Kul Bhushan Saxena
Rachit K. Saxena
Rajeev K. Varshney *Editors*

Genetic Enhancement in Major Food Legumes

Advances in Major Food Legumes

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Foreword

"Legume," a popular French word that was coined in 1676, represents a group of crops that play a significant role in nutritional security and agricultural sustainability in a number of Afro-Asian countries. The consumption of legumes in diets provides a valuable protein-energy balance that is necessary for normal growth of those living below the poverty line. Therefore, in 1972, the CGIAR very wisely assigned chickpea, groundnut, and pigeonpea, the three most important legumes, to ICRISAT's mandate and gave responsibility for their quality research and development. These crops are also known for their high resilience against most common biotic and abiotic yield reducing stresses of semi-arid tropics (SAT) agriculture.

As of now the worldwide demand of legumes is on the increase due to greater awareness of their nutritional and health benefits. Hence, keeping in view the increasing urbanization, rapid population growth, and looming effects of environmental changes, the genetic enhancement of productivity of legumes is obligatory. In the recent past our scientists have achieved remarkable accomplishments against the smart goals set by the legume community. For instance, in the upstream science, ICRISAT and its partner institutes have developed genome assemblies and largescale genomic resources including a range of marker-genotyping platforms in ICRISAT mandate legume crops for advancing legume biology and breeding applications. By using both traditional and genomics-assisted breeding approaches, a number of early maturing, high yielding, disease-resistant, and drought-tolerant varieties have been developed in above-mentioned legume crops. In addition, some special technologies such as machine harvestable varieties in chickpea, high oleate varieties in groundnut, and hybrid technology in pigeonpea have also been developed. Similarly, in groundnut high yielding, drought-tolerant, disease-resistant, high oleic, and high/low oil content varieties have been developed. Similarly, through Tropical Legumes projects (funded by Bill & Melinda Gates Foundation), ICRISAT has worked with other CGIAR institutes like IITA and CIAT and national programs in about 15 countries in Africa and Asia and has contributed towards replacement of old varieties and to enhance legumes production. For this outstanding work and impact in African countries through the Tropical Legumes projects, ICRISAT has been awarded the 2021 Africa Food Prize.

I am happy to see different areas of legumes including market demand, priority setting, genomics, genetic engineering, breeding, pathology, entomology, modeling, and agronomy included in the present book *Genetic Enhancement in Major Food Legumes*. This book elegantly encompasses some past achievements along with the latest research accomplishments and technologies. Besides, it also focuses on the future research areas in various legume crops.

This book, in my opinion, will provide a useful reference to the present as well as future generations of legume scientists worldwide. I congratulate all the authors and the editors in particular for their hard work and quality vision in completing this task. I am sure readers of this book will be benefitted with the knowledge and experience of the authors.

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Arvind Kumar

Preface

For ages, legumes unknowingly, in the pre-historic era or knowingly, in the modern time, have contributed to the well-beings of human race by providing valuable proteins, minerals, vitamins, and fibers to achieve good growth and development. Legumes, in combination with cereals, make a perfect balanced diet, especially for those earning their livelihoods from subsistence agriculture in the arid, sub-tropical and tropical areas of the developing world. Globally, more than a dozen grain legumes including soybean, groundnut, cowpea, common bean, chickpea, faba bean, mung bean, pigeonpea, lentil, urd bean, and dry pea form a major component of rain-fed farming systems as a sole or intercrop. Considering the ever-increasing population and urbanization of agricultural lands, the present production level cannot meet the recommended (54 g/head/day) protein requirements of the masses. On the research and development front, it is pleasing to note that although an appreciable progress has been made in the recent past by achieving an annual production growth rate of 1.5%, it is limited to some crops like soybean, groundnut, and cowpea; and still a lot needs to be done to raise the production and productivity of legumes. Under this scenario, doubling of grain productivity in the shortest possible time appears to be the only way out. To achieve this objective, the present generation of scientists needs to review the situation not only with respect to identifying the major production constraints, but by designing and implementing some innovative crop improvement strategies and development plans. In this context, this book entitled *Genetic Enhancement in Major Food Legumes* covering diverse research aspects would be a great help. The team of authors has made tremendous efforts in compiling information about production trends, genetic enhancement technologies, widening crop adaptation, reducing crop losses, and application of innovating genomics tools. We believe that this book will help in understanding and solving some critical issues, besides planning research and development targets for the overall genetic enhancement of the legume crops.

We are thankful to all the authors for contributing high-quality research, ideas, and plans in different chapters. We would like to thank several colleagues from Springer especially Vignesh Viswanathan, Anthony Dunlap, Eric Stannard, and Nicholas DiBenedetto for all their help and support during the entire course of the book project. Furthermore, the editors are grateful to their colleagues, collaborators, and family members for the support to them while working on this project. In this regard, K.B.S. is thankful to his wife Suman Saxena, who allowed her time to be taken away to fulfil editorial responsibilities. K.B.S. would also like to thank Amrit, Rajita, Sandeep, Aarti, Sanjana and Shuban. R.K.S. is grateful to his wife Shelly Patwar and two young sons (Aniruddha Saxena and Madhav Saxena) for their help and moral support in doing editorial responsibilities in addition to research duties at ICRISAT. R.K.V. is thankful to his wife Monika A. Varshney and children Prakhar Raj Varshney and Preksha Varshney for allowing their family time to go for editing this book.

Finally, we very much hope that the book will be read and cited extensively. We look forward to receiving constructive criticism and suggestions on the book so that the editors can take them into consideration while preparing the next edition of the book, if any.

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Chapter 1
Genetic Enhancement in Major Food Legumes: An Overview

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1.1 Overview on Genetic Enhancement in Food Legumes

An overview of the vital production statistics related to seven prime legumes seems to be the right point for kick-starting the book. Dr. SN Nigam and his colleagues have provided the key statistics parameters, particularly on total area sown, gross production and mean productivity in the chapter "Trends in Legumes Production and Future Outlook". The authors revealed that the combined production of these crops recorded 549% increase between triennium ending in 1961–1963 and 2014–2016. This increase is the consequence of a combined effect of both area expansion (153%) and productivity enhancement (86%). The annual growth rates with respect to cropped area, gross production and average yields were estimated at 1.7%, 3.5% and 1.2%, respectively (Nigam et al. 2021). They concluded that the developing countries need to play a greater role in meeting the future global demand of legumes. The available information also showed that, with the exception of soybean and groundnut, inadequate attention is still going on to the R&D of other legume crops. To meet the required protein needs, this scenario needs a drastic change as early as possible (Foyer et al. 2016).

