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Strategies for Sustainable Maize Seed Production in West and Central Africa

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CIMMYT
International Maize and Wheat Improvement Center

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Foreword

Through the concerted efforts of IITA in collaboration with the National Agricultural Research Systems (NARS) of West and Central Africa (WCA), a number of improved maize varieties and hybrids of various maturity groups with resistance to the important biotic and abiotic stresses prevalent in WCA have been developed and made available to farmers of the subregion. The intensified promotion for adoption of the available varieties and hybrids has resulted in the rapid expansion of maize production in WCA to the extent that it has now become the most important food crop for urban and rural consumers. The subregion has witnessed remarkable success stories as the use of new seeds and improved technologies has increased smallholder maize production. Trends in land area under maize, total maize production, and yield per unit land area have shown dramatic increases in most of the countries in WCA. The area planted to maize has increased from 3.2 million ha in 1961 to 8.9 million ha in 2005; between 1987 and 2007, the area cultivated to maize increased from 7,958,927 ha to 11,752, 136 ha (FAO 2009). Maize production has caught up with or surpassed sorghum and millet in most of the savanna areas. This expansion has been attributed to the adoption of new maize germplasm, the development of road infrastructure in rural areas, relatively good extension services, and increased urban demand, especially for green maize.

Despite the tremendous progress made in increasing maize production and productivity during the past two decades, the seed industry in WCA is faced with a myriad problems. Prominent among these are a lack of seed policy and inadequate funding for seed industry development in most countries, long delays between variety development and variety registration and release, the inadequate involvement of farmers in participatory varietal selection, leading to low adoption of released varieties, a poor enabling environment for private sector participation and survival, a lack of effective and sustainable national seed systems in most of the countries, weak regional seed trade development and seed market information systems. In an effort to improve the availability of improved seeds to the farmers, WECAMAN funded the community seed production projects from 1993 to 2006 as a strategy to ensure the high adoption of released maize varieties in limited communities of member countries. The goal of WECAMAN's intervention in the seed industry was to assist farmers and seed producers to develop sustainable seed production systems, capable of providing a regular supply of high quality seeds of superior varieties to the farming communities. Specific objectives of the community seed production project were to (i) train farmers in the techniques of maize seed production (ii) strengthen the capacity and capability of seed producers to produce good quality seeds (iii) encourage NARS scientists to work with selected farmers and NGOs in the development of on-farm level seed production schemes, and (iv) assist

NARS scientists to produce breeder seeds of released varieties in adequate quantities at the research stations. The support from the Network was through the continuous supply of improved germplasm adapted to local conditions, technical assistance with seed production, training, provision of credit in the form of inputs for seed production, and promotion of improved OPVs to encourage adoption. Large quantities of seeds of early and extra-early varieties were produced annually in WECAMAN member countries through the schemes, resulting in the availability of good quality seeds for farmers. Several schemes within each collaborating country established revolving funds for seed production thereby making the scheme self-sustaining in several communities.

Since 2007, IITA, through the DTMA project and several initiatives including the AGRA-PASS, has been supporting private seed companies and community-based seed producers to produce, distribute, and market improved maize seeds to farmers in remote areas, developing seed storage and processing capacity, promoting policies that accelerate the release of proven new varieties, strengthening seed regulatory systems, eliminating seed trade barriers, and harmonizing regional seed laws. PASS has provided start-up capital for many African seed enterprises resulting in several emerging seed companies and setting the stage for hybrid production and a vibrant seed industry. The DTMA project has provided an adequate quantity of breeder seeds of parental inbred lines and OPVs, organized training courses in quality seed production of hybrids and OPVs, as well as regional and on-farm trials for both the NARS partners and private seed companies. Emphasis has been placed on hybrid seed production by existing and emerging seed companies as a means of ensuring that farmers buy improved seeds annually to ensure the sustainability of seed production and the survival of the seed companies and to make good quality seeds available to farmers at affordable prices.

As a major international partner of the NARS responsible for the development of appropriate maize germplasm and accompanying technologies, IITA has prepared this book, which covers all aspects of sustainable seed production, to contribute to the development of the seed industry. It is hoped that the information provided will go a long way in assisting both small and large-scale entrepreneurs to run their seed business successfully and, ultimately, good quality seeds will be available to farmers so that the benefits of maize improvement at IITA would be realized.

Dr Nteranya Sanginga
Director General, IITA
May 2013

Preface

The availability of high quality seeds is an important factor in attaining good yields of maize and, thus, can have a significant impact on the production potential of farmers. Presently, the seed industry in WCA is meeting less than 10% of the requirements of the subregion. Therefore the seed industry is urgently expected at least to double its present volume of production. This means that the seed industry has a formidable task of producing enough good quality seeds to ensure increased and sustainable maize production to feed the growing population. Despite the critical role that the seed industry has to play for the success of the maize revolution in the subregion, it is presently facing a myriad problems. First, farmers often do not appreciate the logic of purchasing seeds since many of them believe that they can save and use seeds from the previous harvests. As a result, there has been limited commercial demand for improved seeds. Secondly, whenever the Governments of the subregion and their development partners attempted to intervene to improve the seed situation, they often ended up making things worse. Such efforts have often been characterized by inadequate targeting (both commodity and area) and by the introduction of relief programs which invariably are free or subsidized and compete unfairly with emerging commercial seed enterprises. Thirdly, where seed companies have emerged, they have been unable to produce crop varieties that are sufficiently adapted to the wide range of growing conditions prevalent in most countries of the subregion. The result is that the available improved seeds are often not suitable for all the different production environments in each country. Fourthly, because of the high investment costs associated with equipment, research, and overhead for improved seed production, the price of improved seeds is usually too high and not affordable by farmers at the time of planting. The seed situation is further aggravated by the fact that the seed industry in nearly all countries has not been developed. Until recently, Nigeria was the only country in WCA that had a few credible seed industries. Even here, the commercial seed companies have not been servicing smallholder farmers, who grow mainly open-pollinated varieties (OPVs) in this zone. Yet promising improved maize varieties exist and there is a great capacity for seed production and the dissemination of improved varieties in the country. Again, all the seed companies operating in Nigeria do not have functional research farms; they depend solely on contract growers to produce seeds. Faced with this catalog of constraints, smallholder and medium-sized farmers often do not have ready access to the right quantity and quality of improved seeds needed for increased and sustainable seed production to support the on-going maize revolution.

Despite the myriad problems, there are several potential opportunities for the seed industry. Apart from the availability of many high yielding improved varieties developed by the IARCs and NARS, there is an increased awareness among farmers of the economic benefits of improved seeds, expanded markets for increased agricultural outputs, emerging formal and informal seed systems for improved seed production and rural seed delivery systems, emerging small and medium seed enterprises in the region, possibilities of regional seed trade, and regional information systems about the agricultural input market. These positive developments are encouraging and call for sustained effort to support the development of the seed industry.

This book is aimed at contributing to the success and sustainability of the emerging seed companies by providing information on issues that are crucial to the seed sector development. The book has sections on the review of national seed regulations that facilitate the establishment of seed companies, methods for producing good quality seeds in adequate quantities, harvesting and seed processing, variety release and registration, strategies for promoting seed marketing and the adoption of good quality seeds of improved varieties and hybrids. There is also a section on how the seed business should be managed daily to facilitate the implementation of the plans of the company and assess the outputs so that performance could be improved.

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Acronyms and abbreviations

AGRA-PASS	Alliance for Green Revolution in Africa- Program in Africa's Seed Systems
CBO	community based organization
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo
CRI	Crops Research Institute
DNA	Deoxyribo Nucleic Acid
DS	Derived Savanna
DTMA	Drought Tolerant Maize for Africa
DUS	Distinct, Uniform, Stable
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO Statistical Data Base
GDP	Gross Domestic Product
HQ	headquarters
HS	humid savanna
IAR	Institute of Agricultural Research
IARC	International Agricultural Research Centers
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IER	Institut d'Economie Rurale / Rural Economy Institute
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
IITA	International Institute of Tropical Agriculture, Nigeria
INERA	Institut d'Etudes et de Recherche Agricoles / Agricultural Research Institute
INRAB	Institut National de Recherches Agricoles du Bénin / Béninois National Institute of Agricultural Research
IRAD	Institut de Recherche Agricole pour le Développement / Institute of Agricultural Research and Development
ITRA	Institut Togolais de Recherches Agricoles / Togolese Institute of Agricultural Research
ITRAD	Institut Tchadien de Recherche Agronomique pour le Développement / Chadian Institute of Agronomy Research for Development
MOA	Ministry of Agriculture
MSV	Maize Streak Virus
NAERLS	National Agricultural Extension Research and Liaison Services
NARES	national agricultural research and extension systems
NARS	national agricultural research systems
NC	network coordinator
NGO	non governmental organization
NGS	northern Guinea savanna

NVPT	National Variety Performance Trials
NVRC	National Variety Release Committee
OPV	Open-Pollinated Variety
PBR	plant breeders' rights
PROSAB	Promoting Sustainable Agriculture in Borno State
QPM	quality protein maize
RRPMC	Regional Research Project for Maize and Cassava
RUVT	Regional Uniformity Variety Trials
SAFGRAD	Semi-Arid Food Grains Research and Development
SARI	Savanna Agricultural Research Institute
SG 2000	Sasakawa Global 2000
SGS	southern Guinea savanna
SS	Sudan savanna
SSA	Sub-Saharan Africa
STRC	Scientific, Technical and Research Commission
UN	United Nations
UNDP	United Nations Development Program
UNIMAID	University of Maiduguri
UPOV	International Union for the Protection of new Plant Varieties
USAID	United States Agency for International Development
VCU	Value for Cultivation and Use
WA	West Africa
WARDA	West Africa Rice Development Association
WCA	West and Central Africa
WECAMAN	West and Central Africa Collaborative Maize Research Network

Maize in West and Central Africa 1

Introduction

Maize (*Zea mays* L.), commonly referred to as corn in the United States, has been considered a unique plant since the time it became the staple food for the indigenous peoples of the Americas. It is central to many sacred mythologies and creation stories which are still honored today. Maize was introduced from the New World to the Old World in the 1400s, and it was planted between the harvesting of spring and winter crops, filling an important niche as a summer crop (Barreiro 1989). Today, the United States, China, the European Union, Brazil, Mexico, Indonesia, India, and Argentina are the world's largest producers.

The United States is the world's leading producer. In 2008/2009, the US produced 307,386,000 tonnes (t) representing 40% of the world's total production, followed by China (Table 1.1). Together they produce approximately 60% of the world's maize crop. In the same year, over 159 million ha of maize were planted worldwide, with an average yield of over 5 t ha^{-1} in the developed countries; yields as low as 500 kg ha^{-1} were obtained in sub-Saharan Africa (SSA). Production can be significantly higher in certain regions of the world; for example, estimated grain yield for 2009 in Iowa, USA, was 11,614 kg ha^{-1}. The US is also the world's largest exporter with 20% of the crop exported to other countries (Meng and Ekboir 2000)

Maize was introduced from the New World to the Old World in the 1400s after Christopher Columbus discovered the Americas. To start with, maize was only a backyard crop in West and Central Africa (WCA) and for a long time remained a smallholder crop in the subregion. An outbreak of the American rust incited by *Puccinia polysora* that swept across WCA and almost wiped out maize production in the 1940s called attention to its importance as a food crop. From then on, intensive breeding, agronomic, and crop protection research was gradually put in place in most WCA countries. New varieties have been developed from time to time and production has gradually increased to satisfy the demand. There have been several foreign interventions to boost maize improvement in WCA, culminating in the establishment of the International Institute of Tropical Agriculture (IITA) in Nigeria in 1967. Maize is one of the mandate crops of IITA and the Institute, in collaboration with the national agricultural research systems (NARS) has played a major role, in developing improved open-pollinated varieties (OPVs) and hybrids that are resistant/tolerant to the prevalent major biotic and abiotic stresses. One major constraint to the adoption of improved varieties has been the non-availability of high quality seeds.

Uses of maize

Maize accounts for 15–20% of the total daily calories in the diets of people in more than 20 developing countries, mainly in Latin America and Africa, whereas in the developed countries, such as US and Europe, it is instead an important feed grain for livestock and poultry because of the more efficient

Table 1.1. World's Maize Production and Consumption Figures: 2007/2008 and 2008/2009.

	2007/2008	2008/2009
	(thousand t)	
Production		
Argentina	22,000	12,600
Brazil	58,600	50,000
Canada	11,649	10,600
China	152,300	165,900
Egypt	6,174	6,217
EU-27	47,554	62,688
India	18,960	18,480
Indonesia	8,500	8,700
Mexico	23,600	25,000
Nigeria	6,500	7,900
Philippines	7,277	6,846
Russian Federation	3,950	6,600
Serbia	4,054	5,900
South Africa	13,164	12,000
Ukraine	7,400	11,400
Others	69,018	71,210
United States	331,177	307,386
World total	791,877	789,427
Total consumption		
Argentina	7,000	6,400
Brazil	42,500	44,500
Canada	13,769	12,500
China	149,000	152,000
Egypt	10,400	10,300
EU-27	63,900	61,000
India	14,200	17,600
Indonesia	8,500	8,800
Japan	16,600	16,400
Republic of Korea	8,633	7,600
Mexico	32,000	32,600
Nigeria	6,550	7,800
Philippines	7,150	7,300
South Africa	9,200	9,800
Vietnam	5,200	5,200
Others	114,090	116,245
United States	261,632	258,965
World total	770,601	775,056

***Source*:** USDA —Foreign Agricultural Service.
http://www.corn.org/publications/statistics/world-corn-production. Accessed 14/09/2011

conversion of its dry substance to meat, milk, and eggs, compared with other grains. The USA devotes approximately 60% of its maize crop to animal feed (Pingali and Pandey 2000).

Besides the conversion into animal feed, maize is also processed into a multitude of food and industrial products such as starch, sweeteners, corn oil, beverages, industrial alcohol, and fuel ethanol.

Maize refineries in the US also use about 14% of their annual maize crop worth $19 billion to produce corn oil, gluten for animal feed, corn starch, syrup, dextrose (used mainly by the pharmaceutical industry as the starting material for manufacturing vitamin C and penicillin), alcohol for beverages, ethanol (which accounts for 12% of all automobile fuels sold in the US), high fructose maize syrup (used mainly by the soft drinks industry which helped to surpass the use of sucrose in the US, biodegradable chemicals and plastics, paper, textiles, ready-to-eat snack foods and breakfast cereals, such as cornmeal, grits, flour, and additives in paint and explosives (Sprague et al. 1988). It is estimated that the maize crop yields 4000 industrial products and that there are more than 1000 items in American supermarkets that contain maize (Dowswell et al 1996).

Maize production in WCA

Maize is presently the most important cereal crop in WCA because of its high yield potential, increasing role in the human diet, use in animal feed and in agro-allied industries. It was introduced about 500 years ago and has risen to become a staple crop with numerous varieties developed for the various agroecological zones. It has a relatively short growing period and is easy to grow, sole or in mixtures with other crops. It is well integrated into the farming system with a number of maize-based cropping systems featuring prominently. It is now cultivated in the drier areas, traditional niches for sorghum and millet, a feat made possible by the development of extra-early and early varieties led particularly by IITA in collaboration with the different NARS. Maize has an added potential for addressing the food security challenges presently faced in WCA as a result of increasing levels of urbanization. It is also a versatile crop that easily grows across a range of agroecological zones; it is easy to store, process, and market; its preparation as food is relatively simple.

According to FAO, the area in WCA planted to maize increased from 3.2 million ha in 1961 to 8.9 million ha in 2005. Between 1987 and 2007, this area increased from 7,958,927 ha to 11,752,136 ha (FAO 2009). This phenomenal expansion of the land area devoted to maize resulted in increased production from 2.4 million t in 1961 to 10.6 million t in 2005. However, although the average yield in the developed countries is up to 8.6 t/ha, production in several areas of WCA is still very low (1.3 t/ha or below).

A survey conducted by the Drought Tolerance Maize for Africa Project (DTMA) on maize production constraints, showed that in the 13 DTMA project countries in East, Southern, and West Africa, maize is grown on more than 17 million ha in West Africa, with Nigeria accounting for more than 3.6 million ha of the total land area cropped to maize in the subregion. Mali accounted for the smallest area, about 0.3 million ha. By region, East Africa accounted for the largest hectarage while Southern and West Africa had equal areas under maize cultivation. The investigations also showed that the estimated demand for maize seeds in the 13 countries was about 425,000 t. Improved OPVs account for about 24,000 t; hybrid maize seeds account for 83,000 t and the rest of the seeds are sourced from the informal seed sector through seed exchanges and the recycling of OPVs and hybrids (Tahirou et al. 2009). In other words, more than 75% of the maize crop in West Africa is planted to seeds from the informal sector, mostly farmer-to-farmer exchanges and grain purchased from the open market.

IITA has over the years helped to develop early and extra-early maturing varieties which can fill the hunger gap in the drought prone savannas as well as letting the crop tolerate drought, giving reasonable yields where intermediate or late cycle varieties would fail. Most of the modern day developed varieties in WCA have been bred to be resistant or tolerant to the prevalent biotic and abiotic stresses, notably maize streak virus, *Striga*, rust, stem borers, and drought which are among the major constraints to production. Some varieties have also been developed for high productivity under the low soil nitrogen levels that are characteristic of the soils and production systems in the subregion. The rising profile of maize and the impact generated by the crop have been aptly described as a revolution (Fakorede et al. 2003). The crop is considered the vehicle for a green revolution that has already commenced in the subregion (Abalu 2003).

Food value of maize in WCA

In the industrialized countries, such as the US and in Europe, maize is largely used as a livestock feed and as a raw material for industrial products; in the developing countries, maize is mainly used for human consumption in diverse ways with attendant implications for commerce. In WCA, maize is an important staple food for an estimated 50% of the population. It serves as an important source of carbohydrate, protein, iron, vitamin B, and minerals. In addition, the physiologically immature field maize, known as green maize, is consumed as a snack, "maize on the cob", after being roasted or boiled. The dried grain is milled and consumed as a starchy base in a wide variety of gruels, porridges, soups, and pastes. Dough made from the milled grain can also be cooked or fried in oil. The importance of maize as a food is associated with the nutritive value of its kernels.

Composition of the maize kernel

On average, about 70–75% of the kernels, depending on the type, are composed of carbohydrate that is present mostly as starch and sugar. Because of its high carbohydrate content, maize is a major source of calories. The kernels also contain protein (8–15%). About 80% of the protein is in the endosperm while the remaining 20% is contained in the germ. Other components of the kernels are fat (or oil), minerals, and vitamins. The vitamins in the kernels are mostly located in the germ and in the outermost layer of the endosperm.

Carotenoids, which are precursors of vitamin A, are present in yellow types but absent in white maize. The quality of the protein is considered poor because the kernels have a low content of lysine and tryptophan – two of the essential amino acids. Years of research by breeders at CIMMYT have resulted in the development of Quality Protein Maize (QPM) which contains twice the quantity of lysine and tryptophan in the normal maize. Using some of the QPM base populations developed at CIMMYT, breeders in Ghana extracted QPM varieties and hybrids and tested them in WCA as well as in other parts of the world (Twumasi-Afriye et al. 1999). Varieties and hybrids of QPM have now become *nouveaux* varieties spreading all over SSA to feed the rapidly increasing population.

Low maize yields and production in WCA

In general, production in terms of output per area under cultivation is very low when compared with maize growing areas in other parts of the world. Yields below or around 1.5 t ha^{-1} are the average whereas yields in the developed countries, for example in the US, hover between 7 and 11 t ha^{-1}.

This poor performance has been attributed to a number of reasons, among which are the following.

- Non-use of high yielding improved varieties and hybrids; the farmer depends on farmer-saved seeds (up to 80% of the seeds planted annually).
- Non-use of fertilizers and other agro-inputs that have made a change in productivity in other maize growing areas of the world.
- Continuous use of marginal soil with low fertility for cropping year after year without the adoption of modern techniques for soil fertility improvement.
- Land tenure problems in most of the maize growing areas.
- Lack of a seed policy program by most Governments.
- Limited support or none to research for the development of high yielding varieties, hybrids, and other crop improvement technological packages that give higher yields.
- Where there is some research support, the production and use of OPVs dominate and their inherent productivity is low compared with hybrids that prevail in other parts of the world.
- Lack of trained personnel and infrastructure along the entire seed chain.
- Continuous use of rainfed conditions for production in this era of climate change and the annual unreliability of the rains.
- Low perception and adoption of improved certified seeds by the indigenes.
- Prevalence of a myriad diseases and insect pests that attack the crop under cultivation leading to lower yields and quality. These include downy mildew, rust, leaf blight, stalk and ear rots, leaf spot, and maize streak virus. Insect pests, including stem and ear borers, armyworms, cutworms, grain moths, beetles, weevils, grain borers, rootworms, and white grubs, are also a great threat to the survival of maize.

In the Nigerian savanna, for example, weed-related yield losses ranging from 65 to 92% have been recorded in maize fields. A parasitic weed known as witch weed (*Striga*), is a major pest in SSA and causes estimated cereal grain losses worth up to US$7 billion. This adversely affects the lives of about 300 million people.

Low soil fertility, limited use of nitrogenous fertilizers, and declining soil quality are also major problems, resulting in low yields. Also, periodic drought caused by irregular rainfall reduces yields by an average of 15% each year. This is equivalent to at least US$200 million in forgone grain. The effects of prolonged droughts, such as those that have struck WCA in recent years, particularly Mali and Niger, have had disastrous consequences on yields and total food security in those countries.

Maize seed production in WCA 2

Seeds are the source of most foods, and therefore have the greatest socioeconomic benefit on human welfare. However, many developing countries, particularly in SSA, have difficulty in coping with seed supply, especially in emergency situations where recurrent drought has become a fact of life. Hence, understanding the supply system and the factors limiting the production, marketing, adoption, and use of improved seeds is of paramount importance for promoting maize production, improving farmers' income, alleviating poverty, and ensuring food security (Tahiru et al. 2009).

The seed production systems can be characterized under three headings: formal, informal, or a combination of both systems. Irrespective of the level of seed industry development in any of the countries of the subregion, the use of improved certified seeds for planting is very low, ranging from 46.6% in Nigeria to 10.8% in Ghana (Tahiru et al. 2009). In other words, farmer-saved seeds, which are handled as grain, as well as grain purchased from the open market, constitute 50-90% of the maize seeds planted by farmers. Clearly, the bulk of maize seeds used for planting do not pass through regulated seed production channels. Most of the maize seeds, produced and planted in the region, are also from OPVs with hybrids constituting less than 10%. Limited production of the improved varieties is also basically undertaken by State-owned organizations or parastatals with very limited private participation. Although support from NGOs and other donors plays a major part in the seed production programs, the situation is in sharp contrast to that in eastern, northern, and southern Africa where the private sector plays a key role in seed delivery systems and hybrid maize constitutes the bulk of seeds planted annually.

The maize seed industry of WCA is at different levels of development that may be grouped into three categories:

- Relatively well-developed, embracing all the facets found in modern-day seed programs, such as those of Ghana and Nigeria;
- Intermediate development stage, where one or two links in a seed program chain may be lacking, such as in Cameroon, Senegal, and Mali; and
- Rudimentary structures, such as those found in Liberia and Bénin.

The use of improved, certified maize seeds for planting is very low; about 33.2% for the whole of West Africa for the period 1997–2007 (Tahirou et al. 2009). This indicates that the bulk of the seeds used for planting are farmer-saved or from sources that do not pass through the formal controlled and regulated production channels.

Knowledge and understanding of the problems confronting the seed industry of WCA will offer tremendous opportunities for solving them and improving the use of good quality seeds to help achieve food security within the subregion, given that many high yielding improved varieties are already developed by international and national agricultural research systems. These varieties are available to be exploited by the emerging formal and informal, small and medium seed enterprises.

Constraints to maize seed production in WCA

Several constraints have been identified as the factors militating against the production, adoption, marketing, and use of improved certified seeds in WCA (Table 2.1). Prominent among the constraints are the following.

- Low adoption of improved varieties.
- Lack of appropriate seed policy, varietal release system, and support for emerging seed companies.
- Lack of financial and human resources.
- Use of inadequate and inappropriate varieties and hybrids by the farmers.
- Unavailability of sufficient quantities of foundation seeds for certified seed production.
- High prices of complementary inputs.
- Unfavorable weather conditions.
- Lengthy process for variety release.

Infrastructure

Constraints that limit the establishment of seed companies include the following.

Table 2.1. Summary of major constraints to maize seed production in WCA.

- Lack of access to suitable germplasm.
- Poor quality germplasm.
- Long payback period to investment in the seed sector.
- Lack of qualified manpower.
- Unfavorable climatic conditions.
- High initial investment outlay.
- Problem of land/land tenure system.
- Problem of infrastructure (e.g., irrigation facilities).
- Lack of a sustainable market for seeds.
- Lack of access to seed extension services.
- Seed marketing problems.
- Lack of access to seed production technology and infrastructure.
- Lack of access to production credit and other credit facilities.
- Unfavorable climatic conditions currently prevailing.
- Lack of functional and sustainable national seed systems in most countries.
- Weak regional seed trade development and weak seed market information systems.

- Lack of access to production credit.
- High initial investment costs.
- Lack of access to seed production and processing infrastructure.

Seed marketing and distribution constraints

The lack of infrastructure, poor extension support systems, and ineffective promotional campaigns negatively affect the demand for maize seeds.

- Seed price perceived as relatively high.
- Controlled seed markets.
- Lack of awareness of available varieties and hybrids.
- The monopolistic distribution of seeds through a single intermediary.
- Slow reimbursement for seed credit sales.
- Difficulty in getting access to other maize seed buyers, low demand from farmers.
- Poor promotion and marketing efforts, high prices, and the inability of farmers to purchase complementary inputs, especially fertilizer.
- Most rural areas are inaccessible due largely to the poor roads which often prevent extension staff from getting to the communities.
- Unfavorable seed policies such as taxation, import and export restrictions.
- Production and marketing of low quality seeds.
- Poor extension services and other seed promotional activities.

Farmers are well aware of the benefits of high quality seeds. But the lack of wide and discernible differences in the quality of commercial seeds compared with that of farmer-to-farmer exchanged seeds has discouraged many farmers from purchasing commercial seeds, thereby relying on their own sources of seeds for planting.

There is a gross insufficiency of dependable and time-saving retail outlets that ensure the prompt delivery of high quality seeds to farmers at any time and place. This may be partly attributed to the poor road networks in the individual countries.

In the majority of the countries, seed dissemination and other promotional activities are carried out by public units, usually the extension departments of the various Ministries of Agriculture. Such units usually lack trained and experienced staff and are also too poorly funded to enable them to effectively promote to farmers the advantages in the use of improved maize seeds.

Limitations to the rapid dissemination of newly released varieties

- Unavailability of certified seeds in commercial quantities.
- Lack of awareness on available varieties and hybrids.
- Lack of access to credit facilities by farmers, and the relatively high price of seeds,
- Sometimes distribution of seeds is monopolistic, through a single intermediary.
- Slow reimbursement of seed credit sales.

- Difficulty in getting access to other maize seed buyers.
- Low demand for certified seeds by farmers because of lack of awareness.
- Poor promotion and marketing efforts.
- High prices and the inability of farmers to purchase complementary inputs, especially fertilizer.
- Inaccessibility of most rural areas due largely to the poor roads, which often prevent extension staff from getting to the communities.

Retarded varietal release process

- Infrequent meetings of most varietal release committees to approve the release of new varieties.
- Lack of operational funds for variety release committees.

Seed production constraints

- Lack of access to appropriate germplasm.
- Lack of access to production credit.
- Unfavorable climatic conditions limiting the production of maize seeds at all times.
- Lack of organized institutions in the seed value chain.

Institutional problems limiting seed production and deployment

An examination of the typical institutional pattern for seed production and deployment system in West Africa revealed a mixture of public and private sector activities, with various programs charged with the responsibility for ensuring effective production and distribution.

Seed marketing and distribution constraints

Seed producers/dealers/companies, more often than not, suffer the problem of unsold stocks because of the poor market infrastructure. Most rural areas are difficult to reach and communities may lack the appropriate extension services. One of the consequences of the poor rural road systems is the high cost of input delivery as the few dealers who find their way into such areas often exploit the farmers by charging exorbitant prices.

Lack of access to production credit

The seed industry requires substantial capital investment, especially in infrastructure and equipment. Seed production is a business with large economies of scale. Therefore, it is clear that seed providers need financial support to expand production and enjoy these economies of scale. The private seed companies that import the machines, equipment, and chemicals are often victims of macroeconomic instability (such as fluctuating exchange rates and a high level of inflation). This results in high interest rates and depreciation in the value of money, thereby generally discouraging investment. There is the need for a general policy environment that creates incentives for investment in the seed sector.

Policy-related constraints to seed production and deployment

There are country variations in the policy factors limiting expanded sales by seed companies, particularly in drought-affected areas. The private seed sectors in Nigeria and Ghana are relatively better developed than those in Bénin and Mali. Consequently, Bénin and Mali require more policy interventions to get the private seed sector started. Major policy factors in Nigeria include unstable seed policies, a lack of research support from Government, and a lack of an agricultural input subsidy (Tahirou et al. 2009).

Unfavorable seed policy environment

Many countries do not have a seed policy, seed laws or regulations. In the absence of these essentials in the seed business, institutional arrangements are non-existent and the situation becomes the survival of the fittest.

- **Limited support to research**

Many countries do not have a strong research base to develop new varieties for the seed sector value chain to use to support the industry. Where available, such research institutes are publicly owned and underfunded. They may also lack the much-needed technical support staff to run the development and variety release program of the countries because of low motivation and therefore have a higher attrition rate of experienced staff. This situation often leads to long delays between variety development, release, and registration. The consequence is that inadequate attention is devoted to variety maintenance as well as to the availability of adequate breeder and foundation seeds from NARS for use by the certified seed industry.

- **Lack of trained manpower to support the seed industries**

One of the major constraints limiting the growth and expansion of the seed industry is a lack of well-trained and motivated human resources. There are very few who hold postgraduate degrees in seed science and technology in private and public institutions (including universities and research institutes). Training of middle-level seed industry personnel is also limited.

- **Insufficient funding of government agencies**

Seed research, which includes variety development, release, and registration as well as breeder seed production, is carried out by public institutions. Most often, the institutions lack the much-needed funding to perform their mandates as well as to hire and maintain high quality staff. This invariably affects the production, distribution, and use of improved seeds.

- **Lack of well-defined institutional support and policies for private seed industry**

Public agencies interfere and exert a strong influence in the seed industry development plan, thereby limiting private participation. This may be due to the fact that most countries do not have seed policies and seed laws that regulate the industry.

- **Weak institutional linkages**

There is fragmentation and an overlap of roles among the directly involved public agencies where the linkages necessary to promote a virile and growing seed industry are very weak. Where the private sector is involved in seed production, distribution, and marketing, their structures may not be well defined and may not even be in place, thus limiting their efforts.

- **Limited production capacity**

Seed producers in both the private and public sectors have limited capacity to produce, distribute, and market seeds. Most of the institutions lack the required manpower and capital to expand their activities. This situation limits the much- desired and envisaged growth of the seed industry despite the large potential market. Consequently, a majority of the seeds are farm-saved or exchanged among farmers.

Socioeconomic constraints

A number of socioeconomic constraints also limit maize productivity.

i. Non-availability of complementary inputs, such as fertilizers and agro-chemicals, and this limits the rate of adoption of improved maize technologies,
ii. Inefficient markets for agricultural inputs and outputs leading to poor pricing and disincentives to farmers,
iii. Lack of credit facilities for the purchase of needed production inputs,
iv. Absence of market information systems, leading to inefficient marketing,
v. Lack of farmers' organizations to facilitate access to markets.
vi. Inconsistent official policies for production and trade that discourage local production,
vii. Lack of appropriate and adequate processing and storage facilities, resulting in higher losses in agricultural products.

Barriers to new entrants into the seed business

Maize seed production in WCA is mainly in the hands of public sector institutions or parastatals, with limited private sector participation. The private sector faces a number of insurmountable constraints whenever it is involved in seed production. Barriers to new entrants into the seed business, especially the emerging small-scale seed producers, include the following.

