The Sixth Dr. M.S. Swaminathan Award Lecture

Challenges and Opportunities for Food Legume Research and Development

by

Dr. Mohan C. Saxena

Former Assistant Director General, ICARDA, Syria

January 25, 2012

taas
Progress Through Science

Trust for Advancement of Agricultural Sciences

Challenges and Opportunities for Food Legume Research and Development

Dr. Mohan C. Saxena

Former Assistant Director General, ICARDA, Syria

Sixth Dr. M.S. Swaminathan Award Lecture

January 25, 2012

Food legumes, such as chickpea, cowpea, dry beans, dry peas, faba bean, lentil, mungbean, pigeonpea, urdbean and other pulse crops, are a good source of dietary protein, to complement the cereal-based diet, particularly for vegetarians, in the developing world. Their contribution to protein intake is around 7.5% as an average of the developing world, but exceeds 50% in some of the countries in Asia, Africa and Latin America. In India the average contribution is more than 10%. Depending on production systems these food legumes are consumed often as green and dry seeds and the leaves are used as vegetable. In many developing countries they are considered as women's crop and provide an important source of income and nutritional needs of the family. The byproducts of pulses provide nutritious fodder for livestock. Because of their ability to fix atmospheric nitrogen, enhance soil organic matter content and improve soil physical properties, they play a key role in maintaining soil fertility and ensuring sustainability of production systems, particularly in low-input, small-scale agriculture. Therefore, pulses can be harnessed to achieve important development goals namely reducing poverty, improving human health and nutrition and improving ecosystem resilience.

However, the global production of food legumes has not kept pace with increase in the global population. Therefore, there is general historical trend of decline in global per capita availability and consumption of pulses. This should obviously have nutritional consequences for the societies that primarily depend on pulses for enriching their daily food. In India, the production declined from 13.77 kg/yr in 1990 to 11.40 kg/yr in 2006; the global figures were 10.4 and 8.9 kg/yr, respectively. Fortunately, there is some resurgence in the last five years and the availability has improved to 12.44 kg in India and 9.1 kg/ha in the world as a whole.

The major factor responsible for poor growth in production of the food legumes is their low productivity. Averaged over 2006-2010, the global productivity of chickpea, cowpeas, dry beans, dry peas, faba bean, lentil, and pigeonpea was 853, 484, 778, 1594, 1676, 963, and 778 kg/ha, respectively, as compared to the global average yield of soybean of 2393 kg/ha. Although itself a leguminous crop with high protein and oil content, soybean yields almost twice as much as most pulses. This establishes clearly that low yield level of pulses cannot be attributed to their being a leguminous plant.

Globally, pulses harvested area is just one-tenth of harvested area of cereals, which are considered primary crops for food security. Thus, much less research, development and production resources are devoted to pulses and they are considered as secondary crops. The low productivity makes the pulses economically less competitive to other crops. They are therefore entrapped in a vicious cycle of increasingly being pushed to less endowed and marginal areas, particularly in the developing world. The greatest challenge for legume researchers is to enhance the economic competitiveness of these legumes by improving their intrinsic yield potential and their adaptation to niches available in various cropping systems, and reducing their susceptibility to a host of biotic stress factors (diseases, insect pests, parasitic and other weeds) and abiotic stresses (drought, extremes of temperature, salinity, nutrient deficiencies and toxicities, etc.), the major factors that prevent the full realization of yield potential and reduce yield stability. Several of these stress factors are likely to become more severe in the future because of global climate change as growing periods might change because of alterations in the thermal and moisture regimes and new pathogens and pests might develop. As the performance of the legumes is very much dependent on the symbiotic nitrogen fixation, and other symbiotic associations, both host and micro-symbionts have to receive attention. Reducing the cost of production and enhancing end-use quality for diversified uses and adding value through processing would also offer opportunity to enhance economic competitiveness of pulses.

Recent developments in the field of plant physiology, biochemistry, microbiology, molecular biology, genetic transformation and food technology offer unprecedented opportunities to legume researchers for meeting the challenge of enhancing the economic competitiveness of the pulse crops through genetic improvement, through development of appropriate management practices that reduce their cost of production and permit full realization of their genetic yield potential, and through diversifying their end-use quality for producing novel products of higher value than the traditionally used pulses.

While major share in the global production of pulses is in the hands of small subsistence farmers in the developing world who produce these crops mainly for their domestic consumption and any surplus is sold in local market, there is an increasing trend for commercial farming of some of these crops in the industrialized countries. The latter has been mainly triggered by the growing gap between domestic supply and demand of pulses in the developing countries. The challenges faced by these two groups of producers are different because of the differences in their production objectives, labor and capital availability, capacity to withstand production risks and opportunities for value addition and development of new products. For the subsistence farmers there is a need not only to improve productivity but also yield stability. For commercial production there is a need to gain higher competitiveness over the other crop options. The research strategy and approach may have to be suitably adjusted for effectively serving the specific needs of subsistence farmers and those who produce for commercial purposes, although there will be spill over of information from one to the other. Innovative approaches would have to be developed by social scientists for delivery of seeds and other production inputs as well as information to achieve impact on both groups of pulse growers. The challenge can be met by adopting interdisciplinary approach to research, fully utilizing cutting-edge science and capitalizing on indigenous knowledge, and enlisting farmer participation in research where appropriate. Researchers will have to ensure increased flow of public funds for research at least till such time when the private sector starts investing in food legume research.

