailability, and galactooligosaccharides may cause flatulence. On the other hand, same compounds may have protective effects. Phytic acid exhibits antioxidant activity and protects against DNA damage, phenolic compounds have antioxidant and other important physiological and biological properties, and galactooligosaccharides may elicit prebiotic activity. Encouraging awareness of the nutritional value of pulses can help consumers adopt healthier diets and also could be an important dietary factor in improving longevity.

Introduction

Pulse crops represent an important component of agricultural food crops consumed in developing countries and are considered a vital crop for achieving food and nutritional security. They are ideal crops for reducing poverty, improving human health and nutrition, and enhancing ecosystem resilience. Globally, the harvested area under pulse crops is about one-tenth of the harvested area under all cereal crops and a high proportion of pulse area harvested is under rainfed-low input systems compared with cereal crops. Thus, in 2008, the average global yields of pulse crops (0.86 tonne/ha) was only about one-fourth of the average yields of cereal crops (3.54 tonnes/ha). On the bright side, over the past 14 years, the overall pulse production has increased at a rate higher than the growth rate in population both in developing and developed countries. On the demand side, over the past 14 years, a stable and modest positive trend in per capita consumption is observed within the context of a declining overall historical trend. Dietary patterns are changing all over the world and the share of non-cereal foods in the total calorie and protein consumption is increasing. However, at least over the past 14 years, pulses have not seen a dramatic decline in the total calorie and protein contribution as seen by the cereal crops. In dietary terms, food legumes complement cereal crops as a source of protein and minerals, while agronomically they serve as a rotation crop with cereals reducing soil pathogens and supplying nitrogen to the cereal crop.

Pulses are important food crops due to their high protein and essential amino acid content. Interest in the use of pulses for human nutrition has grown considerably in the last decade. Recent research has associated consumption of pulses with a decreased risk for a wide variety of chronic and degenerative diseases such as cancer, obesity, diabetes and cardiovascular diseases. The food values of pulse seeds are high providing 336 to 354 Kcal of energy per 100 g, about the same calorific value per unit weight as cereals. Their protein content is generally about double that of most cereals (Table 1). The seeds of pulse crops are typically made up of 20–25 percent protein compared with 6–10 percent protein content in major cereal crops, however, they are a poor source of sulphur-containing amino acids viz., methionine and tryptophan, but they have high lysine content in which cereal proteins are deficient. Therefore, when they are used along with cereals, the proteins complement one another giving a better quality protein by supplying the respective limiting amino acids and improving the overall quality of protein in the diet.

Table 1. Energy and protein content of major pulse and cereal crops

Crop	Scientific name	Common name	(Value/100 g)	
			Kcal	Protein
Pulses	*Vigna radiata*	Mungbeans	347	23.86
	Vigna mungo	Blackgrams	341	25.21
	Vigna ungiculata	Cowpeas	336	23.52
	Vicia faba	Faba beans	341	26.12
	Cicer arietinum	Chickpeas	364	19.30
	Lens culinaris	Lentils	353	25.80
	Cajanus cajan	Pigeonpeas	343	21.70
Cereals	*Triticum durum*	Wheat, durum	339	13.68
	Triticum aestivum	Wheat, bread	340	10.69
	Zea mays	Maize	365	9.42
	Oryza sativa	Rice, medium grain	360	6.61
	Pennisetum glaucum	Millet	378	11.02
	Sorghum	Sorghum	339	11.30
	Hordeum vulgare	Barley	352	9.91

Source: FAO

Moreover, in recent years there has been a change in the consumption of pulses in several developed countries where they are increasingly considered as health foods (Ipsos Reid, 2010; USDA-ERS, 2011). On an average (unweighted by population) pulses contribute about 3 percent of total calories consumed in developing countries. Compared with cereal crops, this is relatively a small percentage from a global perspective. Because of their higher protein content, pulses contribute relatively more towards total protein intake than calorie consumption. On an average (again, unweighted) pulse crops contribute 7.5 percent of total protein in developing countries as against 2.5 percent in developed countries.

Pulses are a rich source of dietary fibre, complex carbohydrates, resistant starch and a bevy of vitamins and minerals, such as folate, selenium, potassium, Fe and Zinc. All pulses have a low glycemic index (i.e., the carbohydrate is slowly digested) which has been shown to lower glucose and insulin levels. For example, compared with white bread with a GI value of 100, the approximate GI values for chickpea are 40, lentil 42 and pea 45, while GI for beans can vary from 40 to 55. They are low in fat and contain no cholesterol. Pulses are a good source of folate which is useful in the prevention of diseases such as heart disease and cancer. The B vitamin folic acid significantly reduces the risk of neural tube defects (NTDs) like spina bifida in new born babies. Pulses contain antioxidants – vitamin E, selenium, phenolic acids, phytic acids, copper, zinc and manganese. Pulses also contain other compounds like enzyme inhibitors, lectins, pre-biotic carbohydrate, galacto-oligosaccharides and resistant starch, polyphenols, phytates and saponins. These are considered as anti-nutrient factors (ANF's) that affect the digestibility and bioavailability of nutrients in humans and animals.

Despite having many desirable traits in terms of nutrition and environmental benefits, in most countries of the world pulses are considered secondary crops. Globally, the harvested area under pulse crops is about one-tenth of the harvested area under all cereal crops. The area harvested under pulse crops increased at 0.4 percent per year since the mid-1990s, which compares positively to almost a stagnant global trend in area growth rate for cereals, but still not enough to change its status from a secondary to a primary food crop.