Chapter 3 entitled "Genomics: Shaping Legumes Improvement", authored by Dr. Abhishek Bohra and collaborators, provides status and potential application of various genomics technologies for the genetic improvement of the legume crops. They describe new genomics tools that are available for identifying and locating genes of importance in different legumes. Such developments will help breeders in incorporating key trait(s) from even an unproductive genetic stock to elite breeding materials more rapidly and with greater precision (Bohra et al. 2021). The authors also decipher the role of genomics science for some important futuristic breeding

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programmes such as breeding of high yielding hybrids in pigeonpea. One such application is overcoming the most serious constraints related to hybrid seed quality control in pigeonpea. Overall, the genomics technologies will also help in integrating genomics selection procedures with traditional breeding methods (Bohra et al. 2020, Roorkiwal et al. 2020, Pandey et al. 2020). In this context, a sequence-based breeding procedure has also been proposed for combining population improvement with genomics selection and genome-wide association (Varshney et al. 2019a). Besides the above, the authors also summarize the major breakthroughs achieved so far in legumes using genomics and molecular breeding technologies. They have also very rightly highlight the limitations and difficulties often encountered in integrating genomics with traditional crop breeding procedures to develop high yielding widely adapted legume cultivars.

When germplasm doesn't have natural variation for a given trait, genetic engineering technologies are very powerful for trait improvement. Therefore, in Chap. 4 entitled "Genetic Engineering of Grain Legumes: Their Potential for Sustainable Agriculture and Food and Nutritional Security", Drs. Sumita Acharjee and Thomas J. Higgins have summarized the potential role of genetic engineering in sustainable agriculture and nutritional security. They start with a very relevant statement related to the fate of protein-rich legumes. In order to tackle the issue of widespread hunger and the follow-up wave of "green revolution", the policy makers put all the eggs in one basket and ignored the development of legumes, with the exception of soybean and groundnut, perhaps for their valuable oil component and diverse usage. Of the two, soybean always got the top billing for fulfilling the demands of high-protein food for animals. In order to reduce crop losses and enhance yield and stability in legumes, research related to alien gene transfer using transformation, etc. was given priority. These efforts resulted in the development of genetically modified soybean varieties that were tolerant to the herbicide or resistant to pod borers (Grossi-de-Sá et al. 2011). These successes led to the expansion of transgenic research in other legumes such as beans, pigeonpea, cowpea, pea, lentil and chickpea, and the results are awaited. The authors also draw attention towards some plus points in favour of transgenic soybeans, and these were related to their positive impact in farm income, lower carbon footprint and better sustainability of the farm environment. If things go well, it is expected that soon the transgenic cultivars would be available to farmers following approvals from the respective Government authorities. Overall, the authors, in this chapter, have covered a challenging subject in a concise and interesting form, and they deserve appreciation. Gene editing is another powerful technology that will supplement genetic engineering technology for crop improvement (Varshney et al. 2019b).

"Hybrids in legumes" may give strange feelings to many, but it is true in case of pigeonpea. The hybrid breeding is a proven technology that has provided breakthroughs in yield in cereal and vegetable crops, but not in legumes. This discrimination is primarily attributed to the self-pollinating nature of the latter. Some enthusiastic breeders, however, tried to exploit the heterosis in crops like faba bean, soybean and pigeonpea which are blessed with partial natural cross-pollination. Of these, significant progress has been achieved in the case of pigeonpea only. Dr. K. B. Saxena and his colleagues have compiled information about hybrid breeding efforts made in faba bean, soybean and pigeonpea. In faba bean, the stability of cytoplasmic male sterility was the prime issue, while in soybean, efforts are still ongoing to enhance the level of natural outcrossing. In pigeonpea, the insect-aided natural outcrossing was found sufficient to produce large quantities of hybrid seeds, and the cytoplasmic male sterility is also highly stable (Saxena et al. 2018). Besides these, the realized heterosis is also significant. These basic components made the hybrid breeding a possibility in pigeonpea, and subsequently the world's first cytoplasmic male sterility-based legume hybrid ICPH 2671 was released. This hybrid has broken the decades-old low-yield plateau in pigeonpea by recording 30–50% more yields over the local controls in farmers' fields (Saxena et al. 2021). At present, however, all is not well with hybrids, and its technology transfer suffered a serious setback due to the inability to maintain high standards of seed quality. This constraint has now been ably addressed through the contribution of genomics scientists. The exceptionally high yields and greater resilience make pigeonpea hybrids an attractive alternative to pigeonpea farmers. At present, the pigeonpea breeders and genomics scientists are working together with some private seed companies for upscaling of hybrid technology, and soon the farmers will be able to reap the benefits of hybrid vigour in this legume (Sameerkumar et al. 2019; Bohra et al. 2020).

Legumes suffer from a number of soil-borne and foliar pathogens and inflict severe losses globally. In the manuscript on diseases in legumes, prepared by Dr. Mamta Sharma and her colleagues, information on the research and development with special reference to emerging diseases under the backdrop of changing climatic parameters has been presented. High genetic diversity, short generation turnover time, dynamic evolution of pathogens and excessive usage of chemicals are considered potential threats in the breakdown of genetic resistances and ineffectiveness of chemicals in controlling diseases. The authors believe that such situations could be managed ably through proactive resistance breeding programmes. They also rightly recommend that new legume cultivars should be bred with high levels of genetic resistance to more than one disease (Sharma et al. 2021). To achieve this, they advocate the integration the wisdom of plant breeding, genomics and plant pathology. In this context, some genomics tools such as gene editing, identification of diagnostic markers and marker-assisted breeding can play a significant role. The authors also believe that since new diseases are appearing on the scene due to significant changes occurring in key climate parameters and cropping systems, therefore, close monitoring of diseases and their virulence should be carried out on a regular basis so that some anticipatory crop management activities could be formulated and implemented. Dr. Sharma and cooleagues also visualize that interdisciplinary and international institutional research approaches would help in saving the legume crops from the existing and emerging diseases and their new biotypes.