- **Competition from existing larger companies and public-based seed production entities**

New entrants into the seed market face strong competition from the few larger existing companies and the publicly led seed production agencies in terms of infrastructural capacities, total production output, distribution channels, and penetration into the larger outlying market, usually as a result of their low investment capital, the low expertise of their personnel, and the lack of knowledge of the seed market terrain. Whenever these challenges become burdensome, the emerging companies succumb to the pressures in the market and just fold up.

- **Lack of access to production credit and other credit facilities**

Because of the Governments' unfavorable banking policies in many countries, new entrants into the seed business do not get access to advantageous production credit and credit for other activities, such as transport and the hiring of personnel of the highest expertise in seed production and business. Where some credit is available, it is usually not timely; the interest rate may be too high and the amount obtained may be insufficient to achieve the desired goal of the new business.

- **Lack of access to production technology and infrastructure**

Emerging and small-scale seed companies tend to have limited access to production technology. They usually have to compete alongside bigger and often public-owned companies that have the entire governmental machinery behind them. Emerging companies also lack the capacity to go commercial and produce larger outputs because they do not have access to credit for acquiring the infrastructure needed to expand production, processing, and storage facilities.

Seed delivery systems and recommendations for WCA 3

Seeds are the most precious resource of farmers and concern about the viability of agricultural systems usually centers on the diversity and stability of the seed supply system (Tripp 2001). Van Amstel et al. (1996) defined a seed system as the totality of the physical, organizational, and institutional components that determine seed supply and use in quantitative and qualitative terms. A seed system denotes the activities that start from selection and breeding to marketing and the use of seeds by farmers for growing crops and it has close linkages with other systems, particularly research and extension (Venkatesan 1994). An efficient seed system involves a complex combination of public sector support and private sector commercial activities. The public sector plays a bigger role in plant breeding and in some aspects of regulations while the private sector makes contributions in the area of seed multiplication, processing, and distribution (Minot 2008). Furthermore, the characteristics of an appropriate seed system for a country are determined by that coutry's economic policies and the level of development of infrastructure (Venkatesan 1994). It is important to note that with the possible exception of a few countries (such as Nigeria and Ghana), the seed system in West Africa is not well developed and is largely dominated by the public sector, i.e., Government agencies that play dominant roles (Joshua 1997).

Types of seed delivery systems

Seeds used worldwide for crop production can originate from one of three delivery methods or systems: formal, informal, or a combination of both systems.

The formal seed system

The formal seed delivery system consists of chains of interlinked activities, starting from genetic resource management, variety breeding research and crop improvement, variety testing and release through seed multiplication, conditioning, and storage, quality control, marketing and distribution, to the final use of the seeds by farmers. Each of the components complements the others and each link in the chain must be working at its maximum efficiency to achieve an effective supply of high quality seeds to farmers.

The formal seed system usually involves public or private institutions or a combination of the two, depending on the level of agricultural development in the country. Seed production under this system is monitored by an independent external certifying authority to ensure that true-to-type, high quality, and genetically pure seeds are offered to farmers for planting.

Seed multiplication classes in the formal system

In the formal system, the multiplication process goes through a well-coordinated and organized chain of seed classes. This begins with the production of breeder seeds, then of foundation seeds, and registered seeds, and finally certified seeds before the seeds reach the farmer for planting. Thus, the formal seed system tends to produce uniform varieties through scientific breeding within the seed value chain. The formal seed system is highly regulated. Stringent laws regulate the development, release, and registration of new varieties; control the quality seeds; and, increasingly, protect new varieties through plant breeder's rights (PBR). Alongside this chain is a quality control and seed certification unit that monitors the production chain, ensures the genetic purity and the general quality of the seeds produced for farmers to plant, and makes certain that these are of the highest quality and true-to-type.

Advantages of seeds from the formal seed sector

Whenever seeds are purchased from the formal sector, several benefits are inherently built in ensuring that the product has passed through rigorous monitoring and certification checks to ensure that the quality is of the highest standard. Purchasing seeds from the formal sector also ensures the following.

- **Identity and genetic purity**

Seeds have an identity and name. They have the known phenotypic and chemical characteristics described by the originator as well as the knowledge of their maturity period, i.e., the duration from planting to the time of harvest.

The genetic purity of seeds is also ensured since they bear a certificate or tag issued by a certification agency which monitored the production standards and other quality control checks that the seeds had to pass through. It is also certain that seeds from the formal sector would have travelled along the entire seed value chain, beginning with varietal development, release, and registration, and also through breeder, foundation, and certified seed production.

At each of these stages, strict supervision and checks would have been offered by the seed certification unit overseeing production.

- **Known purity and germination capacity**

Seeds from the formal sector must go through quality control checks including the monitoring of purity, percentage germination, and quantity of inert matter present. The germination percentage at the time of sale is usually indicated on the seed bag.

Disadvantages of seeds from the formal sector

- **The relatively high retail cost of the seeds**

Seeds purchased from the formal sector for planting are relatively more expensive compared with those from the alternatives available. The cost is even higher when such seeds tend to be hybrids. The unusually high costs of such seeds are due to the many processes and the length of the value chain the seeds must pass through before reaching a farmer for planting.

- **Formal sector seeds are not easily available**

Seeds from the formal sector constitute about 10% of all maize seeds planted in WCA. Even at this low figure, their accessibility to farmers is very limited as they are mostly sold in and around the areas of production or in big commercial towns and centers.

The informal seed system

The principal seed source for most farmers is the seeds saved on-farm from the previous harvest (about 60–70%); most of the remainder comes from off-farm and other local sources (Franzen et al. 1996). Seeds of these types constitute the bulk of those obtained from the non-formal seed sector.

The informal system tend to generate and maintain less uniform materials adapted to local requirements (landraces) but also may provide a conduit for the exchange of materials derived from improved varieties. It is characterized by all manner of "seeds" that the farmer can lay hands on at planting time and these can be from on-farm or off-farm sources.

On-farm sources

An important component of the informal seed sector is the on-farm seed-saving which is an ancient practice among traditional small-scale farmers. Farmers preserve seeds of the varieties best adapted for their environments. Limitations from this practice are that farmers obtain low yields and seed quality is not guaranteed, although a wide-ranging study of farmers' seed quality in Ghana showed that, for maize, cowpea, and soybean, the average germination potential remained above 70% (Wright et al. 1995). Also, after a short period of cultivation, seeds may become mixed with those of other varieties and lose their desirable characters with the result that they can no longer be maintained uniformly and reliably.

Advantages of farmer-saved seeds

The major advantage of farmer-saved seed systems is the continuous availability of seeds compared with those from the formal sector. Availability is an advantage, particularly for farmers cultivating land in marginal areas who need to plant on time since delayed planting has adverse effects on yield. Such farmers also cannot afford to tie up cash to purchase and store seeds before the planting season. Farmers or communities supplying seeds charge lower prices since they do not incur additional costs in transport, processing, packaging, certification, and market surveys as in the formal distribution system. Thus, farmer-saved seeds are cheaper.

This availability is also an advantage to farmers who wish to plant several local varieties or cultivars. It allows them to match the seeds of each crop to the varied physical environments and planting systems (valley bottom and hillside, different soil types, intercropping, staggered planting, and pure stand), and also the many end-uses of each crop (food grain, leaves, roots, beer-brewing, straw and stover for animal fodder, roofing and fencing, storage, and selling for cash).

Off-farm sources
Another component of the informal seed sector is the trade and exchange of seeds in farming communities. The limitation here is that poorer farmers might be unable to participate in seed exchanges. Seeds can be acquired or traded as payment for other goods and services; they can be gifts from friends, neighbors, and family members. Seeds can be lent and borrowed.

Local markets supply various seed types and varieties to farmers. Food-stuff traders, mostly women, bring selected crop varieties with better physical appearance for sale as seeds. Traders also supply farmers with new seeds and buy their produce at harvest. Through this practice, farmers are able to obtain and maintain their own stock of seeds (Bortei-Doku Aryeetey 1994).

Community-based maize seed production systems
Since the formal sector (mainly public sector-based in most WCA countries) has failed to supply a significant proportion of the seeds required by farmers for sowing their fields, various NGOs, projects, donor agencies, and many such related entities have "developed" types of seed production and supply systems at the community level to help to make high quality and genetically true-to-type seeds commercially available. Such production may be done outside certification or with certification, but seeds are produced, processed, stored, and sold by the communities themselves at the time of planting.

Some communities also accept the help of donors and NGOs and enter into formal seed production. Others combine the formal and informal seed production methods to achieve the same objective of supplying quality seeds at low cost to farmers within their own communities.

Current seed production models in WCA
All indications are that it would take some time and more availability of resources and trained personnel at all stages of the seed production chain, better infrastructure, etc., to enable the formal seed system to provide all the needs of WCA. The current farmer-saved seeds and farmer-owned seed production methods will continue to dominate the seed delivery systems.

This informal seed production system is being supplemented by the formal system in countries such as Ghana and Nigeria that have relatively advanced seed industries. In the short term therefore, measures should be put in place to encourage and promote seed production systems where at least the initial planting materials in the chain should be from research outlets. Then appropriate farmers' production methodologies could be put in place to make more seeds available for all users in all communities at relatively low prices.

The role of IITA in seed systems development in WCA
IITA, realizing the shortfall in the provision of the farmers' maize seed requirements by the formal seed sector, has introduced the concept of "Community Seed Production" as a means to inundate the production areas with improved seeds within the shortest possible time at relatively low costs

(Badu-Apraku et al. 1996; Badu-Apraku 2007). The novelty in the concept is that the scheme involves farmers trained in seed production by the project as well as seed certification agents, extension specialists, and seed production specialists. The scheme essentially uses the communities to produce seeds of improved varieties for themselves. The communities concerned produce, distribute, and market the seeds, usually beginning with a known improved variety. Each IITA community seed production model is a combination of all the three seed systems discussed here earlier and it is recommended that individual countries each take a critical inventory of the available facilities and manpower and adopt what would meet their needs. Currently IITA has proposed seven community-based seed production models which have been found to work very well in WECAMAN member countries, based on the peculiar circumstances of each pilot country (Badu-Apraku et al. 2007). In all of them, IITA scientists worked with the NARS scientists in promoting the community-based seed production schemes. The models are described briefly in the following section, based on outputs from past and on-going IITA projects within WCA. More detailed descriptions, along with some empirical results, are presented in Section 7.

Model 1:

In this model, WECAMAN works in collaboration with NARS in the production of breeder and foundation seeds. The researchers provide the foundation seeds and other inputs to selected farmers through the extension services. Farmers produce and sell the certified seeds after which they reimburse the input costs to the extension services. This model is in use in Burkina Faso, Mali, Bénin, and Cameroon.

Model 2:

In this model, initial surveys are conducted by the national extension services to identify the resource capabilities of farmers to be contracted as seed growers. Farmers are provided with foundation seeds to produce certified seeds. These are sold directly to the extension service, which then deducts input costs. This method is being used in Burkina Faso, Mali, and Bénin.

Model 3:

In some cases in Burkina Faso, farmers received the foundation seeds once from the researchers and produced certified seeds. The farmers were responsible for the purchase and application of inputs in the production of certified seeds and the national scientists provided technical assistance.

Model 4:

In this model, NGOs organize and supply farmers with improved seeds and other inputs for the production of certified seeds. After seed sales, 50% of the initial funds are deducted and provided to the extension services for the encouragement of seed production by other farmers. This model was used in Burkina Faso.

Model 5:
This model, typically used in Ghana, represents a formal seed production system in which the national maize program produces breeder seeds. Foundation seed production is the responsibility of a government parastatal organization, which in Ghana is the Grains and Legumes Development Board (GLDB). Certified seed production is in private hands. The GLDB also provides custom services to the seed growers (drying, processing, and storage of seeds). The foundation seeds produced by GLDB are sold to private commercial and registered seed growers who produce the certified seeds. There are outlets all over the country where farmers can buy the improved maize seeds. The certified seeds are well packaged and labeled and have the seal of the seed inspection unit. Effective quality control is ensured through an autonomous seed certification unit under the Ministry of Food and Agriculture with laboratories across the country for seed testing and seed health testing. Seeds that satisfy quality tests then receive tags and can be sold anywhere within the country and beyond.

Model 6:
In this model, scientists of the national maize program produce breeder and foundation seeds. The scientists also provide training and foundation seeds to community-based seed producers for certified seed production. Efforts are made by national scientists to link community-based seed producers to established seed companies to improve market opportunities. The national scientists work closely with companies and inspectors to assist community producers to produce good quality seeds. The seed companies sign contracts with community-based seed producers so as to ensure market access for seeds. National scientists link community seed producers to credit and input sources as well as markets. This model has been successfully used in Nigeria and has resulted in the production of large quantities of seeds by the community-based seed production schemes. Participants in the scheme in Nigeria include IAR, NAERLS, and UNIMAID in collaboration with Premier Seed, the Seed Project, and Maslaha Seed Companies.

Model 7:
Another classical model that has been successfully tested and is worthy of emulation is that of Nigeria where, to strengthen farmers' efforts in the production and use of improved maize varieties, an approach is used that is slightly different from the traditional on-farm trials for the strategic deployment of identified varieties. The approach here encourages the use of a maximum of two varieties, probably with different maturities, over a wide area, thus combining maize cultivation with seed production. This approach was successfully used in southwestern Nigeria to saturate the Ogbomosho community in three years with maize seeds resistant to downy mildew (Ajala et al. 2003). The good side of this model is that it is sufficiently flexible to accommodate the participation of commercial seed companies, NGOs, and any other form of seed outlet in the pilot community.

Model 6 is presently being promoted by the DTMA project. The WECAMAN member countries involved in the community-based seed production schemes provided both technical advice and (in some cases) credit in the form of seeds and other inputs as well as training to selected seed producers in the community. At harvest, the credit was repaid, either in seeds or in cash. This allowed the establishment of revolving loan funds designed to encourage sustainability and to allow more farmers to be reached each year. Farmers were encouraged to form associations or cooperatives to facilitate community seed production, thus strengthening the informal seed production system and leading to the development of micro-enterprises. The production of seeds, largely undertaken through community-based seed producers, required the training of large number of farmers in seed production. Nearly 2000 received training in both seed production and postharvest seed handling over the period 1994–2006 (Badu-Apraku et al. 2012). From the training, these farmers acquired the capability to produce good quality seeds. Their activities led to the increased availability of seeds of improved early and extra-early maturing maize varieties. In addition, there was an increased awareness among farmers on the importance of planting high quality seeds of improved varieties and of purchasing new seeds of OPVs after every 2–3 seasons.

Challenges to the community-based seed production schemes

Badu-Apraku et al. (2012) have discussed in detail the challenges to community-based seed production in WCA. These include the need to develop a more efficient structure for seed marketing with better promotion to reduce the problem of the lack of market information. Partner organizations that could assist in the collection and relay of market information to potential end-users need to be identified. It would be beneficial to package and label seeds in small bags of 1 and 2 kg and have points of sale at strategic points in communities. For countries that do not yet have seed laws, the promulgation of such laws would help to ensure that unscrupulous people do not sell grains as seeds and farmers have access to good quality seeds. Where seed laws exist and are not functional, there is a need to strengthen the system through the establishment of active seed inspection units. More and better organized associations/cooperatives need to be established with agro-enterprise businesses supported through training and linkages to appropriate markets. These should take into consideration the lessons learnt from recent initiatives. Improved access for seed producers to credit, inputs, and market outlets for their products is also necessary. Successful community-based seed production schemes should be assisted to transform themselves to micro-enterprises for sustainability. This could be further facilitated by the provision of small items of equipment to seed producers. Given that seed producers who may be skilled in production might lack skills in small business management, book-keeping, accounting, and marketing, the DTMA project is currently organizing seed business management courses for seed companies in member countries. Such training needs to be intensified and participants should include community-based seed producers. The greatest impact of a community-based seed production scheme would be in areas not currently served by seed companies and those are where this system should be promoted. Educational awareness campaigns, variety demonstrations, and increased promotional activities by community seed producers are required to stimulate the demand for improved seeds. Apart from adequate quantities of breeder seeds of improved varieties being made available to the informal seed production system, linkages with established seed companies are required. A compilation of released varieties, their characteristics, adaptation, and the sources of their seeds is required as some countries still lack this information. Such lists should be regularly updated as new varieties are released. A database and GIS on community-based seed production schemes would also be useful. An assessment is needed of the impact of WECAMAN's intervention on the production and availability of seeds of improved maize varieties. It would be beneficial for IITA, CIMMYT, and the NARS in the countries participating in DTMA to prepare action plans for scaling-up seed production which should include indicators for seed production and a list of partners.

Maize seed biology 4

Maize is a versatile crop and is adapted to a wide range of environments. The plant grows at altitudes ranging from lowland to more than 3000 m above sea level, under heavy rainfall or in semi-arid areas, in temperate,and tropical climates (Dowswell et al. 1996). The diverse zones in which maize is grown reflects its adaptation to a wide range of environments and its suitability for various cropping systems. Maize is grown in all countries of Africa, from the coast through the savannas to the semi-arid regions of West Africa, and from the sea-level to the mid- and high-altitudes of East and Central Africa.

Basic information on the maize plant include:

- The botanical name is *Zea mays* (L).
- The family name is Poaceae (Gramineae)
- The chromosome number is $2n = 20$

Vernacular names include maize, corn, Indian corn (En). *Maïs* (Fr). *Masara* (Hausa), *Aburoo* (Akan).

The life cycle of the maize plant begins with the sown seeds which germinate and go through a vegetative stage, followed by the flowering stage and finally grain/seed formation which ends ultimately in the mature and dry seeds. Knowledge and understanding of the growth and developmental stages of the maize plant are important as they facilitate the understanding and handling of the agronomic practices critical for the management of the crop to maximize yield.

Maize vegetative developmental stages

The maize plant has the basic structure of the grass family. The seed germinates in a manner similar to that of plants in the grass family. Germination is hypogeal. The radicle, followed by seminal roots are the first organs to emerge from the seed after which the coleoptiles, covering the leaves, rupture the seed coat and are pushed above the surface of the soil by the elongating mesocotyl layers. This later becomes the vegetative aerial part.

A normal plant develops between 20 and 23 leaves which are initiated in a growing point that remains below ground until the primordial tassel is formed. These events occur during the first 4 weeks of plant development The permanent root system forms in successive whorls from internodes between the first node that develops above the mesocotyl.

Researchers' guide for identifying different stages of maize growth

- The maize crop reaches a growth stage when 50% of the plants show the corresponding features (mid-silk and mid-anthesis).
- This standardization is very useful in research and production.
- Growth stages are divided into two broad categories: vegetative (V) and reproductive (R) stages.

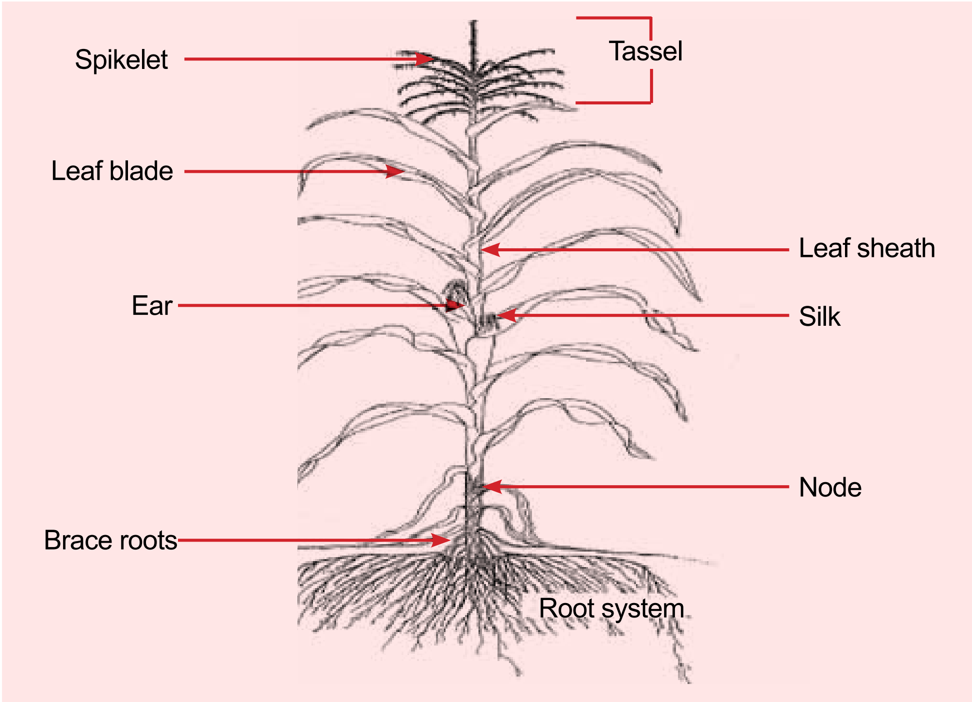


Figure 4.1. Morphological features of the maize plant (adapted from an IITA pamphlet).

Vegetative growth stages

The description of the vegetative stages of the maize plant is based primarily on the appearance of leaves; that of the reproductive stages is based on the appearance of the female flower and developmental changes in the kernels.

Reproductive developmental stages

Maize is different from other cereal crops because it does not possess the typical flower of the grass family. Instead, it produces unisexual flowers on the same plant and is, thus, monoecious. The male flowers are represented by the tassel and the female flowers by the ear (Figure 4.1). Pollen comes from the tassel and the silks are the style of the female.

Development of the reproductive structures begins with tassel initiation. Tassel development continues as the vegetative internodes start their rapid elongation and is completed by the time it emerges from the leaf whorl. After tassel emergence, pollen shed begins and is completed after 7 to 10 days. Pollen dispersal occurs by wind action and gravity dissemination. After fertilization, seed development begins. The endosperm first increases in size and is filled with sugars so that the developing seeds resemble watery blisters. Later the embryo matures, using the established endosperm as energy source.

The maize seeds

Maize seeds differ in color ranging from white to yellow, orange, red, purple, and black. Different colors are attributed to genetic differences in the pericarp, aleurone layer, embryo (germ), or endosperm tissues. The maize kernel is a caryopsis (the grain or fruit of grasses is called a caryopsis). A mature seed has three main parts: the seed coat or pericarp, endosperm, and the embryo which is often called the germ. The pericarp protects the seed from invasion by pathogens, minimizes mechanical injury, and delays water uptake so that imbibitional injury is reduced. The endosperm represents about 75% of the maize seed's dry weight and is the main energy storage area, possessing high quantities of starch.

Maize ear.

Kernel development in maize

Seven kernel types (or cultivar groups) can be found, according to the structure and shape of the grain. These are dent, flint, pod, popcorn, flour, sweet, and waxy. The kernels are arranged in even numbers of rows on the cob which is covered with several layers of husk that has a protective function.

Grain filling

Grain filling takes place in three stages: blister (R2), milk (R3), and dough (R4).

The blister stage follows fertilization, wilting, and browning of the silks. It is characterized by a rapid accumulation of carbohydrates in the kernels which contain a clear fluid during this period. The embryo is visible at the blister stage. In the milk stage, which is about three weeks after silking, the clear fluid in the kernel turns milky. Maize ears can be harvested at this stage for fresh consumption because of their high sugar content. Thereafter, the quality for fresh consumption declines as the content of sugar and water declines and the content of starch and dry matter increases. A line known as the milk line is visible on the side of the kernel opposite the germ at this stage. The milk line, which moves down as the grain matures, separates the mature starch area from the milky region near the base of the kernel.

Table 4.1. Composition as percentages of whole and fractionated corn kernels.

Fraction	Kernel	Starch	Sugar	Protein	Oil
Kernel	100.0	71.5	2.0	10.3	4.8
Endosperm[1]	81.9	86.4	0.6	9.4	0.8
Germ	11.9	8.2	10.8	18.8	34.5
Bran	5.3	7.3	0.3	3.7	1.0

[1] Composed of starchy and aleurone fractions

Dough stages

The dough stage is the last stage of the grain filling period and has two distinct phases: soft-dough and hard-dough. At the soft-dough stage, the kernels are composed of a white paste with the embryo occupying half the width of the kernel. The white paste of the soft-dough stage starts to solidify at the hard-dough stage, beginning from the top part of the kernel. At this stage, a dent in the top of the kernel becomes apparent in the dent type.

Physiological maturity is characterized by a cessation in the transportation of assimilates from the stem to the kernel and is evidenced by the development of the black layer (abscission layer) at the base of the kernel and a disappearance of the milk line. At this stage, the kernels have attained maximum dry weight with a moisture content of about 35%. The kernels at the tip of the ear mature first. An ear is physiologically mature when 75% of the kernels in the central part show the black layer.

The composition as percentages of whole and fractionated corn kernels is presented in Table 4.1. The endosperm in maize is the starchy storage part of the kernel constituting between 82 and 84% of the weight of the dry kernel. It contains about 88% starch and about 8-10% protein. Due to its high starch content, it provides the energy reserve for developing seedlings.

The embryo is between 10–12% of the kernel on a dry weight basis and is enclosed in a shield-shaped organ known as the scutellum. The embryo axis extends from the coleoptile to the coleorhizae. The primordial shoot consists of 5–6 embryogenic leaves, the stem, and the growing point (apical meristem). The embryonic leaves and the stem constitute the plumule. The coleoptile is a sheath protecting the first leaf and growing point. The radicle which is at the root end of the embryo axis has several lateral root initials. As with the plumule, it is protected by a sheath which, is known as the coleorhizae.

Classification of maize by its growing envionments

Maize can be classified into two distinct types based on latitude and the environment in which it is grown (tropical, 0–30 ^{0}N and S; subtropical, 30–34 ^{0}N and S; and temperate, extending beyond 34 ^{0} N and S). Three subclasses of tropical maize based on the environment may be further identified: lowland, mid-altitude, and highland maize.

Breeders' classification

Breeders also classify maize varieties on the basis of their genetic constitution. OPVs or composites - the more traditional germplasm (Stoskopf et al. 1993).

Synthetics - OPVs developed by crossing relatively few inbred lines (6–10) in all possible combinations and the progeny maintained by random mating.

Hybrids - cultivars in which the F1 progeny, produced by crossing inbred parents, is the commercial crop.

Yellow and white maize kernels.

There are several types of hybrid, depending on the parents involved in the production. Examples are single-cross hybrids that involve only two inbred lines, three-way-cross hybrids, produced by crossing a single-cross hybrid with another inbred line (that is, three inbred lines are involved), double-cross hybrids from crossing two single-cross hybrids (that is, four inbred lines) and top- crosses, produced by crossing an inbred line with an OPV.

Conclusion

Botanically, maize is highly vulnerable to genetic contamination during the different stages of the seed multiplication chain because of the nature of its reproductive system. Theoretically, genetic contamination during seed multiplication can be minimized either by increasing the effective population size under cultivation or by keeping strictly to the recommended isolation distances that help to produce genetically true-to-type seed by roguing volunteers and off-type plants or through detasseling the female parents in the production of hybrid maize seeds.

Variety release and registration in WCA 5

Introduction

For farmers to benefit from maize varieties and hybrids developed, released, and registered by the various NARS in WCA, the products must go through stringent testing and evaluation processes to ensure that they conform to the described characteristics as given by the NARS or the breeder involved. For a new maize variety to be released and registered for distribution in WCA, it must be Distinct, Uniform, and Stable (DUS) and have Value for Cultivation and Use (VCU). In most countries of WCA, the National Seed Authorities (NSAs) determine if new maize varieties are DUS and meet the criteria for VCU. Typically, the NSAs are mostly either public-based research institutions, or special committees set up for that purpose and consist of people with expertise in seed production from the key stakeholders in the country, or the assessment can be done by the private company that initiated the maize variety or hybrid development.

Steps in variety release

For a variety to be developed, registered, and released in any country in WCA, it must go through a series of stages of evaluations and testing. Different countries have different protocols required for the release and registration of a new variety for production, promotion, and sale in their respective countries. However, the basic characteristics of each of the individual protocols center on the following:

Variety development

The candidate variety for release and registration must have gone through several years of development and testing on-station and on-farm across locations in the country where the new variety is expected to be cultivated or it should have been tested in a specific area or agroecology if the variety has been developed for a specific ecological zone or growing area. Usually the testing period can be from 3 to 7 years or seasons, depending on the annual number of planting seasons in the country. The candidate maize variety must meet the DUS and VCU standards set for the country concerned which are determined by the National Variety Release and Registration Committee (NVRRC) in the target country or an accredited agent on behalf of the NVRRC.

National Variety Release Committee (NVRC)

When available, the NVRC is the final body which accepts or rejects a variety proposed for release and cultivation in a country within WCA. Whenever a breeder, an institution, or a private seed company has developed a variety, and is satisfied that the variety meets the DUS and VCU standards for the country and must be released for cultivation, permission for release is sought from the NVRRC which ensures that the set of standard procedures, laid down for the verification of information and data on the new variety, has been met.

Procedures for verification of data on new varieties
Verification of DUS and VCU data on the proposed new variety can be done in one of two ways.

Samples of the new variety are given by the originator of the variety to the appropriate NVRRC which will in turn deliver it to an independent verifier, here a research institution, university, or private organization, to test the variety for DUS and VCU, and verify if the data generated compare favorably with the variety information and data submitted by the originator of the variety.

During the verification period, scheduled field visits and inspections at critical stages of crop growth and development are undertaken by the NVRRC to areas growing the variety for them to observe at first hand the performance of the candidate variety. This method is the new verification system available in Ghana for the release of new crop varieties under the new Seed Law that became functional in October 2010.

Where an independent assessor cannot be identified for the verification of DUS and VCU for the NVRRC, the originator may be requested to grow the candidate variety and arrangements are made with the NVRC to visit plots under cultivation during certain critical growing stages for the assessment of the new variety. The candidate variety is normally planted alongside some existing maize varieties in the national list for comparison before being accepted for release or rejected. This was the methodology prevailing for variety release in Ghana before the commencement of the new Seed Law.

Releasing the new variety
When the candidate variety passes the DUS and VCU tests, the NVRRC then declares the variety acceptable and a name for the variety is given by the originator or one is proposed and adopted for marketing the variety in the country during the variety release ceremony. Following the release ceremony, the new variety is put on the catalog of maize varieties in the country, i.e., the national list of varieties eligible for commercialization. The released variety is usually accompanied by data on phenotypic characteristics as well as the physico-chemical and other relevant information required by the NVRRC. This serves as a guide for seed growers for identifying off-types during commercial seed production of the new variety along the value seed chain. Finally breeder seeds of the new variety are produced and given to other value chain components in the national seed program for the purposes of seed production.

Constraints to varietal release and registration

Some countries do not have functional varietal release systems. For example, even though Mali had a variety release committee, it was not functional at the time of the seed sector survey in WCA in 2007. On the other hand, Bénin did not have a varietal release committee and there was no seed law promulgated. In the countries where variety release committees do exist, they often cannot meet due to a lack of funds. This is particularly true for Nigeria where the meetings of the varietal release committees were irregular and by 2007 there were several varieties in the pipeline awaiting release. In some countries, the efficiency of the testing system is very poor, thus delaying the release of varieties. Some countries also have rigid regulations which overlap in release protocols .The implications of the delays in varietal release are that farmers' access to new varieties is delayed and choices are reduced. There is therefore a need to speed up variety release in WCA to ensure that DUS varieties enter the seed market, that the variety has a minimum VCU, and to stimulate the use of better varieties. These will lead to enhanced development of strong maize breeding programs and ultimately protect the breeder and the farmer.

Recommendations for the improvement of the varietal release and registration systems

To improve the varietal release and registration systems there is a need for the following:

- Promotion of a regional variety release system.
- Promotion of the use of data from other countries and breeders' own data.
- Simplification of variety testing.
- More frequent meetings of the NVRC.
- Regional harmonization of seed laws.
- Variety release guidelines.
- Promotion of regional standards for Plant Breeders' Rights (PBRs).
- Production of breeders' seeds of released varieties and hybrids in adequate quantities.