The data on calorie and protein consumption suggests that dietary patterns are changing globally and the share of non-cereal foods (i.e., vegetables, fruits, dairy and meat) in the total calorie and protein consumption is rising. However, in contrast to cereals, pulses have not witnessed a dramatic decline in the total calorie and protein contribution to an increasing quantity of food basket consumed globally at least over the past 14 years but with the rapid economic growth in East Asia and South Asia, the declining share of pulses in total protein intake observed in those two regions may be indicative of what is ahead for other regions as they experience rapid increase in per capita income. For cereals, the picture is more or less the same when it comes to its contribution to total per capita protein intake. All the regions of the world have seen the share of cereals in per capita protein consumption decline over the last 14 years. In Asia total pulse consumption is expected to grow 11.6 percent by 2020 and 23.6 percent by 2030. Per capita pulse consumption is expected to decline slightly from an average 5.5 kg in late 2000s to 5.3 kg in future.

Nutritive and anti-nutritive bioactive compounds in pulses: Implications for nutrition and health

Protein

Protein energy malnutrition affects every fourth child worldwide, according to the *World Health Organization* (2006). *FAO* estimates that 850 million people worldwide suffer from undernutrition, to which insufficient protein in the diet is a significant contributing factor. Seeds contain 17–35 percent of protein on a dry weight basis. In terms of solubility in specific solvents, pulse proteins fall primarily into the albumin (water-soluble) and globulin (salt-soluble) classes. The storage proteins legumin and vicillin are globulins, and the albumins comprise the heterogeneous group of enzymes, amylase inhibitors, and lectins. In general, macronutrient studies have shown that protein is more satiating than carbohydrates or lipids (Weigle *et al.,* 2005; Batterhan *et al*., 2006). Moreover, the protein in pulses (Pai *et al*., 2005) has been implicated in providing satiety. Sufian *et al*. (2007) found that pepsin-derived peptides from *Dolichos lablab* stimulated secretion of cholecystokinin, a gut hormone related to satiety. Thus, pulse proteins may contain bioactive components that contribute to satiety and weight management when consumed.

Most grains have a poor balance of essential amino acids. The cereals (maize, wheat, rice, etc.) tend to be low in lysine, whereas legumes are often low in the sulfur-rich amino acids methionine and tryptophan. Consumption of foods made from these crops potentially can help to prevent malnutrition in developing countries, especially among children. Diets comprising of High-Lys and High-Met cereals and legumes could allow diet formulations that reduce animal nitrogen excretion by providing an improved balance of essential amino acids.

Carbohydrate

The mono- and oligosaccharides represent only a small percent of total carbohydrate in pulses, whereas, starch is the most abundant carbohydrate. Starches account for 22–45 percent of pulse grain weight depending on the source. As is typical of other grains, pulse starches are composed of amylose, a linear α-1,4-linked glucan with few branches in the molecular weight range of 10^5–10^6, and amylopectin, a highly branched and much larger molecule (molecular weight 10^7–10^9) composed of α-1,4-linked glycosyl units of varying lengths connected by α-1,6 branch points. Pulse starches generally have a higher content of amylose compared with cereal and tuber starches; this factor plus their associated high capacity for retrogradation may reduce the starch digestion rate, rendering them either slowly digestible and/or resistant to digestion.

Slowly digestible starch and resistant starch

Slowly digestible starch is a term given to that fraction of starch that is not rapidly digested but digests and absorbs slowly throughout the course of the small intestines. The term resistant starch applies to the fraction that is not digested by the human α-glucosidases, reaching the colon undigested with a general fate to be fermented by saccharolytic bacteria.

Pulses have a unique profile of low digestible carbohydrates including several healthful prebiotic compounds: raffinose-family oligosaccharides (RFO), fructooligosaccharides (FOS), sugar alcohols, and resistant starch. Among the sugars, raffinose, stachyose, verbascose, ajugose and pentosans predominate in most of the pulses. The oligosaccharides of pulses are often considered a negative attribute due to their high fermentability, with their associated rapid gas production and discomfort. Technically known as α-galactosides, they are derived from sucrose and have 1–3 α-1, 6-linked galactosyl units attached. They are commonly known as raffinose (1 galactosyl unit), stachyose (2 galactosyl units), and verbascose (3 galactosyl units). Fructans are an important ingredient in functional foods because evidence suggests that they promote a healthy colon (as a prebiotic agent) and help reduce the incidence of colon cancer. Fructans consisting of linear β-(1$\rightarrow$2)-linked fructose polymers are called inulins. Naturally occurring sugar alcohols include sorbitol and mannitol. These low-digestible carbohydrates are poorly digested by human enzymes and fermented in the large intestine (Grabitske and Slavin, 2009). Fermentation of prebiotics and certain low-digestible carbohydrates elicits a variety of health effects which can be subdivided into two main groups: functional effects and disease risk reduction. The functional effects are physiological effects that can be measured relatively easily, including induction of satiety (Parnell and Reimer, 2012), reduction of caloric intake (Cani *et al.,* 2009), and reduction of serum cholesterol, triglycerides, and glucose concentrations (Pereira and Gibson, 2002). Disease risk reduction, as implied by the name, is the compounding effect over time of one or more functional effects to reduce the risk/severity of chronic diseases. For example, prebiotic-induced satiety, reduced caloric intake, and improved serum lipid profile contribute to reducing the risk and severity of obesity and metabolic syndrome (Delzenne, Neyrinck, and Cani, 2013). Pulse crops are effective at making both polymeric carbohydrates (e.g. starches and fructans) and individual sugars (e.g. sucrose and fructose).