Saving legumes from insects is the most challenging job in agriculture because a range of insects feed on the crop, insects which are dynamic in nature and can hibernate, migrate from place to place and survive on a range of alternate hosts. Besides this, it requires the highest level of skill at farming, research and crop management levels in selecting the right insecticide(s) and spraying technologies and recommends cultural practices that minimize insect losses. The chapter entitled "Identification, Evaluation and Utilization of Resistance to Insect Pests in Grain Legumes: Advancement and Restrictions" written by Dr. Jagdish Jaba and his co-authors highlights various insect-related issues including the present status, limitations and future approach. A range of insect pests damage the legumes at different growth stages in the field and during storage. Of these, pod borers, pod fly, blister beetles, etc. are important insects. The issue of insect control becomes more complicated when farmers resort to using both the recommended and non-recommended insecticides indiscriminately to protect their crops, and this may result in insects' development of resistance to insecticides (Jaba et al. 2021). The authors discuss different insect screening technologies involving no-choice and dual-choice cages, detached leaf and diet incorporation assays. They also highlight the technologies needed for evaluating germplasm, mapping populations and genetically modified crops for resistance to insect pests under field as well as greenhouse conditions. The effective methods for mass insect multiplication and identifying lines with diverse resistance mechanisms are also discussed. These can help in phenotyping plants in segregating populations to achieve the target of gene pyramiding to develop cultivars with the stable resistances to a specific pest. Appreciable levels of genetic resistances for pod borers have been identified in wild relatives of chickpea, pigeonpea and cowpea, but their incorporation into the cultivated germplasm has yet to see the light of day. This aspect needs special consideration in the future, particularly in the light of emerging technologies.

Drs. Chauhan, Chenu and Williams start the chapter "Using Crop Modelling to Improve Chickpea Adaptation in Variable Environments" by emphasizing the need for integrating crop modelling as a research component in chickpea research and development endeavours for different farming systems. This approach would help in optimising the relative contributions of genotype, environment and crop management practices towards realizing high yields. The authors believe that the chickpea genetic enhancement programmes can be enriched if specific environmental parameters such as drought, temperature, uniform agro-ecological regions, etc. are characterized and made an integral part of breeding goals and activities. This review also focuses on the importance of abiotic stresses and suggests the ways to tackle these for improved performance of chickpea. The crop modelling approach could also assist in defining appropriate selection environments for wide and specific adaptation and in identifying suitable adaptation domains for a specific variety. This will increase the heritability of the target trait and enhance the breeding value. The crop models for a given ecosystem, therefore, can play a key role in the overall chickpea improvement programmes.

Research on agronomic components is a continuous process since the new varieties with diverse plant types and maturities are bred at regular intervals and their yield optimizing agronomy will be different from the existing cultivars. The field of agronomy research has assumed an even greater importance in view of the vagaries of climate changes. These may also bring some associated changes in the cultivation scenarios. The team of authors led by Dr. Aman Ullah suggests that an integrated approach should be adopted to optimize yield and minimize the losses caused by various biotic and abiotic stresses. The authors believe that adoption of some critical agronomic practices such as seed priming, early sowing, spatial planting arrangements, raised seeding beds and precise input management could help in increasing and stabilizing legume productivity (Ullah et al. 2021). They also emphasize that the conservation agriculture including minimum tillage, rainwater harvesting, integrated nutrient and insect pest management and diversification of cropping systems would also be of help in regulating the use of herbicides, fertilizers and pesticides, besides enhancing water use efficiency and soil fertility.

The information presented by Dr. SP Wani and his colleagues is very relevant in today's agricultural scenario. The productivity of most legumes is universally low, and the well-known constraints include the lack of high yielding varieties, inappropriate fertilizers, shortage of irrigation water and various biotic and abiotic stresses. To overcome these limitations, the authors suggest the formulation of an integrated approach in which due consideration should be given to overcome the widespread deficiencies of secondary and micro-nutrients that are prevalent in rain-fed areas. This can be done by soil health mapping and quality seed supply. By applying these approaches, they reported productivity enhancement by 20–50% in crops like pigeonpea, chickpea, soybean, green gram, groundnut and black gram. They also concluded that if the farmers spend a little amount on soil test-based fertility management, then they can fetch threefold benefits or even more in their incomes. Mission projects popularly identified as *Bhoochetana* which covered over 4.75 million ha in India conclusively demonstrated the success of the integrated developmental programmes (Wani et al. 2021).

Overall, this book provides up-to-date information on several aspects of research and development in seven important legume crops, grown worldwide. These subjects covered by the authors include various technologies in the fields of genomics, genetic engineering, plant breeding, crop protection, agronomy and technology transfer. Hopefully, this compilation would be of help to both present and next-generation scientists to develop the road map of legume improvements.

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Chapter 2
Trends in Legume Production and Future Outlook

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2.1 Introduction

Legumes have a special place in diverse diets all over the world and are especially important in developing countries as they are a rich source of protein, minerals (Ca, Fe, Cu, Zn, P, K, and Mg), vitamins (thiamine, riboflavin, niacin, vitamin B_6, and folic acid), and water-soluble fibers and are affordable in price to poor communities (Reyes-Moreno and Paredes-López 1993). They are often labelled as the "poor man's meat." There is an inverse relationship between legumes consumption and income of the family (Messina 2014).

Globally, more than a dozen grain legumes, *viz.,* adzuki bean (*Vigna angularis* (Willd.) Ohwi & Ohashi), chickpea (*Cicer arietinum* L.), cluster bean (*Cyamopsis tetragonoloba* L.), common bean (*Phaseolus vulgaris* L.), cowpea (*Vigna unguiculata* L.), dry pea (*Pisum sativum* L.), faba bean (*Vicia faba* L.), grass pea (*Lathyrus sativus* L.), groundnut (*Arachis hypogaea* L.), hyacinth bean (*Lablab purpureus* L.), lentil (*Lens culinaris* Medik), lima bean (*Phaseolus lunatus* L.), mungbean (*Vigna radiata* L.), pigeonpea (*Cajanus cajan* (L.) Millsp.), soybean (*Glycine max* L. Merr.), tepari bean (*Phaseolus acutifolius* A. Gray), urdbean (*Vigna mungo* (L.) Hepper), and vetches (*Vicia sativa* L.), are commonly grown in different parts of the world as a component of subsistence farming in dry areas. In addition to being rich in protein, groundnut and soybean are also rich in fat and as such are sources of edible oil in many countries. They are treated both as food and oilseed crops.

Consumption of legumes reduces the risk of several diseases such as cancer, diabetes, osteoporosis, and cardiovascular diseases (Hu 2003; Pihlanto and Korhonen 2003; Tharanathan and Mahadevamma 2003). As consumers are looking

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for a greater balance between plant- and animal-derived nutrition, legumes offer a practical solution for diet diversification between plant and animal food sources. Addition of legumes in crop rotation has a beneficial impact on growing concerns about the negative influence of agricultural practices on the environment, as they have the capacity to fix atmospheric nitrogen in the soil, thereby, reducing the need for chemical fertilizers and improving soil health.