Activities to promote variety release and registration

The following activities should be carried out to support variety release and registration:

i. Promotion of the use of the West African Catalog of Plant Species and Varieties (COAFEV), published in 2009. The catalog was prepared in conformity with the decision of 17 countries, members of the WCA Economic and Monetary Union (UEMOA), ECOWAS, and the Permanent Interstate Committee for Drought Control in the Sahel (CILLS). It contains the names of varieties whose seeds can be produced and commercialized within the territories of the 17 member countries. It is an aggregate of the varieties registered in the national catalogs of the member states. For a variety to be registered in the catalog, it must have been previously registered in a national catalog.

ii. Strengthening seed systems for multiplication and distribution of varieties and hybrids. IITA and NARES collaborate with the private sector to strengthen the seed production and distribution of stress tolerant maize cultivars. Furthermore, IITA works with NARES to promote community-based seed production of the existing best drought tolerant (DT) varieties. Links are established with seed producers and farmers' associations in areas where the supply of seeds of improved maize varieties is limited. NARES and the private seed companies receive DT varieties and hybrids from IITA for production and marketing.

iii. Acceleration of the mechanisms for releasing varieties and hybrids. Efforts are being made by IITA scientists to assist the NARS in Benin Republic to establish a formal variety release mechanism and to establish a private seed company. Support is also being provided to the community-based seed production schemes (CBS) in Ghana, Bénin, and Mali. Efforts are being made to link community-based seed production schemes in Nigeria to the existing seed companies, such as Premier Seeds Co., Seed Project, and Maslaha to ensure enhanced availability of markets, credit, and ultimately the sustainability of the CBS.

Development and release of new varieties in SSA

IITA and CIMMYT have over the years consistently supported the development, testing, and release of new maize varieties as well as their dissemination throughout SSA. Through its numerous projects, such as those of WECAMAN and DTMA, IITA has assisted the NARS to develop, release, register, and disseminate many varieties and hybrids with appropriate characteristics and yields required for the attainment of food security in WCA (Tables 5.1 and 5.2). Setimela et al. (2009), through the funding support of the DTMA project, conducted surveys of variety testing and release approaches in selected countries in SSA. The objective was to define the magnitude of variety releases and the time span between variety development and release, to summarize the variety release requirements and procedures in selected countries, to identify constraints hampering the release of elite maize germplasm to smallholder farmers, to develop strategies to hasten the release of new elite maize germplasm, and to clarify factors influencing the time span between identification and release. Results of the survey showed that varietal release rates were the highest in southern Africa, including the Republic of South Africa (Tables 5.3 and 5.4) as well as the highest adoption rate of improved maize varieties of 52% compared with 4% for West Africa. The public sector in Angola, Mozambique, Ethiopia, Bénin, Nigeria, and Tanzania dominated the maize varietal release rates from 2002 to 2006 (Fig. 5.1) although the number of varieties released was very low. In contrast, the private seed sector dominated the maize varietal release rates in Kenya, South Africa, Malawi, Zambia, and Zimbabwe. With the emergence of a flourishing private seed industry, the share of hybrids in varietal releases and seed sales dominated the market compared with OPVs. The private sector released a larger number of varieties than the public maize breeding programs in SSA (Table 5.5).

Table 5.1. Variety release under DTMA in West Africa, 2007–2012.

Country	Year of release	Release Name	Code/Pedigree	Company	Hybrid/ OPV
Bénin	2007	2000 SYN EE W / Ku Gnaayi	2000 SYN EE W	IITA/ INRAB	OPV
Bénin	2007	EV 97 DT STR W / Mougnangui	EV 97 DT STR W	IITA/ INRAB	OPV
Bénin	2010	TZE COMP 3 DT / Ya Kouro Goura Guinm	TZE COMP 3 DT	IITA/ INRAB	OPV
Bénin	2010	BAG TZE COMPISITE 3 x 4 / Orou Kpintéké	BAG TZE COMPISITE 3 x 4	IITA/ INRAB	OPV
Bénin	2010	IW DC2SYN F2 / Djéma- Bossi	IW DC2SYN	IITA/ INRAB	OPV
Bénin	2010	DT SR W C2	DT SR W C2	IITA/ INRAB	OPV
Ghana	2007	CSIR-Etubi	GH110 x Entry 85	CRI/IITA	Hybrid
Ghana	2010	CSIR- Enii-Pibi (Enibi)	GH110 x Entry 75	CRI/IITA	Hybrid
Ghana	2010	CSIR-Abontem	TZEE-Y Pop STR QPM C0	CRI/IITA	OPV
Ghana	2010	CSIR-Omankwa	TZE-W Pop DT STR QPM C4	CRI/IITA	OPV
Ghana	2010	CSIR-Aburohemaa	EV DT-W 99 STR QPM C0	CRI/IITA	OPV
Ghana	2012	CSIR-Ewul-boyu	IWD C3 Syn F2	SARI/CRI/IITA	OPV
Ghana	2012	CSIR– Bihilifa	TZE-Y DT STR C4	SARI/CRI/IITA	OPV
Ghana	2012	CSIR-Wang Dataa	TZE-W DT STR C4	SARI/CRI/IITA	OPV
Ghana	2012	CSIR-Sanzal-sima	DT SYN -1 - W	SARI/CRI/IITA	OPV
Mali	2009	Jorbana	EV DT 97 W STR C1	IER/IITA	OPV
Mali	2010	Brico	TZEE -Y Pop STR C4	IER/IITA	OPV
Mali	2011	Tieba	Top-cross White Hybrid	IER/IITA	Hybrid
Mali	2012	Sanu	IITA hybrid TZEI 60 x TZEI 86	IER/IITA	Hybrid
Mali	2012	Mata	IITA hybrid TZE-Y Pop DT STR C4 x TZEI 13	IER/IITA	Hybrid
Nigeria	2009	Sammaz 15	IWD C 2SYN	IAR	OPV
Nigeria	2009	Sammaz 18	Tillering Maize	IAR	OPV
Nigeria	2009	Sammaz 19	S.14DKD DT	IAR	OPV
Nigeria	2009	Sammaz 20	TZE Comp3DT	IAR	OPV
Nigeria	2009	Sammaz 22	MO826-1	IAR/IITA	3-way cross hybrid
Nigeria	2009	Sammaz 23	MO826-3	IAR/IITA	3-way cross hybrid
Nigeria	2009	Sammaz 24	MO826-7	IAR/IITA	Top cross Hybrid
Nigeria	2009	Sammaz 25	MO826-11	IAR/IITA	Top cross Hybrid
Nigeria	2009	Sammaz 26	DTSR-WC1	IAR/IITA	OPV
Nigeria	2009	Sammaz 27	EV 99 DT-W-STR	IAR/IITA	OPV
Nigeria	2009	Sammaz 28	TZEE Y Pop STRC4	IAR/IITA	OPV
Nigeria	2009	Sammaz 29	2000Syn EE-W-STR	IAR/IITA	OPV
Nigeria	2009	Oba Super 7	SYN/ZDL1/TZL1	Premier/IITA	3-way cross hybrid
Nigeria	2009	Oba Super 9	SYN/ZDL1/TZL2	Premier/IITA	3-way cross hybrid
Nigeria	2011	Sammaz 32	99TZEE-Y Pop STR QPM C0	IAR/IITA	OPV
Nigeria	2011	Sammaz 34	IAR Multicob Early DT	IAR	OPV
Nigeria	2011	Sammaz 35	2000EV DT-Y STR C4	IAR/IITA	OPV
Nigeria	2011	SAMMAZ 38	2000 Syn EE - W STR QPM CO	IAR/IITA	OPV

Table 5.2. DT hybrid and OPV maize varieties in the pipeline for release in WA in 2012.

Country	No. of varieties/ hybrids	Name of varieties
Nigeria	10	EV DT-W 2008 STR, EV DT-Y 2008 STR, TZE-W DT STR C4, TZE Y DT STR QPM C0, EV DT 2000-Y STR QPM, 2008 DTMA – Y STR, DTE W STR SYN, TZE-Y Pop DT STR x TZEI 11, (TZEI 17 x TZEI 157) x TZEI 129, (TZEI 135 x TZEI 17) x (TZEI 16 x TZEI 157), TZEEI 29 x TZEEI 21, TZE-W STR C5 x TZEEI 6.
Ghana	8	2004 TZE-W Pop STR C4, 2004 TZEE-W Pop STR C4, TZE COMP 3 DT C2F2, DT SR W CO F2, DT SYN 1 W, IWD C2 SYN F2 TZE-Y Pop DT STR x TZEI 11, (TZEI 129 x TZEI 17) x TZEI 157
Bénin	9	EV DT- Y 2000 STR QPM C0, TZEE-W POP STR C4, EV DT-Y 2000 STR QPM C0, TZE-W DT STR C4, TZE-Y DT STR C4, DT SR6 W CO, DT SR Y SYN 2 TZE-W Pop DT STR x TZEI 22 (TZEI 135 x TZEI 17) x TZEI 157
Mali	8	TZE Comp 3 DT C2F2, EV DT-Y 2000 STR QPM C0, 2000 Syn EE-W QPM, TZEE- W Pop STR QPM C0, TZEE-W POP STR C4, DT Syn-1 W, DT SR-W C0 F2 TZE-W Pop DT STR x TZEI 4, (TZEI 129 x TZEI 17) x TZEI 157, TZE I 60 x TZEI 86, TZE-W Pop DT STR C4 x TZEI 13.

Table 5.3. Time taken to release a maize variety in selected DTMA Project countries.

Country	Actual time to seed release (years)			Time from release to when seeds are available to farmers in significant quantities (years)
	Mean	Min	Max	Mean
Kenya	3.1	1.5	6	2.4
Malawi	3	2	7	1.9
Tanzania	2.2	1	3	2
Uganda	2.2	1	4	2.1
Zambia	2.1	1	3.5	2.5
Zimbabwe	2.2	1	3	2.4
South Africa	2	2	2	2.5
Ghana	2	2	2	2
Nigeria	3	4	3	0.03

Source: DTMA seed sector survey, 2007/2008 (adapted from Setimela et al. 2009).

Table 5.4. Average numbers of maize varieties released per year in the DTMA project countries in SSA, 2002–2006.

Country	Number of varieties released per year					Total for 2002–2006
	2002	2003	2004	2005	2006	
Angola	5	3	7	6	8	29
Bénin	2	0	0	3	2	7
Ethiopia	4	0	6	8	0	18
Ghana	0	0	0	0	0	0
Kenya	10	22	25	21	4	82
Malawi	8	5	1	3	0	17
Mali	0	0	0	0	0	0
Mozambique	0	4	2	0	0	6
Nigeria	0	4	0	2	0	6
South Africa	68	67	79	69	59	342
Tanzania	2	3	4	0	0	9
Zambia	12	9	11	7	15	54
Zimbabwe	2	5	4	3	8	22
Total	113	122	139	122	96	592

Source: DTMA national variety testing and release survey, 2007/2008 (adapted from Setimela et al. 2009).

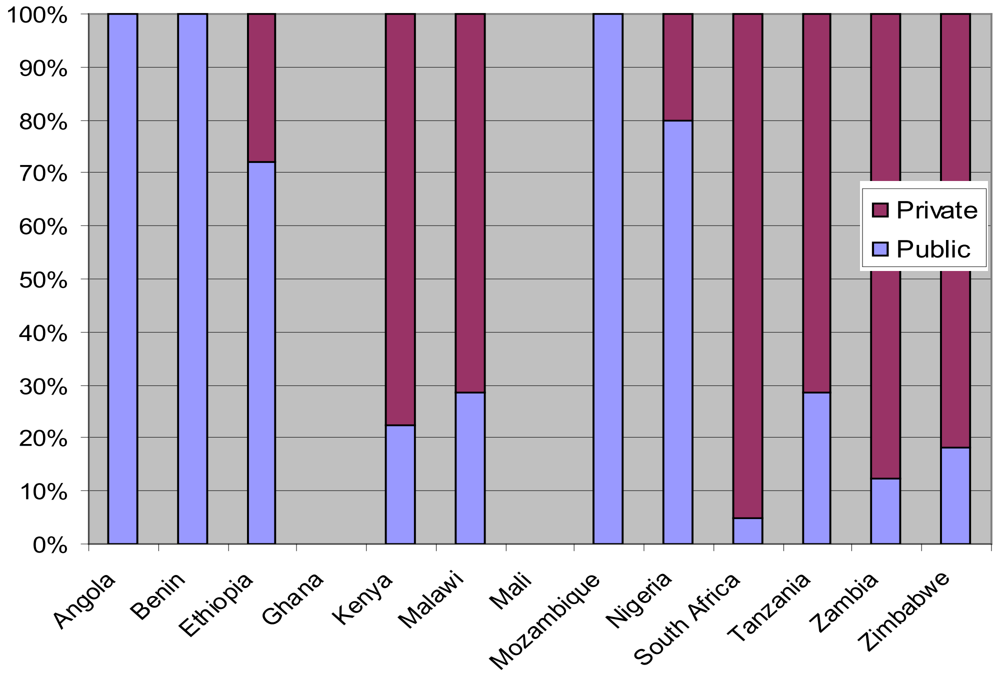


Figure 5.1. Percentage of public and private seed sector maize releases 2002–2006.
Source: DTMA national variety testing and release survey 2007/2008 (adapted from Setimela et al. 2009).

Table 5.5. Estimated numbers of maize varieties by type released by public and private breeding programs in DTMA project countries in SSA, 2002–2006.

	OPVs		Hybrids		
Country	White	Yellow	White	Yellow	Total
Angola	9	2	14	6	31
Bénin	6		1	0	7
Ethiopia	6	0	12	0	18
Ghana	0	0	0	0	0
Kenya	6	0	49	0	55
Malawi	0	0	7	0	7
Mali	0	0	0	0	0
Mozambique	4	0	0	0	4
Nigeria	3	1	2	0	6
South Africa	19	6	134	154	313
Tanzania	1	0	6	0	7
Zambia	5	0	40	6	51
Uganda	?	?	?	?	?
Zimbabwe	5	0	13	1	19
Total	58	9	277	167	518

Source: DTMA national variety testing and release survey (adapted from Sentimela et al. 2009).

The differences in the varietal release rates reflect the investment made by public and private breeding programs. The difficulties with existing release system in the various countries have resulted in delayed access by farmers to new varieties and to a limited choice of new varieties. The existing systems have allowed few varieties to be released. This is costly and duplicative, as the same variety must be tested in all countries where it is being targeted for marketing.

IITA has through its special projects studied and documented the current status of available maize varieties and their release and dissemination within selected NARS in WCA and has documented the information and data for use by the various NARS and others. The results from some of the investigations have confirmed the information given earlier in this document, that for new maize varieties to be marketed in WCA, the variety must have been released and registered. The registration process requires that tests for DUS as well as VCU be conducted before the new variety is accepted for registration. The registration establishes legal ownership of the new maize variety.

Results of the survey conducted by Setimela et al. (2009) further showed that the DUS and the VCU tests in WCA took between 1 and 3 years before variety registration. In addition, there were seed laws and regulations in individual countries to regulate variety testing and release as well as seed production. The work of IITA, through its two special projects (WECAMAN and DTMA) on variety development, release, and dissemination, has generated a lot of data and information and has given insight into the status of variety release systems.

Public and private sector releases

Summary information on maize varieties released by the public and private sectors in SSA during the period 2002 to 2006 is shown in Figure 5.1.

Constraints to variety releases

Information available from the NARSs and through the research findings of IITA's WECAMAN and DTMA projects cataloged the following as some of the constraints facing variety release mechanisms in WCA and SSA. To ensure the continuous delivery of good quality improved seeds to farmers within the subregion, the identified constraints must be addressed.

- **Lack of an effective variety release system**. This constraint is one of the major impediments in the transfer of available elite maize varieties to smallholder farmers in the DTMA countries in SSA.
- **Long delays between variety development, registration, and release.** The turnover of new varieties in most countries is very low for several reasons. Most of the countries lack functional NVRCs and, when available, most are publicly funded and therefore face financial constraints to their effective work. Most often, the committees also lack good coordination and meet very infrequently to decide on varieties that must be released and registered.
- **Non-existence of seed policy, laws and regulations.** Many countries lack functional seed policies and seed laws as well as seed regulations guarding the seed laws. Where available, the seed laws and regulations of affected countries are often very rigid, precluding the use of data from other countries with similar agroecologies, thus creating a delay because re-testing has to be done each time a new variety is released in a different country.
- **Lack of national variety lists and catalogs.** Most countries do not have national variety lists and catalogs identifying the phenotypic characteristics of released varieties. This makes it very difficult for emerging seed producers and companies to advertise and commercialize varieties in the country.
- **Non-existence of Plant Breeder's Rights in Breeding Programs of NARS**. Only a few countries in WCA have PBRs and the lack of PBRs discourages many private seed companies from introducing their best products, since their products are not protected. It also discourages public breeding stations from releasing varieties as they become available "illegally" in other subregional countries without any benefit to the originators of the varieties.
- **Dominance of OPVs over hybrids in maize programs.** Most breeding programs concentrate on the breeding and release of OPVs. This is a disadvantage to the seed industry because farmers continually keep and re-use their own seeds in contrast to the regular practice of purchasing seeds each year.

Maize seed production techniques 6

Goals of seed production

Seeds of improved varieties need to be multiplied, distributed, and cultivated by farmers for the benefits of improved varieties to be realized. A major goal of seed production enterprises is to obtain high seed yields of genetically pure and uniform stocks. In addition, the conditions of physical purity and uniformity have to be fulfilled. In general, seeds must be genetically pure, clean, and without any extraneous matter or pathogenic organisms. Other goals include the production of easily storable seeds with high longevity in storage, as well as consumer acceptability and high field emergence.

Maize is basically a warm-season crop but breeders have, over time and through genetic manipulations, developed varieties and lines that can grow under almost any climatic conditions. However, it grows best between temperatures of 21–32 ^{0}C (70–90 ^{0}F) with 15–20 cm of rain over 3–4 consecutive months. These conditions are prevalent in almost all ecologies of WCA.

Maize seed production areas

Throughout the tropics and subtropics, small-scale farmers grow maize mostly for subsistence as part of agricultural systems that feature several crops and sometimes livestock production. Unlike the developed countries where hybrid maize varieties are commonly grown with high inputs and mechanized operations, the production systems in SSA often lack inputs, such as fertilizer, pesticides, improved seeds, irrigation, and labor.

Maize seeds produced in the semi-arid areas, such as the Guinea and Sudan savanna zones of WCA, are of better quality than seeds produced in the forest and the forest-savanna transition zones. Fungal infection and insect infestation are lower in dry areas, and seeds therefore store well and also germinate better. Maize seeds can be sun-dried down to less than 10% moisture content in the open when seeds are produced in the Guinea and Sudan savanna zones where there is only one season in a year or produced in the second season in the forest and the forest- savanna transition zones where there is usually a long dry sunny period before the next season's rain commences.

Agronomic practices in maize seed production

Agronomic practices used for the production of maize seeds are the same as those for grain except that some additional requirements must be provided to ensure two cardinal essentials: seeds must always be true-to-type and viable when planted, irrespective of how long they have been stored.

Classes of maize seeds

Basically, the maize seed value chain, from the breeder to the final grain producer, goes through the four classes of seed production in any seed value chain: breeder, foundation, registered, and certified seeds.

Breeder seeds

Breeder seeds are the seeds of a variety produced under the direct control of the breeder who developed the variety. Breeder seeds are often produced in small quantities but are of the highest genetic purity owing to strict production controls and maintenance of quality. Breeder seeds may be produced in two stages to make available an adequate quantity of seeds required for the production of foundation seeds.

Foundation seeds

Foundation seeds are the direct seed increase resulting from growing breeder seeds. In other words, they are the progeny of the breeder seeds. Their production is carried out to ensure that varietal identity and genetic purity are maintained as closely as possible to those of the breeder. Foundation seeds are usually produced by a seed production expert or under the control of an agricultural experimental station or seed production agency, but with the assistance of a breeder.

Registered seeds

Registered seeds are the progeny of the foundation seeds, or sometimes the breeder seeds. For their production, the requirements and standards of the seed certifying agency must be met. The production of registered seeds is sometimes omitted in some seed production programs.

Certified seeds

Certified seeds are the progeny of the registered seeds, or sometimes the breeder or foundation seeds. Their production is carried out by seed growers and must be certified by the regulatory agency which ensures the maintenance of the identity of the variety as well as its genetic purity.

Registration of the seed farm

A seed farm may be registered by the appropriate seed certifying agency which would monitor and inspect the fields and finally certify the produce after conditioning and testing to enable the grower to market the seeds. Normally the seed field should be inspected before and during planting. In addition, inspections are conducted during flowering and harvesting periods. Also, the equipment used for planting, harvesting, and cleaning and the storage and marketing facilities are all inspected. Seeds produced from fields and facilities that satisfy the inspection requirements are certified and tagged for marketing. Irrespective of the class and type of maize seeds being produced, certain basic agronomic practices are universal and must be followed to ensure the genetic purity and ultimately the high quality required by farmers. The following are the most important among the agronomic practices.

Site selection
Site selection is one of the major considerations in the production of good quality seeds. In general, the land selected for seed production must be fairly flat, well drained, and loamy. It should be easily accessible to vehicles for inspection and carting harvested produce. The location should also permit successful isolation of the maize seeds being produced from contamination by pollen from different varieties grown by nearby farmers to maintain genetic purity.

Isolation
Maize seed production fields must be adequately isolated from neighboring fields planted to different varieties of maize. Isolation can be achieved in two ways: by distance or by time.

Isolation by distance
The isolation distances to be observed depend on the class of seeds being produced, the layout of the land, and the barriers (natural or artificial) surrounding the maize crop as well as the color of the variety under cultivation. In general, the minimum isolation distance, whether for OPVs or hybrids, must be between 300 and 400 m, depending on the variety and the class of seeds being produced.

Recommended minimum isolation distances for the various classes of seeds are 400 m for foundation seeds and 200 m for certified seeds.

Isolation by time
Isolation by time is usually the method used when land is limited. Here two (or more) different varieties may be planted close to each other but care is taken that they have different maturity periods and also plantings are at intervals of 2–3 weeks between different varieties. Close monitoring of maize isolated by time must be made to rogue out weak and slow growing plants in order not to allow varieties to be contaminated.

Seedbed preparation
Fields must be plowed and harrowed carefully when necessary to make a seedbed with a good environment for the seeds to germinate and produce strong and healthy seedlings. Alternatively, the no-tillage method can be adopted by applying appropriate chemical herbicides on low grassy vegetation.

Planting the crop
The weather pattern in the growing area must be known so that planting would take place when the rains had come to stay. Calculations must also be made to ensure that harvesting of the crop coincides with the non-rainy season to ensure good seed quality. The use of a field that had not been planted to maize for at least 2–3 seasons is usually recommended to avoid contamination from carry-over seeds in the soil.

Spacing for OPV seed production

The spacing to be adopted for planting the seed field would depend upon the class of seeds, the maturity group of the variety, and the season of cultivation. However, in general, to achieve a better seed yield, an optimum density must be achieved. For early and extra-early maturing varieties, planting may be done at a spacing of 75 × 40 cm, three seeds later thinned to two at 2 weeks after planting (WAP) to give a plant population of 66,666 plants/ha. Other plant spacings may be used as pertains in Ghana and shown in Table 6.1 below.

Spacing for hybrid seed production

The ratio of female (seed-producing) parents to male (pollen) parents to be adopted for hybrid seed production depends on the type of parental lines being used for the hybrid maize seed production as well as the seed class. However, a general recommendation of three rows of the female parent with one row of the male parent is often used in Ghana. This alternation is continued throughout the field. The outside two rows on all sides of the field should usually be planted to male parents to saturate the environment with the much-needed pollen at flowering time. The plant population, row width, and plant spacing would be the same as for OPVs.

Fertilizer application

Maize and other cereals normally require high amounts of fertilizer, usually NPK, for good grainfilling and good yield. The requirements for fertilizer vary depending on the ecology, variety, and farming practices in the area of production. Usually soils in the forest zone are more fertile than those in the savanna and soils that have been cropped continuously to cereals are low in soil fertility. Rates of fertilizer application should be based on soil tests and must be within the limits set by the extension services in the area of production. Usually a split application is recommended. A basal application of a compound fertilizer is usually made within 14 days after planting the seed crop followed by side dressing with ammonia or urea applied between 4 and 6 WAP, depending on the variety under cultivation. Other nutrients such as calcium, magnesium, sulfur, and zinc may be applied in trace amounts to soils that are deficient in these nutrients.

Table 6.1. Recommended plant spacing for seed production of OPVs in Ghana.

Spacing	Maturity		
	105-110 days and 120-days	90-95 days	80-85 days
Between rows	80	80	60
Within rows	40	30	30
Seeds/ hill	1	1	1
Population (plants ha^{-1})	32,500	42,500	55,600

Weed control

Weeds compete with the maize seed crop and rob it of valuable nutrients. The critical period for weed control is usually within 6 WAP. Control weeds manually or by the use of pre-emergence and post-emergence herbicides as well as with crop rotation. In mechanized farming, however, mechanical cultivators may also be used to control weeds 30–35 days after planting.

Roguing of off-types and other volunteer plants

The vegetative and post-flowering characteristics of the variety under cultivation must be well known to help identify off-types which may be growing in mixtures with the seed crop. In the production of breeder, foundation, and certified seeds, off-types and volunteer plants must be eliminated at every stage of crop growth. Field inspection for off-types and volunteer plants must be carried out throughout the growing season. To avoid volunteer plants which may not be readily identified, it is helpful to use a field which was planted to a different crop in the previous season. Remove plants showing disease and pest symptoms and plants whose characteristics do not conform to the prescribed characteristics of the variety under cultivation.

In hybrid seed production, female (seed) rows are detasseled before they shed pollen. The male plants (source of pollen for the hybrid) are not detasseled but must be harvested a day or two before the female lines to avoid admixtures.

Harvesting

Harvesting is the last field activity to be done before conditioning the harvested produce into seeds for storage and planting the following season. It is an activity in the seed production chain which, if not done at the right time, would result in seeds of low quality. The seed crop should be harvested on time to avoid weathering on the field and which would also lead to poor quality seeds. For maize, harvesting is done on cobs so that admixtures and any cob that is not true to type with reference to the described and planted variety can be picked out to avoid mixing it with the good seeds. Ears can best be harvested after they reach physiological maturity (30-36% seed moisture content), especially when facilities are available for artificial or mechanical drying to the safe moisture content for storage. When means of artificial drying are not available, the ears should be allowed to further dry in the field (18–25% seed moisture content) before being harvested. Early, premature, and delayed harvesting will lower seed yield and quality.

Indicators of when to harvest

- **Seed moisture content**. Check the ears' seed moisture content and see if it is in the safe region for conditioning after harvest. This can be between 18 and 35% depending on whether mechanical drying will take place and the weather at the time of harvest.

- **Visible kernel black layer**. Check to see if the black layer is visible in a kernel pulled from the cob. This is an indication that no more partitioning of dry matter from the leaves to the seeds is taking place and that harvesting can be done safely, provided that facilities are available for mechanical or sun drying.
- **Maturity period of variety**. Knowledge of the days to maturity of the variety as described by the breeder provides a good indication of when to harvest.

All the above are subject to the influence of the seed production environment and variety.

Methods of harvesting maize
This can be mechanical, where corn pickers are used, or manual, when dehusking of the cobs is done physically by hand.

The seed crop should be harvested on time to avoid weathering on the field which may lead to low seed quality. Seed ears can be harvested after seeds reach physiological maturity (30–36% moisture content). If weather conditions are favorable (dry), the seeds should be allowed to field-dry and then harvested at 18 to 25% moisture content.

As ears are harvested, the husks are removed so that the cobs and seeds on them can be seen, and undesirable ears can be identified and discarded to make drying more efficient.

Seed production and maintenance of OPVs

Freely interbreeding individuals make up the OPV populations. Seed production of OPVs must avoid genetic drift which is defined as a change in gene frequency as a result of a small population size. In the production of seeds of OPVs care must be taken to prevent inbreeding as much as possible.

Sources of genetic contamination

Genetic contamination of stocks results from spontaneous mutation, which is defined as a sudden heritable change in a gene. Contamination can also result from inadvertent mechanical mixing and pollen movement from plants of a different population to another. Contamination as a result of mechanical mixing usually results during the processing of seeds. Although this is physical in nature, it becomes genetic when genes of the contaminating plant are dispersed through the population by cross-pollination. Rates of mutation are very low and over short intervals of time, its contribution to genetic contamination may be low or negligible. The effect of mutation is cumulative, and over long periods of time it may contribute considerably to genetic contamination. The effects of contamination are visible on the progeny resulting from the contaminated stock. For some traits, the effects are observable on the kernel formed following pollen contamination. This effect is called Xenia. An example is when pollen from a yellow kernel variety pollinates the ovule of a white kernel variety. Given that white (y) is recessive to yellow (Y), the developed kernel is of yellow color. The intensity of the yellow color is a dosage effect. The kernel color is the color of the vitreous starch of the endosperm which is 3n, the result of the fertilization of the 2n polar nuclei and the n sperm nuclei. Genotypes with YYY constitution for the endosperm are deep yellow; those with YYy are moderate; Yyy are light yellow; yyy are white. Similarly, when a super sweet *shrunken*-2 maize ovule is fertilized by pollen from normal maize with a starchy endosperm, the developing kernel is no longer supersweet but normal. The super-sweet gene is recessive to the gene for normal starch production.

Overcoming field contamination

A number of strategies may be used to overcome contamination. These are implemented at different stages.

- The first is to use pure breeder seeds; this can be achieved by obtaining breeder seeds directly from the originating institution.
- The second is to use a large population size for seed production, since frequency of contamination can increase sharply with small population size.

Contamination resulting from pollen movement and from mechanical mixing is controllable by exercising great care in the production and processing stages.

- Isolating fields for seed production in time or space will prevent pollen contamination. Recommended isolation distances between maize fields planted to different stocks must be maintained.
- Roguing is also carried out for off-types and volunteer maize plants.
- Cleaning of seed processing equipment each time new stock is to be processed will reduce the contamination due to mechanical mixing.

With OPVs, cross-pollination accounts for about 95% of all pollinations; about 5% of seeds are formed from self-pollination. Strategies are available to keep the level of self-fertilization at an acceptably low level. Contamination resulting from mutation cannot be eliminated. However, stocks can be cleaned up or purified when characteristics are observed that should not be present. Attack by many field and storage pests can also contribute to physical contamination. Adoption of recommended agronomic practices, quality assurance, and storage practices will minimize physical contamination, pest attack, and the deterioration of maize seeds in storage.

Maintenance of OPVs

Any variety, OPV or hybrid, must be maintained true-to-type and the identity of the variety must be kept the same, year after year. Seed increase of an OPV, following development, testing, and release, is required if the variety is to be available for cultivation by farmers and the benefits of its superiority are to be enjoyed. A seed supply system must be in place to make available to farmers a regular supply of good quality seeds.

Maintenance of an OPV is more difficult because of the possibility of contamination as a result of the pollination system. Seed multiplication for marketing to farmers is an operation that may involve a combination of official, commercial, cooperative, and private agencies. Supervision of private farmers involved in seed production is the function of the seed certification agency. Approved private farmers under a certification scheme can produce certified seeds for sale at a premium price 15–25% above the grain price.

Hybrids and OPVs

Seeds harvested from a field planted to a hybrid must never be saved and used for the next cropping season because of the expected substantial decline in yield. Fresh seeds of hybrids would therefore need to be purchased every season. With OPVs, farmers could save their seeds and use these to plant their fields in the following seasons for about three generations without a substantial decline in grain yield. It is therefore recommended that seeds of OPVs be purchased after every two to three generations, since a decline in performance occurs as a result of the contamination of the variety by pollen from adjacent fields. Maintenance of an OPV can be done by open pollination under proper isolation.

Breeder seed production of OPVs

Varietal purity during the production of breeder seeds can be ensured by isolation in space, time, or by controlled pollination. These precautions are required in areas where other fields in the environment are planted to maize. Isolation in space requires that a minimum distance of up to 400 m be maintained from the nearest field planted to a maize crop.

Isolation in time ensures that there is no overlap in the flowering time of the variety being maintained or multiplied and those in the surrounding area, even if they are planted in close proximity. This can be achieved by planting very early or very late. Two populations that differ in flowering time by about 10 days (for example, if one reaches 50% flowering in 45 days and the other in 55 days) can be isolated by about 25 days if the early flowering variety is planted first and the later variety is planted 15 days later. Two populations of similar maturity cycle would need to be planted about 28 days apart to ensure purity.