Dietary fibre

Fibre is a group of substances chemically similar to carbohydrates, but non-ruminant animals including humans poorly metabolize fibre for energy or other nutritional uses. Dietary fibre has been recognized as a healthy food component (Walker, 1998). It consists of a mixture of polymeric non-starch substances, which resist enzymatic digestion in the human gastrointestinal tract. Most of these substances are complex carbohydrates like cellulose, hemi-cellulose and pectin. Health benefits associated with adequate intake of these substances include: lower blood cholesterol and sugar levels, reduced risk of constipation, obesity, dieabetics, heart complications, colon and rectal cancer, gallstone, piles and hernia. Lignin, cellulose and some hemi cellulose typically constitute the insoluble dietary fibre (IDF), whereas pectin, some hemi cellulose and other non-starch dietary fiber polysaccharides make up the soluble dietary fiber (SDF). Legumes seeds typically contain more dietary fiber than cereals and are better sources of metabolically active SDF.

In their raw state, pulses are high in fibre with 15–32 percent of total dietary fibre. Of this, approximately one-third to three-quarters is insoluble fibre and the remainder is soluble fibre. Insoluble fibre is associated with fecal bulking through its water-holding capacity, whereas soluble fiber ferments, positively affecting colon health through production of SCFA, lowered pH, and potential microbiota changes. Viscous soluble fibre (pectin and a few other non-starch polysacchariedes) may increase gastric distention and help to slow gastric emptying rate (Howarth *et al.,* 2001). The soluble fibre being a viscous liner along the walls of the intestine reduces glucose and cholesterol absorption into the blood stream (Anderson *et al.,* 1984). This helps in reducing blood sugar and cholesterol levels which is most beneficial for diabetic and heart patients. Because legumes are a better source of soluble fibre than cereals, they are particularly recommended in the diets of both diabetic and heart patients. Public health organizations recommended that adults should take 25 to 35 g dietary fibre per day. The dietary fibre content of grain legumes are presented in Table 1. It is evident that the total dietary fibre (TDF) content of legume seeds varied from 11.5 to 33.2 percent. Chickpeas were the richest source of fibre followed by, pigeonpeas, green peas and lentils.

Table 2. Dietary fibre content in major pulses

Sl. No.	Crop	Insoluble dietary fibre (% dry wt.)	Soluble dietary fibre (% dry wt.)	Total dietary fibre (% dry wt.)
1.	Peas (green)	10.2	3.2	13.4
2.	Lentils	9.5	2.0	11.5
3.	Chickpeas	17.2	5.5	22.7
4.	Pigeonpeas	12.2	3.5	15.5

Source: Khan *et al.,* (2007). Dietary Fibre Profile of Food legumes. *S. J. Agric. Vol. 23, No. 3, 2007.*

Folic acid in pulses

Folic acid also known as vitamin B9, or folacin and folate, as well as pteroyl-L-glutamic acid, pteroyl-L-glutamate, and pteroyl-monoglutamic acid is required to synthesize DNA, repair DNA, and methylate DNA. It also helps in maturation of red blood cells and prevents anaemia. Folate deficiency is a global problem affecting millions of people in both developed and developing countries. Inadequate intake of folic acid during pregnancy increases the risks of pre-term delivery, low birth weight, fetal growth retardation, and developmental neural tube defects (NTDs). In addition, low folate intake and elevated homocysteine levels are associated with the occurrence of neurodegenerative disorders, cardiovascular diseases, and a range of cancers, while adequate intake of both folates and folic acid in diets decreases total homocysteine levels in plasma. Tetrahydrofolate and derivatives, collectively called folates, are water-soluble B vitamins. Humans and animals cannot synthesize folates, and therefore they must be supplied from plant-based and animal foods including liver and eggs.

Most staple food crops, including cereals, potato (*Solanum tuberosum* L.) and banana (*Musa* sp) are poor sources of dietary folates, and diets based on these foods often do not reach the folate RDA of 400 μg/day. Generally, leafy vegetables contain more folates than roots and fruits. The USDA nutrient database shows that lentils (*Lens culinaris* L.) and common beans (*Phaseolus vulgaris* L.) are two pulses that are rich in folates. Although pulses are very good sources of folates, they are not readily available due to complex binding with bio-molecules (Neilson, 1994). Chickpeas have a higher content of folate than peas. Folate content in raw chickpeas was 149.7 μg/100 g and 101.5 μg/100 g in peas. In boiled chickpeas and peas the corresponding figures were 78.8 μg/100 g and 45.7 μg/100 g, indicating that some folate may have leached in the water used for processing.

In addition to the above nutritive compounds, pulse seeds contain a large number of compounds which qualify as phytochemicals with significant potential benefits to human health (for example, as anticarcinogenic, hypocholesterolemic or hypoglycemic agents). Antinutritional compounds vary considerably in their biochemistry. They can be proteins (protease inhibitors, α-amylases, lectins), glycosides (α-galactosides, vicine and convicine), tannins, saponins, alkaloids. Hence, methods for their extraction, determination and quantification are specific for each compound. They do not appear equally distributed in all pulses, and their physiological effects are diverse. Some of these compounds are important in plant defence mechanisms against predators or environmental conditions. Others are reserve compounds, accumulated in seeds as energy stores in readiness for germination.