2.2 Global Status of Legumes

Among the legumes, common bean, chickpea, cowpea, lentil, pigeonpea, groundnut, and soybean are the major legumes grown across the world. Common bean (126 countries), groundnut (114 countries), and soybean (89 countries) are widespread followed by chickpea (55 countries), lentil (52 countries), cowpea (37 countries), and pigeonpea (23 countries). These seven legumes together occupy 212.5 m ha area with a total production of 421.8 m t and an average productivity of 1240 kg/ha (FAOSTAT 2016) (Table 2.1). Among these, soybean contributes largest (56.5%) followed by common bean (14.2%), groundnut (12.8%), chickpea (6.0%), cowpea (5.8%), pigeonpea (2.5%), and lentil (2.2%) to the total global area of these major legumes during 2014–2016. Soybean (76.2%) is also the largest contributor to the total global production of these legumes followed by groundnut (10.6%), common bean (6.4%), chickpea (2.3%), lentil (1.3%), cowpea (1.2%), and pigeonpea (1.1%). There is large variation in the average productivity of these legumes across the world. The highest average yield was recorded in the case of soybean (2678.7 kg/ha) and the lowest in cowpea (499.9 kg/ha) during 2014–2016. The average yields in the remaining five legumes were as follows: groundnut (1652.3 kg/ha), lentil (1154.1 kg/ha), chickpea (948.5 kg/ha), common bean (899.9 kg/ha), and pigeonpea (847.6 kg/ha) (Table 2.1).

Globally, these major legumes have experienced a total production gain of 548.6% (356.77 m t) during the past five and a half decades (1961–1963 to 2014–2016) due to a combined effect of area expansion by 152.6% (128.37 m ha) and yield enhancement by 85.9% (573.2 kg/ha). However, the gains vary among these legumes across the regions (Tables 2.2a and 2.2b). The maximum gain in production is observed in the case of soybean followed by cowpea, lentil, groundnut, pigeonpea, common bean, and chickpea. But the maximum gain in yield was observed in soybean followed by lentil, groundnut, common bean, chickpea, cowpea, and pigeonpea. Among these legumes, the highest increase in area is recorded in soybean followed by cowpea, lentil, pigeonpea, groundnut, common bean, and chickpea (Tables 2.2a and 2.2b).

Table 2.1 Global distribution of seven major legumes across the world during 2014–2016

Crop	Area (m ha)	Production (m t)	Yield (kg/ha)	Major countries for			Number of countries grown in the world
				Area	Production	Yield	
Common bean	30.13 (14.2%)	27.11 (6.4%)	899.9	India, Myanmar, Brazil	Myanmar, India, Brazil	Mali, Ireland, Barbados	126
Chickpea	12.82 (6.0%)	12.18 (2.3%)	948.5	India, Pakistan, Australia	India, Australia, Myanmar	China, Israel, Moldova	55
Cowpea	12.27 (5.8%)	6.13 (1.2%)	499.9	Niger, Nigeria, Burkina Faso	Nigeria, Niger, Burkina Faso	Iraq, Palestine, Macedonia	37
Groundnut with shell	27.15 (12.8%)	44.84 (10.6%)	1652.3	India, China, Nigeria	China, India, Nigeria	Israel, Malaysia, Palestine	114
Lentil	4.77 (2.2%)	5.50 (1.3%)	1154.1	Canada, India, Turkey	Canada, India, Turkey	New Zealand, Croatia, China	52
Pigeonpea	5.37 (2.5%)	4.55 (1.1%)	847.6	India, Myanmar, Tanzania	India, Myanmar, Malawi	Saint Vincent and the Grenadines, Trinidad and Tobago, Puerto Rico	23
Soybean	119.99 (56.5%)	321.49 (76.2%)	2678.7	USA, Brazil, Argentina	USA, Brazil, Argentina	Turkey, Italy, Georgia	89
Total/average	212.50	421.80	1240.3				

Figures in parentheses indicate % share in the column totals
Source: FAOSTAT 2016

Table 2.2a Region-wise area (m ha), production (m t), and yield (kg/ha) of seven major legumes during the 1961–1963 and 2014–2016 periods

Region	Year	Common bean			Chickpea			Cowpea			Groundnut with shell		
		A[a]	P[a]	Y[a]	A	P	Y	A	P	Y	A	P	Y
Asia	**1961–1963**	**11.65**	**5.57**	**477.4**	**10.98**	**6.72**	**612.2**	**0.05**	**0.03**	**743.1**	**9.63**	**7.65**	**794.2**
	2014–2016	**15.27**	**12.10**	**792.6**	**11.14**	**10.05**	**901.3**	**0.16**	**0.15**	**922.3**	**11.52**	**26.72**	**2324.5**
	% Change[b]	**31.1**	**117.4**	**66.0**	**1.5**	**49.7**	**47.2**	**240.8**	**323.3**	**24.1**	**19.6**	**249.5**	**192.7**
Central Asia	1992–1994	0.02	0.02	918.3	0.01	0.01	721.6	–[c]	–	–	0.01	0.02	1505.6
	2012–2014	0.08	0.11	1459.5	0.03	0.02	789.8	–	–	–	0.00	0.01	2937.1
	% Change	232.4	425.9	58.9	128.0	139.5	9.5	–	–	–	−57.5	−16.9	95.1
South Asia	1961–1963	6.99	1.91	273.6	10.73	6.55	610.8	–	–	–	7.04	5.15	731.7
	2014–2016	10.30	4.55	441.8	10.29	8.89	861.4	0.01	0.01	1346.8	5.16	7.19	1412.0
	% Change	47.3	137.8	61.4	−4.0	35.7	41.0	–	–	–	−26.8	39.7	93.0
East Asia	1961–1963	3.72	2.90	778.6	–	–	–	0.01	0.01	1042.7	1.48	1.43	964.5
	2014–2016	1.07	1.50	1413.1	–	–	–	0.01	0.01	1072.7	4.61	16.60	3600.6
	% Change	−71.33	−48.1	81.5	–	–	–	−8.3	−5.4	2.9	211.2	1058.5	273.3
Southeast Asia	1961–1963	0.82	0.61	750.9	0.12	0.05	438.1	0.03	0.02	622.0	1.08	1.02	940.6
	2014–2016	3.64	5.55	1526.1	0.37	0.57	1527.4	0.13	0.12	867.4	1.69	2.72	1606.7
	% Change	346.0	807.5	103.2	221.3	1002.8	248.6	434.8	648.0	39.4	56.3	167.2	70.8
West Asia	1961–1963	0.12	0.14	1148.6	0.13	0.12	872.5	–	–	–	0.02	0.05	2423.6
	2014–2016	0.11	0.26	2453.0	0.46	0.58	1252.4	–	–	–	0.05	0.19	3800.4
	% Change	−13.5	84.9	113.6	247.5	399.3	43.5	–	–	–	169.3	322.0	56.8
Africa	**1961–1963**	**1.72**	**1.03**	**596.4**	**0.37**	**0.20**	**546.0**	**2.88**	**0.85**	**304.2**	**6.27**	**5.38**	**859.0**
	2014–2016	**7.28**	**6.51**	**894.7**	**0.61**	**0.76**	**1234.7**	**12.03**	**5.88**	**489.2**	**14.25**	**13.54**	**950.2**
	% Change	**322.0**	**533.1**	**50.0**	**64.1**	**270.6**	**126.2**	**318.0**	**589.9**	**60.8**	**127.3**	**151.6**	**10.6**
East Africa	1961–1963	1.04	0.72	699.0	0.19	0.13	652.2	0.17	0.09	568.9	1.06	0.61	569.2
	2014–2016	4.72	4.51	954.4	0.50	0.65	1313.3	0.91	0.48	522.5	3.39	2.62	762.1
	% Change	355.4	521.8	36.5	156.1	415.9	101.4	448.7	403.7	−8.2	219.4	332.7	33.9