For the maintenance and breeder seed production of a variety that is characterized by a recessive trait, such as the super-sweet trait conditioned by the *shrunken*-2 gene, and for which the Xenia effect is manifest, contamination resulting from pollen movement from normal endosperm can be easily identified as the production of normal kernels.

Cultural practices

Cultural practices must be optimum to ensure good growth, development and seed production. Purity and uniformity of the variety are also ensured after harvesting and threshing by removing cobs and kernels that do not conform to the general characteristics of the variety.

Seed production methods for OPVs

There are several methods for producing seeds of OPVs. These methods either use the various isolation techniques or controlled pollination.

Mass selection or modified mass selection method

At least 8000 plants from the breeder seeds of the variety from an assured source are planted in an isolated field. It is important to have an adequate number of plants to minimize selfing. It is also important to ensure the minimum isolation in distance or time. Open-pollination is allowed among the established plants while employing various strategies to ensure purity. About 600 to 800 cobs with well-set kernels are selected and equal quantities of seeds from the central portion of each cob are composited as the breeder seeds. To minimize the effect of the environment on selection, the field may be divided into grids of 20 plants with 6 to 8 plants selected in each grid. Remnants of clean breeder seeds must be dried and kept in cold storage.

Modified half-sib method

In this method, a minimum of 2000 plants from the breeder seed plot is established. Some rows are designated as male rows and others as female rows. One male row to three or four female rows may be adequate since the breeder seeds will be obtained from ears harvested from the female rows. Off-type plants in the male rows are removed before pollen shed. Female rows are detasseled so that ears of the female plant get pollinated by pollen from the male row plants. About 400–500 cobs harvested from plants of the female rows are selected and seeds from these cobs are bulked as breeder seeds. Ears harvested from plants in the male rows may be harvested and used as seeds of the variety.

Controlled pollination methods for breeder seed production

Half-sib method

Breeder seed production can also be done by hand pollination. This obviates the need for isolation in time or space but requires the use of shoot covers and pollination bags. About 2000 plants are established from the breeder seeds. Shoots are covered before silk emergence. To prevent selfing, the field is divided into two: pollen collected from plants on one half of the field showing characteristics of the variety is bulked, mixed thoroughly, and used to pollinate plants on the other half, and vice-versa. From about 600 ears selected, seeds from the central portion of about 400 cobs are bulked as the breeder seeds.

Full-sib method

In this method, a similar number of plants as in the half-sib method described above are established and the appropriate measures to ensure varietal purity are undertaken. Shoots are covered before pollen shed (anthesis). Plants with the characteristics of the variety in the field are mated in pairs by collecting pollen from one designated as male and using the pollen for the

Table 6.2. Schematic presentation of a large seed multiplication program.

Seasons	Stage	Seed	Area needed
1	Stage-1	100–200 kg bulk breeder seeds.	1000 m^2 needed for each variety
2	Stage-2	1–6 t basic seeds	1–4 ha needed for each variety
3	Stage-3	Large-scale registered seed production (1) of 40–500 t.	Between 16 and 200 ha needed for each variety
4	Stage-4	2nd large scale certified seed production of up to 500 t of certified seeds (2) for distribution to farmers	Up to 1500 ha needed for each variety

pollination of plants designated as female. At least 600 cobs formed on the females of plants mated in pairs are harvested from which 400 are selected and their seeds are bulked.

Foundation seed production

Foundation seed production is required to supply the seeds to be used for the production of certified seeds. Breeder seeds are planted in a 400-500 m^2 field isolated from other fields by the minimum isolation distance, (usually 400 m) or by at least 28 days if isolation is to be in time. The area actually depends on the quantity of foundation seeds required which also is a reflection of the total certified seed requirements plus a carryover stock, usually about (20% of the total seeds).

Genetic purity in foundation seed production fields is maintained by roguing plants that show characteristics different from those of the variety. At harvest, the ears are carefully examined and off- types are discarded. The remaining ears are dried, shelled, and bulked as the foundation seeds. If the certified seed requirement is high, another cycle of foundation seeds may be produced. For example, Table 6.2 summarizes the sequence and the dimensions needed for seed multiplication of up to 5000 t of certified seeds of OPVs to be distributed to maize growers. Assuming the final seed quantity is 500 t or less, only three stages may be necessary to produce the seed quantity (IITA 1982).

Certified seed production

As with foundation seeds, certified seeds are produced in isolation. The isolation distance may be slightly less than that required for breeder and foundation seeds, usually about 300 m. Certified seed production is usually carried out by certified seed producers who have received some level of training in seed production technology.

Certified seed producers could be individuals or seed companies or community seed producers. The activity is under the control of the seed certification agency which pays repeated visits to the field during production. The objective is the production of high quality certified seeds. Roguing is

Table 6.3. Factors to be considered for the production and marketing of different types of hybrids.

Types of hybrids	Yield potential	Uniformity	Number of plantings	Amount of seed produced	Cost of seed production	Price of seed
Single cross	Decreases	Decreases	3	Increases	Decreases	Decreases
Modified as single cross			5			
Three-way cross			5			
Modified three-way cross			7			
Double cross			7			
Top cross			3			
Varietal cross			3			

carried out for off-types at all times but, most importantly, immediately before and at flowering. The produced seeds are dried, shelled, and bulked as certified seeds. Certified seeds usually carry labels of certification with information on the name of the variety and percentage germination, among other details.

Hybrid maize seed production

Hybrid varieties are the first generation offspring of a cross between inbred line parents, OPVs, and other populations used for commercial planting. The greatest development of hybrids has been the use of inbred lines which are developed by several generations of inbreeding followed by tests for combining ability. Conventional hybrids include single, three-way, and double-crosses

The two important characteristics of hybrids are high yields due to hybrid vigor and outstanding uniformity. To ensure the purity and uniformity for which hybrids are known, their seeds must be produced with special care. Seeds harvested from a field planted to hybrids must not be saved for use in planting in subsequent seasons as such a practice will result in a substantial reduction in yield and in non-uniformity. Hybrid types differ in their yield potential, uniformity, number of plantings (seasons) needed for seed production, potential seed productivity, cost of seed production, and seed sales price. The trend of these characteristics among the various types of hybrids is shown in Table 6.3.

When maize is self-pollinated, each generation becomes weaker. Self-pollination is the process of taking the pollen from a single plant and applying this to the silks of the same plant. This is called ***inbreeding*** and, after successive generations, it leads to weakened plants called inbred lines. These inbred lines are small in size, have small cobs, and reduced yields. However, when two inbred lines are crossed, the vigor is restored in the resulting seeds, and the yield of the plants grown from the seeds is greatly increased. This is called ***hybrid vigor***. It occurs as a result of the interaction between the sets of genes obtained from the two different inbred lines. The effect of some of the harmful genes expressed in one of the inbred lines will be masked by more beneficial genes found in the other parent plant. This is called ***heterosis***, and has been exploited to develop hybrid cultivars that are now widely grown by farmers.

The characteristics of hybrid maize

- It is uniform in appearance.
- It has vigor (makes varieties more competitive with weeds).
- It is high yielding.
- It is selected for improved grain quality.
- A particular hybrid can be selected for drought tolerance or resistance to a specific pest or disease.

Developing new hybrids

Hybrid maize is produced by cross-pollinating two unrelated male and female plants or different inbred lines. By the nature of the maize plant that has separate male and female flowers, the tassel and the cob, it is possible to control the crossing or mating of the plants. A plant may be used as either a male or female parent. If a plant is used as male, the pollen from the plant is used to cross onto the silks of a different female plant. The pollen from the female plant is eliminated, usually by physically removing the tassel from the female plant before it sheds its pollen (a process called detasseling). The resulting seeds on the female plant give rise to hybrid plants that are uniform in color, maturity, plant heights and other characteristics. To produce seeds of hybrid maize, the male and female inbred lines must be grown under strict conditions and evaluated for yield potential and field characteristics.

Types of hybrids

Crosses between males and females can be made in four different ways to give rise to different kinds of hybrids.

Single-cross hybrids

Single-cross hybrids are the most modern commercial hybrids. They are crosses between two unrelated inbred lines. A field planted with single-cross seeds is impressive because plant height, ear height, tasselling, silking, pollen shedding, and all other characteristics are uniform. As only two inbred parents are involved, a higher level of resistance to diseases, insects, and unfavorable weather is evident in single-cross hybrids. Pollen shed occurs during a shorter period since all the plants are genetically alike. Single-crosses therefore have the potential to produce lower yields, especially under stress conditions.

Three-way-cross hybrids

Three inbred parents are involved in three-way-cross hybrid formation. The female of a three-way hybrid is a single-cross hybrid (A × B), while the male is an inbred line (C), resulting in a three-way hybrid [(A × B) × C] when they are crossed. Three-way-cross hybrid seeds are produced on single-cross plants so that yield and quality may be equal, or nearly so, to double-cross seeds. Three-way-crosses are more variable than single-crosses and less variable than double-crosses. The advantages and disadvantages of three-way crosses are between those of double- and single-crosses.

Double-cross hybrids

In this type of hybrids, both parents are single-cross hybrids. That is, they are produced by crossing two different single-crosses, giving the pedigree [(A × B) × (C × D).] This permitted four different unrelated inbred parents with desirable characteristics to be brought together into one hybrid.

Advantages of double-cross hybrids

Double-cross hybrid seed production is a practical and economical way of producing adequate seeds for farmers. This is as a result of both parents originally being hybrids. They are also more variable than single- or three-way crosses and they are not all alike genetically, a situation which allows breeders to bring more different desirable characteristics together into one hybrid than is possible in a single-cross. Double-cross plants also have a longer pollination period, a condition that tends to provide more complete filling of the ear with seeds, often resulting in higher yields. Double-cross hybrids obviously have a lower seed cost advantage because their yield is equal to or better than that of the best single-crosses.

Disadvantages of double-cross hybrids

The major disadvantage with double-cross hybrids are that the fields do not possess the "eye appeal" of single-cross hybrids because the plants and ears tend to be more variable and there may be more difficulty in obtaining a high level of disease and insect resistance than in single-crosses, (osu.edu/HCS630_ Accessed: 11/09/2011).

Top-cross hybrids

In this case, one of the parents is an OPV and the other is a single-cross hybrid or an inbred line.

Hybrid seed production

Plant breeders carefully select the parents of hybrids over many years of testing. They are chosen based on performance, disease resistance, drought tolerance, and days to maturity. Only the best hybrids are released for commercial production and sale. The production of seeds is done in a very controlled manner.

Hybrid seed production must be strictly monitored to avoid contamination. Male and female parents are inter-planted in alternating rows. There are normally 3 to 6 female rows and 1 or 2 male rows. The female plants are de-tasseled before they shed any pollen, i.e., the tassels are physically removed. Only the male plants will shed pollen in the field. Inspectors check to see that all emerging female tassels are removed and that neighboring maize plants are at least 400 m away. This is to ensure that pollen from nearby crops do not fall onto the silks of the female plants. Thus, the female plants are fertilized by pollen that comes from only the male plants in the field. Once the male plants have provided the pollen, they are removed from the field to ensure there is no mixing of seeds between the male and female plants. Only the seeds from the female plants constitute the hybrid seeds.It is important that the male and female plants flower at the same time and that the pollen is shed from the male plants when the female silks are receptive, to produce the maximum amount of seeds. This is called nicking.

There are basically three stages in commercial hybrid seed production:

Production of the breeder seeds– this is when the breeder selects and produces the seeds for the inbred lines. Only a small amount of seeds will be produced as inbred lines are not very vigorous. This seed will then be used for the production of foundation or basic seeds.

Production of foundation or basic seeds –this is the first multiplication of the breeder seeds (inbred lines). This is also the stage in which the single-cross hybrids will be produced for the three-way or double-cross hybrids. Enough seeds of the parents should be produced in order to produce the hybrid seeds.

Production of certified seeds –this is the last stage in seed multiplication. Seed companies usually contract approved and capable farmers to plant the foundation seeds in the ways described above to ensure genetic purity and produce enough seeds for the farmers.

Throughout the production of hybrid seeds, the seed company and the seed producer have to adhere to strict but standardized certification requirements.

The seed fields are constantly checked for isolation, off-types, and purity; the harvested seeds are verified for lack of defects, adequate germination rate, and freedom from pests and diseases. Any crop that fails to meet the standards is rejected and may not be sold as seeds. Seeds that have been certified by the authorizing agency are labeled accordingly and may be sold.

Advantages of growing hybrid maize

- Hybrids are generally higher yielding than OPVs if grown under suitable conditions.
- Hybrids are uniform in color, maturity, and other plant characteristics; this enables the farmer to carry out certain operations, such as harvesting, at the same time.
- The uniformity of the grain harvested from hybrids can also have marketing advantages when sold to buyers with strict quality standards.

Disadvantages of growing hybrid maize

- Hybrid seeds are more expensive than seeds of OPVs.
- The farmer needs to have yields of 3-5 t/ha to justify the cost of the seeds. Farmers situated in an environment with low potential and who cannot afford extra inputs such as fertilizer will not recover the costs.
- Fresh hybrid seeds need to be bought every planting season.

Table 6.4. Male (M) to female (F) ratios used in hybrid maize seed production.

Type of hybrid	Female: Male row ratio	Remarks
Single-cross	3F:1M or 4F:1M	
Modified single-cross	6F:2M	If male shed pollen for 5-7 days
Three-way-cross	6F:2M	If male shed pollen for 5-7 days
Modified three-way	6F:2M	If male shed pollen for 5-7 days
Double-cross	6F:2M or 8F:2M	If male shed pollen for 5-7 days
Top-cross	6F:2M	If male shed pollen for 5-7 days
Varietal-cross	6F:2M or 8F:2M	If male shed pollen for 5-7 days

- The grain from a crop grown with hybrid seeds should not be used for seeds. The farmer cannot replant grain as seeds without major reductions in yield, which might be a decrease of 30% or more.
- The farmer might not always be able to source new seeds in time for the planting season.

Choice of parental lines

Several factors need to be taken into consideration in choosing the parental lines of commercial hybrids.

Parental lines must have good pollen shed-silking synchrony. This will obviate the need for planting at different times. For this, an accurate assessment of the days to tasseling and silking of the parental lines is required. Inbred lines that shed pollen a few days after the silking of the female lines may be suitable for use as male parents. The male parent should be as tall as or taller than the female parent for effective pollination under isolation. For three-way crosses, vigorous inbred lines with good pollen production should be used as the male line while the single-cross is used as the female parent. Parental lines should be resistant to important pests and diseases.

Number of female to male rows

Seeds are harvested from the female parent. Therefore, the number of rows of the female parent is directly related to seed yield, provided that yield is not limited by pollen production. The number of female to male rows depends on the type of hybrid to be produced, the pollen production potential of the male parent, and the duration of pollen supply (Table 6.4). If detasseling is practiced, it is desirable to plant male rows around the field to minimize contamination from neighboring fields.

Detasseling and removal of off-types

For hybrid seed production, detasseling and the removal of off-types are two critical operations that ensure good seed quality. Off-types in both the female and male rows are removed before flowering. Plants in the female rows are detasseled when the tassel appears on about 5% of the plants. Detasseling should be done daily, preferably early in the morning, and this should continue for about 10–14 days. No single plant in the female rows should be allowed to shed pollen before detasseling as this will significantly reduce seed quality.

Community-based seed production in WCA

7

In many countries of Asia and Africa, despite substantial investments to strengthen the capacity of seed production organizations, the formal sector provides only a small proportion of the seeds available to farmers. Most of the available seeds are supplied by the informal supply system made up of a network of farmers and small-scale merchants. Seeds sourced from the public sector and commercial companies constitute at most 10% and often as little as 2% of the supply in developing countries (CIAT 1982; Almekinders et al. 1994). In WCA, seeds saved on-farm from the previous harvest constitute about 60–70% of the supply while most of the remainder comes from off-farm local sources (Franzen et al. 1996; Tripp 1997) and even from grain meant for human consumption.

To date, a large number of OPVs have been released in WCA. Although they come with the advantage that farmers could save some seeds of their harvests for use in establishing the next season's crop, the impact of improved OPVs on maize productivity and production is not as high as is desirable. A major problem limiting the impact of improved varieties, which is not peculiar to OPVs, is the low availability of good quality seeds due to a lack of suitable mechanisms for producing and marketing seeds.

Advantages of seeds from the formal seed sector

There are several benefits in purchasing seeds.

Such seeds have passed through rigorous monitoring, certification, and other checks to ensure that the quality is good. Purchasing seeds from the formal sector ensures that (see pages 15–16, this publication):

1. Identity and genetic purity are ensured.

Seeds have known characteristics described by the originator of the variety, specifying their field duration from emergence to harvest. The genetic purity of seeds purchased from the formal sector is certified, having gone through a breeder, a foundation seed producer, and finally a certified seed producer. All stages of the production value chain were monitored and postharvest conditioning was done in a proper seed conditioning plant.

2. Seeds have known purity and germination capacity.

Seeds from the formal sector also have to pass testing standards set by the certification agency that monitored their production. The farmer is therefore assured of good germination and field establishment.

Disadvantages of seeds from the formal sector

1. Seeds have a relatively high retail cost.
Seeds purchased from the formal seed sector for planting are relatively expensive even higher when such seeds tend to be hybrids.

2. Seeds from the formal sector are not readily available.
Seeds from the formal sector constitute about 10% of all maize seeds planted in WCA (Tahirou 2009). Thus, accessibility is very limited. They may therefore not be available to farmers in the rural areas who need them.

Seeds from the non-formal sector

Seeds saved on-farm from the previous harvest (about 60–70%) are the principal sources for planting annually by most farmers; most of the remainder comes from off-farm local sources (Franzen et al. 1996). This is the non-formal seed sector.

Community-based maize seed production

Since the formal sector (mainly public sector-based in most WCA countries) has failed to supply a significant proportion of the seeds required by farmers, various NGOs, projects, donor agencies, and many such related entities have "developed" some types of seed production and supply systems at the community level to help to make high quality and genetically true-to-type seeds commercially available to farmers. Seed production may be done with or without certification but the communities produce, process, store, and sell the seeds at the time of planting. Some communities accept the help of the donors and NGOs and enter into formal seed production. Others combine the formal and informal production methods to achieve the same objective of supplying quality seeds at low cost to farmers within their own communities.

Community-based seed production in WCA

Public and private seed companies produce and market seed in WCA. There are only few seed companies in WCA **(**Tables 7.1 and 7.2**)** and some countries are without any seed company. Seed companies produce only about 28% of the total requirement. Remaining seeds are sourced from the informal market through exchanges and the recycling of OPVs and hybrids. CBOs supplement production even where there are functional seed companies. Therefore, IITA through some of its past and present projects, such as WECAMAN and DTMA, has over the years promoted *nouveaux* community-based seed production schemes that take into consideration the socioeconomic and cultural peculiarities of the subregion. The scheme is aimed at assisting farmers and producers to develop a seed production system capable of providing a regular supply of high quality seeds of superior varieties to their farming communities at all times when needed, thus bypassing the bureaucracies usually existing in the formal sector.

Table 7.1. Functioning maize seed producers in selected countries in West Africa, 2006/2007.

Country	Public/ NARS	Private National	Regional/ Multinational	CBO	Total
Bénin	1	–	–	10	11
Ghana	1	3	–	10	14
Mali	1	3	–	8	12
Nigeria	1	9	–	17	27
Total	4	15	–	45	64

Table 7.2. Functioning maize seed producers in selected countries in West Africa, 2012.

Country	Public /NARS	Private National Seed Companies		Regional/Multi-national Seed Companies	Community-based Seed Producers (CBOs)	Total
		No.	Names			
Ghana	1	6	1. M&B seeds and Agro-Services 2 ANTIKA Company LTD 3. Heritage Seeds ltd 4. Lenbog seed company 5. Alpha Seed Co. 6. Savanna Seed Co.	1. Pioneer Seed Co. 2. Pannar Seed Co. 3. Seed Co. 4.Monsanto Seed Co.	10	21
Mali	1	4	1. Comptoir 2000 2. Faso Kaba 3. NAKOSHI 4. SOSEM	1. Seed Co. 2.Monsanto Seed Co.	8	15
Nigeria	1	16	1. Manoma seeds' 2. Maslaha seeds 3. Premier seed Nig. ltd 4. Alheri seeds Nig. Ltd 5. Da-Allgreen seeds Ltd 6. Gesadadoo seeds & Seedlings 7. Nagari Seed Nigeria 8. Savannah seeds & Livestock Ltd 9. Inganie Seed Company 10. Maina Seeds Ltd 11. Value Seeds Ltd 12. NYAM Agric. Venture 13. Asmau memorial farm 14. Jirkur Cooperative Seed Producers 15. IAR seed improvement unit	1. Seed Co.	14	32
Bénin	1	–			10	11
Total	4	26		7	42	79

The schemes enable communities to manage their own seed production for their own benefit. The schemes involve the following activities:

- Training farmers in techniques of maize seed productions,
- Strengthening the capacity and capability of producers to produce good quality seeds,
- Encouraging NARS scientists to work with selected farmers and NGOs in the development of farm-level seed production, and
- Assisting NARS scientists to produce breeder seeds of released varieties in adequate quantities at their research stations for such community producers to have access to them.

IITA's strategies for community-based seed production

The details of the community-based seed production schemes in WCA have been described by Badu-Apraku et al. (2012). The strategy is to encourage scientists from IITA's maize program to work closely with a team of national scientists, extension agents, seed certification agents, farmers, and NGOs to provide reliable and sustainable seed production for their communities. The team helps farmers to determine the area of land to be planted, the field to be selected (taking into consideration the need for isolation), the variety to be produced, and the steps to be taken to ensure quality control and certification under the informal seed sector. Other issues addressed include postharvest handling and marketing. The strategy involves the provision of technical advice, breeder and/or foundation seeds, and fertilizers to farmers. After the harvest, farmers are requested to pay back the cost of the input, in cash or with part of the seeds produced. For the sustainability of the scheme and to allow more farmers to be reached each year, member countries of the WECAMAN network established revolving funds. At each community level, the scheme involves at least a plant breeder, an agronomist, a foundation or certified seed producer, and structures for the marketing and distribution of the produced seeds. Altogether, six community-based models were adopted for seed production. The detailed features of each model and the countries that have adopted them within WCA have earlier been described in Section 3 of this book.

It is important at this stage to emphasize the special features of the seed production model 6 which has been successfully adopted in Nigeria. The research institutes IAR, NAERLS, and UNIMAID are working closely with companies, including Premier Seed and Maslaha Seed, to ensure the success of the scheme. CBOs that have been linked to seed companies to ensure the sustainability of the scheme, access to seed markets, inputs, and credit in Nigeria include the following.

- 3 CBOs in the northern Guinea savanna (Malunfashi, Ikara, and Antchau) linked to Premier Seed Company
- 6 CBOs in Zamfara State (Tazame, Damba GP1, Damba GP2, Fufuri, Bunzubu, Bela) linked to Maslaha Seed Company

Table 7.3. Seeds produced by community-based seed producers linked to private seed companies in Nigeria, 2007–2012.

Seed company	Varieties	Quantity of seed produced (t)					
		2007	2008	2009	2010	2012	Total
Maslaha Seed Nig. Ltd	EVDT 99W STR, SYN2000EE W STR 99TZEE Y STR	5	8	21	21	14	69
Premier Seeds Nig. Ltd	TZE Comp 3 DT 99TZEE Y STR EVDT99W STR	6	5	7	3	12	33
	EVDT 99W STR, SYN2000EE WSTR 99TZEE Y STR		4	4	4	7	19
Govt./ Jikur	99TZEE Y STR EVDT 99W STR 2000SYNEE W STR		4	11	17	18	50
	EVD-Y QPM 2000 STR 2008 DTMA-Y STR		–	–	–	2	2
	Total	11	21	43	45	53	173

- 3 CBOs in Borno State (Sandia, Lokodisa, and Yamtake) linked to the Seed Project Company in Kano.

Large quantities of seeds were produced by the community-based producers linked to private seed companies in Nigeria from 2007 to 2012 (Table 7.3). Furthermore, a large number of farmers were trained in the techniques of quality seed production (Fig. 7.1). In addition, using the seed production models described earlier, large quantities of good quality seeds were produced by WECAMAN member countries involved in the community-based seed production schemes (Figs 7.2–7.4).

Impact of community seed production

The production schemes implemented by IITA through WECAMAN and DTMA have had a positive impact on maize productivity and production. Farmers have been organized into cooperatives to facilitate community seed production, thus strengthening the informal system and leading to the development of micro-enterprises.

Through the community-based production scheme, NARS scientists have been supported to work with selected farmers and NGOs to produce seeds at on-farm level. This activity involves the collaboration of the national maize scientists, extensionists, seed certification agents, selected farmers, and, whenever possible, NGOs. All the collaborators in the scheme work

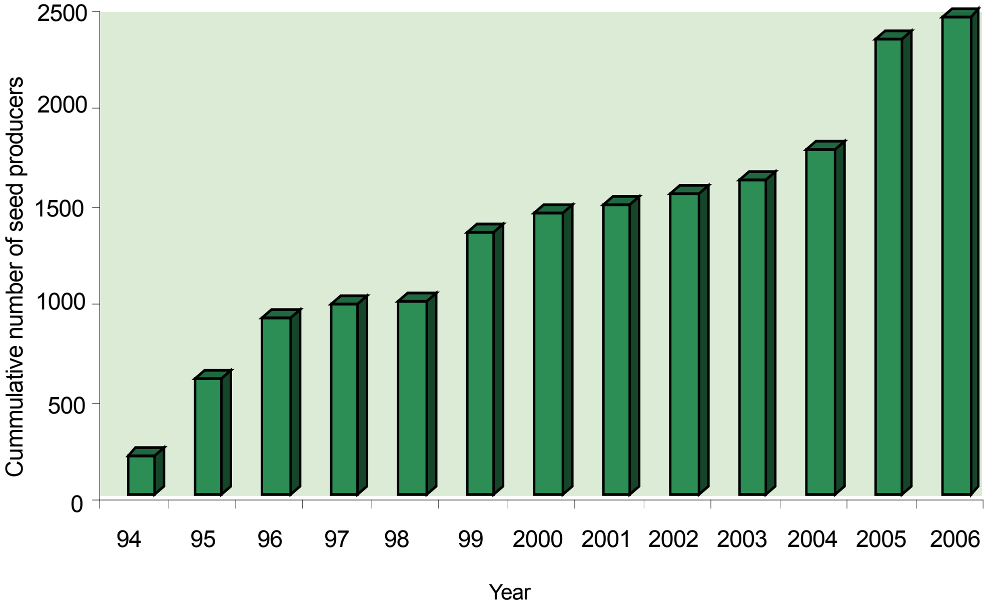


Figure 7.1. Farmers trained in seed production in WECAMAN member countries under the Community-based Seed Production Scheme from 1994 to 2006.

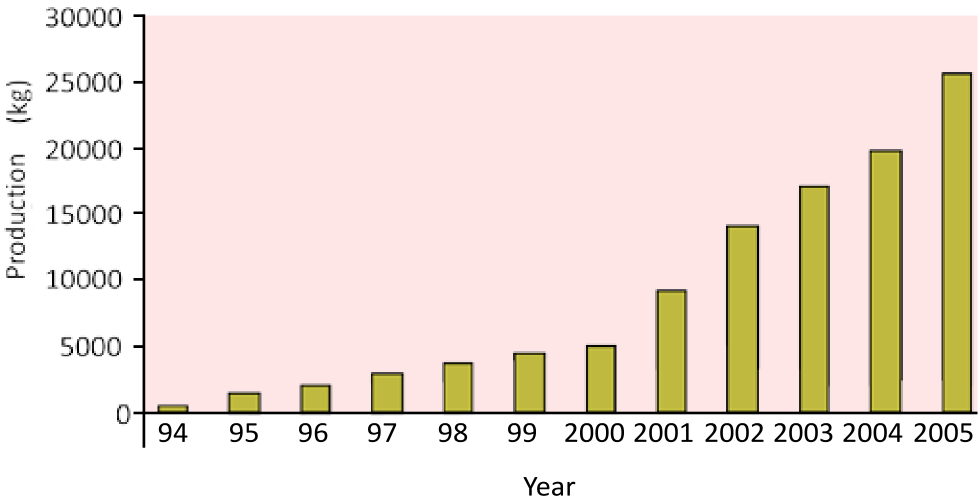


Figure 7.2. Quantities of breeder seeds (kg) produced in WECAMAN member countries from 1994 to 2005.

together in a coordinated manner to provide a reliable and sustainable seed production system for their communities. The seed production team, made up of maize breeders, seed technologists, extensionists, and seed service staff, helps farmers to plan all aspects of production, including the area to be planted, selection of the field in terms of isolation, variety to be used to obtain breeder and foundation seeds, and in all aspects of postharvest handling, quality control, and certification, and also marketing in some cases. The team visits the seed farms several times during the growing season and harvesting to offer technical advice. On-the-job training is provided to

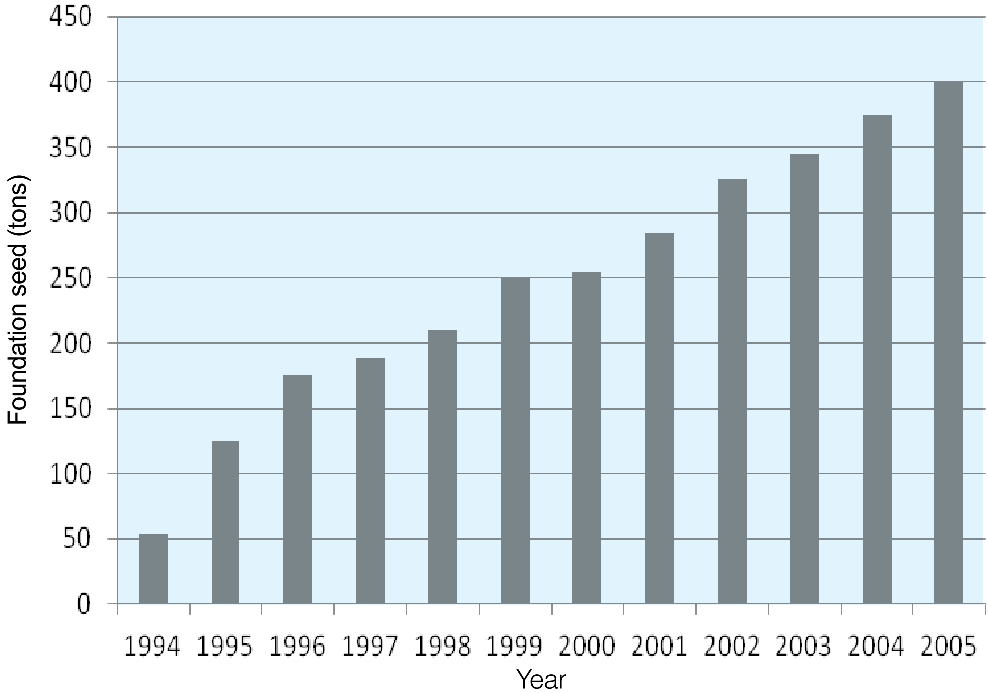


Figure 7.3. Cumulative foundation seed production in WECAMAN member countries from 1994 to 2005.

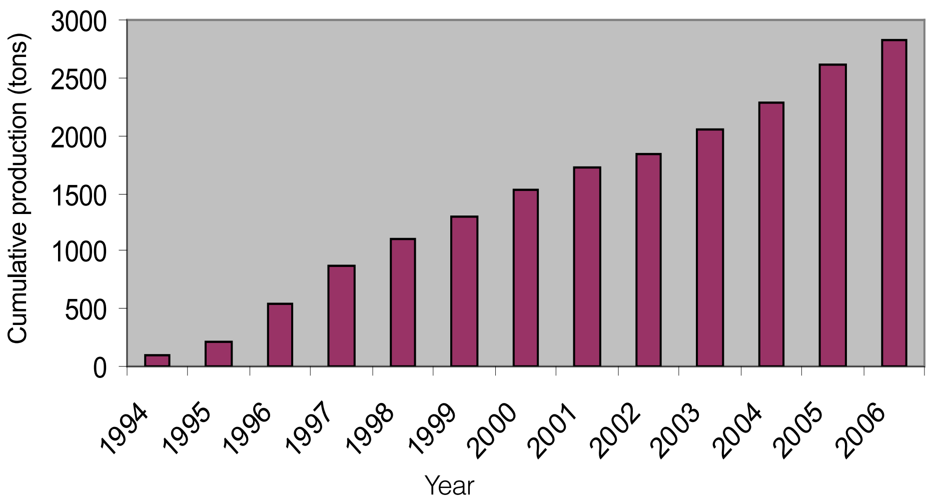


Figure 7.4. Cumulative commercial seeds production by commumnty-based seed producers from 1994 to 2006.

the growers as the technical staff and the farmers work together to grow the crop. Through the technical and financial assistance provided to the seed producers, most of the farmers are managing their fields well and are being rewarded with high yields and incomes. Collaborating farmers are developing skills as seed growers while the extension staff and scientists providing technical advice are gaining more experience.