Processing generally improves the nutrient profile of legume seed by increasing *in vitro* digestibility of proteins and carbohydrates and at the same time there are reductions in some antinutritional compounds. Most antinutritional factors are heat-labile, such as protease inhibitors and lectins, so thermal treatment would remove any potential negative effects from consumption. On the other hand, tannins, saponins and phytic acid are heat stable but can be reduced by dehulling, soaking, germination and/or fermentation. However, in order to exert an effect, either local or systemic, these substances have to survive at least to some extent the digestive process within the gastrointestinal tract. The scientific interest in non-nutritional factors is now also turning to studies of their possible useful and beneficial applications as gut, metabolic and hormonal regulators and as probiotic/prebiotic agents.

In this new era of intense bioactive research, the same ANF's are undergoing a reappraisal. Many of these non-nutritive bioactive components have been found to have positive health effects associated with their consumption. Phytic acid exhibits antioxidant activity and protects DNA from damage, phenolic compounds have antioxidant and other important physiological and biological properties, saponins have a hypocholesterolaemic effect and anti-cancer activity. Pulses are gluten-free – they offer a great variety for those on a gluten-free diet (e.g. for Celiac disease, a gastro-intestinal disorder). The on-going research is examining how whole pulses and the individual components offer protective and therapeutic effects to such chronic health conditions such as obesity, cardiovascular disease, diabetes and cancer and how consumption of legumes could potentially help people live longer.

Phenolic acids

The major polyphenolic compounds of pulses consist mainly of tannins, phenolic acids and flavonoids. The seed color of pulses is mainly due to the presence of polyphenolic compounds viz., flavonoids such as flavonol glycosides, anthocyanins, and condensed tannins (proanthocyanidins). The pulses with the highest polyphenolic content are dark, highly pigmented varieties, such as red kidney beans (*Phaseolus vulgaris*) and blackgrams (*Vigna mungo*). Condensed tannins (proanthocyanidins) have been quantified in the hulls of several varieties of field beans (*Vicia faba*) and are also present in pea seeds of colored-flower cultivars. Lentils have the highest phenolic, flavonoid and condensed tannin content (6.56 mg gallic acid equivalents g^{-1}, 1.30 and 5.97 mg catechin equivalents g^{-1}, respectively), followed by red kidney and black beans (Xu and Chang, 2007). The seed coat in lentils is very rich in catechins, procyanidins dimers and trimers. It was reported that the major monomeric Xavan-3-ol was (+) catechin-3glucose, with lesser amounts of (+)-catechin and (-)-epicatechin (Duenas *et al.,* 2003). Until recently, phenolic compounds were regarded as non-nutritive compounds and it was reported that excessive content of polyphenols, in particular tannins, may have adverse consequences because it inhibits the bioavailability of iron (South and Miller, 1998) and thiamine (Wang and Kies, 1991) and blocks digestive enzymes in the gastrointestinal tract (Shahidi and Naczk, 2004). Phenolic compounds can also limit the bioavailability of proteins with which they form insoluble complexes in the gastrointestinal tract. Later the significance of phenolic compounds was gradually recognized and several researches have now reported that phenolics offer many health benefits and are vital in human nutrition (Scalbert, *et al.,* 2005). Pulses with the highest total phenolic content (lentils, red kidney, and blackbeans) exert the highest antioxidant capacity assessed by 2, 2-diphenyl-1-picryhydrazyl (DPPH) free radical scavenging, ferric reducing antioxidant power (FRAP), and oxygen radical absorbance capacity (ORAC) (Xu and Chang 2007).

Chickpeas contain a wide range of polyphenolic compounds, including flavonols, flavone glycosides, flavonols, and oligomeric and polymeric proanthocyanidins. Total phenolic content in chickpeas range from 0.92 to 1.68 mg gallic acid equivalents g^{-1} (Xu and Chang 2007). Xu and Chang (2010), investigated the chemical and cellular antioxidant activities and phenolic profiles of 11 lentil cultivars and found that five phenolic acids of the benzoic types and their derivates (gallic, protocatechuic, 2, 3, 4-trihydroxybenzoic, *p*-hydroxybenzoic acid, and protocatechualdehyde) and four phenolic acids of the cinnamic type (chlorogenic, *p*-coumaric, *m*-coumaric, and sinapic acid) as well as two flavan-3-ols [(+)-catechin and (–)-epicatechin] and one flavone (luteolin) were detected in all lentil cultivars. Among all phenolic compounds detected, sinapic acid was the predominant phenolic acid, and (+)-catechin and (–)-epicatechin were the predominant flavonoids. Tsopmo and Muir (2010), studied the chemical profile of lentil (*Lens culinaris* Medik.) cultivars. Extracts (100% methanol and methanol – water (1:1) were analyzed by RP-HPLC. Chromatographic separations of the methanol extract afforded several compounds including the novel 4-chloro-1*H*-indole-3-*N*-methylacetamide as well as itaconic acid, arbutin, gentisic acid 5-*O*-[β-D-apiofuranosyl-(1→2)-β-D-xylopyranoside], and (6S,7Z,9R)-9-hydroxymegastigma-4,7-dien-3-one-9-*O*-β-D-apiofuranosyl-(1→2)-β-D-gluco-pyranoside.