Middle Africa	1961–1963	0.45	0.20	447.6	–	–	–	0.05	0.03	580.9	0.72	0.52	730.9
	2014–2016	1.72	1.11	644.4	–	–	–	0.38	0.25	674.4	2.31	2.41	1040.0
	% Change	280.9	448.3	44.0	–	–	–	605.4	718.3	16.1	222.7	360.0	42.3
North Africa	1961–1963	0.01	0.01	1076.2	0.18	0.08	431.4	–	–	–	0.31	0.38	1247.3
	2014–2016	0.04	0.14	3121.2	0.11	0.10	915.8	0.25	0.11	418.8	2.07	1.83	876.8
	% Change	226.1	847.6	190.0	−36.6	32.1	112.3	–	–	–	569.4	380.2	−29.7
Southern Africa	1961–1963	0.07	0.05	639.7	–	–	–	0.02	0.01	503.7	0.30	0.25	824.6
	2014–2016	0.07	0.07	912.8	–	–	–	0.01	0.01	425.7	0.05	0.05	1001.5
	% Change	1.3	47.4	42.7	–	–	–	−40.7	−51.0	−15.5	−83.0	−78.2	21.5
West Africa	1961–1963	0.15	0.04	273.7	–	–	–	2.63	0.71	278.0	3.88	3.62	935.5
	2014–2016	0.72	0.69	964.1	–	–	–	10.48	5.04	481.0	6.42	6.63	1032.3
	% Change	373.8	1567.2	252.2	–	–	–	298.0	607.9	73.0	65.6	83.0	10.4
Americas	**1961–1963**	**5.70**	**3.84**	**666.8**	**0.19**	**0.15**	**796.9**	**0.05**	**0.03**	**516.3**	**1.37**	**1.89**	**1356.9**
	2014–2016	**6.84**	**7.24**	**1049.1**	**0.28**	**0.43**	**1519.4**	**0.03**	**0.04**	**1065.7**	**1.32**	**4.50**	**3316.3**
	% Change	**20.0**	**88.7**	**57.3**	**52.5**	**191.2**	**90.7**	**−43.5**	**41.8**	**106.4**	**−3.6**	**138.3**	**144.4**
Central America	1961–1963	1.95	0.85	437.0	0.14	0.12	891.3	–	–	–	0.08	0.09	1250.8
	2014–2016	2.39	1.77	738.4	0.08	0.14	1720.1	–	–	–	0.11	0.29	2694.7
	% Change	22.6	107.6	68.9	−37.9	19.3	93.0	–	–	–	41.4	203.9	115.4
South America	1961–1963	3.14	2.07	659.3	0.05	0.03	546.0	–	–	–	0.73	0.99	1361.5
	2014–2016	3.67	3.90	1060.4	0.06	0.06	1059.3	0.02	0.02	1324.4	0.61	1.63	2666.9
	% Change	16.7	88.1	60.8	23.4	139.6	94.0	–	–	–	−15.6	64.7	95.9
North America	1961–1963	0.60	0.91	1512.0	–	–	–	0.05	0.03	617.3	0.57	0.80	1421.2
	2014–2016	0.78	1.57	2027.7	0.14	0.22	1609.4	0.01	0.02	1808.1	0.60	2.58	4319.5
	% Change	28.6	72.5	34.1	–	–	–	−73.8	−23.1	192.9	5.7	221.1	203.9
Caribbean	**1961–1963**	**0.19**	**0.09**	**478.7**	**–**	**–**	**–**	**0.07**	**0.03**	**437.0**	**0.07**	**0.07**	**936.5**
	2014–2016	**0.31**	**0.27**	**859.0**	**–**	**–**	**–**	**0.04**	**0.03**	**729.3**	**0.05**	**0.05**	**947.5**
	% Change	**61.5**	**189.76**	**79.4**	**–**	**–**	**–**	**−36.54**	**5.88**	**66.9**	**−27.48**	**−26.73**	**1.2**

(continued)

Table 2.2a (continued)