Success of the community seed production scheme is very much dependent on the seed production skills of the collaborating farmers, extension, and seed service staff. From the initiation of the project, Network member countries involved in the scheme emphasized the training of the collaborators. In these training programs, the collaborating farmers, extension, and seed service staff learned more about the techniques of seed production, processing, storage, and packaging. In addition, field days and on-farm demonstrations have been organized for the communities involved in this activity.

In an effort to strengthen the capacity of seed producing agents to organize and manage seed production, the first seed production course was organized in Ghana 14–25 August 1995 by WECAMAN in collaboration with the Group Training Unit of IITA and the Crops Research Institute of Ghana. Twenty-eight seed producers, researchers, and extensionists, from Mali, Nigeria, Togo, Sierra Leone, Kenya, Uganda, Côte d'Ivoire, Guinea, Ghana, Burkina Faso, Bénin, and Cameroon attended the course.

During the course, the participants reviewed and analyzed

- the constraints and opportunities of the traditional seed production system for their communities,
- how to alleviate the constraints of the traditional seed production systems,
- how to design and manage maize seed production systems, and
- how to design and execute activities for improved communication among seed users and seed producers.

The course also covered the following.

- Informal surveys of traditional seed production systems
- Communication in the management of seeds
- Germplasm management and exchange
- Seed certification and seed quality
- Seed multiplication, production, and storage
- Major diseases and pests in seed production
- Harvesting and seed production
- Organization of field days for farmers

Course presentations were in the form of lectures, demonstrations, practical sessions, and group assignments. Resource persons were from CRI and other Ghanaian institutions, IITA, WECAMAN, and Premier Seeds of Nigeria Ltd. The participants were given the opportunity to make presentations on the organization of seed production in their respective countries. About 40%

of the total course time was devoted to hands-on practicals in the field. The activities included informal surveys in farmers' fields and field days. The participants had the opportunity to work in groups and to transform the acquired skills into messages for farmers which were later used in a field day organized at Asuyeboah and Kwadaso, near Kumasi.

The training communication and publication unit of CRI in collaboration with the resource persons produced eight training manuals for the course. These were supplemented with handouts and training materials from IITA and CIMMYT. The facilities for the course were provided by CRI.

Since the first seed production course in 1995, a large number of other farmers have also been trained in production techniques and have acquired the capability to produce good quality seeds. Their activities have led to the increased availability of seeds of improved early and extra-early maturing varieties. In addition, there is increased awareness among farmers on the importance of using high quality seeds of improved varieties for planting and also on purhasing new seeds of OPVs after every 2 to 3 seasons.

Maize production has expanded into the drier areas of WCA, replacing traditional staple food, particularly sorghum and millet. The widespread adoption of improved maize varieties in the savannas, greatly facilitated by the community-based production schemes, has also changed the status of maize from a backyard crop to a major cereal grown for both cash and food. Other impacts of the community-based schemes are as follows.

- Some community-based producers have become contract growers for seed companies.
- A community-based production scheme under the PROSAB project has evolved into a registered seed company called Jikur Cooperative Seed Producers.

Challenges to community-based seed production

- Absence of efficient structures

A major challenge is the lack of permanent institutional structures in place to oversee its sustenance over time. Ad hoc measures are most often used to run the community seed production and marketing units and this practice has negative effects on the long-term sustainability of the system. There is therefore the need to develop a more efficient structure for the marketing of seeds produced.

- **Lack of publicity and promotional activities to attract seed sales**

Promotional activities are not in place to educate and inform the communities about the importance and need to use the available seeds produced from the community farms. There is therefore the need to publicize this and educate the communities to reduce the problem of marketing because of the lack of market information. Partner organizations that can assist in the collection and relay of market information to potential end-users need to be identified and encouraged to assist in this area.

- **Unattractive packaging of seeds and non-availability of smaller-sized packs**

Most often, the packaging of the seeds produced is not attractive and the smaller-sized sachets or packages that are often required by subsistence farmers may not be available. It would be beneficial to make packaging attractive and also market the product in smaller sachets/packages of 1 and 2 kg. Points of seed sale are needed at strategic places in all maize growing communities.

- **Absence of seed legislation**

Many countries lack functional seed laws thereby allowing unscrupulous producers and seed merchants to get the chance to cheat the system.

For countries that do not have seed laws, the promulgation of such laws will help to ensure that unscrupulous people do not sell grain as seeds and that farmers have access to good quality seeds all the time. Where seed laws exist and are not functional, there is the need to strengthen the system through the establishment of active inspection units.

- **Need for more cooperatives and agro-enterprises**

In most countries, the cooperatives and seed enterprises needed to play leading roles in community seed production activities are just not there.

There is a need for more and better organized cooperatives and agro-enterprises to be established through training and linkages to appropriate markets. Such development should take into consideration the lessons learnt from current initiatives in other communities.

- **Lack of credit and other funding**

Access to credit by seed producers is limited. There is therefore the need for improved access to credit, inputs, and market outlets for their products.

Future perspectives of community-based seed production

All indications are that, with the failure of the formal production system to meet farmers' seed requirements, leading them to look for alternatives, the community-based production system should be encouraged in all ways to take a leading role by making the system efficient. Successful community-based production schemes should be assisted to transform themselves into micro-enterprises for sustainability. This can be further facilitated by the provision of small items of equipment to seed producers within the communities. In addition, given that producers who may be skilled in seed production may lack skills in small business management, book-keeping, accounting, and marketing, seed business and management courses must be organized for seed companies within WCA. Such training must be intensified and participants should be made to include community-based producers.

The greatest impact of the community-based production schemes in WCA would be in areas not currently served by seed companies. Consequently, there is the need for this system to be promoted in such areas. Educational awareness campaigns, variety demonstrations, and increased promotional activities by community producers must take place to stimulate the demand for improved seeds.

Apart from making available adequate quantities of breeder seeds of improved varieties to the informal seed production sector, the giant international agricultural research centers with all their experience in this area must establish linkages with existing seed companies.

There is also the need for the compilation of all maize varieties released in all countries in WCA, showing also their characteristics, adaptation, and the sources of seeds as this information is lacking in some countries. Such lists could be regularly updated when new varieties are released.

A database and GIS on community-based production schemes are also essential to help all communities engaged in such production activities to be easily located.

An assessment is needed of the impact of the community-based schemes on the production and availability of seeds of improved varieties. It would be beneficial for IITA, CIMMYT, and the NARS to prepare action plans for scaling-up seed production in the countries participating in the DTMA project which should include indicators for seed production and a list of partners.

Strategies adopted by the DTMA project to support production of good quality seeds in West Africa

Strengthening seed delivery systems for improved varieties and hybrids

The seed industry in WCA is poorly developed due to the lack of seed policy and also inadequate funding. In most countries, there are long delays between variety development, release, and registration and a poor enabling environment for private sector participation and survival. The public seed sector agencies are grossly under-resourced for effective production and marketing. The NARS give inadequate attention to variety maintenance as well as to the production of breeder and foundation seeds. Regional development of the seed trade is weak and information systems about the seed market are inadequate. However, there are several opportunities for the seed industry. These include the availability of many high yielding improved varieties developed by IITA, CIMMYT, and the NARS, greater awareness among farmers of the economic benefits of improved seeds, emerging formal and informal systems for improved seed production and rural seed delivery systems, emerging small and medium enterprises in the region, and the possibilities of improved regional seed trade and regional agricultural input and market information systems.

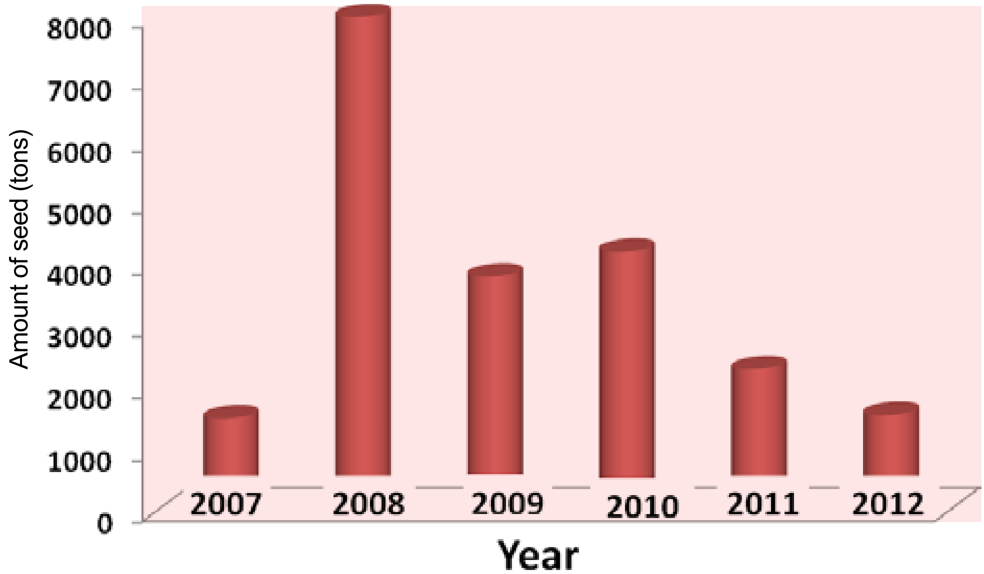


Figure 7.5. Seeds of drought tolerant varieties and hybrids produced and disseminated for regional and national variety trials, 2007–2012.

Public and private seed companies
There are only few seed companies in the subregion; some countries have none (Tables 7.4 and 7.5). Where there are companies, they produce only about 28% of the total seed requirement (Tahirou, 2009). The remaining seeds are sourced from the informal markets through exchanges and the recycling of OPVs and hybrids. Even where there are functional seed companies, CBOs supplement their production. Predominant varietal types in WCA are improved OPVs. Although the area under hybrid production is increasing, the proportion of hybrid seeds produced is still very low. Production of OPVs seeds is about 1.26 million t while hybrid seed production is estimated to be about 264,000 t (Tahirou, 2009). As a result, IITA has adopted a number of strategies to promote seed production. These include (i) support to community-based production schemes to meet the shortfall in seed production in countries without seed companies, and communities which are not adequately served by existing companies, (ii) support to the NARS, seed companies, and CBOs/NGOs in the deployment of seeds of varieties and hybrids. The production of seeds of new maize varieties by private companies is increasing, but there is a need to find ways to scale-up production especially of hybrids.

Strengthening the capacity of seed companies
Support is being provided to small and emerging companies to produce seeds of available OPVs and hybrids and to procure handling, processing, and storage facilities to increase the dissemination of seeds of improved varieties to a larger number of farmers. Over the past 5 years through the AGRA project and other initiatives many entrepreneurs and communities interested in seed production have emerged. Many have established contact with IITA, DTMA, and the NARS for germplasm and technical

backstopping. It is expected that the seed business environment in target countries will generally improve in the near future through the growth of the seed market, easier access to venture capital and general business know-how, and regionalized seed laws and regulations. To address the problem of the availability of seeds to farmers, there is a need to support the establishment and effective functioning of a seed stockists' network. There is also a need to provide backstopping and strengthen the capacity of all

Table 7.4. Sets of DTMA Regional Trials dispatched to NARS partners and seed companies on request, 2007–2012.

	Year						
Country	2007	2008	2009	2010	2011	2012	Total
Nigeria	36	92	74	160	122	73	557
Ghana	–	21	39	52	74	51	237
Bénin	24	21	20	48	35	28	176
Mali	–	9	21	29	39	35	133
Total	60	143	154	289	270	187	1103

Table 7.5. Number of sets of Regional Uniform Early and Extra-early Variety Trials dispatched to partners in Africa in 2012.

Country	RUVT–Early	RUVT–Extra-early	RSVT–Extra-early	RSVT–Early	Regional Early Inbred Trial	Regional Extra-early Inbred Trial
Nigeria	4		1	1	2	1
Ghana				1	1	
Sudan	1	1	2	2	1	1
Gambia	2	2	1	1		
Egypt	1			1	1	1
Zimbabwe	1	1	1	1	2	2
Burkina Faso	2	2	2	2	3	3
Congo	2	2				2
Uganda						1
Total no. of sets	13	8	7	9	10	11
No. of countries	7	5	5	7	6	7

Table 7.6. On-farm trials and demonstrations conducted by DTMA project partners, 2007–2011.

	Year					
Country	2007	2008	2009	2010	2011	Total
Nigeria	48	166	166	166	170	716
Ghana	–	32	62	70	42	206
Bénin	26	26	56	42	39	189
Mali	36	36	36	36	32	176
Total	110	344	320	314	283	1287

key players to ensure the delivery of agreed outputs. Through the funding support of the DTMA project, in-service training in techniques of quality seed production of OPVs and hybrid seeds was provided to 36 technicians from the anglophone NARS and seed companies in West Africa to upgrade their skills in production and the conduct and management of field trials. A similar course was organized in 2011 in Cotonou, Benin Republic, for the NARS partners from the francophone countries. In addition, some CBOs in Nigeria have been linked to seed companies to ensure access to markets, inputs, and credit.

Provision of maize parental lines, hybrids, and OPVs

The DTMA project has since 2007 provided germplasm to seed companies and NARS as follows:

i. Provision of relatively large quantities of parental lines and seed of DT varieties to seed companies and CBOs on request for testing, seed production, and promotional activities.
ii. Sets of regional and international trials have been made available to seed companies on request. Information about the sets of Regional and International Trials dispatched to NARS partners and seed companies on request is presented in Fig. 7.5, Table 7.4, and Table 7.5. Based on the results of these multilocation trials, the superior varieties and hybrids were identified for on-farm trials by the national scientists in the respective countries (Table 7.6). A total of 1287 on-farm trials were conducted in Nigeria, Bénin, Mali, and Ghana during the period of 2007–2011 under the DTMA project.
iii. Financial support has been provided to selected NARS partners for breeder seed and parental line production.
iv. IITA project scientists pay regular visits to seed companies to encourage their involvement in conducting collaborative trials and in identifying and commercializing maize varieties and hybrids to farmers.
v. Staff from seed companies are invited each year to visit IITA's maize breeding nurseries and trials and to select promising entries for their companies.
vi. Staff from seed companies are invited to participate in the planning meetings of the DTMA project to share information on the performance of varieties evaluated.
vii. Information is provided to NGOs on the sources of seeds and available improved varieties and hybrids.
viii. Results of multi-location and on-farm trials are summarized each year for the NARS and seed companies to promote the release of varieties.

Ensuring the efficient delivery of quality seeds

In Nigeria and Ghana, seed output from the formal sector is not readily available to most small-scale farmers. Moreover, most private seed companies are interested in marketing hybrids. To ensure that seeds are available at all times, the DTMA project is promoting the production of foundation seeds by the NARS, which are then used by community-based producers. The objectives of the seed production schemes are to strengthen farmers' capacity in the techniques of good quality seed production, and to encourage the Seed Certification Organizations to work with selected farmers and NGOs in the development of on-farm community-level production schemes. In this way, improved seeds will be made readily available in communities. This would enhance access to improved varieties and promote technology adoption on a large scale.

Large quantities of foundation seeds are being produced at research stations and by selected seed companies under the supervision of DTMA project staff. Production of quality seeds of improved varieties is contracted to selected farmers or farmers' groups. These farmers are given training in seed production and management, provided with all the required inputs on a credit basis, and closely monitored by researchers. Special attention is paid to the needs of farmers or farmers' groups deterred from large-scale seed production by a lack of storage facilities. These farmers will be linked to the seed companies and other institutions for the proper storage of their products and better access to the seed market, and to ensure sustainability. The resulting seeds are bought in the first year of the project and eventually distributed to other farmers or farmers' groups by the second year on a credit basis. This approach will ensure that farmers have access to improved seeds every year.

Strengthening CBOs

Working with existing farmer groups and CBOs, encouraging the formation of new ones and building their capacity through technical, organizational, and leadership training will strengthen common interest groups. These will evolve into farmer-owned and managed organizations that are capable of providing services to members. The support of the DTMA project to the community-based schemes is through the following.

i. Training farmers and producers in the techniques of quality seed production.
ii. Strengthening the capacity and capability of producers to produce good quality seeds.
iii. Encouraging NARS scientists to work with selected farmers and NGOs in the development of on-farm seed production.
iv. Assisting NARS scientists to produce breeder seeds of released maize varieties in adequate quantities at the research stations.

NARS scientists provide technical advice, breeder and/or foundation seeds and other inputs to collaborating farmers. At harvest, farmers are required to pay back either in cash or in kind. Each community production scheme is a chain and involves breeder, foundation, and commercial or certified seed production, marketing, and distribution.

Supporting the development of new seed enterprises
Through the community-based seed production supported by WECAMAN, some successful schemes in Benin Republic have evolved into cooperatives which buy seeds produced by the schemes, process, store, and sell to other farmers. Efforts are being made to organize other successful community-based producers in the DTMA partner countries into farmers' cooperatives. Similarly, a community-based scheme under the PROSAB project has evolved into a registered seed company. Efforts are being made to catalyze other successful community-based schemes in partner countries into micro-enterprises.

Capacity building
Small and emerging seed entrepreneurs are being trained in maize-specific know-how, using a modular applied curriculum relevant to the maize seed business environment in SSA. It is anticipated that in the short term, small and emerging seed companies will be more effective in establishing viable and growing maize seed businesses, in particular as they direct their efforts to new markets in target areas. In the long term, increasing numbers of farmers will have sustainable access to seeds of improved varieties and hybrids.

Backstopping of small and medium seed enterprises
The target countries of this project can provide scenarios of different kinds for seed system development. Mali and Ghana have emerging private seed sectors which need to be strengthened and supported. Ghana has three emerging and several private seed mini-companies, with the Government providing custom services (processing and storage facilities) for a fee. These companies package seeds of improved varieties and hybrids in different quantities and distribute them to vendors in various parts of the country. DTMA is providing an opportunity to strengthen the emerging companies to evolve into independent, large, and viable companies. Small and medium enterprises are being backstopped and mentored as they build up a producer base in a smallholder environment and target new markets in drought-prone areas. Both private and community-based entrepreneurs are provided with competent advice on production and dissemination.

Private sector engagement
There is a need to engage the private seed companies to improve the delivery of improved seeds to smallholder farmers. To achieve this, DTMA is working closely with seed companies in project countries, such as Premier Seeds, Maslaha Seed Co., and the Seed Project Co. in Nigeria, Faso Kaba in Mali, Savannah Seeds and M&B Seeds Co. of Ghana, to improve farmers' access to seeds. Strategic incentives are being used to engage seed companies/producers in self-sustained multiplication, NARS and NGOs in the promotion and dissemination of seeds to reach farmers through two main channels: (i) from seed companies to retail outlets and (ii) from seed companies to NGO and NGO-assisted seed production and dissemination programs. Currently it is estimated that 25% of all the maize areas are planted to seeds channeled to farmers. Additional impact will be generated

by farmer-to-farmer dissemination of new varieties. Seed companies or producers will invest in elite public maize varieties as long as they have confidence in their adoption potential and agronomic performance in a large target environment/market, have been given rights to commercialize distinct varieties with good seed production characteristics, and receive sufficient amounts of breeder seeds and technical backstopping for a rapid scale-up of activities. Hence, agreements for the rights to produce different maize varieties and hybrids will be made with private seed companies/producers, either directly or through the NARS. Sufficient breeder seeds of new varieties (or their parents) also are expected to be produced and provided to companies/producers, along with technical backstopping to ensure the rapid initiation of certified seed production of new cultivars. The multiplication and distribution of seeds to farmers in the various target areas will continue throughout the life of the DTMA project. Seed producer groups will be linked to appropriate markets for the sale of surplus seeds in close collaboration with the AGRA PASS initiative.

Seed certification and quality control 8

In traditional agriculture, farmers usually use unimproved crop varieties (landraces). They seldom change their seeds and continue to save their own seeds year after year for planting. Occasionally they may purchase from or exchange seeds with neighbors. In modernized agriculture, however, research has developed improved crop varieties and hybrids that must be multiplied in a systematic way to ensure that their genetic identity is not lost during seed production. Seed certification is the link between research and the farmer, and it aims at maintaining and making available to seed producers and farmers high quality seeds produced under a legally authorized system that guarantees or ensures that the varieties meet the laid down minimum quality standards set by the regulatory organization. Seed certification can therefore be summarized as the procedures and processes through which seeds in a sealed container and meant for grain production possess the characteristics required by legislation and/or as indicated on the label attached to the container.

Enlisting for seed certification

Before a seed producer can request certification, he must be prepared to produce a specified class of seeds and the variety to be produced must have a name and attributes that have been characterized to ensure verification and authentication during the entire certification process before the seeds reach the market.

To be able to enlist a producer for certification, the Seed Certification Agency must take steps to ensure the following:

- Approval of cultivars is given based on tests for distinctness, uniformity, and stability (DUS). Most seed production schemes require that such cultivars have superior agronomic values when compared with existing varieties in at least one region of the country.
- Existence of an advisory board which recommends and suggests to the Minister of Agriculture the cultivars that should be approved.
- Availability of a statutory list of approved cultivars in which a new cultivar is registered for a specific time (generally 10 years) (Van Gastel et al. 1996). Seed certification therefore gives the consumer (farmer) an assurance regarding the quality of the seeds which cannot be determined by the naked eye (Achaab 2010).

General Seed Certification Standards

General Seed Certification Standards are available for all crops which are eligible for certification, and, with field and seed standards for the individual crops, shall constitute the Minimum Seed Certification Standards. The word "seed" or "seeds" as used in these standards includes all propagating materials.

Seed Certification Agency

Seed certification shall be conducted by a Seed Certification Agency which must be autonomous and well equipped for the process and should ensure that all certification standards are met by a seed producer before he can market the seeds. Seed quality control, testing and certification play pivotal roles in all stages of the seed production system – covering production, conditioning, packaging, distribution and marketing of all classes of seeds (Figure 8.1 and 8.2). It is therefore imperative that the Certification Agency is backed by law or appropriate legislation to enable it to enforce the rules and standards set in the certification scheme.

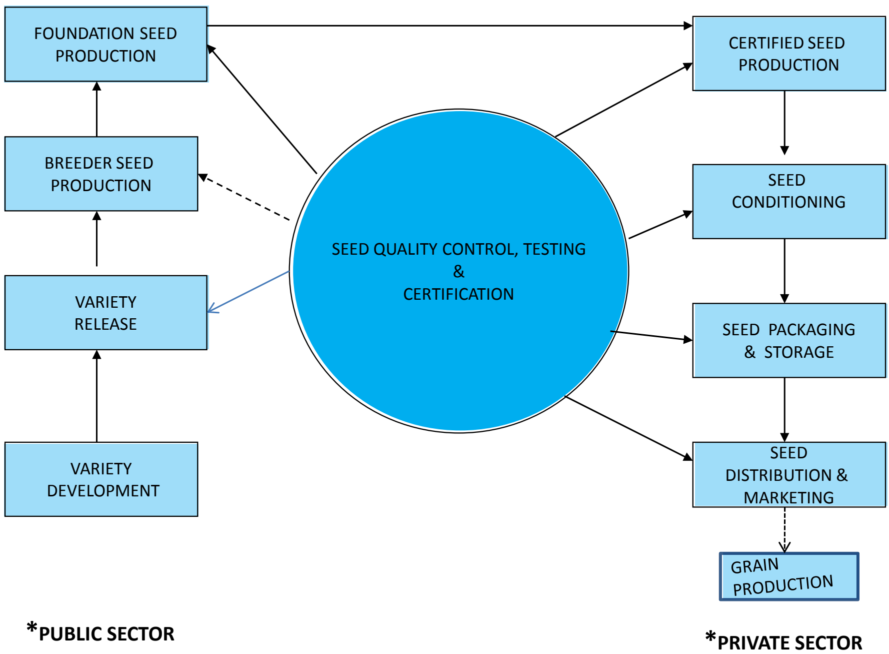


Figure 8.1. Structure of a seed system.

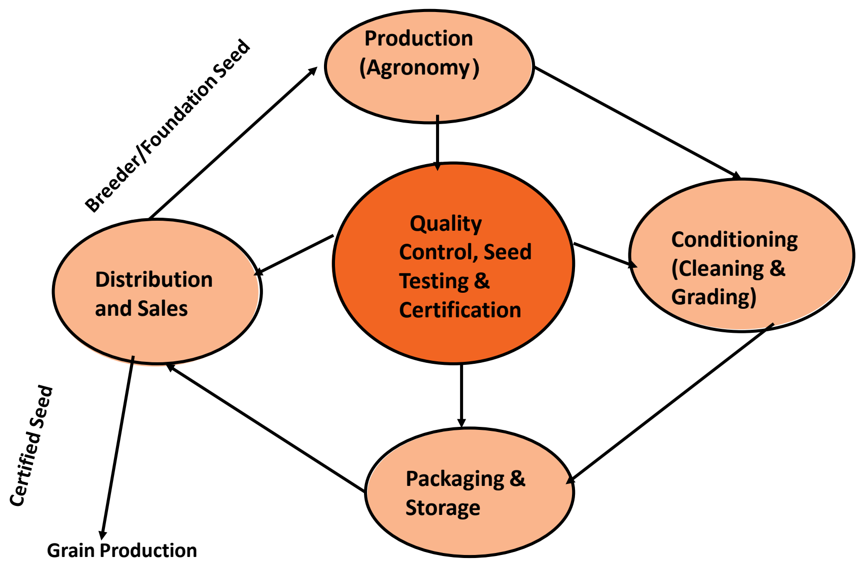


Figure 8. 2. Stages of seed production in a seed system.

Certified Seed Producer

A Certified Seed Producer is any person or organization that grows or distributes seeds of a particular class in accordance with the procedures and standards set by the Seed Certification Agency. The producer can be an entirely public organization, or a private one, or a combination of the two where the public-based organization is usually responsible for the seed production but with private persons used as out-growers. It is usually recommended that only one class of seeds be produced by an entity to forestall admixtures and prevent genetic quality adulterations during the different stages of seed production.

Eligibility requirements for certification

Seeds of only those varieties which are released and have been registered and listed in the national variety catalog may be put under certification. This is usually backed by law or the right legislation.

Classes and sources of seeds

Generally four main classes of seeds can be put under certification, depending on the seed law in the country. These are breeder, foundation or basic, registered, and certified seeds.

Breeder seeds

Breeder seeds are seeds (or vegetative propagating materials) directly controlled by the originating or sponsoring plant breeder of the breeding program or institution and/or seeds whose production is personally supervised by a qualified plant breeder and which provides the source for the initial and recurring increase of foundation seeds. Breeder seeds shall be genetically pure so as to guarantee that in the subsequent generation the registered foundation and certified seed classes shall conform to the prescribed standards of genetic purity. The other quality factors of breeder seeds, such as physical purity, inert matter content, germination percentage, etc., shall be indicated on the label. The breeder seeds shall be packed and supplied by the breeders in the form and manner indicated in the seed law of the country.

Foundation seeds

Foundation seeds shall be the progeny of breeder seeds, or be produced from foundation seeds that can be clearly traced to the breeder seeds. In other words, foundation seeds can even be produced from foundation seeds. During the production of certified foundation seeds, the following guidelines shall be observed.

i. Foundation seeds produced directly from breeder seeds shall be designated foundation seeds stage-I.
ii. Foundation seeds produced from foundation seeds stage-I shall be designated foundation seeds stage-II.
iii. Foundation seeds stage-II cannot be used for the further increase of foundation seeds and shall be used only for the production of certified seeds.

iv. Minimum Seed Certification Standards shall be the same for foundation seeds both stage-I and stage-II and shall contain the information about the stage.
v. Production of foundation seeds stage-II shall ordinarily be adopted in respect of such crop varieties provided it is expressly felt by the Certification Agency that breeder seeds are in short supply.
vi. Production of foundation seeds stage-II may be adopted for vegetatively propagated crops, apomictically reproduced crops, and self-pollinated crops. They may also be adopted for cross-pollinated crops to increase the seeds of composites, synthetics, and parental lines of hybrids if adequate measures are taken to safeguard genetic identity and purity.

Production of foundation seeds stage-I and stage II shall be supervised and approved by the Certification Agency and be so handled as to maintain specific genetic identity and genetic purity and shall be required to conform to certification standards specified for the crop/variety being certified.

Certified seeds

Certified seeds shall be the progeny of foundation seeds and their production shall be so handled as to maintain specific genetic identity and purity according to standards prescribed for the crop being certified. Under extreme cases of the shortage of breeder and/or foundation seeds in a seed system, certified seeds may be used to produce certified seeds, provided this reproduction does not exceed three generations beyond foundation seeds stage-I and the following conditions can be met.

– It is determined by the Certification Agency that genetic identity and genetic purity will not be significantly altered and the Certification Agency is satisfied that there is a genuine shortage of foundation seeds despite all reasonable efforts being made by the seed producer.

– Certified seeds produced from certified seeds shall not be eligible for further seed increase under certification. Certification tags for such production which is not eligible for further seed increase under certification shall be labeled "Not eligible for further seed increase under certification."

Phases of seed certification

Certification shall be completed in six broad phases, listed below.

i. Receipt and scrutiny of application.
ii. Verification of seed source, class, and other requirements of the seeds used in producing the seed crop.
iii. Field inspections to verify conformity with the prescribed field standards.
iv. Supervision at postharvest stages including processing and packing.

v. Seed testing involving sampling and analysis, including a genetic purity test and/or a seed health test, if any, to verify conformity with the prescribed standards.
vi. Grant of the certificate and certification tags, tagging, and sealing for sale.

Establishing the source of seeds

Each country has certification rules with which seed producers must conform. Usually the seed producer would need to identify himself and register, and apply with the certification authority to enable them ascertain his eligibility to produce the seed class for which he is applying. The individual intending to produce seed under certification shall also submit to the Certification Agency one or more pieces of relevant evidence, such as certification tags, seals, labels, seed containers, purchase records, sale records, etc., as may be demanded by the Agency during the submission of the application for its scrutiny and/or during the first inspection of the seed crop. This is to confirm that the seeds used for raising the crop had been obtained from the approved source and conform with the provisions contained in the rules and regulations of the body.

Field area for certification

Depending on the level of sophistication of the seed program, that of the Certification Agency as well as the experience of the seed producer, there is usually no minimum or maximum limit for the area a person can offer for the production of seeds and thereby require certification, provided the certified seed production meets all the prescribed requirements. However, in emerging seed systems in WCA where seed growers are relatively new to the business and may not own the facilities and equipment for post-harvest handling and storage, there may be the need to regulate the area that may be offered for seed production under certification. This becomes even more relevant when production is under rainfed conditions and many seed producers may be depending on the few existing processing and storage facilities. Whatever the situation, it is recommended that plantings are staggered over time and that fields are blocked into reasonable sizes to ensure the harvesting and processing activities do not all occur at one time but over a longer period to ensure that high quality seeds are obtained.

Unit of certification

For the purpose of field inspections, the entire area planted under seed production by an individual shall constitute one unit provided as follows.

i. It is all under one variety.
ii. It does not exceed ten ha.
iii. It is not divided into separate fields with more than 50 m between them.
iv. It is planted with or is meant to produce seeds belonging to the same class and stage in the generation chain.

v. The crop over the entire area is at more or less the same stage of growth so that observations made are representative of the entire crop.

vi. The total area planted, by and large, corresponds to the quantity of seeds reported to have been used; (the Certification Agency's permission has to be obtained if there is a need to plant a larger area by economizing on the seed rate, if necessary).

viii. The seeds are raised strictly as a single crop and never as mixed.

ix. The crop is not so heavily and uniformly lodged that more than one-third of the plant population is trailing on the ground, leaving no scope for it to stand up again, thus making it impossible for the Certification Agency to inspect the seed crop at the appropriate growth stage in the prescribed manner.

x. The crop, as far as possible, is maintained to show adequate evidence of good husbandry, thereby improving the reputation of certified seeds.