Antioxidant activity in pulses

In the past few years, the antioxidant properties of food have been extensively studied since excessive production of free radicals/reactive oxygen species (ROS) and lipid peroxidation are widely believed to be involved in the pathogenesis of diseases such as cardiovascular diseases, cancers, autoimmune disorders, rheumatoid arthritis, various respiratory diseases, cataract, Parkinson's, or Alzhemier's diseases, and also ageing. Beninger and Hosfield (2003), showed that pure flavonoid compounds such as anthocyanins, quercetin glycosides and protoanthocyanidins (condensed tanins), present in the seed coat methanol extract and tannin fractions from 10 coloured genotypes of common beans *Phaseolus vulgaris*, displayed antioxidant activity, while the highest activity was obtained with extracts rich in condensed tannins. The Total antioxidant capacity (TAC) value for chickpeas was reported as 10.7±1.3 mmol Trolox/kg (Açar Özge *et al.,* 2009). Lentils showed a high total antioxidant capacity (TAC) value probably related to the high content of condensed tannins present in lentils (Duenas *et al.,* 2003). Xu and Chang (2010), reported that caffeic acid, catechin, epicatechin, and total flavonoids significantly (p <0.05) correlated with peroxyl radical scavenging assay in lentil cultivars. Sreeramulu *et al.* (2009) evaluated the antioxidant activity of pulses, commonly consumed in India and assessed the relationship with their total phenolic content. The total phenolic content (TPC) in pulses ranged from 62.35 to 418.34 mg/100 g. Among the pulses blackgram dhal had the highest TPC (418.34 mg/100 g), while greengram dhal had the least (62.35 mg/100 g). The antioxidant activity as determined by three different methods showed a wide range of values. DPPH radical scavenging activity (1.07 TE/g), FRAP (373 µmol/g) and reducing power (4.89 mg/g), all three were highest in Rajmash. Sreeramulu *et al.* (2009), further showed that in pulses the total phenolic content (TPC) was poorly correlated with antioxidant activity (AOA), suggesting thereby that only TPC might not contribute significantly to the antioxidant activity in pulses.

Isoflavones

Flavones and isoflavones have been isolated from a wide variety of plants, though the isoflavones are largely reported from the Fabaceae/Leguminosae family. According to the USDA survey on isoflavone content, lentils do not contain significant amounts of these isoflavones (USDA, 2002). Chickpeas contain daidzein, genistein, and formononetin (0.04, 0.06, and 0.14 mg 100 g^{-1}, respectively), and approximately 1.7 mg 100 g^{-1} biochanin A. Soybeans have significantly higher levels of daidzein and genistein (47 and 74 mg 100 g^{-1}, respectively) but contain less formononetin and biochanin A compared to chickpeas. There are many biological activities associated with the isoflavones, including a reduction in osteoporosis, cardiovascular disease, prevention of cancer and for the treatment of menopause symptoms (Cassidy *et al*., 2006).

Enzyme inhibitors

Protein inhibitors of hydrolases present in pulses are active against proteases, amylases, lipases, glycosidases, and phosphatases. From the nutritional aspect, the inhibitors of the serine proteases trypsin and chymotrypsin found in plant foodstuffs are the most important (Belitz and Weder, 1990). Beans are the second largest group of seeds after cereals reported as natural sources of α-amylase inhibitors (Lajolo *et al.,* 1991). Protease inhibitors isolated from pulses are generally classified into two families, referred to as Kunitz and Bowman-Birk on the basis of their molecular weights and cystine contents. Kunitz type inhibitors have a molecular mass of ~20 kDa, with two disulfide bridges, and act specifically against trypsin.

Bowman-Birk type inhibitors with a molecular mass of 8–10 kDa, have seven disulfide bridges, and inhibit trypsin and chymotrypsin simultaneously at independent binding sites. High inhibitor activity is found in soybean seeds which are usually reduced by processing. Bur null mutants for both Bowman-Birk and Kunitz have been identified in soybeans, allowing very low trypsin inhibitor cultivars to be developed. In common beans, lima beans, cowpeas, and lentils, protease inhibitors have been characterized as members of the Bowman-Birk family (Belitz and Weder 1990; Lajolo *et al.,* 1991). In peas large genetic variability is available for the activity of Bowman-Birk trypsin/chymotrypsin inhibitor proteins (Table 2). Protease inhibitor content is moderate in kidney beans and cowpeas (8 and 10.6 g of trypsin and 9.2 g of chymotrypsin inhibited kg^{-1}, respectively) (Grant *et al.,* 1995). The content of α-amylase inhibitors differs greatly among legumes, with the highest amount found in dry beans.

Table 3. Range of variation for trypsin inhibitor activity in grain legume seeds

Sl. No.	Crop	Trypsin inhibitor activity (TIU/mg)	Reference
1.	Peas	1-14.6 1.9-6.8 6-15	Bastianelli *et al.,* 1998 Gabriel *et al.,* 2008 Guillamon *et al.,* 2008
2.	Lentils	1-9-2.8 3-8	Wang *et al*., 2009 Guillamon *et al*., 2008
3.	Chickpeas (Desi lines) Chickpeas (Kabuli lines)	12.7 10.3 15-19	Singh and Jambunathan, 1981 Guillamon *et al*., 2008

