SOYBEANS for the TROPICS

RESEARCH, PRODUCTION and UTILIZATION

Edited by
S.R. Singh, K.O. Rachie
and K.E. Dashiell

TROPICAL SOYBEAN

International Institute of Tropical Agriculture

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Research, Production and Utilization

Edited by *S. R. Singh, K. O. Rachie* and *K. E. Dashiell*

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Soybeans for the Tropics

Dedicated to the poor in the tropics who need better nutrition

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Preface

My introduction to soybeans is very recent, only 6 years ago. Since I took the responsibility of leading the group for soybean research at the International Institute of Tropical Agriculture (IITA), I have explored and learned much about the crop. I have come to the same conclusion as many before me: it is a 'golden bean', a 'miracle bean', 'crop of the planet', and now I firmly believe it is 'God's sent golden bean', with much promise in tropical Africa and in many parts of Asia and Latin America. The people who know the value of the crop and have utilized it fully are in China, Japan, Korea and Indonesia and in a few other Southeast Asian countries. It produces high-quality oil—about 20 per cent of its content—and protein—about 40 per cent of the bean. The oil is highly digestible, high in unsaturated fatty acids and contains no cholesterol. Its protein content is superior, with substantial levels of most essential amino acids. Consumed with a cereal (such as maize) to supply methionine and cystine, soybeans are a cheap substitute for meat and fish. The carbohydrate content is about 30 per cent, with total soluble sugars equal to about 10 per cent. The oligosaccharides, which cause flatulence, are minimal compared with other grain legumes so soybean is an ideal food for infants. In addition, it is a good dietary source of calcium and phosphorus. Today, it is used in milk, tofu (a cheeselike product), a textured substitute for meat, flour (alone or with wheat to improve the nutrients in bread) and many snack foods.

By far the largest commercial cultivation of soybeans is in the USA, with Brazil next. In China, soybeans are mostly consumed by the local population. The USA yearly produces more than 60 million tonnes of soybean and exports half the crop, the value of which is about US$5 billion. Brazil, which before 1960 hardly grew any soybeans, today exports close to 15 million tonnes annually, valued at about US$2 billion.

In the developing world, soybean cultivation and utilization have been restricted for several reasons, the main one being that until very recently no serious effort has been devoted to improving the crop's performance in the tropics. Most soybeans in the tropics yield little, produce seed with short viability, nodulate poorly and shatter easily when ripe. The research on utilization has also been minimal. There is a need to develop recipes that suit local taste and cook relatively quickly so that soybeans processed or unprocessed become a part of the daily diet of the people. There is also a need to establish village-level industries for prccessing inexpensively foods with a long shelf-life.

In this book, we have reviewed the constraints on soybean production and utilization in the tropics and the research being conducted to overcome them. We have avoided details of crop origin, taxonomy and genetics since this information is avilable elsewhere. We have concentrated on current efforts in breeding in the tropics and have highlighted the progress made on pest, disease and weed control, and agronomic practices. The status of soybean research in different tropical regions is covered as well.

The need for a book such as this was expressed at the 'Tropical Soybean Workshop' held at IITA from 30 September to 4 October 1985. Some of the papers presented at that workshop are included in this book.

We wish to express our sincere thanks to the Federal Department of Agriculture, Water Resources and Rural Development of Nigeria, for supporting the cost of this publication and their deep support for soybean research at IITA. We also thank the Commission of European Communities (CEC) for co-sponsoring the conference and supporting the soybean project at IITA. Without aid from these agencies, IITA would hardly have been able to bring together the contributions to this publication. We owe our gratitude also to the International Soybean Program (INTSOY), University of Illinois, USA, and to several private companies both national and international for supporting the workshop held in 1985.

Special thanks are due our colleagues in the IITA Grain Legume Improvement Program for their assistance, and our appreciation goes to Amy Chouinard for her editing of the manuscripts. We thank the director general and the management of IITA for their encouragement to publish this book.

