Shabir Hussain Wani · Mukesh Jain
Editors

Pulse Improvement

Physiological, Molecular and Genetic Perspectives

Springer

Pulse Improvement

Shabir Hussain Wani • Mukesh Jain
Editors

Pulse Improvement

Physiological, Molecular and Genetic Perspectives

Springer

Editors
Shabir Hussain Wani
Mountain Research Centre for Field Crops
Khudwani, Sher-e-Kashmir University
of Agricultural Sciences and Technology
of Kashmir
Srinagar, Jammu and Kashmir, India

Mukesh Jain
School of Computational & Integrative
Sciences
Jawaharlal Nehru University
New Delhi, India

ISBN 978-3-030-01742-2 ISBN 978-3-030-01743-9 (eBook)
https://doi.org/10.1007/978-3-030-01743-9

Library of Congress Control Number: 2018962000

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Dedication

Dr. R. S. Paroda

Dr. Raj Paroda, former Director General, Indian Council of Agricultural Research (ICAR), and Secretary, Department of Agricultural Research and Education (DARE), Government of India, is an accomplished plant breeder and geneticist by profession and an able research administrator. He has made significant contributions in the field of crop science. He is known for the modernization and strengthening of Indian National Agricultural Research System (NARS). He is the main architect of one of the world's largest and most modern National Gene Banks in New Delhi. He has received numerous prestigious awards and recognitions, namely, Padma Bhushan by the

Government of India, Rafi Ahmed Kidwai Prize, ICAR Team Research Award, FICCI Award, Om Prakash Bhasin Award, BP Pal Gold Medal, Borlaug Award, Mahindra Shiromani Award, Asia-Pacific Seed Association Special Award, CGIAR Award for Outstanding Partnership, Life Time Achievement Award by Association of Agricultural Scientists in America, Dr. Harbhajan Singh Memorial Award, ISCA Gold Medal for Excellence in Science, Gold Medals from Ministry of Agriculture of Armenia and Vietnam, Life Time Achievement Award of "Agriculture Today," Dr. A. B. Joshi Memorial Award, Prof. S. Kannaiyan Memorial Award and Awasthi-IFFCO Award, for Life Time Achievement in agricultural science and development.

Dr. Paroda had been the Founder Chairman of Global Forum on Agricultural Research (GFAR) based at FAO, Rome. He also served for more than two decades as the Executive Secretary of Asia-Pacific Association of Agricultural Research Institutions (APAARI), Bangkok, a well-known regional organization fostered by him to strengthen regional collaboration. He had served as Chairman as well as Vice-Chairman of ICRISAT Board, Member of Board of Trustees of IRRI, Member of WMO High Level Task Force on Climate Services, Member of Advisory Council of Australian Centre for International Agricultural Research (ACIAR), Member of Finance Committee of CGIAR and Member of the Governing Board of the Commonwealth Agriculture Bureau International (CABI). Currently, he is a *member of high-level Strategic Impact, Monitoring and Evaluation Committee (SIMEC) of CGIAR.*

He also was the President of Indian Science Congress in 2000–2001 and President of the National Academy of Agricultural Sciences, besides being president of a dozen national scientific societies in agricultural sciences. He has been conferred the Fellowship of several National Science Academies like INSA, NAAS and NASI and was elected as the General President of the prestigious Indian Science Congress in 2000–2001. Among international recognitions, he was elected as a Fellow of Agricultural Academies of Russia, Georgia, Armenia, Tajikistan and the Third World Academy of Sciences (TWAS).

Seventeen universities have awarded him D.Sc. (Honoris Causa) degree including Ohio State University, Columbus, and Indian Agricultural Research Institute, New Delhi. Dr. Paroda also worked as Chairman, Farmers Commission of Haryana, Chairman of Working Group on Agriculture and Member of Rajasthan Planning Board. Currently, he is the Chairman of the Trust for Advancement of Agricultural Sciences (TAAS).

Preface

With the increase in human population which is believed to exceed 9.7 billion by 2050, the growing demand for food and nutritional requirements is increasing at an alarming rate, and pulse crops act as a proficient spring of plant-derived proteins which involve negligible inputs. Also, pulses are principal and inexpensive source of proteins and minerals, which play a major part in improving the protein calorie malnutrition. However, pulses are grown in low-input and rain-fed conditions which result in lower yield and poor nutritional quality. In addition to the rising pulse requirement, the varying climate scenario has led to the increase in innumerable production limitations, including abiotic and biotic stresses. Pulse researchers globally and particularly in India have made strenuous efforts to defy the above challenges, and also with the progression of biotechnological tools, novel avenues for increased pulse production have come up in the last decade. Recent advancements in plant molecular biology and genomics in the form of the whole genome sequence, physical maps, genetic and functional genomic tools, integrated approaches using molecular breeding and genetic engineering put forward innovative prospects for improving production and productivity of many pulse crops. Many genes have been discovered which include regulatory genes that regulate stress response (e.g. transcription factors and protein kinases) and functional genes, which guard the cell (e.g. enzymes for generating protective metabolites and proteins). These genes are used to enhance stress tolerance in pulses. Advances in genomic tools have resulted in availability of genome-wide scattered molecular markers and the transcriptome and whole-genome assemblies. Through this book *Pulse Improvement: Physiological, Molecular and Genetic Perspectives*, effort has been made to include chapters unravelling the molecular and genomic mechanisms behind improved yield, quality traits and tolerance to biotic and abiotic stress tolerance in pulse crops using molecular breeding, and modern genomic and genome editing tools.