Region	Year	Common bean			Chickpea			Cowpea			Groundnut with shell		
		A[a]	P[a]	Y[a]	A	P	Y	A	P	Y	A	P	Y
Europe	**1961–1963**	**4.10**	**1.03**	**251.6**	**0.42**	**0.22**	**530.6**	**0.01**	**0.04**	**3625.6**	**0.02**	**0.03**	**1723.3**
	2014–2016	**0.39**	**0.96**	**2443.9**	**0.25**	**0.25**	**1006.0**	**0.01**	**0.03**	**3237.8**	**0.00**	**0.00**	**3090.5**
	% Change	**−90.5**	**−7.2**	**871.5**	**−38.9**	**13.3**	**89.6**	**−18.2**	**−24.7**	**−10.7**	**−90.8**	**−83.5**	**79.3**
Eastern Europe	1961–1963	1.84	0.26	140.4	–	–	–	–	–	–	–	–	–
	2014–2016	0.21	0.45	2211.7	0.19	0.19	1019.2	–	–	–	–	–	–
	% Change	−88.8	77.2	1475.3	–	–	–	–	–	–	–		–
Western Europe	1961–1963	0.10	0.10	1077.4	–	–	–	–	–	–	–	–	–
	2014–2016	0.01	0.01	2430.8	–	–	–	–	–	–	–	–	–
	% Change	−94.3	−87.2	125.6	–	–	–	–	–	–	–	–	–
Southern Europe	1961–1963	2.17	0.67	308.0	0.41	0.22	528.9	0.01	0.04	3625.6	0.01	0.03	1807.4
	2014–2016	0.06	0.10	1609.2	0.06	0.06	1028.0	0.01	0.03	3237.8	–	–	–
	% Change	−97.0	−84.5	422.5	−85.4	−71.7	94.3	−18.2	−24.7	−10.7	−91.3	−84.2	81.6
Oceania	**1961–1963**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**0.02**	**0.02**	**1159.7**
	2014–2016	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**0.01**	**0.02**	**1925.7**
	% Change	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**−34.3**	**8.5**	**66.0**
Australia and New Zealand	1961–1963	–	–	–	–	–	–	–	–	–	0.02	0.02	1187.4
	2014–2016	0.04	0.03	941.9	0.54	0.69	1279.3	–	–	–	0.01	0.02	2863.8
	% Change	–	–	–	–	–	–	–	–	–	−57.1	2.5	141.2
World	**1961–1963**	**23.37**	**11.56**	**494.4**	**11.95**	**7.29**	**610.1**	**3.05**	**0.98**	**330.4**	**17.37**	**15.04**	**865.1**
	2014–2016	**30.13**	**27.11**	**899.9**	**12.82**	**12.18**	**948.6**	**12.27**	**6.13**	**499.9**	**27.15**	**44.84**	**1652.3**
	% Change	**28.9**	**134.6**	**82.0**	**7.3**	**67.0**	**55.5**	**302.0**	**523.9**	**51.3**	**56.3**	**198.2**	**91.0**

[a]A = area, P = production, Y = yield
[b]Percent change in 2014–2016 over the 1961–1963 period
[c]– indicates the crop is either not grown or grown in <10,000 ha area in the region. Source: FAOSTAT 1961 to 2016

Table 2.2b Region-wise area (m ha), production (m t), and yield (kg/ha) of seven legumes in 1961–1963 and 2014–2016

Region	Year	Lentil			Pigeonpea			Soybean			All seven legumes		
		A[a]	P[a]	Y[a]	A	P	Y	A	P	Y	A	P	Y
Asia	**1961–1963**	**1.25**	**0.66**	**529.3**	**2.53**	**1.71**	**676.3**	**11.31**	**7.75**	**686.0**	**47.38**	**30.08**	**645.5**
	2014–2016	**2.47**	**2.18**	**883.1**	**4.49**	**3.56**	**792.7**	**19.88**	**25.81**	**1298.5**	**64.93**	**80.58**	**1130.7**
	% Change[b]	**98.5**	**230.9**	**66.8**	**77.9**	**108.5**	**17.2**	**75.8**	**233.0**	**89.3**	**37.0**	**167.9**	**75.2**
Central Asia	1992–1994	0.02	0.02	670.5	–[c]	–	–	0.01	0.01	1016.2	0.08	0.07	966.4
	2012–2014	0.01	0.01	1034.7	–	–	–	0.10	0.20	1949.8	0.22	0.35	1634.2
	% Change	−65.2	−46.2	54.3	–	–	–	1178.5	2288.6	91.9	183.7	399.2	69.1
South Asia	1961–1963	1.04	0.49	473.6	2.46	1.68	684.0	0.02	0.01	491.0	28.29	15.80	546.1
	2014–2016	1.99	1.52	765.6	3.85	2.96	768.8	11.57	11.26	974.3	43.16	36.38	938.7
	% Change	91.3	208.5	61.6	56.5	76.0	12.4	59598.8	118679.1	98.5	52.6	130.3	71.9
East Asia	1961–1963	–	–	–	–	–	–	10.61	7.28	687.0	15.82	11.63	868.2
	2014–2016	0.06	0.14	2280.2	–	–	–	7.15	12.66	1770.9	12.90	30.94	2449.0
	% Change	–	–	–	–	–	–	−32.6	73.9	157.8	−18.4	166.1	182.1
Southeast Asia	1961–1963	–	–	–	0.07	0.03	411.8	0.68	0.46	674.2	2.78	2.18	620.4
	2014–2016	–	–	–	0.65	0.60	934.0	1.01	1.50	1481.7	7.50	11.06	1228.2
	% Change	–	–	–	886.9	2163.7	126.8	49.8	229.2	119.8	169.3	407.4	97.9
West Asia	1961–1963	0.21	0.17	805.8	–	–	–	–	–	–	0.49	0.48	1136.6
	2014–2016	0.37	0.46	1237.0	–	–	–	0.04	0.16	4330.5	1.03	1.65	2647.2
	% Change	81.3	176.9	53.5	–	–	–	–	–	–	109.9	247.0	132.9
Africa	**1961–1963**	**0.15**	**0.10**	**656.2**	**0.17**	**0.09**	**530.1**	**0.21**	**0.08**	**388.1**	**11.78**	**7.74**	**554.3**
	2014–2016	**0.15**	**0.19**	**1237.2**	**0.72**	**0.85**	**1196.0**	**1.94**	**2.42**	**1250.3**	**36.98**	**30.16**	**1036.0**
	% Change	**0.1**	**87.8**	**88.5**	**310.5**	**821.1**	**125.6**	**827.6**	**2873.9**	**222.2**	**213.9**	**289.4**	**86.9**
East Africa	1961–1963	0.08	0.04	460.3	0.17	0.09	527.4	0.02	0.01	604.4	2.73	1.69	583.1
	2014–2016	0.11	0.15	1394.2	0.71	0.85	1203.8	0.48	0.63	1343.5	10.82	9.89	1070.5
	% Change	33.0	303.1	202.9	317.1	846.6	128.3	2535.3	5623.6	122.3	296.5	485.1	83.6

(continued)

Table 2.2b (continued)