We hope that this book will enable researchers, administrators and policy-makers to understand the value of soybean, its constraints and how to solve them. We trust the book will stimulate exchange of germ plasm as well as collaboration among scientists for their mutual benefit.

Finally, it is the hope of all who contributed to this book that the information will assist in promotion of the cultivation of soybean as food for people in the tropics.

S. R. SINGH

Introduction

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Soybean is a remarkable plant. In the short span of three or four decades it has become the preeminent source of protein for animal diets aimed at high volume and has gained popularity around the globe for human nutrition. It has also become the leading source of edible oils and fats, constituting about 20 per cent of the world supply and more than any other single source of these essential nutrients. Fewer than 50 years ago, the plant was considered an obscure crop cultivated to a limited extent in the Far East.

Why has this crop among the several grain legumes risen so rapidly to prominence? Its primitive relatives—both cultivated and near wild—are notoriously poor seed producers compared with maize, sorghum and millets. Even today, after several decades of effort, the progress to improve soybean is much slower than that for several species of the genera *Phaseolus* and *Vigna*.

Some people suggest that soybean proved more useful than other grain legumes by virtue of its dual purpose—protein and oil—and mainly its protein and adaptation to temperate conditions. Others suggest that soybean was easier than its competitors to improve genetically as a consequence of its higher number of chromosomes (2n = 40 compared with 2n = 14 and 2n = 20 for other grain legumes). Also they note this crop has been particularly adaptable to current needs.

Although Chinese farmers who first grew soybeans more than 5000 years ago probably made substantial—even if painstaking—improvement in this crop, major credit for bringing this plant into the 20th century must go to a small group of brilliant, highly dedicated crop scientists who began using modern methods of plant improvement during the past 50 years, particularly in the United States (Federal Department of Agriculture), Canada, China, Brazil and Australia. Less successful were attempts to introduce soybeans into cool summer environments, like those of the intermediate elevations and northern Europe, and into the lowland tropics.

Recognizing the key role of soybeans in national agriculture, especially for production of animal feeds and cooking oils, several subtropical and tropical countries have introduced this crop and have made determined efforts to adapt it to local conditions and needs. Good progress has been made in the subtropical to subtemperate zone (from about 15° to 30° north and south of the equator). From its traditional environment in the Far East, soybean has now become an established and significant crop not only in southern Brazil (especially from Sao Paulo to Rio Grande do Sul) but also in central–northern India (Madhya Pradesh and Uttar Pradesh) and in subtropical Australia (Queensland).

Despite repeated efforts to introduce soybean to the lowland tropics, the crop has played a negligible role in the farming systems except for its traditional one in Southeast Asia. The successes in introducing this crop occurred in regions where the subtemperate materials could be adapted.

PRODUCTION

The world production of soybean increased by 55 per cent from 58.1 million to 89.9 million tonnes from 1976 to 1984. Total area harvested increased from 37.8 million to 52.1 million hectares and yields from 1536 kg/ha to 1727 kg/ha during the same period. Of the total, the United States produced 56.3 per cent, whereas Brazil and China contributed 17.2 per cent and 10.8 per cent, respectively. Developing countries as a group produced 26.3 million tonnes (29 per cent), but Latin America contributed most of this amount—23.9 million tonnes or 27 per cent of the total. Next was the Far East (excluding China) with 1.87 million tonnes, and much below this level was the Near East and Africa with 300,000 t and 200,000 t, respectively. Yields in Africa were lowest, at 660 kg/ha, with the Far East next lowest in productivity with 960 kg/ha in 1984.

The scope for soybeans in the lowland tropics, especially in Africa and Asia, is considerable: an FAO study indicates a potential in Africa of about 145 million hectares where inputs would be low and up to 270 million hectares under high-input conditions. Similarly, vast areas would be available for this crop in the low latitudes of Latin America, particularly in the Amazon Basin—on the fringes first and then in the more heavily forested areas. Also, demand and improvement undoubtedly will contribute to expanded production in tropical and subtropical Asia but not to the extent that could occur in Africa and the Americas.