Lectins

Lectins are proteins or glycoproteins that agglutinate erythrocytes of some or all blood groups *in vitro* and depend on their specificity and high binding affinity for a particular carbohydrate moiety on the cell surface (González *et al.,* 2002). Lectins can reduce the digestibility and biological value of dietary proteins and inhibit the growth of experimental animals (Grant *et al.,* 2000). These antinutritional effects are most likely caused by some lectins that can impair the integrity of the intestinal epithelium (Reynoso-Camacho *et al.,* 2003) and thus alter the absorption and utilization of nutrients (Radberg *et al*., 2001). The administration of lectins to experimental animals can also alter the bacterial flora (Pusztai, 1996). Lectin is one of the major proteins found in lentils (*Lens culinaris*). Studies have suggested that lectins affect the immune response against ovalbumin and may promote the development of food allergies to plants containing lectins. Cooking effectively removes trypsin inhibitor and lectin from vegetable peas and significantly reduces protein and amino acid solubility (Habiba, 2002). Lectin can be completely removed from lentil flour after 72 h fermentation at 42°C with a flour concentration of 79 g L^{-1} (Cuadrado, *et al.,* 2002). Amount of lectin in pulses vary significantly (Zhang *et al*., 2009). High levels of lectins have been reported in kidney beans (840×10^{-5} hemagglutinating activity units (HU) kg^{-1}) and very low amounts in cowpeas (3×10^{-5} HU kg^{-1}). Lectin accounts for about 2.4–5 percent of the total protein (17–23 percent) in kidney bean seeds, 0.8 percent in soybean and lima bean protein (34 percent and 21 percent, respectively), and around 0.6 percent of the total protein (24–25 percent) in garden peas.

Dietary lectins have generally been considered toxic, and having an anti-nutritional factor. However, many lectins are non-toxic, such as those from lentils, peas, chickpeas and faba beans. *Vicia faba* agglutinin (VFA), a lectin present in broad beans, aggregated, stimulated the morphological differentiation, and reduced the malignant phenotype of colon cancer cells (Jordinson *et al.,* 1999). Inclusion of raw kidney beans in the diet of obese rats reduced lipid accumulation that was related to a decrease of insulin level caused by lectins. However, no body or muscle protein losses occurred, even at high doses, as with normal rats, suggesting a possible use of lectins as therapeutic agents to treat obesity (Pusztai, 1998). Lectin from kidney bean seeds directly inhibits

HIV-1 reverse transcriptase, an enzyme crucial for HIV replication, as well as β-glucosidase, which has a role in HIV-1 envelope protein *gp120* processing, therefore a very potent element of antiretroviral chemotherapy.

Phytosterols

In pulses, phytosterols are present in small quantities, and the most common phytosterols are β-sitosterol, campesterol, and stigmasterol (Benveniste, 1986). These compounds are also abundant as sterol glucosides and esterified sterol glucosides, with β-sitosterol representing 83 percent of the glycolipids in defatted chickpea flour (Sanchez-Vioque *et al.,* 1998). Total phytosterol content detected in the legumes ranged from 134 mg 100 g^{-1} (kidney beans) to 242 mg 100 g^{-1} in peas (Weihrauch and Gardner, 1978).

Total β-sitosterol content ranged from 160 mg 100 g^{-1} (chickpeas) to 85 mg 100 g^{-1} (butter beans). Chickpeas and peas contained high levels of campesterol (21.4 and 25.0 mg 100 g^{-1}, respectively). Stigmasterol content is higher in butter beans (86 mg 100 g^{-1}) and squalene content in peas (1.0 mg 100 g^{-1}). Weihrauch and Gardner (1978) reported 127 mg 100 g^{-1} phytosterol level for kidney beans, with much lower concentration of phytosterols in chickpeas (35 mg 100 g^{-1}). The consumption of pulse grains has been reported to lower serum cholesterol and increase the saturation levels of cholesterol in the bile. A dietary study conducted by Duane (1997), on humans over a seven week period showed that serum LDL cholesterol was significantly lower during the consumption of a diet consisting of beans, lentils and field peas. The study showed that consumption of pulses lowers LDL cholesterol by partially interrupting the entrohepatic circulation of the bile acids and increasing the cholesterol saturation by increasing the hepatic secretion of cholesterol. The study concluded that other pulse components in the diet may also have contributed to the observed effect; in particular, saponins, which are hydrolyzed by intestinal bacteria to diosgenin, may have exerted a positive effect (Fenwick and Oakenfull, 1983). Several studies have demonstrated the efficacy of plant sterols and stanols in the reduction of blood cholesterol levels, and plant sterols are increasingly being incorporated into foods for this purpose (Gylling and Miettinen, 2005).

Phytic acid

Phytic acid (myo-inositol hexaphosphate or $InsP_6$), a major phosphorus storage form in plants, and its salts known as phytates regulate various cellular functions such as DNA repair, chromatin remodeling, endocytosis, nuclear messenger RNA export and potentially hormone signaling important for plant and seed development (Zhou and Erdman, 1995), as well as animal and human nutrition (Vucenik and Shamsuddin, 2006). It is often regarded as an antinutrient because of strong mineral, protein and starch binding properties thereby decreasing their bioavailability (Weaver and Kannan, 2002). Phytate plays an important role in plant metabolism, stress and pathogen resistance in addition to their beneficial effects in human diets by acting as anticarcinogens or by promoting health in other ways such as by decreasing the risk of heart disease or diabetes (Welch and Graham, 2004). Wholegrain cereals and pulses have a high content of phytate (Sandberg, 2002). In pulse seeds, phytate is located in the protein bodies in the endosperm. Phytate occurs as a mineral complex, which is insoluble at the physiological pH of the intestine (Fredlund *et al.,* 2006). Raw lentils contained 0.3 mmol kg^{-1} of $InsP_3$. The most abundant inositol phosphate in raw, dry legumes is $InsP_6$, accounting for an average of 83 percent of the total inositol phosphates, ranging from 77 percent in chickpeas to 88 percent in blackbeans. The $InsP_6$ concentration tends to be higher in raw dry beans, blackeye peas, and pigeon peas than in lentils, green and yellow split peas, and chickpeas and ranged between 14.2 and 6 mmol kg^{-1} in blackbeans and chickpeas, respectively (Morris and Hill, 1996). Varietal and agronomic factors, alone and in combination, often result in a wide variation in phytate content of mature legume seeds and cereal grains (Dintzis *et al.*, 1992) (Table 3).