Field inspection

Inspection of seed production fields at pre-determined times during the crop production period is insurance to ascertain and verify the final genetic purity of the varieties under multiplication through the elimination of genetic adulterations and physical admixtures, and this activity must be done with all the seriousness it deserves. Field inspections are conducted to achieve the following.

- Ensure that registered seed fields are checked at the critical stages of crop growth to help to rogue off-types that may dilute the genetic purity of the growing crop.
- Ensure that desired field standards are fully met.
- Establish good public relations between the Certification Agency and the seed producers.
- Educate seed growers on visiting times for good production practices.
- Identify sources and levels of contamination that would lead to rejection of seeds of the variety under production.

After the completion of the field inspection, a copy of the inspection report is handed over to the seed producer or his representative.

Re-inspection

After an inspection, the Certification Agency would give reasons why any seed field does not meet the prescribed seed certification standards in place for that crop. The Agency shall then request the seed producer to take corrective measures (if possible) and prepare the field for re-inspection later.

Attributes of seed inspectors

Seed inspection staff must be personnel with the requisite training and experience. They must also be able to do the following.

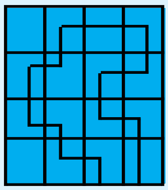
– Identify the morphological characteristics and attributes of the major crops under certification in the country.

Sampling of seed fields for inspection

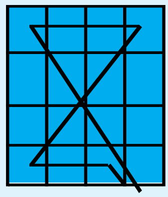
- **Goal is to get maximum coverage while walking a minimum distance.**

Some patterns to use when inspecting seed fields for certification.

A) Alternate Change of Directions



B) Model X with Linked Ends



– Identify the common diseases and insect pests of crop varieties under certification in the country.
– Apply all methodologies of field sampling for inspection.
– Determine the levels of off-types, rogues, and noxious weeds.

Equipment/supplies for field inspection
– Suitable transport
– Map of the field area under certification
– Certification standards for the crop in question
– Field report forms
– Measuring tape
– Suitable envelopes for the collection of specimens (for reference and further check-up) and consultations
– References on crop variety characteristics
– Disease reference manual
– Pocket calculator

Essential points to note when inspecting seed fields
- Cover as much of the area as possible.
- Check all corners.
- Pay attention to trouble spots.
- Cross all rows in the field.
- Move out of the field to check isolation distance from potential sources of contamination.

Post-harvest activities under certification

Seed testing
Certification activities continue after harvest when the seeds are taken to the processing and storage centers. Certification ends when the Certification Agency has followed all the production activities of the seed

producer until final packaging and tagging. Seed testing is performed as part of the certification process in dedicated laboratories by trained and usually certified seed analysts who are part of the certification team. The tests are designed to evaluate the quality of the seed lot in question for cultivation before they can be sold. Seed testing is the second operation under formal seed quality control systems. It has the following functions.

- It is responsible for evaluating the various seed quality parameters.
- It validates and concludes seed certification by providing all the needed information about the seeds it represents.
- It assesses the physical, physiological, and sanitary quality of the seeds.
- It fulfils the legal requirements of seed certification.
- It provides the basis for price and consumer discrimination among the several seed lots that are available for planting purposes.

Objectives of seed testing

The main objective of seed testing is to assess the quality of seeds for sowing. Seed testing is designed to provide protection for farmers and other people in the trade who handle seeds before they reach the farmer. It helps to minimize the risk of farmers using seeds that do not have the capacity to produce a good crop of the required cultivar.

Seed testing methods

Several methods are available for testing the quality of seeds before planting. The method adopted for testing seeds should be based on scientific knowledge of seeds and on the accumulated experience of seed analysts. It must be accurate and reproducible. The main methods used include seed sampling, analytical purity, germination capacity, moisture content, and varietial purity.

Seed sampling

To validate the quality standards set by the Certification Agency for marketing purposes, only a small quantity of the seeds produced under certification (usually not more than 1 kg out of the total quantity produced) is usually required to be sent to a laboratory for testing. Much care and experience in using set rules and equipment for taking that small quantity of seeds for laboratory analysis are therefore required. This is the basis for seed sampling. The acceptance or rejection of the entire seed lot depends on the sample taken to the laboratory for analysis. The main object of sampling therefore is to obtain a representative volume of seeds of a size suitable for tests, in which the probability of a constituent being present in the whole seed lot is determined only by the level of occurrence in the representative volume. To ensure that the entire seed lot is not for any reason rejected for sale at the end of testing, producers are usually advised not to treat their entire produce in bulk but rather to apportion it into bits (lots), based on the history of production and processing. Seed testing is then done on the different lots instead of on the bulk production.

- A seed lot is therefore a specified quantity of seeds, physically identifiable, (of one cultivar, of known origin and history, and controlled under one reference number) and for which one certificate is issued.

Types of samples

- Primary sample
- Composite sample
- Submitted sample
- Working sample

Samples can be taken at any stage during seed processing and selling. However, the most usual times are before the seeds enter the processing plant, after the seeds have been cleaned, graded, etc., and are ready for sale, and when seeds have been in storage for more than 9 months.

Sampling equipment

The sampling methods include the use of the hands, hand-held instruments such as a "thief trier/probe" and the stick or sleeve trier/probe, and automatic samplers.

The purity analysis

This is a laboratory test done to inform the buyer of the seeds, by means of a label or tag on or in the seeds about the entire constituents of the seeds to be purchased. The main objective therefore is to determine the percentage composition by weight of the sample being tested and by inference the composition of the seed lot, and the identity of the various species of seeds and inert particles in the sample.

Components of the purity test

The pure seed component includes the following.

- All intact seeds of the species submitted for testing even if they are small, shriveled, immature or diseased, so long as they can definitely be identified as belonging to that species.
- Seeds of several different varieties of the species, when found.
- All damaged and broken seeds if they are bigger than half their original size.

Other crop seeds

This component include seeds of all other species found in the sample even if they are small, shrivelled, immature, or diseased, so long as they can definitely be recognized as seeds on the basis of morphological characteristics.

Inert matter

This includes all seeds, regardless of species, which are half of their original size, or less, ergots, other fungal sclerotia, smut balls, and nematode galls. Soil, sand, stones, straw, chaff, and all matter other than that included in the pure seeds and other seed fractions are also considered to be inert matter.

Facilities and equipment for purity analysis

- Clean work surface/purity work board when available
- Good lighting
- Balances
- Sieves
- Hand lenses and magnifying glasses.

These are not absolutely essential for purity analysis but are a useful aid, for example, in pre-cleaning the working sample to remove small particles.

Germination testing

In seed testing, germination is defined as the emergence and development of the seedling to a stage where the aspect of its essential structures indicates whether or not it is able to develop further into a satisfactory plant under favorable conditions in the soil (ISTA, 2010). The objectives of the germination tests are to determine the maximum germination potential of a seed lot, which can then in turn be used to compare the quality of different lots and also to estimate the field planting value of the seeds in soil outside or in the laboratory.

Essential seedling structures

- Root system
- Shoot axis
- Cotyledons
- Terminal buds
- Coleoptile

Normal seedlings

These are those seedlings that possess the capacity for continued development into normal plants when grown in good quality soil and favorable conditions of water supply, temperature, and light or seedlings, which possess all essential structures when tested on artificial substrates. For cereal species the following are essential: a well developed primary leaf either within or emerging through the coleoptile, and a well developed root system.

Abnormal seedlings

These are seedlings that do not have the capacity for continued development into healthy plants when grown in good quality soil and under favorable conditions or seedlings which possess serious defects when grown on artificial substrates. The results of the germination test under certification determine whether the seeds produced can or cannot be sold to farmers with reference to standards set by the Seed Certification Agency. Post-harvest processes and handling should be given careful attention to ensure good results from germination tests.

Seed health testing (SHT)

Seed health testing is not a mandatory requirement in seed certification schemes but in recent times it has become a necessity because it can help to avoid the introduction of unwarranted seed-borne and seed-transmitted disease pathogens into areas where they may not be present, especially in the international seed trade. It has therefore become a crop safety assurance test that some countries demand as a requisite for their buying seeds on the international market.

What is seed health?

"Health'' of seeds refers primarily to the presence or absence of disease-causing organisms, such as fungi, bacteria, and viruses, and animal pests, such as eelworms and insects, but physiological conditions such as trace element deficiency may also be involved" (ISTA 1999).

Why test seeds for health?

The primary objective of seed health testing is to ensure that healthy seeds are used in the field, harmful organisms do not travel from infected to non-infected areas within a country or across international boundaries, bacteria, fungi, and viruses as well as other micro-organisms cannot inhabit seeds and cause diseases in them.

Seed health testing methods

Several methods are available for testing for fungi, bacteria and viruses. The most common testing methods for the presence of fungi include the following.

- Dry seed inspection
- Washing test
- Blotter method
- Agar plate method
- Examination of embryos
- Seedling symptom test

Dry seed inspection

Here the seeds are examined physically for the presence of fruiting structures of fungi. The method also provides quick information on insect and mechanical damage to seeds as well as on seed treatment with pesticides so that the samples are handled with appropriate precautions.

Washing test

The test consists of shaking the seeds in water to which a wetting agent has been added. The suspension obtained is then examined under a compound microscope and the presence of fungi whose spores are present on the seed surface is then recorded.

Blotter method

This is the most common method practiced in seed health testing laboratories worldwide. Seeds are plated on blotters well soaked with water and incubated for 7 days at 22 °C under 12 h alternating cycles of light and darkness. Fungi are then identified based on their "habit characters", and on the morphological characters of fruiting bodies, spores, and conidia observed under the microscope.

Agar plate method
Surface-disinfected seeds are plated on an agar medium and the plated seeds are incubated for 7 days at 22-25 ^{o}C under 12 h alternating cycles of light and darkness. Fungi developing from incubated seeds are examined and identified.

Examination of embryos
There are a few fungal diseases where the seed-borne inoculum is located only in the embryo which can cause diseases in the subsequent generation. Here, embryos are separated from the rest of the seed tissues and examined under the microscope for infection. Infections from such fungi are often found in trace amounts, usually less than 1%.

Seedling symptom test
Some seed-borne fungi are capable of attacking seeds, reducing germination, or resulting in seed rot, disease symptoms on young seedlings, or even death. The seedling symptom test identifies such seed-borne fungi.

Conclusions on seed testing
- No single seed test is sufficient.
- The Standard Germination Test (SGT) is usually the most important seed testing required for seeds to be marketed.
- Other tests help to provide more information on the quality of the seeds.

Maize seed conditioning and storage 9

Maize seed conditioning is the most important process in the seed supply chain as it determines viability, storability, as well as the physical appearance of the finished produce while waiting for planting when required. It involves machines, engineering operations, biology, physics, plant physiology and pathology, science, and business. It must be accurate, economic, and practical. Conditioning of harvested maize seeds also turns the raw harvested seeds into pure seeds that are free from undesirable materials, safe from pests and diseases, and can be planted for a good stand of healthy plants of the desired crop (Gregg 2009**)**. Maize seed conditioning is also another major activity that differentiates seed production from grain production after the crop has been harvested.

Why must seeds be conditioned?

Harvested seeds from the field are never pure. They contain trash, such as dried leaves, weeds, other crop seeds, damaged or deteriorated seeds, and insects which, when not removed, would lower the final quality. The seeds must therefore be quickly conditioned to a state where maximum quality can be ensured and also for storage until they are required for planting. Seed conditioning includes activities such as dehusking, sorting, drying, shelling, pre-cleaning (scalping), cleaning, grading, seed treatment, and packaging (Fig. 9.1).

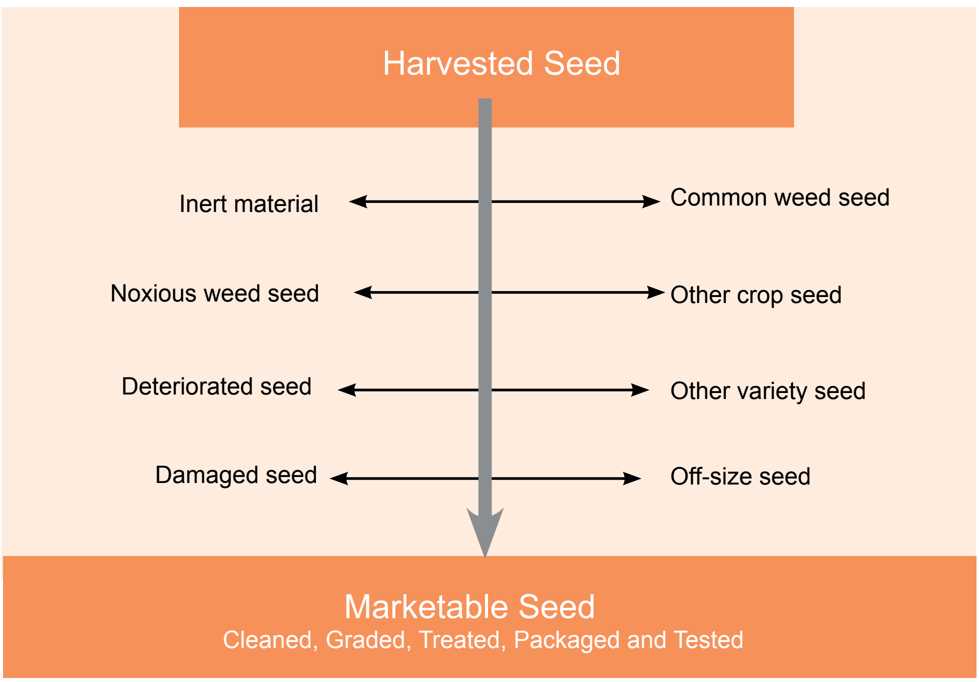


Figure 9.1. Constituents of raw harvested maize seeds from the field before conditioning.

Steps in the maize seed conditioning process

Maize seeds are harvested "on the ear" with the husks attached to minimize mechanical damage to the kernels. When possible, dehusking can be done in the field to accelerate the conditioning process. It is then followed immediately by sorting by hand. Dehusking and sorting are necessary to ensure the proper drying and shelling of maize seeds because any husk remaining on the ears will prevent adequate airflow, resulting in poor and uneven drying. Prior to drying, maize seed ears are sorted by hand after dehusking to remove off-types, diseased ears, crop residues, or any other material that may interfere with drying.

After dehusking and sorting, the cobs are dried to about 18% moisture content and then threshed. Moisture content above 18% may cause mechanical damage and this may reduce seed quality. The threshing is done mechanically with one of the many different small-scale or large-scale commercial mechanical threshers available in the market. During threshing, all seeds on the cobs must be removed without being broken or damaged. To prevent mechanical damage during threshing, the threshing equipment should be adjusted in such a way that the cob feeding rate and the running of the equipment would turn out only unbroken kernels to ensure good seed quality.

Drying maize seeds

Moisture content above 12% causes rapid deterioration. Seeds must therefore be dried to about or below 12% moisture before storage. At this moisture content, seeds can be maintained for longer durations, especially when stored under cold conditions. Seeds should therefore be dried immediately after harvesting when the initial moisture content is above that which is safe for conditioning and storage. The seed drying process should be done quickly after harvesting, sorting, and threshing. Prolonged holding of seeds with high moisture content affects the final seed quality.

Maize seed drying methods

Maize seeds may be dried using custom built seed dryers (artificial or mechanical drying) or using the sun (natural drying). The drying method adopted is dependent on several factors including the following.

- The class of seeds
- The quantity of seeds to be dried
- Facilities and equipment available
- The weather during the drying period
- Availability of technical personnel to handle mechanical drying
- The economics of drying the seeds

Artificial drying

Seed drying by artificial means is done with the use of electricity, gas, or fossil fuel which can be diesel or kerosene. Custom built artificial dryers with different capacities are readily available in the market. Heaters and fans are combined to work together for the drying. The principle behind artificial drying is that seeds to be dried are emptied into a container (wooden or metal) with a perforated base to hold them. The container with seeds would be sitting on a similar-sized box with a hollow base. Hot air from one end of the box is forced through the hollow chamber below the seeds with the aid of a fan or blower. The heating source can be electricity, diesel, kerosene, or combinations of these. The fan or blower in turn is fitted with electric motors to help to force the dry air through the seed chamber. During the entire drying process, samples are taken and tested for moisture until the required moisture level for storage is achieved. To ensure that the germination potential of the seeds is not killed through exposure to excessive temperatures, a thermostat is fitted into the heating chamber to regulate and maintain the temperature uniformly at 40 °C during the entire drying period.

Natural sun-drying

Maize seed drying is achieved through the exposure of the seeds to the sun's energy. The method is used when it is sunny during and after the time of harvest. In addition, sun-drying is often used when the quantity of seeds to be dried is fairly small. The use of this method is also often an indication of the level of development of the seed program in a country.

Methods of sun-drying

Use of narrow cribs

The use of cribs for sun-drying dehusked cobs of maize is a method found in areas where seed production may be in the infant stages and the quantities of seeds harvested by seed growers are small. It is effective when the crib is well built and located in an area where there is free flow of air around the structure and where the solar radiation levels are high. The drying structure is usually made of wood which is raised to a height about 1 m above the ground, and constructed in such a way that the width is narrow but the length is variable, depending on the quantity of maize stored. The walls and floor of the crib must be porous to enable air flow and moisture loss to take place. The structure can be roofed with corrugated iron sheets or with locally available thatch. Pieces of corrugated iron sheet are often wrapped around the wooden legs of the structure to serve as a barrier to rodents that would want to climb into the crib to damage seeds. Maize on cobs are neatly arranged in the crib and monitored over time until they are dry at which time the cobs are removed and threshed. Further sun-drying on flat drying floors may be required if the moisture content at the time of threshing is above that required for safe storage. The major problem with this method is the high level of weevil infestations especially when the cobs are not treated with insecticides before ears are put into the crib.

Use of flat drying floors

This is the most common method used in areas where the quantities of seeds produced are small and seed driers and other sophisticated machines for drying may not be available. The method can be used for both unshelled

Table 9.1. Physical characteristics of seeds and the conditioning machines used for their separation

Physical characteristics	Machine
1. Size	
(a). Gross	Screen section of Air-Screen Cleaner
(b). Length	Indented Cylinder, Disc Separator
(c). Width	Width and Thickness Separator
(d). Thickness	Width and Thickness Separator
2. Weight	Gravity Table, Aspirator, Stoner, Fan section of Air-Screen Cleaner
3. Surface texture	Roll Mill, Magnetic Separator, Vibrating Separator
4. Shape	Spiral Separator, Roll Mill
5. Color	Color Sorter

and shelled maize seeds. In principle, smooth concrete floors or similar structures are used in areas with a good flow of air and the threshed or unthreshed seeds are spread out in the open for drying. The practice is laborious as the seeds being dried are at the mercy of the weather, birds, rodents, and domestic animals, and may require to be covered periodically, usually with plastic sheets.

Maize seed cleaning

Seed cleaning entails the removal of unwanted materials from the seed lot to achieve the purity standards required in the seed trade. The unwanted materials may be broken cobs, pods, husks, dead insects, plant parts, and other kinds of crop seeds mixed with the true seeds.

Traditionally, dry and shelled seeds are cleaned manually by winnowing, sifting, sieving, and hand picking of all unwanted materials in the seed lot. This method is laborious and usually used when only small quantities of seeds are to be cleaned. Instead, mechanical seed cleaning machines are often used. All the mechanical seed cleaning machines available in the market exploit the characteristics of seeds, such as dimension, shape, density, surface texture, seed color, terminal velocity, electrical properties, and resilience, either in single machines or in combinations to clean the seeds (Brandenburg 1977). Examples of the major seed cleaning and finishing machines are the air-screen cleaner, the gravity separator, length separators such as the disk and indented separators, the color sorter, and the spiral separator. Table 9.1 presents some physical characteristics of seeds and the conditioning machines used for their separation.

Seed treatment

Seed treatment entails the use of chemical fungicides, insecticides, nematicides, or other pesticides in liquid, slurry, or powdery forms to coat seeds so as to prevent or reduce insect attack, infection by disease-causing organisms, or to ensure good storability of cleaned dry seeds. Seed treatment can be done manually using hand sprayers or by the use of sophisticated mechanical seed treaters.

Maize seed packaging

Maize seeds can be packaged into 50 or 100 kg bags as well as in smaller bags of 2, 5, 10, or 20 kg, depending on market demand. When produced under certification, seed packs must bear a certification tag or certificate that identifies the seed kind, provides the variety name and data from purity seed testing, states the area, year, and season of production, as well as a code identifying the seed certification officer who issued the tag declaring the seeds to be of high quality and marketable. Two labels per pack are usually issued: one is placed inside the pack, one outside the pack (usually sewn into the pack). This helps in identifying the seeds in case the external label is lost during handling. For the purpose of certification, the name of the variety, year, and season of production as well as other seed quality information may be attached as labels for identification purposes.

Maize seed storage

After cleaning, treatment, and packaging, the maize seeds can be marketed or stored until the planting season. Where possible, maize seeds must be stored at fairly low temperatures (10–15 ^{o}C) to protect the living embryo and maintain the capacity of the seeds to germinate when planted. Maize seeds meant for storage should be dried to between 10 and 12% moisture content. Storage should be in cool or cold rooms, free of insects and rodents. An appreciable reduction in percentage germination is expected when maize seeds are stored at room temperature under dry and well-ventilated conditions. A high germination percentage over a period of 4 years or more can be attained when seeds are stored at low temperatures of about 10–15 ^{o}C and a relative humidity of 45–50%. Cold seed storage structures fitted with dehumidifiers maintain seed quality over a longer period than when seeds are stored without dehumidifiers.

Some seed storage rules

- Cool and dry storage conditions and the use of moisture-proof packaging materials are ideal for the storage of maize seeds.
- Air-conditioned rooms are better alternatives for the storage of maize seeds than the use of deep freezers or refrigerators under ambient room conditions.
- The duration of storage should be given a higher priority than the storage condition when taking seed storage decisions.
- Except for a very short period, subsequent exposure of maize seeds to a higher temperature than the initial storage temperature accelerates seed ageing.
- Seed moisture content in storage should be 10–12%.
- Bad seeds cannot be made better by storing them in ideal conditions.

Figure 9.2 shows some rules of thumb applicable to maize storage; Figure 9.3 shows the effect of duration of storage on seed viability and germination.

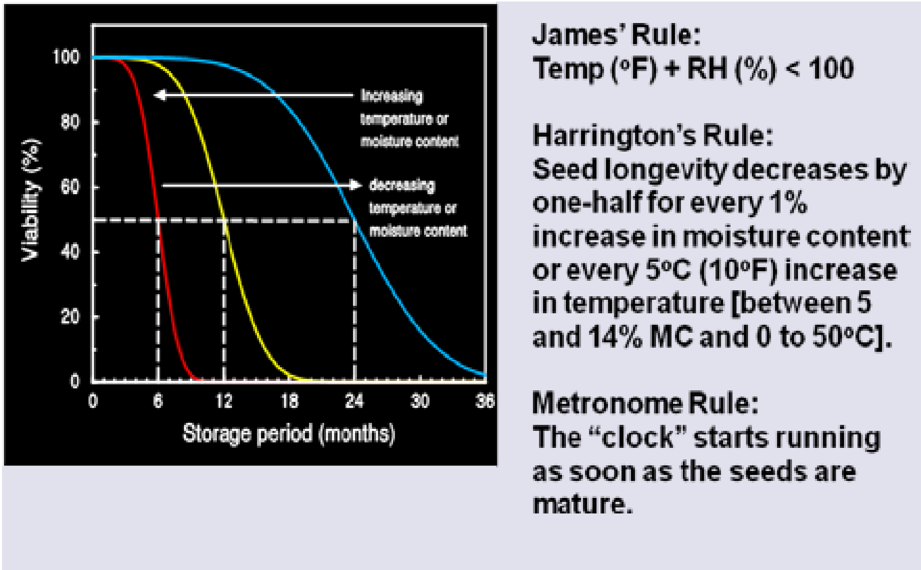


Figure 9.2. Rules of thumb governing seed storage.

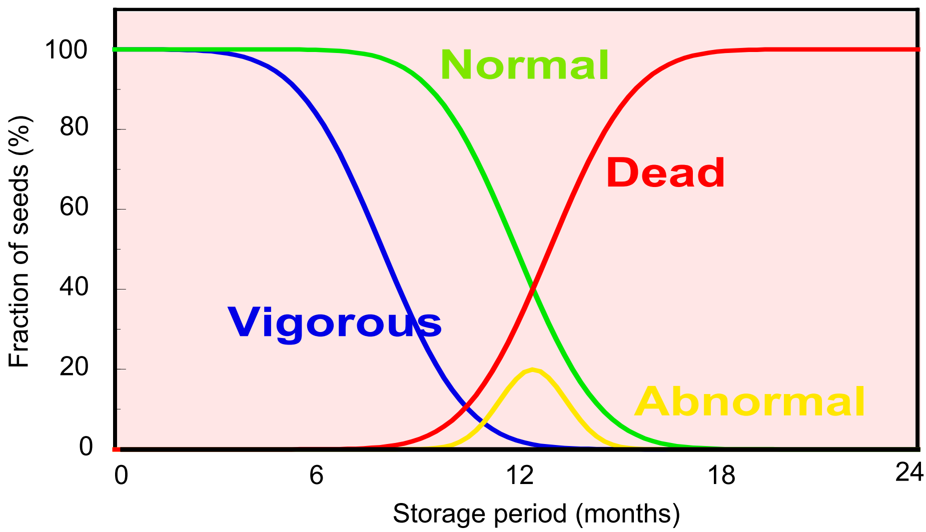


Figure 9.3. Effect of duration of storage on seed viability and germination.

Maize seed marketing and promotion in WCA

10

Introduction

The use of improved certified maize seeds in WCA is very limited despite the numerous efforts of IITA and other international centers and the NARS of the different countries to continuously breed, release, and promote the adoption of high yielding and disease resistant OPVs and hybrids that are suitable for all the major agro-climatological zones of the subregion. Most of the farmers continue to use own-saved seeds and even grain to cultivate their fields at the expense of the improved certified seeds.

Why is there limited use of improved/certified seeds?

Different reasons have been assigned for the continuous use of farmer-saved seeds even though many good quality and high yielding varieties have been released by national research institutes as well as international centers. Among the reasons given are the following.

- Farmers do not know about the advantages or benefits of using improved certified seeds.
- Improved certified seeds are not available where and when the farmers mostly need them.
- The production of certified maize seed in WCA is not attractive because of the numerous production constraints associated with the industry.
- The majority of the sales outlets are centralized in or around the regional/ commercial capitals. From the farmers' perspective improved certified seeds are costly.
- There are inadequate numbers of extension officers to educate and advise farmers on the methods and advantages of using improved certified seeds.
- Other variable inputs that complement the use of improved certified seeds, such as fertilizers, applicable crop management technologies, etc., are costly.
- Farming is not seen as a business but as a way of life and therefore the farmers use anything they can get for production without other considerations.
- There is a lack of confidence in the improved/certified seeds available in the market due to adulteration and the sale of "fake"' certified seeds.
- Seed marketing is also not taken as a business but combined with other interests.

Despite the low volumes of improved certified seeds produced in the subregion, marketing and distribution are problems in making quality improved seeds available to farmers in the right quantities and at the right time. Seed marketing, thus, has become a way of life for the few distributors and agents with their limited knowledge on how to market and distribute seeds using marketing principles.

Definition of seed marketing

Seed marketing is a continuous and systematic determination of consumers' needs and the accumulation of the seeds and services to satisfy those needs. It is the communication of information to potential consumers about the seeds and services available, the distribution of seeds to the farmers, and then the gathering of information from the consumers concerning the results of having used the seeds and services.

A dependable seed production program requires an effective seed marketing organization that ensures adequate quantities of improved seeds are available to the farmers at the right time and place (www.knowthis.com). Seed marketing should aim to satisfy the farmers' demand for a reliable supply of a range of improved seed of varieties with assured quality at an acceptable price. Marketing is the most important, yet misunderstood business activity for those in the seed business in WCA as it frequently means different things to different people.

To the farmer, marketing is simply selling what he produces on his farm. To the retailer in the agricultural sector, marketing is the selling of seeds to the farmer along with other inputs. Historically, more attention and resources are devoted to the physical aspects of seed production and storage than to the difficult organizational issues involved in managing sales and distribution. However, whatever the circumstances, a well-defined sequence of events has to take place to promote the product and to put it in the right place, at the right time and price for a sale to be made. For the marketing process to be successful the consumer's needs must be satisfied and the seed company's objectives must be realized.

Stakeholders in the seed marketing business in WCA

Until recent times, the production and marketing of seeds in most countries within WCA were done by public-based institutions. Generally, public institutions and agencies were solely responsible for all activities along the seed value chain in the various countries where improved seeds were available.

Breeding and varietal development, as well as the production of breeder, foundation, and certified seeds were in the hands of public research institutions and the universities and sometimes were undertaken by parastatals or units under the various Ministries of Agriculture. As a result of the public nature of the seed industries then, the distribution and marketing of the small quantities of improved seeds produced were not done with all the seriousness they deserved, as often observed with public-based enterprises.

The role of Governments in marketing and distribution

Experience from other economies shows that the role of Governments in the seed business should be the enactment of laws and legislation to control the seed business along the entire seed value chain and thereby create a level playing field for all teams. Governments should also provide the much-needed infrastructure, such as access roads and effective and reliable public transportation to the hinterland and all corners of the country to enable seed delivery to be done on time when needed.

The role of the private sector in marketing and distribution

Taking a cue from western economies and also from neighboring countries in southern and east Africa, Governments in WCA have recently released the monopolies of public organizations in seed development, production, marketing and distribution. Seed policies and seed laws have been enacted to give authority to the private sector to enter the seed trade. As a result of this change, private seed companies and seed distributors have started emerging with notable examples in Nigeria, Ghana, and Mali.

As is expected, a lot of initial problems are faced by the emerging businesses and Governments need to set up a smooth and level playing field, especially for those in the marketing and distribution channels to perform creditably. In short, the role of Governments should be to create legislative frameworks which support national seed institutions, create the appropriate economic environment, and minimize Government's interference in the market. In such circumstances, the private sector may be encouraged to play a greater role while guaranteeing the availability of seeds of reliable quality to the farmer at all times in all areas of the country.

Before entering the seed market

The general observation with the emerging seed marketing and distribution businesses in WCA is that many of them are small-scale with limited capacities for distribution and marketing. Businesses are low-key and lack the aggressive marketing and distribution strategies needed. Usually activities within the company are limited to a few people, usually not well planned, and also devoid of the essential integrated management approach and processes involving several employees at every level of the business. To make an impact and be able to effectively distribute and market all the seeds produced in the sub-region, seed marketing and distribution businesses should incorporate marketing strategies at all stages of their enterprise.

What to know in seed marketing

To enter the seed market, answers to the following questions must be obtained.

- Who are your main customers?
- Who are your profitable customers?
- Who are your most loyal customers?
- How many times will your company visit your best agro-dealers?
- How much time and money are you willing to invest in modern technology to help you to gain new customers?

To achieve your objectives and targets set in your marketing and distribution business, ensure that your seeds are well packaged and distributed widely in areas where they are needed for planting or where farmers can easily get access to them. The seeds must be available for planting at the onset of the rains in quantities required by the farmers and the price must be affordable. To equip you to be successful in the seed marketing and distribution business, the following are a list of must-do activities:

Market research and analysis

Market research and analysis are vital activities for any entrant into the seed market and distribution channel. This will involve finding out about the market and learning everything possible about it through studying the nature of the products, where and by whom they are needed, and at which times of the year they are needed and why.