This book provides a detailed and novel reference material for researchers, teachers and graduate students involved in pulse crop improvement using recent advanced molecular and genomic tools. The chapters are written by world-class reputed researchers and academicians in the field of pulse crop improvement. We express sincere thanks and gratefulness to our esteemed authors; without their strenuous efforts, this book project would not have been possible. We are also thankful to Springer Nature for providing such opportunity to complete this book. We are also thankful to all our family members for their support during the entire book project completion.

Srinagar, India Shabir Hussain Wani
New Delhi, India Mukesh Jain

Contents

Chapter 1
Pulses for Human Nutritional Security

Manisha Goyal, Jitender Singh, Pankaj Kumr, and Anil Sirohi

1.1 Introduction

Pulses belong to the family Leguminosae and are the second most economically important—as well as nutritionally important—crop (International Legume Database and Information Service 2006–2013). It is estimated that pulses have been consumed for at least 10,000 years, and they are among the most widely consumed foods in the world. Pulses play important roles in contributing to food and nutritional security and replenishing soil nutrients, with a huge potential to address needs such as future global food security, nutrition, and environmental sustainability.

The higher financial returns from the production of cereals have contributed to pulses being grown on marginal land and to their low levels of cultivation in general. Adding pulses to crop rotations produces environmental, social, and economic benefits of pulse production as it fulfils needs for protein, minimizes soil degradation, and supports diversification in food production and consumption. The livelihood and development impacts of increased pulse production and consumption need to be understood by pulse producers and all stakeholders. The legume research program conducted by CGIAR [formerly known as the Consultative Group for International Agricultural Research] (2012) reported that the share of arable land is 36% in Myanmar, 30.6% in Niger, 27% in Kenya, 22% in Mozambique, 20% in Burkina Faso, and around 10–18% in Uganda, Nigeria, Tanzania, Ethiopia, India, Mexico, and Pakistan. Increasing population is a leading cause of penury in terms of scarcity of nutritional food worldwide. The greatest shares of all forms of malnutrition are borne by Africa and Asia (WHO 2016). According to World Bank estimates, India is one of the highest-ranking countries in the world for the number of children suffering from malnutrition. In 2017 the Global Hunger Index (GHI) reported that India ranked 97th out of 118 countries with a serious hunger situation. With a GHI

M. Goyal · J. Singh (✉) · P. Kumr · A. Sirohi
College of Biotechnology, S. V. Patel University of Agriculture & Technology,
Meerut, 250110, Uttar Pradesh, India

S. H. Wani, M. Jain (eds.), *Pulse Improvement*,
https://doi.org/10.1007/978-3-030-01743-9_1

score of 29.0, India ranked third after Afghanistan and Pakistan among all South Asian nations. From the above estimated data emerges an immediate need to discuss various measures to deal with human nutritional security for human beings. To eradicate the world food problem, extensive breeding work is going on to increase the nutritional values and yields of several edible seeds worldwide. Moreover, developed countries account for only about an eighth of global pulse cultivation areas but more than a fifth of global production, because the yields in developed countries are almost twice those in developing countries. In developing economies, to achieve food and nutritional security, more efforts are needed to harness extrusion technology for producing cost-effective food, utilizing locally grown pulses with more inputs. Moreover, by improving cropping patterns using pulses, farmers can improve their yields, limit the long-term threat to food security, and improve the availability of pulses. This review considers the environmental friendliness of pulses as a crop, as well as the extensive uses and demands for pulses as a nutritional food source.

1.2 Benefits of Pulse Production

Pulse crops play a leading role in the global nitrogen cycle by fixing atmospheric nitrogen in soils by symbiotic association with rhizobia, making them self-sufficient in nitrogen and enabling them to grow in almost any soil without any or with much less fertilizer input. From 1960 to 2000, nitrogen fertilizer use increased by roughly 800%, with half of that being utilized for wheat, rice, and maize production (Canfield et al. 2010). Cereal crops such as wheat, rice, and maize utilize 40% of the fertilizer that is applied, leading to significant waste and environmental impacts such as eutrophication of coastal waters and creation of hypoxic zones (Canfield et al. 2010). Incorporation of pulses into crop rotation reduces the fertilizer requirement for self crop, as well as following cereals or any other crops. Systematic crop rotation based on incorporating pulses into cereal-based systems reduces synthetic fertilizer use and optimizes the timing and amounts of fertilizer application to crops, which are the two most important interventions to decrease nitrogen application (Canfield et al. 2010). Biological nitrogen fixation is an alternative source of nitrogen, which can be enhanced along with other integrated nutrient management strategies such as use of animal manure, as well as recycling of the nutrients contained in crop residues (Lal 2004). The greater availability of nitrogen for subsequent cereal crops also benefits the yields of those cereal crops.