CONSTRAINTS

Soybean production is deterred in the tropics primarily because of biologic constraints on the crop and the lack of markets. Soybeans have long been included in a minor way in the farming systems of tropical Asia. Beginning in the late 1800s in Africa and somewhat later in Latin America, they began to be tested. Germ plasm predominantly from temperate regions was grown in limited areas, but the early efforts were largely doomed for a number of poorly understood reasons. Markets and uses did not develop mainly because production was not assured.

The lack of early progress on production in the tropics is mainly attributed to the lack of a critical mass of researchers working in a multidisciplinary fashion, the lack of a clear understanding of the unique problems of the tropics (by scientists in both the tropics and the temperate regions), and the lack of improved germ plasm.

Gradually, the technical obstacles to production began to be understood and addressed by soybean researchers at international centres (especially at the International Institute of Tropical Agriculture and the Asian Vegetable Research and Development Center) and several national programmes.

Increasingly, scientists in developed countries, where much of the world's germ plasm had been collected and where knowledge about soybeans in the tropics had accumulated, began to lend their expertise and materials. Among the most helpful were the International Soybean Program (INTSOY) at the University of Illinois and the NIFTAL Project (study of nitrogen-fixing plants) at the University of Hawaii. Also, several major universities and other institutions in the USA, Canada, United Kingdom, Europe, Australia and Japan have contributed directly or indirectly.

By the mid-1970s, systematic study of major constraints began. Leading these investigations were small cadres of scientists at IITA, AVRDC and certain national programmes. The major biologic constraints identified during this period included:

- Seed longevity under ambient storage. Soybean germination dropped precipitously after only 2–3 months of storage in the tropics. Loss of seed viability was not always recognized, as some of the seeds usually germinated and poor stands were attributed to other factors. (Asian farmers were aware of the problem and often planted an intervening seed crop from the main season.)
- Poor nodulation where the appropriate *Rhizobium* spp. were not available or were poorly handled in application (e.g. improper storage and application). This problem was particularly acute in Africa where inoculum was often not available for commercial use.
- Shattering in temperate varieties, particularly at low and intermediate elevations in the tropics where temperatures and humidities fluctuate widely. The combination of rapidly rising air temperatures and declining humidities has a powerful shattering effect on susceptible cultivars.
- The pest complex. Although soybean, as a recently introduced crop in Africa and the Americas, was generally less susceptible to pests and diseases than indigenous species of *Vigna* and *Phaseolus*, it suffered some damage from

insects and diseases that differ from those in temperate regions. Perhaps the most destructive insect pests are pod feeders, foliage feeders and beanflies. The disease complex includes bacterial, viral and fungal organisms, as well as nematodes and phanerogamic parasites.

- Sensitivity to photoperiod and other environmental factors. The temperate varieties were not adapted to the uniform, short days in the tropics, and environmental stresses such as pH extremes; toxic levels of metals (especially Al, Fe and Mn) and nutrient deficiencies (P, K, Mo and S) in the soil; moisture deficiencies or excesses and temperature extremes (e.g. below 10°or above 38°C), have proved somewhat more limiting to soybean than to native species like *Vigna* and some *Phaseolus*.

Added to the biologic constraints are agronomic constraints. For example, in general, soybeans may be said to require, or respond better to, higher levels of management and inputs than do other grain legumes. That is, they are particularly sensitive to soil infertility, inadequate moisture, ineffective weed control, etc. They also require more precise care (planting, weed control, inoculum application and harvesting) than do the rustic native species. The agronomic constraints to growing and handling soybean could be minimized by appropriate mechanical aids for sowing, intercultivation, weed control, harvesting and threshing so mechanization has become a focus for research.