Many entrants in the seed marketing and distribution business in WCA do not acquire the relevant knowledge of the area they want to enter. They may have very limited knowledge about the commodities they are handling and the ways they should be handled, especially during transportation and storage. They also have limited knowledge about the areas with the potential markets. Most people enter the business because someone they know is doing well and then they also enter but without learning about it. As a result, stocks may be piled up at areas of production with most parts of the country devoid of their commodities. In the end, most of the seeds in the marketing channels lose quality fast and cannot be re-sold after the season expires.

Market research and analysis, when done far in advance of seed movement, would inform people in the seed business about what volume of their products to make available on time and where. Without planning, seeds may get to places where they are needed at the wrong time during the planting season and this would not be beneficial to either the distributor or the farmers. Getting seeds to areas where they are wanted in the right quantities and at the right times is essential in a good seed marketing and distribution system.

As a service to the seed marketing and distribution channels, Governments in the sub-region, through their Ministries of Trade and Agriculture, could set up information channels to help educate and inform seed dealers about trends and forecasts in the seed industry.

Forecasting

This is the gathering of seed marketing and distribution information for the purposes of planning and making sound business decisions, such as how many bags of which class of seeds should be produced and how many would be sent where, when, and by whom, to capture potential sales and markets. This activity usually should be undertaken by all the major stakeholders in the seed business and ensures that overproduction and underproduction of a particular class of seeds do not occur.

One of the major problems in the seed business as it is today is the inability of all the major stakeholders within the entire seed value chain to forecast demand for particular classes of seeds at any point in time. Linkages between the major stakeholders in the seed delivery chain are nonexistent and it is not uncommon to see research coming out with varieties that have a low demand and seed producers producing seeds with no potential market value.To avert this situation, Governments should, as a service, periodically facilitate stakeholders' meetings at which production and marketing demands and forecasts can be discussed to improve the seed trade of the country.

Advertising, promotion, and public relations

There is the need to create product awareness, influence farmers' buying decisions, (PR) and build up a positive perception of seed companies. These can be achieved through advertising, promotion, and public relations activities. Doing business without the above is like selling a product without the seller being sure of what he is selling. Catchy adverts in the print and electronic media and on bill boards, the use of hand-bills, posters, and pamphlets are ways of advertising merchandise meant for sale, especially to people who may not be aware of its existence.

A good seed marketing and distribution enterprise should have a functional advertising, promotion, and public relations unit. The activities of such a unit would be to look for new outlets where the product could be introduced. When possible, samples to try out should be doled to farmers right on their farms and during planting seasons, especially new varieties just released and therefore having limited circulation on the market. This is a sure way to increase sales and introduce the products to new areas where they might not yet be available.

Other key marketing tools for a seed company

- Company literature (brochure, flier, posters, etc.)
- Promotional items such as caps, T-shirts, writing pads, pens, etc.
- Laminated photos of product performance and satisfied customers
- Field days and demonstration plots
- Crop signs, vehicle signs, etc.
- Good product packaging and labeling
- Radio advertising of jingles
- Bill boards
- Strategically located company shop and display

Little things that matter in seed marketing

- Educate farmers on the characteristics of maize varieties. As they are highly visual, display all the attributes of your seeds (roots, plants, grains).
- Think through your logos and field signs. They should translate well from color to black and white applications.

- Make them readable. Ask yourself whether your logo will still be pertinent if your line-up expands. Could your logo be easily placed or painted into a field sign?
- Demonstrations should be carefully sited and planned, with a check of non-improved varieties or local farmers' practice. Do not use a late maturing variety as a check in a demonstration of an early maturing cultivar. Plan a farmers' visit when the potential of your demonstration is showing. Be smart; make sure that the farmers who come to see it have a convenient option for purchasing your seeds.
- Plan successful field days, i.e., start early enough to think about the farmers to invite and attract, also the things to provide for farmers to see.
- Future growth should be part of a plan of a serious seed company. Costing is important, i.e., how much does it cost to provide, or deliver, one tonne of seeds?
- Do not ignore paper work in seed marketing, Some drivers dislike it, but it is essential for a good seed company to keep adequate records of sales, waste, left overs, etc. Records required include load sheets, routing sheets, and delivery receipts. All paper work must be returned to the company (Tahirou et al. 2012).

Stock control and quality assurance

This involves managing the seed stocks to ensure the maintenance of high germination and vigor over time, especially when in storage. Seeds are living things and, when not properly managed, especially when in storage and during distribution, they quickly lose quality in terms of viability and vigor.

Once farmers have lost trust in a seed distributor through the supply of low quality seeds the career of such a distributor is ended as no one would like to buy his seeds and such information travels far among farmers. To forestall this, seeds for the market should initially be kept in custom-built storage facilities, when available, or in a dry and well aerated storage environment when not needed for sowing. Such seeds should be constantly lifted in the right quantities for distribution and marketing so that not much carryover stock is returned to the storage room when the planting season is over. Naturally, most of such unsold seeds when returned from the market would have lost quality over time.

The appropriate form of transportation should also be used to move seeds from storage centers to the markets and back to ensure that water infiltration is greatly minimized to forestall loss in seed quality.

Seed pricing

Currently, the cost of seeds is the lowest item in the total crop budget for maize production in WCA. This is so because the bulk of the seeds planted are farmer-saved seeds, grain or, at best, improved seeds which almost invariably are OPVs. The use by farmers of hybrid maize seeds, which are much more expensive, is negligible but gaining momentum of late.

Pricing of maize seeds is always a dilemma for people in the marketing and distribution channels since any scaling up of prices usually leads to prospective buyers shunning the commodity. Pricing, however, creates sales revenue and is important in determining the total value of the sales made. In WCA, seed prices are determined by what farmers perceive to be the value of the seeds of a particular variety. It is important to investigate before pricing seeds and understand how farmers value seeds as well as how much they are prepared to pay in relation to the benefit they expect to gain. Seeds should be priced in such a way that farmers would not perceive them as too expensive and so shun them. However, the price of seeds should be above that of grain so farmers would not be encouraged to buy and consume them for food. A good research and analysis of the seed and grain markets must be done by seed merchants so as to help them price their seeds to increase demand and the profit of the seed producers as well.

11 Genotype × Environment interaction in maize variety testing, release, and seed production in WCA

From 1987, WECAMAN offered, on an annual basis, improved early and extra-early maturing maize varieties to NARS in WCA through the Regional Uniform Variety Trials (RUVT): RUVT-Early and RUVT-Extra-Early. The Network also collaborated with the IITA Maize Program in the distribution of trials for the intermediate and late maturing OPV and hybrid maize varieties. Each of the NARS received, on request, 1-3 sets of any of the trials for in-country evaluation at appropriate locations. The NARS followed up with requests for seeds of one or two varieties identified as promising in the respective countries for further experimentation on-farm and prospective adoption. The Network also provided funds in support of on-farm trials and demonstrations in member countries. This approach promoted collaboration among national and international scientists in the sub-region to develop, test, and transfer to farmers high yielding and adapted maize cultivars and accompanying agronomic practices. The Regional Trials provided an important vehicle for a wide testing of the varieties and for the exchange of germplasm among all participating countries. Also through the Regional Trials, member countries, less endowed with respect to technology development, were offered the opportunity to identify varieties for their target ecologies.

It is essential for the success of the seed industry of a country that national performance field trials and consumer evaluations are conducted in the relevant agroecological zones so as to determine the varieties and hybrids that qualify to be released and are worth further multiplication. Each country in WCA, therefore, has a system of performance trials which allow promising varieties and hybrids identified in Regional and International Trials to be evaluated alongside established local varieties for comparison. Invariably, a national variety release system is established which is supposed to be absolutely unbiased, transparently organized, and controlled by an independent agency. Before a variety or hybrid is approved for release in a country, the Variety Release Committee has to be satisfied that the candidate variety or hybrid is Distinct, Uniform, and Stable (DUS) and has Value for Cultivation and Use (VCU).

The savanna of WCA is characterized by limited and erratic rainfall and deficiencies in soil nutrients, all of which act and interact to create contrasting growing environments (Menkir et al. 2003; Badu-Apraku et al. 2005, 2006). Therefore, multi-environmental trials (METs) in WCA usually show significant genotype × environment interaction (GEI) due to the differential response of cultivars to varied growing conditions (Badu-Apraku et al. 2008, 2009). METs are therefore routinely conducted by the IITA Maize

Program in Nigeria to identify genotypes with stable and high yields. The information obtained from such trials is also invaluable to the national maize programs with similar growing conditions. It allows them to identify and select high yielding cultivars with specific or broad adaptation to their conditions for further testing on-farm and for release for commercialization and seed production. In addition, the information helps national scientists to identify appropriate germplasm with specific stress tolerance, desirable agronomic traits, and end-use quality attributes for use in national breeding programs (Badu-Apraku et al. 2009). Results of multi-locational trials in WCA have demonstrated the existence of GEI, (Fakorede and Adeyemo 1986; Badu-Apraku et al. 1995, 2003, 2007, 2008). This implies the need for extensive testing of cultivars in multiple environments over years before decisions are taken on cultivar recommendations. However, because of the limited resources of the national maize research programs of WCA, there is a need to conduct cultivar evaluation in a limited number of environments. As pointed out by Yan et al. (2007), it is important to re-examine target environments for their uniqueness as some environments may never provide unique information in separating and ranking genotypes because they are similar to some other environments. This allows the identification of core test locations where testing of cultivars can be done without losing valuable information about genotypes. Furthermore, the stratification of maize evaluation environments can help increase the heritability of measured traits, accelerate the rate of gain from selection, strengthen the potential competitiveness for seed production, and maximize grain yields for farmers (Gauch and Zobel 1997).

The signing of the protocol on seeds by the Heads of States of ECOWAS member countries in 2009 and the availability of the West African Catalog of Plant Species and Varieties (COAFEV) offered a unique opportunity for the movement of good quality seeds of improved maize varieties and hybrids across the borders of the ECOWAS countries for production and marketing. The seed catalog, which contains the varieties whose seeds can be produced and commercialized within the territories of the 17 member countries, is an aggregate of the varieties registered in the national catalog of the member states. This development in the seed sectors of the ECOWAS member countries called for the identification of core testing locations in each of the current mega-environments to facilitate the selection of high yielding and stable cultivars for seed production and marketing across the countries of WCA. Therefore, a study was conducted to examine the effects of genotype and GEI in early maturing maize cultivars, evaluate agronomic performance and stability of cultivars, and identify core test locations in the mega-environments of the lowlands of WCA.

Yan et al. (2007) proposed that test locations may be classified into three types: (1) locations with low genotype discrimination that should not be selected as test locations; (2) locations with high genotype discrimination, representative of the mega-environment as well as close to the ideal mega-environment and should, therefore, be chosen for superior genotype selection, when few test locations can be managed due to budget constraints; and (3) locations with high genotype discrimination that do not represent the mega-environment, which could be used for unstable genotype evaluation. The discriminating power of an environment refers to the ability to identify an ideal test environment while the representativeness refers to the ability of a test location to typify the mega-environment. The test environments and discriminating power versus the representativeness view of GGE biplot analysis of the results of the early maturing varieties evaluated in test locations in WA are presented in Figures 11.1 and 11.2. Test environments were classified into four mega-environments as follows: Katibougou, Sotouboua, Ejura, and Bagou constitute the first group. The second group consists of Manga, Nyankpala, Bagauda, Yendi, Angaredebou, Mokwa, Katibougou, and Zaria. The third group comprises Ativeme, Ikenne, and the fourth consists of Ina. Test locations Katibougou, Sotouboua, Ejura, and Bagou were highly correlated in their ranking of the genotypes in group 1, suggesting that a promising, early maturing cultivar selected in one of these locations in one country would also be suitable for production in the other locations within the same mega-environment in different countries. Similarly, Manga, Nyankpala, Bagauda, Yendi, Angaredebou, Mokwa, Kita, and Zaria were highly correlated in their ranking of the genotypes in group 2 and therefore, a promising cultivar identified in one location will be likely to be adapted to the other locations. Selecting cultivars out of these two locations will be likely to result in varieties adapted to Ikenne and Ativeme within the same mega-environment. Ina stands alone in mega-environment 4 and was unique in the ranking of the genotypes. Kita was identified as the ideal location while Zaria was close to the ideal location. Based on this study, groups of test locations that rank the early maturing cultivars similarly have been identified in the different countries and are expected to facilitate the exchange of germplasm with a high probability of it being recommended for release and production by farmers, using the ECOWAS protocol on seeds.

In another study, 18 extra-early varieties were evaluated at 17 locations in four countries of WA (Fig.11.3) between 2006 and 2009 to validate the existing mega-environments, and to identify core testing sites within each mega-environment for cultivar evaluation, release, and marketing across countries in West Africa. Locations (Zaria, IIorin, Ikenne, Ejura, Kita, Babile, Ina, and Angaredebou) were identified as the core sites of the three mega-environments for testing the extra-early varieties in the Regional Uniform Variety Trials RUVT (Fig. 11.4). It is proposed that the research facilities at the core testing sites identified for the early and extra-early varieties in the two studies should be upgraded for conducting regional trials. This will ensure the collection of reliable data to support the release of improved varieties and hybrids across the borders of the ECOWAS countries for production and marketing based on the seed protocol.

Because GEI affects differently the performance of inbred lines and hybrids as well as the quality and quantity of seeds produced in a hybrid program,

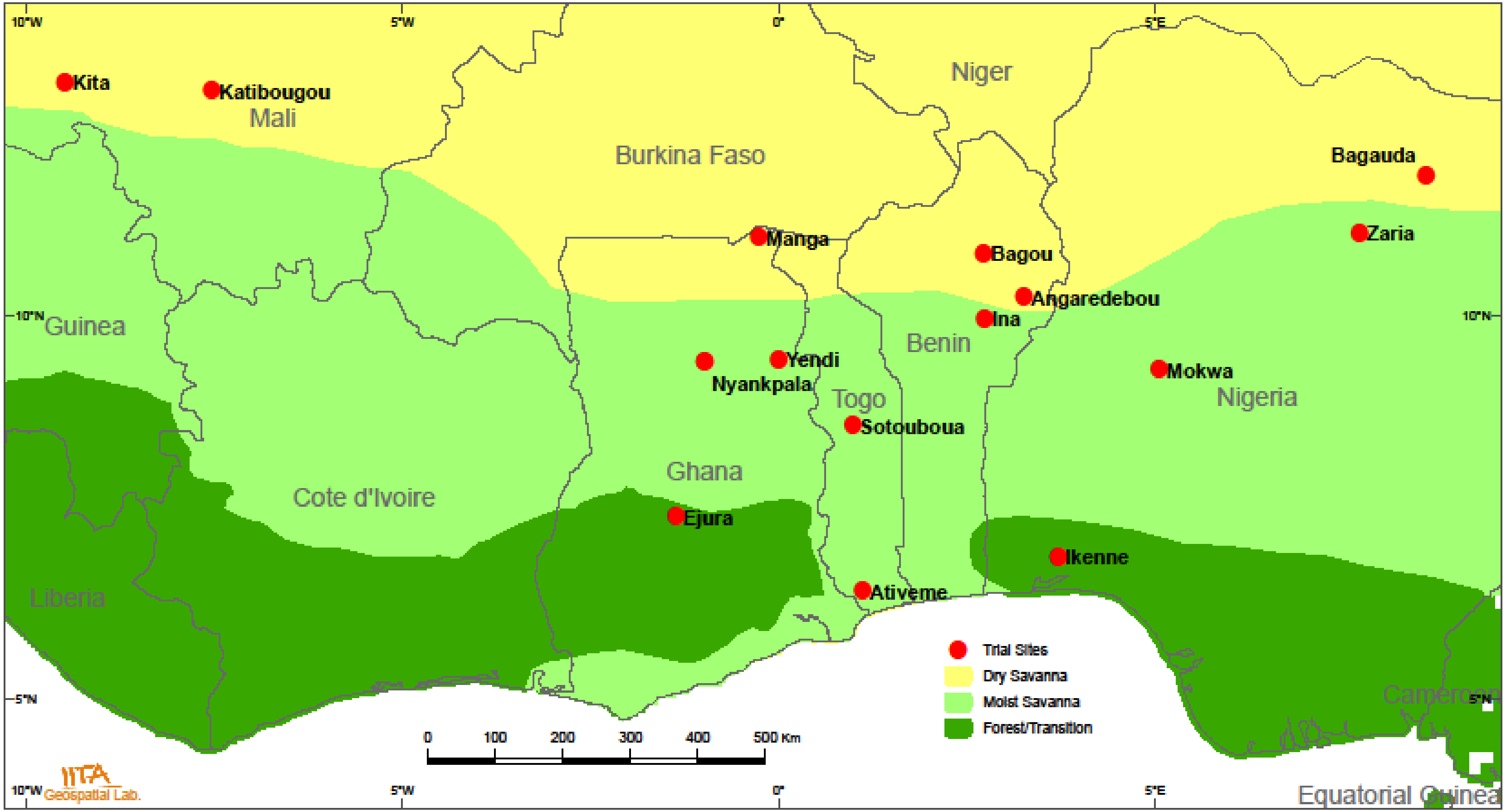


Figure 11.1. Locations in the major agroecological zones in West Africa used for testing early maize varieties in the RUVT from 2006 to 2008.

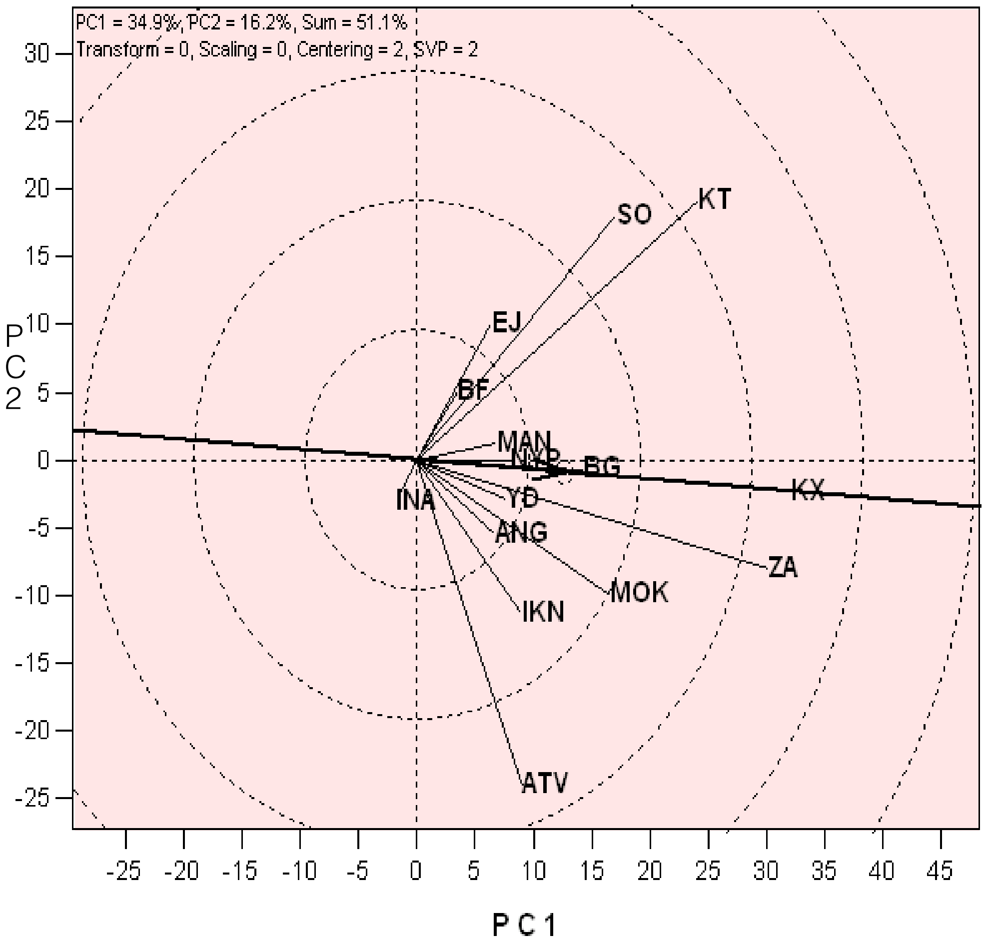


Figure 11.2. The "discriminating power and representativeness" view of the GGE biplot based on a genotype × environment yield data of 18 early maturing maize cultivars evaluated in 15 locations across WA between 2006 and 2008. Ikenne = IKN; Mokwa = MOK; Zaria = ZA; Bagauda = BG; Nyankpala = NYP; Yendi = YD; Angaredebou = ANG; Ina = INA; Manga = MAN; Ejura = EJ; Kita = KX; Ativeme = ATV; Katibougou = KX; Sotuboua = SO; Kita = KT.

there is a need to examine the stability of the inbreds and hybrids under stress and non-stress environments (Setimela et al. 2009). As a new variety or hybrid approaches variety release and registration, it becomes very important that it is evaluated for seed production characteristics, including female seed yield, pollen-silk synchrony, female agronomic characteristics (tassel exertion, plant and ear heights, standability, disease resistance, and tolerance to biotic and abiotic stresses) as well as the male agronomic characteristics, particularly pollen production. It therefore becomes imperative at this stage for the seed research program to evaluate the female and male components of the hybrid scheduled for release under a range of management practices, including planting dates, different plant densities, and fertilizer levels (MacRobert 2009). This information is crucial in taking the decision whether to advance a variety or hybrid into the registration, release, and commercialization stages.

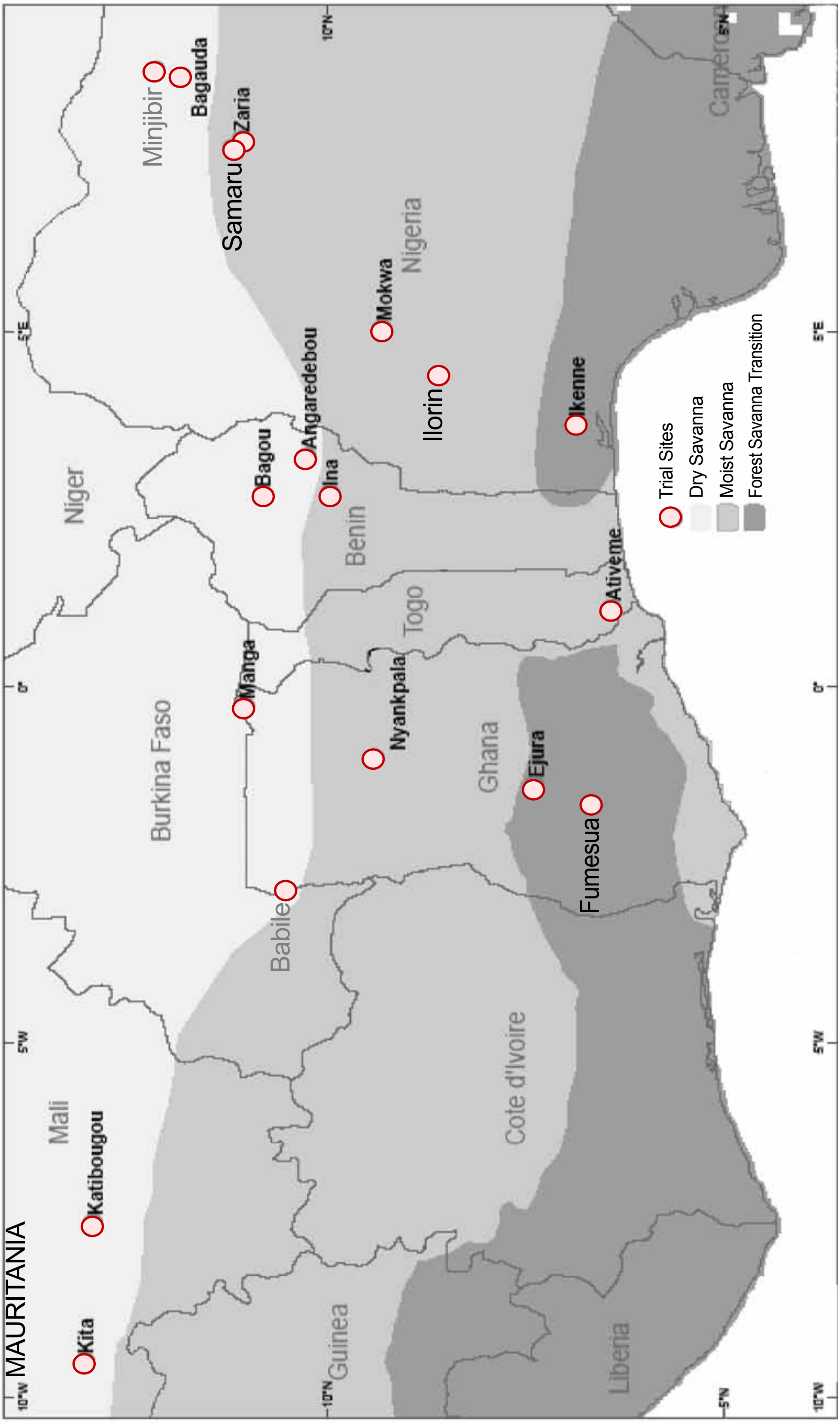


Figure 11.3. Locations in the major agro-ecological zones in West Africa used for testing extra-early maize cultivars in the RUVT extra-early from 2006 to 2009.

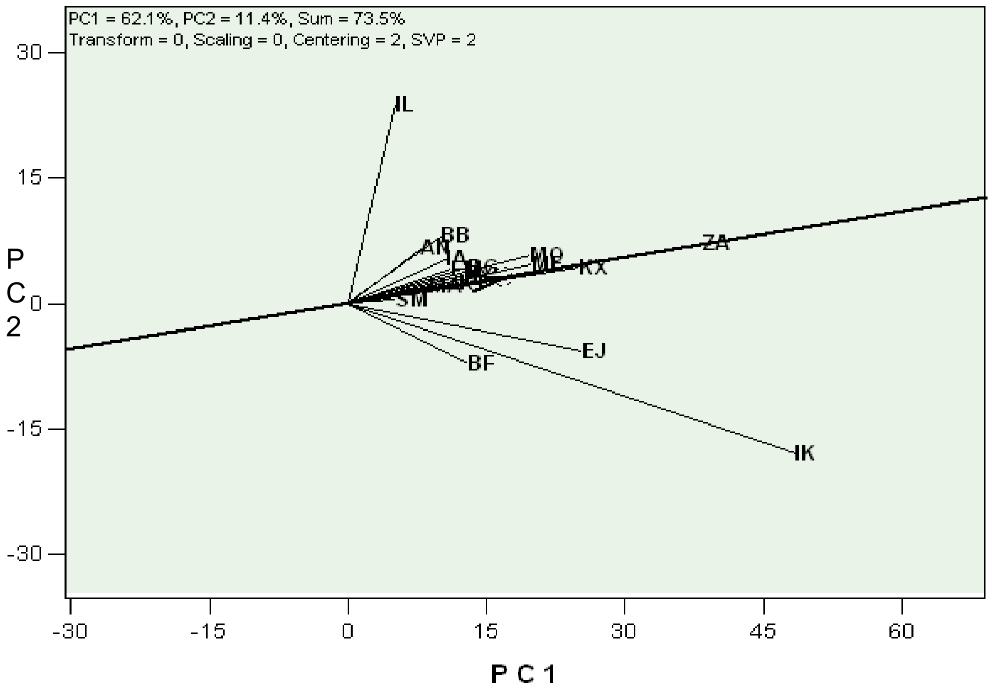


Figure 11.4. The 'discriminating power and representativeness' view of GGE biplot based on a genotype x environment yield data of 12 extra-early maturing maize cultivars evaluated in 17 locations across WA between 2006 and 2009. Ikenne = IK; Mokwa = MO; Zaria = ZA; Bagauda = BG; Ilorin = IL; Nyankpala = NY; Minjibir = ME; Samaru = SM; Angaredebou = AN; Ina = IA; Katibougou = KT; Manga = MA; Babile = BB; Ejura = EJ; Bagou = BF; Fumesua = FM; Kita = KX.

Most of the few seed companies operating in WCA have concentrated their seed production activities in the savanna regions, understandably because of higher seed yield and ease of natural drying at little or no cost. Seeds produced under the conditions of the savanna regions are sold to farmers in all other agroecologies. The variety being grown for seed production must be adapted to the prevailing agroecological conditions of the location for seed production. There is little or no information on the effect on seed quality of the location for seed production as demonstrated in locations other than that in which the seeds are produced. Similarly, differences in the quality of seeds produced in different locations in WCA are little known. In other words, the effect of GEI on seed quality has not been researched sufficiently. One of the few studies conducted on this subject involved the seed production of ten hybrids in a rainforest location (Ikenne) and two savanna locations (Zaria and Saminaka), all in Nigeria (Personal communication with Professor S.A. Ajayi (2012), Obafemi Awolowo University, Ile-Ife, Nigeria). The seeds were subjected to quality tests in the Seed Science Laboratory of Obafemi Awolowo University. Location mean squares were highly significant for percentage germination (%G), germination index (GI) and germination rate index (GRI). Similarly, genotype and GEI mean squares were significant for %G and GRI, but not GI. Germination was higher (greater %G) and faster (lower GI and GRI) for seeds produced in the savanna than for those produced in the rainforest location.

The Ghana seed program (1990–2010): achievements, challenges, and future directions

12

Introduction

The seed program of Ghana is presented as a case study so that other countries of the subregion could share the experiences and lessons of the country in the development of the seed industry. From its inception in the 1950s to the present, the seed program has gone through several developmental stages and re-organizations, beginning with the period when there were no research stations in the country to develop, release, and register new varieties for production. The country at that time depended on certified seeds, produced in countries such as the United States, which were donated for planting. Today, Ghana can boast of a robust and vibrant seed industry that combines both the formal and informal seed production systems, able to deliver seeds of several crop varieties developed, released, and registered by Ghanaian institutions, marketed across the country, and exported to other countries in WCA and beyond.

History of the Ghana seed industry

The formal seed sector in Ghana was initiated in 1958 with the establishment, within the Ministry of Agriculture, of a Maize Hybrid Seed Multiplication Unit. The Unit specialized only in hybrid maize seed production until 1961 when it evolved into the Seed Multiplication Unit (SMU) with the inclusion of other crops. Between 1961 and 1969, the SMU evolved into a contract growers' system with contract growers being used to produce all the seed requirements of the country. The SMU in 1969 became the Ghana Seed Company (GSC) with the mandate to produce all classes of seeds except breeder seeds which were the mandate of the research institutes. The food crops serviced by the formal seed sector at the time were maize, rice, groundnut, cowpea, and imported vegetables. Also at that time, other predominantly public sector institutions and parastatals were set up and charged with the production and marketing of seeds of specific commodities, particularly cash crops (Ocran 1998).

Reforms in the Ghana seed industry

The Government of Ghana became concerned about the effectiveness of many agencies and parastatals in those years, and when an Economic Recovery Program was launched in 1983, the seed industry was identified as a key area that needed reform and restructuring. As a result, between 1984 and 1988, various studies conducted supported this view and recommended the restructuring of the formal seed sector with initiatives to encourage the development and inclusion of the private seed sector (Brobbey-Kyei et al. 1994). Based on the studies and recommendations as well as a change in Government policy, the GSC, a parastatal, as it was then, was dissolved in September 1989, paving the way for a new Ghana seed program. The new policy also directed that the production and sale of certified seeds in Ghana should be a private sector commercial activity. Hence, there was the birth of a new program with private sector involvement. As a show of its active support and commitment to the new seed industry and also to help it to survive from the start, the Government gave active support for the development and strengthening of public sector institutions mandated for the provision of essential services, such as research, the production of foundation seeds, seed quality control, and certification.

To buttress the efforts of Government for the new seed industry to succeed, the Ministry of Food and Agriculture (MOFA) embarked upon intensive educational and promotional programs through the news media and the agricultural extension services to create awareness of the change that had dawned on the Ghana seed industry. The Ministry also registered and trained potential seed growers and dealers in the dynamics of seed production and the marketing of seeds as a business. The private sector responded positively and within a short time about 100 small and medium seed producing and marketing enterprises were established in the country (Ocran 1998).

The new Ghana seed industry

With the dissolution of the GSC in 1989, a new and well- structured Ghana seed industry was put in place in 1990 comprising public and private institutions with clear cut mandates. The policy and administrative structures required to implement the seed law available at that time were put in place and made functional.

Institutional support to the Ghana seed industry

For the effective implementation of the National Seed Program, the following bodies and institutions as well as their functions and mandates were established to support the different components.