In vivo and *in vitro* studies have demonstrated that inositol hexaphosphate ($InsP_6$, phytic acid) exhibits significant anticancer (preventive as well as therapeutic) properties. It reduces cell proliferation and increases differentiation of malignant cells with possible reversion to the normal phenotype and is involved in host defense mechanism, and tumor abrogation (Shamsuddin, 2002). $InsP_6$ has been suggested to be responsible for the epidemiological link between high-fibre diets (rich in $InsP_6$) and low incidence of some cancers. Phytic acid delays postprandial glucose absorption, reduces the bioavailability of toxic heavy metal such as cadmium and lead, and exhibits antioxidant activity by chelating iron and copper (Minihane and Rimbach, 2002).

Dietary and endogenous phytic acid have protective effects against cancer and heart disease and may be responsible for the cancer-protective effects of high-fibre foods (Grases *et al*., 2001). The anticarcinogenic properties of phytic acid may result from numerous factors, including its ability to chelate metal ions; this depends on the phytate retaining its integrity in the colon (Steer and Gibson, 2002). The backbone of most inositol phosphates in cells is *myo-inositol.* Inositol phosphates from seeds are a significant food source of *myo-inositol,* as are the phospholipids and free inositol from many plant- and animal-based foods (Berdanier, 1992). *Myo-inositol* has been evaluated for its ability to improve the mental health of patients with various psychiatric disorders (Einat and Belmaker, 2001). In addition to *myo-inositol,* smaller amounts of *epi-* and *scyllo-inositol are* present in human brains. *Myo-inositol* and $InsP_6$ have synergistic or additive effects in inhibiting the development of cancer (Shamsuddin, 1999). In mice, dietary *myo*inositol has been shown to be effective in preventing cancer of the lung (Wattenberg *et al*., 2000), fore stomach (Estensen and Wattenberg, 1993), liver (Nishino *et al.,* 1999) colon, mammary gland, prostate, and skin (Jenab and Thompson, 1998).

Table 4. Range of variation for phytic acid in major pulses

Sl. No.	Crop	Phytic acid (g/kg)	Reference
1.	Peas	1.3-10.2 0.2-1.3%	Bastianelli *et al.,* 1998 Champ, 2002
2.	Lentils	6.2-8.8 0.15-2.34%	Wang *et al.,* 2009 Champ, 2002
3.	Chickpeas (Desi lines) Chickpeas (Kabuli lines) Chickpeas	7.7-12.3 5.4-11.7 0.4-1.1%	Chitra *et al.,* 1995 Champ, 2002
4.	Mungbeans	10.2-14.8	Chitra *et al.,* 1995
5.	Pigeonpeas	6.8-14.9 9.9-16.4	Chitra *et al.,* 1995 Singh, 1999
6.	French beans	0.2-1.9%	Champ, 2002

Saponins

Saponins are glycosidic compounds, structurally they are composed of a lipid-soluble aglycon consisting of either a sterol or more commonly a triterpenoid and water soluble sugar residues differing in type and amount of sugars. Their biological activity is closely related to chemical structures that determine the polarity, hydrophobicity and acidity of compounds. Saponins have long been considered undesirable due to toxicity and their haemolytic activity. Although the toxicological properties of plant saponins have long been recognized, there is renewed interest in these biologically active plant components because recent evidence suggests that saponins possess hypocholesterolemic (Oakenfull and Sidhu, 1990), anti-carcinogenic (Tokuda *et al*., 1991) and immune-stimulatory properties (Wu *et al.,* 1990). There is enormous structural diversity within this chemical class, and only a few are toxic (Shi *et al.,* 2004). Most of the saponins occur as insoluble complexes with 3-*b*-hydroxysteroids; these complexes interact with bile acid and cholesterol, forming large mixed micelles (Oakenfull and Sidhu, 1989). In addition, they form insoluble saponin-mineral complexes with iron, zinc, and calcium (Milgate and Roberts, 1995), hence saponins lower nutrient availability (West and Greger, 1978).

The most widely studied saponins in legumes include the soya saponins, which are classified into group A, B, and E saponins on the basis of the chemical structure of the aglycone (Rochfort and Panozzo, 2007). Field peas were initially thought to contain soyasaponin I (S-I) (and then soyasaponin VI (S-VI) as the only soyasaponin, but recently field pea extracts were shown to contain dehydrosoyasaponin I (D-I) as a minor component (Taylor and Richards, 2008). D-I from peas has insecticidal and anti-feedant properties against stored product insect pests. This triterpenoid saponin dehydrosoyasaponin I is a natural product present in chickpeas and other legumes and is known to be a potent calcium-activated potassium channel opener and as such can be used for treating cardiovascular, urological, respiratory, neurological, and other disorders. Soybeans and chickpeas constitute major sources of saponins in the human diet (Oakenfull, 1981).