1.3 Conservation Tillage

Conservation tillage is defined as physical, chemical, or biological soil manipulation to optimize conditions for germination, seedling establishment, and crop growth (Lal 1985). Conventional plow-based farming leaves soil vulnerable to water and wind erosion, increases agricultural runoff, degrades soil productivity, and releases greenhouse gases (GHGs) through both soil disturbance and fossil fuel use. No-tillage or direct seeding under a mulch layer from the previous crop reverses this process by implementing a package of practices, which includes minimum mechanical soil disturbance, permanent organic soil cover, and diversification of crop species grown in sequences and/or associations (FAO 2013). Conservation tillage involves the introduction of pulses and oilseeds into cereal-based crop rotation. With implementation of multiple years of no-tillage, it has been demonstrated that the nitrogen fixation benefits of conservation tillage or no-tillage with pulse and oilseed bean nodulation improves and nitrogen fixation rates also increase to a large extent (Van Kessel and Hartley 2000).

1.4 Reduced Greenhouse Gas Emissions

Pulse crop cultivation also plays an important role in reducing GHG emissions in agricultural production through lower fertilizer requirements, as pulses supply their own nitrogen, as well as contributing nitrogen to succeeding crops (Lemke et al. 2007).

A study conducted by Lal (1985) depicts the considerable effects of no-tillage in comparison with conventional tillage on soil chemical properties after 6 years of tillage imposition (Table 1.1).

1.5 Social Benefits

1.5.1 Nutritional Benefits

Pulses have several health benefits, which vary according to the species and cultivar. Pulses contain approximately 20–30% protein content (Iqbal et al. 2006), which is about twice the amount of protein present in wheat, oats, barley, and rice (GPC 2016). Pulses are a very rich source of lysine but are relatively low in sulfur-containing amino acids such as cysteine, methionine, and tryptophan; this can be balanced by intake of pulses together with cereals, which are abundant sources of these essential amino acids (Boye et al. 2010). Pulses are relatively low in energy density (i.e., 1.3 kcal/g) but possess a high carbohydrate content (McCrory et al.

Table 1.1 Chemical properties of soil after implementation of no-tillage

Soil property	Conventional tillage	No-tillage
pH (1:1 in water)	4.7	5.3
Organic carbon (%)	1.35	1.48
Total nitrogen (%)	0.195	0.191
Bray – phosphorus (ppm)	42.8	25.0

ppm parts per million

2010) and are excellent sources of fiber, containing mostly insoluble fiber, as well as soluble fiber (Tosh and Yada 2010). Moreover, pulses are characterized by densely packed storage of micronutrients such as folate, zinc, iron, calcium, potassium, and magnesium (Patterson et al. 2009; Kearney 2010). Pulses are also well known for containing other healthy components such as vitamin E, vitamin A, riboflavin, niacin, pyridoxine, mono- and polyunsaturated fats, and plant sterols (Lovejoy 2010; Iqbal et al. 2006; Patterson et al. 2009; USDA 2012). In contrast to dried pulses, sprouted pulses are a significant source of vitamin C (Raatz 2010).

All around the world, pulses are primarily used to feed animals, but they are also emerging as an ethanol alternative fuel (Tigunova et al. 2013). Among several benefits of pulse crops such as peas and lentils are nitrogen fixation, with little or no requirement for nitrogen fertilizer (Burgess et al. 2012) along with chickpea, pigeon pea, urad, and mung beans. Limiting the amount of GHG release helps in lowering the carbon footprint of other crops grown in rotation (Gan et al. 2011; Harrison 2011). Thus, farming of pulses is highly beneficial for sustainability of the environment, and inclusion of pulses in the daily diet is a healthy way to reduce the risks of several chronic diseases. The human body requires a daily intake of about 50 g of protein, whereas in India the per capita daily intake is only about 10 g, which has direct adverse effects on the health and work efficiency of the people. Only 14 essential amino acids are supplied by the human body itself; the remaining six have to come from food. If all six amino acids are present in a single food item, it is called a complete protein food (Table 1.2).

By combining pulses with other nutritious food items, the nutritional value of pulses can be further enhanced, as other foods enhance the absorption of all nutrients found in pulses. Studies suggest that when beans are eaten with grains the body is better able to absorb iron and other minerals found in pulses. Therefore, for the vegetarian population, combinations of two or more pulses or other crops are needed in the diet.

Table 1.2 Nutritional content of various pulses

Bean variety	Calories	Protein (g)	Carbohydrates (g)	Fiber (g)	Calcium (mg)	Iron (mg)	Potassium (mg)
Faba bean	187	12.92	33.40	9.2	61	2.55	456
Mung bean	15	17.05	2.67	0.16	18	0.54	34
Green bean	36	20.00	8.40	3.6	58	2.16	220
Lima bean	209	11.58	40.19	9.0	54	4.17	969
Adzuki bean	294	17.30	56.97	16.8	64	4.60	1224
Black bean	227	15.24	40.78	15.0	46	3.61	611

Source: http://www.scind.org/462/Health/nutritional-benefits-of-pulses.html