Region	Year	Lentil			Pigeonpea			Soybean			All seven legumes		
		A[a]	P[a]	Y[a]	A	P	Y	A	P	Y	A	P	Y
Middle Africa	1961–1963	–	–	–	0.01	–	620.0	–	–	–	1.23	0.76	606.6
	2014–2016	–	–	–	0.01	0.01	614.8	0.09	0.06	669.6	4.51	3.84	728.7
	% Change	–	–	–	88.2	86.7	0.8	–	–	–	266.9	404.0	20.1
North Africa	1961–1963	0.07	0.06	883.9	–	–	–	–	–	–	0.58	0.54	1052.8
	2014–2016	0.04	0.04	797.3	–	–	–	0.01	0.04	3184.6	2.54	2.25	1552.4
	% Change	−38.3	−42.1	−9.8	–	–	–	–	–	–	339.6	317.1	47.5
Southern Africa	1961–1963	–	–	–	–	–	–	0.01	–	508.1	0.40	0.31	619.0
	2014–2016	–	–	–	–	–	–	0.56	0.92	1639.2	0.70	1.05	994.8
	% Change	–	–	–	–	–	–	11186.7	36115.7	222.6	75.5	238.5	60.7
West Africa	1961–1963	–	–	–	–	–	–	0.18	0.07	360.6	6.85	4.44	462.0
	2014–2016	–	–	–	–	–	–	0.79	0.76	966.5	18.41	13.13	832.0
	% Change	–	–	–	–	–	–	329.6	1049.2	168.0	168.9	195.5	80.1
Americas	**1961–1963**	**0.10**	**0.06**	**672.3**	**0.01**	**–**	**972.4**	**11.67**	**19.13**	**1640.7**	**19.04**	**25.11**	**946.0**
	2014–2016	**1.86**	**2.82**	**1531.8**	**0.01**	**–**	**860.9**	**93.17**	**283.60**	**3043.0**	**103.50**	**298.64**	**1769.5**
	% Change	**1849.4**	**4282.5**	**127.8**	**−23.7**	**−24.6**	**−11.5**	**698.6**	**1382.2**	**85.5**	**442.6**	**1089.5**	**87.0**
Central America	1961–1963	0.01	0.00	867.5	–	–	–	0.02	0.04	2049.1	2.19	1.12	1032.6
	2014–2016	0.01	0.00	752.7	–	–	–	0.27	0.47	1744.6	2.86	2.68	1356.1
	% Change	29.0	12.9	−13.2	–	–	–	1147.6	954.9	−14.9	30.6	139.4	31.3
South America	1961–1963	0.07	0.04	566.8	0.01	–	514.8	0.33	0.35	1085.4	4.33	3.49	789.0
	2014–2016	0.01	0.01	764.6	–	–	–	57.35	166.71	2905.6	61.73	172.33	1488.4
	% Change	−82.2	−76.0	34.9	–	–	–	17298.4	46879.3	167.7	1327.0	4843.5	88.7
North America	1961–1963	0.02	0.02	956.5	–	–	–	11.32	18.74	1656.1	12.56	20.50	1232.6
	2014–2016	1.84	2.80	1541.4	–	–	–	35.55	116.43	3274.8	38.91	123.63	2430.1
	% Change	8792.4	13556.5	61.2	–	–	–	214.2	521.4	97.7	209.9	503.0	97.1

Caribbean	**1961–1963**	**–**	**–**	**–**	**0.03**	**0.03**	**1090.2**	**–**	**–**	**–**	**0.36**	**0.22**	**801.9**
	2014–2016	**–**	**–**	**–**	**0.15**	**0.13**	**874.4**	**–**	**–**	**–**	**0.56**	**0.48**	**857.3**
	% Change	**–**	**–**	**–**	**409.28**	**308.51**	**−19.8**	**–**	**–**	**–**	**54.43**	**116.13**	**6.9**
Europe	**1961–1963**	**0.14**	**0.09**	**635.6**	**–**	**–**	**–**	**0.83**	**0.44**	**525.7**	**5.52**	**1.84**	**1215.4**
	2014–2016	**0.10**	**0.09**	**912.9**	**–**	**–**	**–**	**4.97**	**9.59**	**1935.6**	**5.72**	**10.92**	**2104.4**
	% Change	**−33.0**	**-2.6**	**43.6**	**–**	**–**	**–**	**499.2**	**2097.3**	**268.2**	**3.6**	**492.2**	**73.2**
Eastern Europe	1961–1963	0.05	0.03	591.0	–	–	–	0.82	0.43	520.8	2.71	0.71	657.4
	2014–2016	0.04	0.04	914.0	–	–	–	4.26	7.34	1726.4	4.70	8.02	1471.6
	% Change	−6.6	53.8	54.7	–	–	–	419.2	1614.3	231.5	73.7	1022.6	123.9
Western Europe	1961–1963	0.01	0.01	695.2	–	–	–	–	–	–	0.11	0.11	886.3
	2014–2016	0.02	0.02	1345.0	–	–	–	0.18	0.47	2692.9	0.20	0.50	2156.2
	% Change	39.0	168.6	93.5	–	–	–	–	–	–	80.3	346.2	143.3
Southern Europe	1961–1963	0.09	0.06	651.2	–	–	–	0.01	0.01	1053.8	2.70	1.01	1329.1
	2014–2016	0.04	0.03	688.0	–	–	–	0.53	1.79	3382.8	0.71	2.01	2204.7
	% Change	−56.4	−53.9	5.7	–	–	–	5971.3	20713.9	221.0	−73.9	98.1	65.9
Oceania	**1961–1963**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**0.02**	**0.02**	**853.9**
	2014–2016	**0.19**	**0.22**	**1185.8**	**–**	**–**	**–**	**0.03**	**0.07**	**2139.8**	**0.81**	**1.03**	**1494.5**
	% Change	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**3759.2**	**4290.1**	**75.0**
Australia and New Zealand	1961–1963	–	–	–	–	–	–	–	–	–	0.02	0.02	863.1
	2014–2016	0.19	0.22	1185.8	–	–	–	0.03	0.07	2139.8	0.80	1.03	1682.1
	% Change	–	–	–	–	–	–	–	–	–	4626.2	5201.1	94.9
World	**1961–1963**	**1.64**	**0.92**	**559.2**	**2.74**	**1.84**	**671.4**	**24.01**	**27.40**	**1141.1**	**84.14**	**65.02**	**667.4**
	2014–2016	**4.77**	**5.50**	**1154.1**	**5.37**	**4.55**	**847.6**	**119.99**	**321.49**	**2678.6**	**212.50**	**421.80**	**1240.1**
	% Change	**191.0**	**499.9**	**106.4**	**96.0**	**147.6**	**26.2**	**399.7**	**1073.2**	**134.7**	**152.6**	**548.7**	**85.8**

[a]A = area, P = production, Y = yield
[b]Percent change in 2014–2016 over the 1961–1963 period
[c]– indicates the crop is either not grown or grown in <10,000 ha area in the region. Source: FAOSTAT 1961 to 2016