To enhance intrinsic yield potential of pulses, major efforts are needed to analyze physiological and biochemical limitations to the current crops and cultivars in harvesting solar energy by carbon assimilation and in the use of mineral nutrients and water to design more efficient types for various production systems and niches. In this regard, comparative physiology of better yielding legumes such as soybean, and even peanuts, dry peas and fababean would be useful in attempting genetic enhancement of low yielding pulses. Application of a multi-disciplinary approach involving plant physiology and biochemistry, breeding, molecular biology and microbiology is essential for this. Needed attention will have to be given to the genotype of the micro-symbiont as well.

For realizing full yield potential, the cultivars have to be ecologically well adapted to the available niches in the production system. Characterization of various niches and identification of those that provide most comparative advantage to pulses will be needed. Crop phenology will have to be matched with the prevailing macro- and micro-climatic conditions in the selected niches. For optimizing crop genotype environment combination, in situ selection of genotypes for various cropping systems and niches will be necessary, particularly when developing cultivars for marginal areas and harsh environments.

Yield potential realization can be maximized in a production system by maximizing the operation of favorable growth factors while reducing the effect of yield retardants. Yield gap analysis of several pulses has attributed these gaps to inadequate agronomic management involving one or more of the factors such as the cropping sequence, time and method of sowing, plant population, management of key mineral nutrients, water management, and biological nitrogen fixation. Substantial body of evidence is present showing that large increases in productivity, yield stability and resource-use efficiency is possible, when these management factors are optimized.

A major factor responsible for lack of realization of full yield potential of pulses is their susceptibility to various abiotic and biotic stresses. Abiotic stresses commonly encountered are those caused by drought, extremes of temperature, incipient waterlogging and anoxia, salinity, mineral nutrient deficiency and metal toxicity. These stresses are best managed by genetic enhancement although agronomic management would further add efficiency. Considerable progress has been made in devising techniques for screening germplasm and breeding material and using these, breeders have made some spectacular progress in developing stress tolerant cultivars. The same is true for biotic stresses, caused by fungal, bacterial, viral and nematode pathogens, a wide range of insect pests, and flowering parasitic weeds. With reliable field and laboratory screening techniques, useful germplasm is being identified and improved cultivars being developed. Modern development in molecular biology is being increasing used in these efforts. The resistant/tolerant genotypes, as a key component of the integrated pest management system, provide economic and environmentally sound management of these major yield retarding factors.

Devising cost-saving operations in the production of pulses can enhance their economic competitiveness. Developing more energy-efficient and energy-saving equipment for field operations and adopting conservation tillage can reduce costs.

Improving nutritional quality of pulses by enhancing the content of sulfur-containing essential aminoacids and micronutrients, and reducing the content of various anti-nutritional factors, particularly the flatulence factor, can lead to the opportunity of farmers getting better price in the market. Improving the functional characteristics of the seed content for various uses can likewise add value to the produce to fetch higher prices. Developing new high-value products, which can be promoted as nutritious foods, can enhance the demand of pulses by processing industries, opening a more remunerative market for the farmers. Efforts of food technologists and marketing specialists will be crucial here.

Considerable progress has been made in recent years on several fronts in enhancing adaptation to different environmental conditions, improving yield potential, stabilizing yields by enhancing tolerance/resistance to various stresses. However, this has been uneven and several pulses have received lesser attention than needed. A lot more needs to be done to meet the challenge, particularly of increasing adaptation to harsh environmental conditions and improving tolerance/resistance to stresses. The global climate change is going to make it even more challenging.

The conventional plant breeding will have to be complemented with emerging sciences based on molecular biology and biotechnological tools. Progress in genomic studies in pulses has been slow but steady. Genome sequencing efforts in peas, faba bean, lentil, chickpea and pigeon pea, following the pioneering work on model legume Medicago truncatula, have been promising. Syntany can be harnessed in other pulses. Momentum will have to increase in the field of applied genomics and gene manipulation to isolate and investigate function of important genes, also from alien species, develop DNA chips for genome-wide high throughput expression screening of stress responsive genes, and to undertake gene transfer in appropriate background. Some progress is already occurring in developing transgenic materials with enhanced tolerance to some of the key stresses. Sustaining research efforts to achieve productivity breakthrough and enhance economic competitiveness of pulses would necessitate sustained invest in research. Research in the developing world is mainly being conducted by national agricultural research institutions with their own national resources. Support groups have emerged in the industrialized world to help the international efforts. Some national institutions in the industrialized countries have also been devoting resources for pulses research, and they are collaborating with researchers of the developing countries. Several CGIAR centers have been devoting efforts on some selected pulses and have developed innovative partnerships with the national programs in the developing countries and research institutions in the industrialized countries to harness synergy in achieving sustainable increases in productivity of these pulses.

A recent study by Michigan State University scientists for SPIA indicates that the overall consumption of pulses would globally increase by 10% by 2020 and 23% by 2030, over the current level; the increases particularly occurring in Asia and Africa. Assuming that the growth in area under pulses would continue to be at 0.37% per annum as was the case in the last 14 years, the increased demand for consumption would necessitate an yield increase of 70 kg/ha by 2020 and by 120 kg/ha by 2030, the rates that are more than 1.5 times those achieved in the last 14 years. Application of science and technology, along with effective technology transfer and policy and institutional support to farmers, should make this target reachable. However, the future challenge for research and effective delivery of research outputs to pulse growers lies in ensuring sustained public sector funding in both industrialized and developing countries, encouraging the private sector to invest more resources and enhance partnerships with public sector, targeting research for both commercial and subsistence farmers adopting appropriate methodologies, and developing effective information and technology delivery systems. Fortunately for India, the largest producer and consumer of pulses in the world, the recent policy initiatives and actions taken by the Government of India will go a long way in strengthening the R&D efforts that the ICAR has been undertaking through its research network of national research and technology transfer institutions in partnership with Central and State Agricultural Universities, civil society organizations and international agriculture research centers.