Saponins have been reported in many pulses, lentils (Ruiz *et al.,* 1996), and chickpeas (El-Adawy, 2002), as well as in various beans, and peas (Shi *et al.,* 2004). Saponin content may vary even among the same species of edible beans, because of variations in cultivars, varieties (Khokhar and Chauhan, 1986), locations, irrigation condition, type of soil, climatic conditions, and the year during which they are grown. Chickpeas, blackgrams, moth beans, broad beans and peas can contain 3.6, 2.3, 3.4, 3.7, and 2.5 g kg^{-1} dry matter of saponins, respectively (Khokhar and Chauhan, 1986). Saponin content in dehulled light and dark colored peas ranges from 1.2 to 2.3 g kg^{-1} dry matter (Daveby *et al.,* 1998). The saponin content varies from 0.3 to 1.1 g/kg in peas (Table 4). Some saponin is lost during processing as has been reported in moth beans (Khokhar and Chauhan, 1986), blackgrams (Kataria *et al.,* 1989) and pigeonpeas (Duhan *et al.,* 2001).

Recent evidence suggests that legume saponins may possess anti-cancer properties (Xu and Chang (2007) and be beneficial for hyperlipidemia (Shi *et al.,* 2004). In addition, they reduce the risk of heart diseases in humans consuming a diet rich in food legumes containing saponins (Geil and Anderson, 1994). Epidemiological studies suggest that saponins may play a role in protection from cancer (Shi *et al.,* 2004). Metastatic events are critical in cancer proliferation, and there is evidence that glycosylation is an important event in this process. Aubert *et al.* (2000) and Xu and Chang (2007) have recently demonstrated that soyasaponin I decreases the expression of R-2, 3-linked sialic acid on the cell surface, which in turn suppresses the metastatic potential of melanoma cells. The observed anticancer activity may therefore in part be due to this observed sialyltransferase inhibition activity. Additional mechanistic studies indicate that there is evidence for saponin regulation of the apoptosis pathway enzymes (AKT, Bcl, and ERK1/2), leading to programmed cell death of cancer cells (Godlewski *et al.,* 2006). Research on colon cancer cells suggests that it is the lipophilic saponin cores that may be responsible for the biological activity.

Table 5. Range of variation for saponin in major pulses

Sl. No.	Crop		Reference
1.	Peas	1.1	Koslovska *et al.,* 2001
		0.3-1.0	Bastianelli *et al.,* 1998
2.	Lentils	1.1	Koslovska *et al.,* 2001
3.	Chickpeas	2.3	Koslovska *et al.,* 2001

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VIII. Annex

CLOSING REMARKS
by
Hiroyuki Konuma
Assistant Director-General and
Regional Representative for Asia and the Pacific
delivered at the

Regional Consultation on promotion of pulses for the multiple benefits in Asia
Bangkok, Thailand
30 June 2015

It is once again my utmost pleasure to be able to be here amongst all of you at the closing ceremony of the **Regional Consultation on promotion of pulses for the multiple benefits in Asia**. To begin with, I would like to express my sincere thanks to everyone for their hard work, commitment and dedication during the last two days. My heartfelt gratitude goes to Professor Swaminatan for his kind presence and guidance in order to help this regional consultation achieve its objectives. The presence of ICARDA, ICRISAT, and all reputed experts working in this field has, furthermore, enhanced the technical values of this event.

During the last two days, we have discussed and tried to touch upon almost all relevant and pressing issues that the pulse development sector in this region is facing. With everyone's contribution, we attempted to find ways and means on how to move forward to bring back the glorious past of this group of crops in order to improve not only food and nutrition security of the millions of families dependent on this sector but also increase their employment and incomes in addition to improving soil fertility.

My understanding is, this forum discussed in details how to fit pulses in farmers' cropping patterns in line with the recent development in the field of climate change, natural disasters and rapid changes in the cropping patterns.

I was told that the consultation has achieved its objectives and quite a good number of recommendations came up. Appropriate implementation of these recommendations will undoubtedly help in enhancing productivity in this sector.

Dear All,

It is the responsibility of the country to make efforts to implement these recommendations. In order for this to happen, our first task will be to bring changes in the country's policies and strategies that would ensure that pulses are included as focused crops, and allocate sufficient resources to facilitate the implementation of these policies and strategies.

I firmly believe that until and unless we are able to bring a breakthrough in this sector, poor people's food and nutrition security will still be at stake. This sector should receive a renewed thrust from all of us which is also why the coming year has been declared as the year of pulses, so as to direct attention towards the pulse sector and to help everyone realise the benefits that can be derived from simple interventions to increase productivity in this area.

With the year 2016 being the "International Year of Pulses", these recommendations have come in very timely and will help in developing relevant and appropriate programmes to boost production of pulses. FAO would be happy to provide support if member countries require it. FAO is also committed to working with the CGIAR institutes to take forward the momentum created through this regional consultation.

To conclude, I would like to inform you that FAO will give high priority and considerations required to further highlight these recommendations and to provide the thrust, when opportunity comes. We will provide all our support, if and whenever necessary, to implement these recommendations both at country and regional levels.

With this, I thank you all again for your kind contributions and wish you a safe return to your home countries. We are hopeful that there will be more opportunities to meet you all in other programmes when the whole world joins hands to celebrate the International Year of Pulses in 2016.

Thank you very much.

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