2.2.1 Global Annual Growth Rates

The annual growth rates (AGRs) of area, production, and productivity of seven major legumes across the regions for the 1961–1963 to 2014–2016 period are presented in Tables 2.3a and 2.3b. The global AGRs of total area, production, and yield of these major legumes are 1.7%, 3.5%, and 1.2%, respectively. The global AGR for the area of soybean is 3.0% followed by cowpea (2.6%), lentil (2.1%), pigeonpea (1.4%), groundnut (0.7%), common bean (0.4%), and chickpea (0.2%). The maximum AGR for production across the globe is observed in soybean (4.5%) followed by cowpea (4.1%), lentil (3.5%), groundnut (2.2%), pigeonpea (1.8%), common bean (1.5%), and chickpea (1.1%), whereas the highest AGR for yield is observed in groundnut (1.5%) followed by soybean (1.4%), cowpea (1.4%), lentil (1.4%), common bean (1.1%), chickpea (0.9%), and pigeonpea (0.4%).

2.3 Region-Wise Crop Performance and Future Outlook

This section highlights crop-wise performance across regions over time. This analysis (see Tables 2.2a and 2.2b) provides a deeper understanding of crop-wise gains and losses across major production regions in the world. IMPACT (International Model for Policy Analysis of Agricultural Commodities and Trade) model version 3.3, developed by the International Food Policy Research Institute (IFPRI) (Robinson et al. 2015), was used to assess future demand and supply projections of each crop for 2030 and 2040 across regions and major producing countries in the world. They are based on shared socioeconomic pathway (SSP-2) baseline projections with no climate change into consideration. This analysis will help in identifying future demanding traits across regions and their potential.

2.3.1 Common Bean

Common bean is the second largest legume crop after soybean grown in the world with an area of 30.1 m ha and production of 27.1 m t. The average global productivity level of common bean is around 900 kg/ha. Among the regions, the average yield is highest in the case of Europe (2444 kg/ha) followed by the Americas (1049 kg/ha), Oceania (942 kg/ha), Africa (895 kg/ha), and Asia (793 kg/ha). A significant enhancement in its production was achieved through expansion in area and an increase in its productivity. The global AGRs of area, production, and yield are 0.4%, 1.5%, and 1.1%, respectively. India (9.9 m ha), Myanmar (3.0 m ha), Brazil (2.9 m ha), Mexico (1.6 m ha), and Kenya (1.2 m ha) are the top five common bean producing countries in the world. In spite of significant area under the crop in India, Myanmar is the largest producer of common bean (4.92 m t) in the world. It is

Table 2.3a Annual growth rate (%) of area, production, and yield of common bean, chickpea, cowpea, and groundnut (with shell) across different regions of the world, 1961–2016

	Common bean			Chickpea			Cowpea			Groundnut with shell		
Region	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
Asia	*0.4*	*1.5*	*1.1*	*0.1*	*0.9*	*0.8*	*3.3*	*4.1*	*0.9*	*0.4*	*2.7*	*2.3*
Central Asia[b]	8.8	12.9	3.8	7.8	8.7	0.8	–[a]	–	–	−3.7	0.3	4.2
South Asia	0.4	1.4	1.1	−0.1	0.7	0.8	1.8	3.1	1.3	−0.5	0.7	1.2
East Asia	−1.9	−0.7	1.2	3.6	7.1	3.4	−9.1	−9.0	0.0	2.3	5.1	2.7
Southeast Asia	3.1	4.3	1.1	2.0	4.2	2.2	4.6	6.1	1.3	1.0	2.4	1.4
West Asia	0.3	1.2	0.9	3.4	3.7	0.3	−5.1	−3.0	2.3	1.4	2.4	0.9
Africa	*2.8*	*3.3*	*0.5*	*0.8*	*1.8*	*1.0*	*2.6*	*4.2*	*1.5*	*1.2*	*1.7*	*0.5*
East Africa	3.0	3.1	0.1	1.7	2.6	1.0	3.8	3.6	−0.2	1.4	1.7	0.3
Middle Africa	2.3	2.8	0.5	–	–	–	3.8	4.0	0.2	1.9	2.6	0.7
North Africa	2.0	3.9	1.8	−1.1	−0.2	0.9	7.5	4.2	−3.1	2.7	2.5	−0.2
Southern Africa	−0.6	0.1	0.7	–	–	–	−0.7	−1.9	−1.2	−3.9	−3.1	0.8
West Africa	3.7	7.3	3.5	12.9	14.2	1.2	2.5	4.3	1.7	0.9	1.6	0.7
Americas	*0.2*	*1.1*	*1.0*	*0.4*	*1.9*	*1.5*	*0.8*	*3.6*	*2.0*	*−0.8*	*0.8*	*1.6*
Central America	0.2	1.2	0.9	−1.5	0.0	1.5	–	–	–	1.0	2.8	1.8
South America	−0.1	1.1	1.0	−2.1	−0.4	1.7	1.1	2.1	1.0	−1.6	−0.2	1.4
North America	0.5	1.3	0.8	12.8	14.5	1.5	–	–	–	−0.2	1.4	1.5
Caribbean	*0.9*	*2.1*	*1.2*	–	–	–	*−1.5*	*−0.3*	*1.2*	*−1.4*	*−1.5*	*−0.1*
Europe	−5.4	−1.2	**4.4**	**−2.3**	**−1.2**	**1.1**	**1.8**	**1.6**	**−0.2**	**−4.4**	**−4.2**	**0.2**
Eastern Europe	−5.1	0.3	5.7	9.2	9.0	−0.2	–	–	–	−1.8	−1.4	0.4
Western Europe	−5.8	−4.2	1.7	–	–	–	–	–	–	–	–	–
Southern Europe	−6.6	−3.6	3.2	−4.0	−2.9	1.1	1.8	1.6	−0.2	−6.5	−5.3	1.3
Oceania	*7.1*	*8.9*	*1.7*	*9.7*	*10.2*	*0.5*	–	–	–	*−1.5*	*−0.1*	*1.4*
Australia and New Zealand	7.1	8.9	1.7	9.7	10.2	0.5	–	–	–	−2.2	−0.2	2.0
World	*0.4*	*1.5*	*1.1*	*0.2*	*1.1*	*0.9*	*2.6*	*4.1*	*1.4*	*0.7*	*2.2*	*1.5*

[a]The crop was either not grown in the region or grown only for a few years during the 1961–2016 period
[b]Data for Central Asia are available only from 1992 to 2016 (Source: FAOSTAT 1961 to 2016)