OUTLOOK

Recent advances in the improvement of soybeans have addressed and at least partially resolved some of the major deterrents to the production of this crop in the lowland tropics. They have opened the way for soybean to become a primary source of human food in the protein-deficient subhumid and humid tropics where a large proportion of the world's population will live in the 21st century. However, several challenges remain for scientists, developers and promoters. The most immediate and crucial concern is to develop attractive, easily prepared local dishes from this bean. Fortunately, Asians already have traditional foods made from soybean, but the people of tropical Africa and the Americas are just becoming acquainted with the crop.

Although soybean's other uses—for animal feedstuffs, processed protein and oil—may be sufficiently attractive for national policymakers to encourage production in their constituencies, the greatest potential for soybean is as a regular component of people's diets. In the humid tropics, diets tend to be protein-deficient, high in carbohydrates and low in plant or animal proteins. Two countries—India and Nigeria—with well-defined food preferences have developed several local dishes from both unprocessed and processed soybeans. Thus soybeans have become established as a market commodity in the growing regions of these countries. Also heartening is the move to scale down processing with appropriate machinery so that small industries can develop in the villages.

To deliver the promise in the outlook, biologic scientists and agricultural engineers must focus for the foreseeable future on:

- Controlling pests. An increase in pests and diseases can be expected as production intensifies, especially in new regions. Most worrisome are insects attacking the flowers, developing pods and maturing seeds. The number and importance of viruses will rise; and new pests, like phanerogamic parasites (e.g. *Striga*) and nematodes, will become limiting under certain conditions. Ongoing problems like changing races of rust and foliage diseases, outbreaks of soil-wilting organisms and bacterial diseases will certainly continue.
- Solving agronomic problems. While considerable progress has been made toward increasing seed longevity, promoting nodulation, eliminating shattering, improving stability and increasing yield, much remains to be done to enhance the characters; widen adaptation; and stabilize yields. Future activities must include studies on local cropping systems so improved varieties and agronomic practices can be fashioned to fit the system. Special attention needs to be given to controlling weeds, the bane of farmers everywhere, as weeding is often the most costly and time-consuming operation.
- Removing stresses. The soybean may become established on good soils of the subhumid, lowland tropics, but production will not expand until progress is made on increasing the crop's tolerance of low pH, fertility-depleted soils, aluminum and other elemental excesses, drought, waterlogging, and temperature extremes (especially large diurnal fluctuations at high elevations).
- Improving seed quality. The grain still could be improved especially its cooking qualities—in particular, the off-flavour resulting from improper cooking, metabolic inhibitors, and cooking time. Some progress can be made through genetic manipulation and, for the long term, special-purpose varieties may prove desirable—for example, protein-rich, low-oil types that can be prepared directly like a pulse without extraction of the oil; or types with high contents of oil grown primarily as sources of good quality vegetable oil.
- Developing appropriate mechanization. Small, inexpensive tools and machines designed for planting, interrow cultivation, harvesting and threshing would be a great boon for the smallholder. Also, machines can be further downsized for oil extraction and extrusion so that they can be used in small villages growing perhaps a 100 hectares or less.

The world's population is destined to reach 6 billion by the turn of the century; at least a third will face serious food shortages. It will be much easier to meet human energy needs than to provide the protein and other nutrients. Daily requirements of carbohydrates should be met with increasing reliance on food crops like roots and tubers, which are easy to grow and well adapted to the humid tropics.

At present, the most serious problems of food shortage ranging from outright famine to the more insidious protein-deficiency diseases occur in Africa. The region affected is a broad belt 20° north and south of the equator, stretching across the continent and encompassing an anticipated population of 650 million by the year 2000. The soybean could become a home-grown solution to part of the problem of feeding the groups at risk of malnutrition. Even if only 10 per cent of daily protein requirements (5 g/day or 5 kg/year) for 200 million Africans were met by soybeans from average yields of 1 t/ha, an annual production of 1 million tonnes would be required, or 4.2 times the 1984 production of this crop.

Given these statistics, one must conclude that the support for soybean improvement and utilization must continue at this critical juncture.

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