- **National Seed Committee.** The National Seed Committee (NSC) is the highest body in the seed industry. It addresses policy issues for implementation by both the public and private seed sectors in the industry.
- **National Seed Service.** The National Seed Service (NSS), which is part of the Department of Crop Services of MOFA, provides leadership and technical support for seed production, seed sales, and seed enterprises. The NSS organizes training courses on all aspects of the seed industry; it also serves as the secretariat of the NSC and thus coordinates the activities of all institutions and agencies involved in the seed industry. It also regularly advertises information in selected national newspapers each year on seed growers and seed dealers and their activities and locations where certified seeds and other inputs could be purchased.
- **Ghana Seed Inspection Division (GSID).** GSID is a public but autonomous division within the Plant Protection and Regulatory Services Department of MOFA and it is the Certification and Quality Control Division of the seed industry. It is legally mandated to certify

seeds of all kinds on behalf of MOFA to enable them to be put up for sale across the country. The Division is empowered to undertake the following functions.

- Register all categories of seed producers and dealers.
- Conduct field inspections.
- Reject or accept inspected fields and seed lots.
- Monitor seed dealers at storage and sales periods.
- Certify seeds.
- Implement the national seed laws, i.e., Seeds (Certification and Standards) Decree, 1972 and The Seed Act, 1995.
- Train seed inspectors and seed producers in internal seed quality assurance, processing, marketing, and packaging.

- **Research Institutes.** Two research institutes in the country have the mandate to conduct agricultural research into crops, develop new varieties for release and registration, and produce breeder seeds to service the seed industry. The Crops Research Institute (CRI) in Kumasi has the mandate for crop research in the coastal savanna, the forest belt and the forest-savanna transition agro-ecologies of Ghana. The Savannah Agricultural Research Institute (SARI) has the mandate for crop research in the Guinea savanna and the Sudan savanna agroecologies. The two institutions produce breeder seeds of their mandate crops. Currently maize, rice, cowpea, sorghum, soybean, and groundnut seeds are available from the two research institutes.
- **Grains and Legumes Development Board.** The Grains and Legumes Development Board (a parastatal of MOFA) produces foundation seeds from the breeder seeds released by the two research institutes.
- **Department of Agricultural Extension Services.** This is a department of MOFA and its role is seed extension. The department's front-line staff carry seed information as well as other technological packages that the researchers would like to deliver to farmers. They show farmers the sources of improved certified seeds and educate them in the proper use of improved seeds.

Evolution of Ghana's seed multiplication program

In Ghana, an institutionalized seed multiplication program started at the close of the 1950s with maize as the only crop. New crops were gradually added and, by 1964, maize, rice, groundnut, sorghum, millet, and local vegetable seeds as well as tree crop seedlings were being produced. The seed program of Ghana was handled from its inception by the SMU of the Ministry of Agriculture which gave rise to the GSC. The GSC did not carry out extension activities – except for the limited production education program that was organized among its seed growers – but it had well-equipped laboratories, both at the head office in Accra and at its five area offices in Bolgatanga, Ho, Kumasi, Tamale, and Winneba, to conduct internal quality assurance of its seeds before sales. The GSC continued until 1989 when it was replaced by the GSID which was formed to provide independent quality control services.

In the Northern Region, MOFA's extension effort was supplemented by two bilateral development programs, the Ghanaian/German Agricultural Development Project and the Northern Region Rural Integrated Program which had the sole responsibility for extension.

Certified seeds as a source of supply in Ghana

Until the Ghana seed industry was restructured in 1989, all cereal and legume seeds were produced and marketed without certification. Seeds sold by production and marketing institutions nevertheless met some quality assurance standards through internal quality control checks. The GSC, in particular, had the relevant seed-testing equipment and trained personnel to conduct internal quality assurance tests on their products. However, no mandatory certification tags were issued by an independent agency to indicate that growers, processors, and distributors of seeds had met the appropriate field, laboratory, and legal standards.

Under the current restructured seed industry, seed production and marketing are undertaken by the private sector with measures put in place to ensure that all seed producers continue to supply high quality products to their customers under certification.

Variety release mechanism in Ghana

The CRI and SARI of the Council for Scientific and Industrial Research (CSIR) are responsible for the development and on-station evaluation of maize varieties and hybrids in Ghana (Fig. 12.1). The two institutes have several experiment stations scattered throughout Ghana for extensive multi-location trials. At least 2 years on-station data, 2 years on-farm data, as well

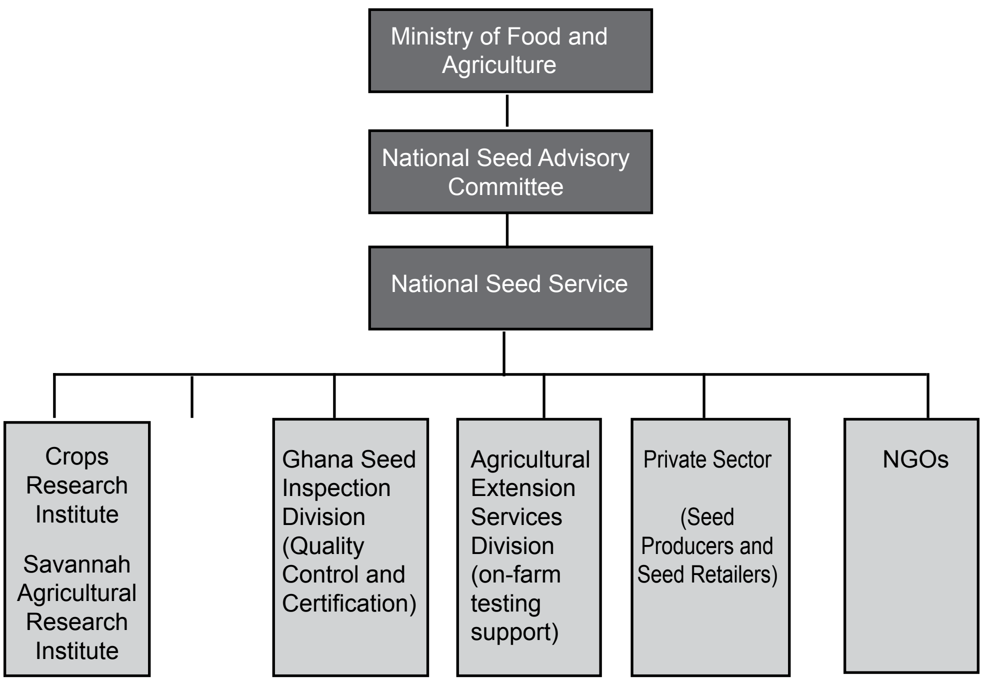


Figure 12.1. Structure of the Ghana Seed Industry until October 2011.

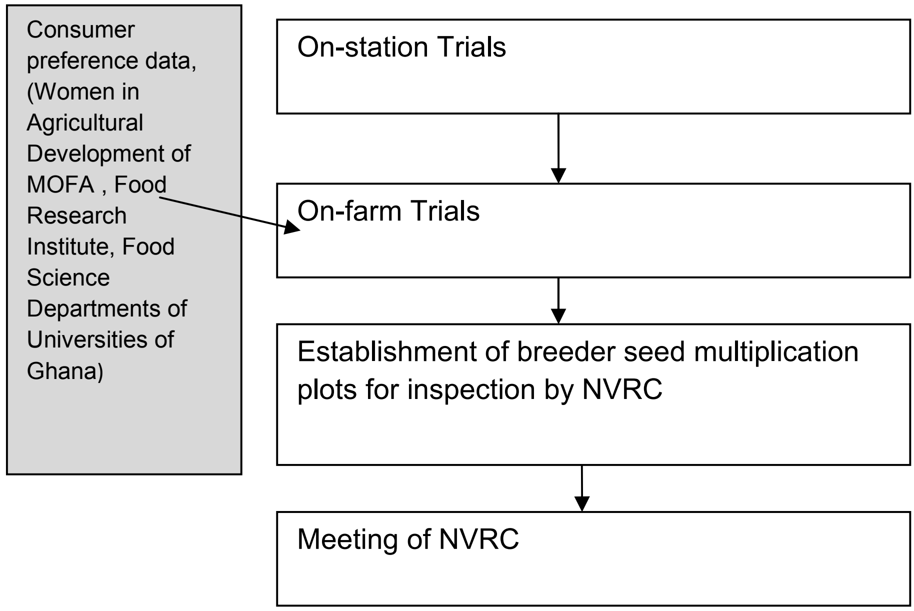


Figure 12.2. Variety Release Channels in Ghana.

as consumer preference data and physicochemical and economic analysis are required for a variety to be released (Fig. 12.2). The on-farm trials are conducted by the researchers of CRI and SARI in collaboration with the extension staff of MOFA. The consumer preference data are collected by the women in agricultural development division of MOFA and the physicochemical analyses are conducted by the Department of Food Science at the University of Ghana, and the Food Research Institute (FRI) of CSIR. The economic analyses are carried out by the economists at CRI and SARI.

Once all the required data for the release of a variety have been assembled, an application for the release of the variety is submitted to the National Variety Release Committee (NVRC) which is composed of the Directors of CRI, SARI, Department of Agricultural Extension Services, Women in Agricultural Development, Crops Services Division, Grains and Legumes Development Board, Plant Protection Regulatory Services Division, the representative of the universities, a plant breeder, a representative of the Seed Growers' Association, a seed technologist, the Head of the Ghana Seed Inspection Division, the Head of the NSS, a representative of the seed dealers' association, and a farmers' representative.

The members of the NVRC visit the breeder seed fields at least twice during the growing season. The first visit is at the flowering stage and the second is at harvesting. Based on these visits and supporting data, the Committee decides whether or not the process for the release of the variety should go on. If the Committee is happy with the performance of the variety in the breeder seed plot, then a date is fixed for a meeting to consider the release of the variety. The sponsoring breeder of the candidate variety is responsible for the presentation of the necessary data during the meeting of the NVRC to support the release of the variety.

The informal seed sector in Ghana

On-farm sources

An important component of the informal seed sector is on-farm seed-saving which is an ancient practice among traditional small-scale farmers. Farmers preserve seeds of the varieties best adapted for their environment. Limitations with this practice are that farmers obtain low yields and seed quality is not guaranteed, although a wide-ranging study of farmers' seed quality in Ghana showed that, for maize, cowpea, and soybean, average germination potential remained above 70% (Wright and Tyler 1995). Also, after a short period of cultivation, seeds may become mixed with other varieties and lose their desirable characters; they can no longer be maintained uniformly and reliably.

Off-farm sources

Another component of the informal seed sector is the trade and exchange of seeds in farming communities. The limitation here is that poor farmers might be unable to participate in seed exchanges. Seeds can be acquired or traded as payment for other goods and services; they can be gifts from friends, neighbors, and family members; and seeds can be lent and borrowed (Ocran et al. 1998).

Local markets supply various seed types and varieties to farmers. Food-stuff traders, mostly women, bring selected crop varieties with better physical appearance for sale as seeds. Traders also supply farmers with new seeds and buy their produce at harvest. Through this practice, farmers are able to obtain and maintain their own stock of seeds (Bortei-Doku Aryeetey 1994).

Achievements of the Ghana seed industry

The Ghana seed industry has since its inception in the early 1950s gone through a number of phases, reviews, and restructurings to reach the level where it is today. Over the years the seed industry, using all the production systems known, has been able to meet some of the seed requirements of Ghanaian farmers in most crops. Today, the seed industry is very vibrant and with the passing of a new seed law by parliament in the last quarter of 2010, the stage has been set for improvement in the quantity and quality of seeds both for local consumption and for export.

The Ghana seed industry can boast of a number of successes over the past years, notable among which are the following.

- The industry has been able to sustain itself despite the constraints that it faces and has successfully combined both the formal and informal seed delivery systems to make available new varieties of the major cereals and legume staple crops for farmers to plant annually. The industry has in place all the major seed chain actors working hand in hand to make quality seeds available to farmers.
- In the formal seed delivery sense, the country has in place two reputable crop research institutes that develop, release, and register new varieties to meet the needs of the country.

- The country has a functional NVRC which continually makes sure that only superior crop varieties are accepted for release and cultivation in the country.
- There is a strong autonomous seed certification and quality control unit in charge of seed certification and quality assurance in place in the country. The unit is another plus for the country as not many countries in WCA have a functional seed certification and quality assurance component in their seed program.
- The country has an ISTA-registered seed laboratory, probably the only one in all the countries of WCA as of date. The laboratory is currently seeking accreditation from ISTA.
- Over the past years the country has put in place and implemented three seed laws as follows:
  - The Seeds (Certification and Standards) Decree, 1972.
  - The Seed Act, 1995 (Draft), which was never passed but had some positive sections implemented.
  - The Plants and Fertilizer Act, 2010 (ACT 803).

The seed industry has between 200 and 300 certified seed producers from the private sector registered and the majority of them annually produce certified seeds of the various crops for sale within and outside the country. In the 2011 planting season, about 4000 t of certified maize seeds were produced by the private sector, beside seeds of other crops for sale to farmers across the country.

Challenges faced by the Ghana seed industry

Despite the numerous successes in recent times, Ghana, like other countries of the subregion, has had its fair share of challenges militating against increased seed production and seed use. Among the major challenges are the following.

- Government policies over the years have not been sensitive to the seed industry as most do not support investments in agri-business in general. Credit availability, especially from the non-public banking institutions, is one notable example. Potential new entrants into the seed business lack the required initial capital. Credits from private banks are not available as they do not offer concessional loans with low interest to people in agri-business. As a result potential new entrants do not take off. The Government should, as a policy, encourage the private banks to institute quotas from their operational funds as credit to new entrants in agri-business at attractive low interest rates. Policy can also influence tax rebates and concessions from Government to new entrants into the seed sector, especially on the acquisition and import of equipment and other facilities required for use in seed business.
- Limited availability of seed business facilities and equipment as well as other items of infrastructure has also become a major constraint facing the seed industry. Equipment, machinery, and requisite transport facilities needed for use in the seed industry are lacking. The road networks are

not the best across the country and the movement of seeds and other seed-related products to producing and marketing centers is a problem.

- Variety development and releases are slow because of the problems faced by research and other agencies in the seed business. The research institutes and other agencies servicing the seed sector are under-funded and this places a limit on how much they can do. Furthermore, manpower limitations, in terms of numbers and quality, are sometimes also a problem because of budgetary constraints.
- Private sector support is lacking or limited within the Ghana seed industry. Government most of the time shoulders all the finances of public sector seed value chain actors. Government finds it difficult to meet the total budgetary needs of the seed industry.
- Potential new entrants into agri-business often face production and technical constraints and many businesses give up before they see the light of day.

Future perspectives of the Ghana seed industry

The sky is the limit for the new Ghana seed industry. With the promulgation of the new seed law and the liberalization of the seed industry, it is expected that the much-needed private investments will be attracted along the entire value chain to help produce enough seeds for local consumption and also for export to countries within the sub-region and beyond. With a little reorganization and setting of priorities, it would not be out of place for Ghana to continue to play the leading role in the WCA seed industry. The Government of Ghana is also expected to give the right stimulus to the seed industry in terms of policies that would be favorable to new entrants into the seed business. The day is very near when Ghana will become the hub of the entire seed industry in WCA.

The Nigeria seed program (1990–2010): achievements, challenges, and future directions

13

History of the Nigerian seed industry

The use of improved quality crop seed cultivars for profitably rewarding experiences by farmers has been recognized as the most important strategy in boosting agricultural production. Improved quality seeds are not only the cheapest basic potential method for increasing yield, but also fundamental in raising the efficiency of other inputs, such as fertilizers and agro-chemicals. It has been estimated that over 50% of the improvement in agricultural production has come from the use of improved seeds. In essence, other agricultural practices, such as spacing, fertilizer application, irrigation, and weeding, cannot improve crop production beyond the limit set by seeds (Shobowale 2010).

Nigeria stands out probably as the major country in WCA where the private sector has emerged as the kingpin in the production and marketing of improved certified seeds throughout the country to help accelerate the attainment of food security.

In recognition of the importance of seeds in improving agricultural production and farm income, the Federal Government of Nigeria in 1975, through the Technical Assistance project provided by the Food and Agriculture Organization (FAO), put in place an organized seed program in the country. This culminated in the establishment of the National Seed Service (NSS) as a specialized Unit of the Federal Department of Agriculture (FDA) in the Federal Ministry of Agriculture to oversee the development of the emerging National Seed Program.

The Seed Program was further strengthened through three phases of FAO's Technical Assistance projects from 1975 to 1990 and a World Bank-Assisted National Seed and Quarantine Project (NSQP) from 1991 to 1997. The NSQP was to encourage greater private sector participation in the Nigerian seed industry. This was consistent with the primary goal of the NSS, which was aimed at developing and sustaining a reliable supply, at market prices, of high quality seeds of improved varieties that are well adapted to local agricultural conditions and capable of meeting demand, with the private sector in the driver's seat.

Prior to 1974, research into crops were confined to the then existing agricultural research institutes. These institutes were highly localized at that time within what was termed their catchment areas. With this arrangement, the Institute for Agricultural Research (IAR), ABU, Zaria, for example, focused on research suitable to the Northern Region; the Institute for

Agricultural Research and Training (IAR&T), Ibadan, conducted research relevant to the Western Region, and the National Root Crop Research Institute (NRCR1), Umudike, focused on the Eastern Region.

Objectives of the NSS

The main objective of the NSS was to coordinate all the seed activities of the different stakeholders in the industry within the country and also to create national awareness on the importance of improved seeds and the need for their utilization to help boost agricultural productivity. It was also to make findings from the various agricultural research institutes available to all parts of the country where such findings could be fully utilized to increase productivity.

Operational strategies of the NSS

At its onset in 1975, the NSS operated solely as a governmental agency responsible for all the major roles and value chain actors in the seed industry at that time. To achieve its objectives, the NSS worked in phases in the early days.

NSS Phase 1: Awareness creation

Phase 1 was used to create national awareness among scientists and farmers on the utilization of improved seeds as an engine to increase productivity. To achieve this, the main focus of the NSS at its inception included the following:

- Production and distribution of large quantities of improved seeds to farmers free of charge to create awareness and the advantages to be derived from their use.
- Regular consultations with all the agricultural research institutes to demonstrate the need to acquire and disseminate new technologies emanating from such institutes for the use of farmers across the country.
- Widespread training of personnel in the areas of seed science and technology.
- Extension of research findings from each institute to all parts of the country where such findings were considered appropriate.

NSS Phase 2: Foundation seed production

The second phase of the NSS (1981–1985) was used to provide essential technical back-stopping for all the seed value chain actors in the national program. As a result, Phase 2 was used to strengthen foundation seed production. The foundation seeds were to be collected from the Ibadan headquarters of the NSS by the Seed Multiplication Unit (SMU) of each State and used to produce certified seeds for distribution to farmers.

NSS Phase 3 (1987–1989): Seed certification and quality control

The third phase of the NSS Seed Project (1987–1989) was used to set up the National Seed Certification and Quality Control Unit with the responsibility for overseeing the quality of the emerging seed industry.

By the end of the third phase in 1989, the activities of the NSS in the country had two major components:

– National Seed Production, Processing, and Storage.
– National Seed Certification and Quality Control.

The private sector in the Nigerian seed industry

During the second phase of the NSS Seed Project, it became evident that public sector agencies alone could not meet the total requirements of Nigerian farmers for certified seeds. First, the arrangement of the NSS with the SMU to produce certified seeds was not effective. Most States, for one reason or another, either failed to collect the foundation seeds or did not collect in good time for planting to produce the certified seeds. Therefore, much of the foundation seed production was wasted through loss of viability since the seeds were not in conditioned storage. Secondly, during this phase, the Technical Committee of the Green Revolution Program of the Federal Government was strongly in favor of hybrid maize development for Nigeria. Under the Chairmanship of Chief (Dr) S.B. Aribisala, this Committee had, in 1982, recommended to the Federal Government that funds be provided to IITA to develop hybrids for Nigeria within three years. The hybrid development program was vigorously pursued by IITA in collaboration with national scientists. The Federal Ministry of Science and Technology (FMST) was, at that time, establishing and actively supporting the Nationally Coordinated Research Programs, one of which was the Nationally Coordinated Maize Research Program (NCMRP). During the first 1–2 years of the introduction of hybrids, all national agricultural extension agencies together conducted over 3000 mini-kit trials (now commonly referred to as on-farm trials) all over the country (Akinwumi and Adenola 1995). The agencies included the National Accelerated Food Production Project (NAFPP), Agricultural Development Projects (ADPs), and the National Agricultural Extension and Research Liaison Services (NAERLS). Hybrid demonstration plots were sited in farmers' fields, near farm market places, highways, and secondary schools, in university farms, home gardens, and other places where people showed interest. Results from the many studies were presented at the annual meetings of the NCMRP to which top government officials of the FMST were invited. The results strongly convinced the policymakers of the superiority of hybrids over OPVs and justified Government's investment in hybrid maize production.

However, the problem of how to produce hybrid maize seeds in commercial quantities stared all stakeholders in the face. This situation led to the encouragement of the private sector's participation in the Nigerian seed value chain activities. Therefore, *pari pasu* with the development of hybrids for Nigerian farmers between 1982 and 1985, the Federal Government set up a Committee to draft the National Seed Decree. Among other items in the terms of reference, the Committee was to make recommendations to the Federal Government on the type of hybrid to be released for farmers and the type of seed enterprise (private, public, or joint private-public) to be adopted nationwide. The country adopted private sector participation in the production of hybrid maize seeds in commercial quantities; the decision on the type of hybrid to be produced was left to the seed companies. From the foregoing, it is clear that hybrid maize seed production was the vehicle through which the private sector entered into the seed sector of Nigeria. The early entries of the private sector witnessed the establishment of major seed companies, such as the following:

– Ag-Seed Nigeria Ltd, Zaria
– Temperance Seed Nig. Ltd, Otta
– UAC Seed Nig. Ltd (an affiliate of PANNAR SEEDS of South Africa), Zaria)
– Pioneer Seed (a merger between Ag-Seed and Temperance Seed Nig. Ltd), Zaria)
– UTC Seed, Tenti, Jos

Challenges of the private sector and remedies

Majority of the new private seed companies collapsed after a short while due to large overheads and production costs and lack of technical know-how in organizing and managing seed businesses. To help overcome the challenges faced by these early private sector entrants, the Federal Government in 1990 secured a World Bank loan to help to develop the Nigerian seed industry and also to assist the private sector to "survive" in the industry. With this loan, the NSQP was implemented between 1991 and 1997. The foci of the NSQP were as follows:

– Encouragement of greater private sector participation in the seed industry with the establishment of a full component, the Seed Industry and Skill Development Unit, to take adequate care of their interests.
– Passage into law of an Agricultural Seeds Act to guide the operations of the seed industry.
– Re-orientation of the public sector seed pricing policy along commercial lines, initially with full cost recovery and later making profit for sustainability.
– Strengthening of the seed production, certification, and quality control of the existing national seed program.
– Establishment of a National Agricultural Seeds Council together with its subordinate Committees to act as apex bodies on seeds and related matters at the Federal level while State Seed Coordinating Committees were to act as apex bodies at the State levels.
– Support for the formation of viable seed associations in Nigeria to act as a pressure group for consultations with Government on seed matters.

With the appropriate environments created by this World Bank Project between 1991 and 1997, a number of new breed private seed companies sprang up. A national workshop was also held in 1992 to finalize the

Seeds Act and put in place a National Seed Development Plan, spanning 1991–2000. Other achievements of the World Bank project included the following.

– Extensive training of staff on the job in different areas of seed science and technology.
– Promulgation of the National Agricultural Seeds Decree No. 72 of 1992.
– Inauguration of the National Agricultural Seeds Council as the apex body to guide the operations of the seed industry (1992).
– Publication of several statutory documents to support the seed trade in Nigeria (2004).

Some of these statutory documents were as follows:

i. National Seed Rules and Regulations
ii. Nigerian Minimum Seed Certification Standards
iii. Seed Testing Manual
iv. Seed Processing and Storage Manual
v. Seed Certification Manual
vi. Seed Law Enforcement Manual

– Development of community-based seed production systems to complement the supply of good quality seeds to farmers in the rural areas where the existing seed companies did not have marketing outlets (1998).
– Establishment of a Seed Technology Center at the University of Agriculture, Makurdi, for the training of personnel at undergraduate and postgraduate levels (1994).

The National Seed Act

To help strengthen and consolidate the achievements of the Nigerian Seed Program, a National Agriculture Seed Act (Act 72 of 1992) was put into place to achieve the following:

- Provide a legal framework for regulating the various aspects of seed research, production, processing, marketing, and quality control activities in the country.
- Allow the establishment of a National Agricultural Seeds Council.
- Define the roles and responsibilities of the various stakeholders in the seed value chain in the national seed industry.

The regulations in the Seeds Act covered the following areas:

– Variety development
– Variety registration, release, and certification of seeds
– Seed quality control
– Seed law enforcement
– Seed planning, monitoring, and management.
– Seed production and marketing

- Institutional structure, giving broad outlines of the roles and responsibility of various stakeholders
- Seed imports and exports
- Seed promotion, seed extension, and capacity building

Strategies of the Nigerian seed industry

The seed policy in Nigeria was given a legal status with the enactment of the Agricultural Seed Decree No. 72 of 1992. The Decree established the National Agricultural Seed Council to promote and stimulate the development of a dependable seed industry, regulate and control the registration of released varieties, protect the farmers from the sale of poor quality seeds, facilitate the production and marketing of high quality seeds, and provide legal backing for official testing, certification, sales, importation, exportation, and use of seeds (FRN 1992).

The goal of Nigeria's agricultural policy was the attainment of self-sustaining growth in all subsectors as well as the realization of the structural transformation necessary for the socioeconomic development of the rural areas. The specific objectives of the policies in the agricultural sector included the following:

i. Self-sufficiency should be attained in basic food commodities with particular reference to those food commodities which consume a considerable share of Nigeria's foreign exchange and which can be produced within the country.
ii. Production of agricultural raw materials should be increased to meet the growing needs of an expanding industrial sector.
iii. Production and processing of export crops should be increased to improve their foreign exchange earning capacity and to diversify the country's export base and sources of foreign exchange.
iv. Agricultural production, processing, storage, and distribution should be modernized through the infusion of improved technology and management so that the sector could be more responsive to the demands of developments in the other sectors of the economy.
v. Increased rural employment opportunities should be created through improvements in infrastructural facilities so as to productively absorb an increasing labor force.
vi. The quality of life of rural dwellers should be improved through the provision of social amenities, such as potable water and improved health and educational facilities.
vii. Protection of agricultural land resources from drought, desert encroachment, soil erosion, and flooding should be improved (Kormawa et al. 2000).

The National Agricultural Seeds Council

The National Agricultural Seeds Council was established with the enactment of the National Agricultural Seeds Act and charged with the responsibility of ensuring the implementation of the seed policy guidelines and the monitoring and development of the national seed system.

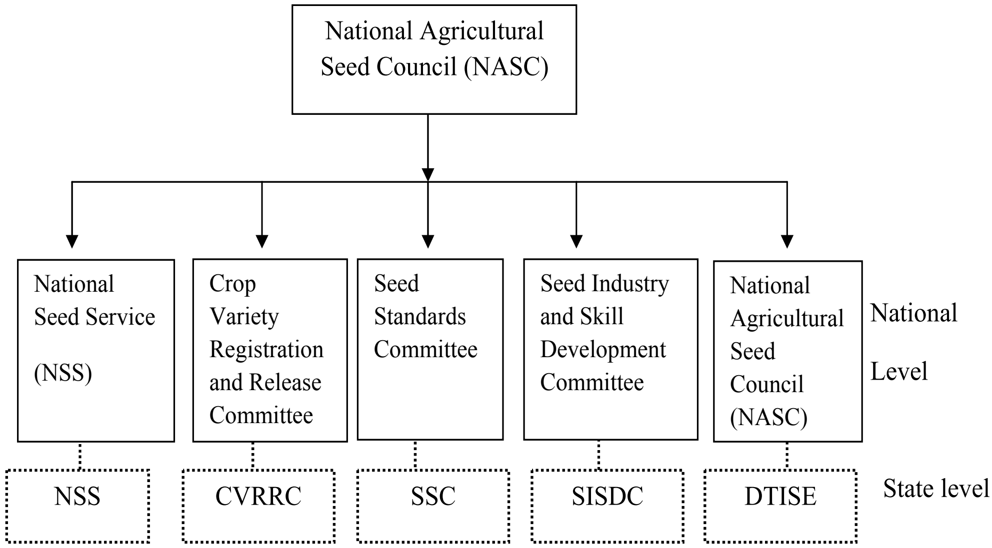


Figure 13.1: Organizational structure for the implementation of the National Agricultural Seed Policy in Nigeria.

Table 13.1. Operational zones and the secretariats of the National Agricultural Seed Council.

Zone (and Secretariat)	States covered
Central (Ilorin)	FCT Abuja, Benue, Kwara, Kogi, Niger
Northeast (Jos)	Adamawa, Bauchi, Borno, Plateau, Taraba, Yobe
Southeast (Umudike)	Abia, Akwa Ibom, Anambra, Cross River, Enugu, Imo, Ebonyi, Bayelsa, Rivers
Southwest (Ibadan)	Delta, Edo, Lagos, Ogun, Ondo, Ekiti, Osun, Oyo
Northwest (Zaria)	Jigawa, Kaduna, Kano, Katsina, Kebbi, Sokoto

Five bodies [the National Seed Service (NSS), the Crop Variety Registration and Release Committee (CVRRC), the Seeds Standards Committee (SSC), the Seed Industry and Skills Development Committee (SISDC), and the Department of Training, Information, and Seed Extension (DTISE)] were also established to work for the Council in facilitating the development of the seed industry.

At the State level, the functions of the various implementing bodies at the national level are performed by the States' Seed Coordinating Committees. These Committees are in existence in some States under the chairmanship of the Commissioners of Agriculture, with the Program Managers of the ADPs as Secretary. Each body or unit is responsible to the Council on matters pertaining to its mandate. Figure 13.1 and Table 13.1 show the organizational structures for the implementation of the National Agricultural Seed Policy.

The Council has five operating zones and five zonal secretariats (Table 13.1). By this arrangement the Council's presence would be felt in all the

Table 13.2. The different agricultural research institutes with their crop development focus and mandate crops.

No.	Institute	Mandate crop
1.	Institute for Agricultural Research, IAR, Samaru	Maize, cowpea, sorghum, cotton, groundnut, sunflower, jatropha, artemisia, castor
2.	National Cereals Research Institute, Badeggi	Rice, beniseed, castor oil, soybean, sugarcane
3.	Institute for Agricultural Research and Training, Ibadan	Kenaf, maize, jute
4.	National Institute for Horticultural Research and Training, Ibadan	Vegetables and horticultural crop seedlings
5.	Lake Chad Research Institute, Maiduguri	Wheat, barley, millet
6.	National Root Crops Research Institute, Umudike	Yam, potato, ginger, cocoyam, cassava

States of the Federation and Abuja and the Council would, among other duties, readily monitor the seed development activities in the States. Hence, the organizational structure is appropriate for effective performance. The various institutions involved in the national seed systems and their roles and actions are presented in Fig. 13.2.

Current implementation structure of the Nigerian seed industry

Seed production and multiplication involves the multiplication of the breeder seeds into commercial or certified seeds that are then distributed to the farmers. There are three broad classes of seeds that are recognized for seed production.

Breeder seeds are the seeds of a newly developed variety that are produced under the supervision of the plant breeder.

Foundation seeds are the progeny of the breeder seeds and consist of the generations of seeds between breeder and commercial seeds.

Commercial or certified seeds are the seeds that are produced and sold to the farmer.

The seed production chain

Four groups of agencies are involved in the seed industry. These are the crop research institutes and the universities, the NSS, the ADPs' Seed Multiplication Units/Contract Seed Growers, and the private seed companies.

Seed research and breeder seed production

Nigeria has six national (Table 13.2) and three international research institutes (IITA, ICRISAT, and Africa Rice), that are directly involved with seed production. Activities of the NARS were initially co-coordinated by FMST. However, these have now been transferred to the Ministry of Agriculture and Rural Development.

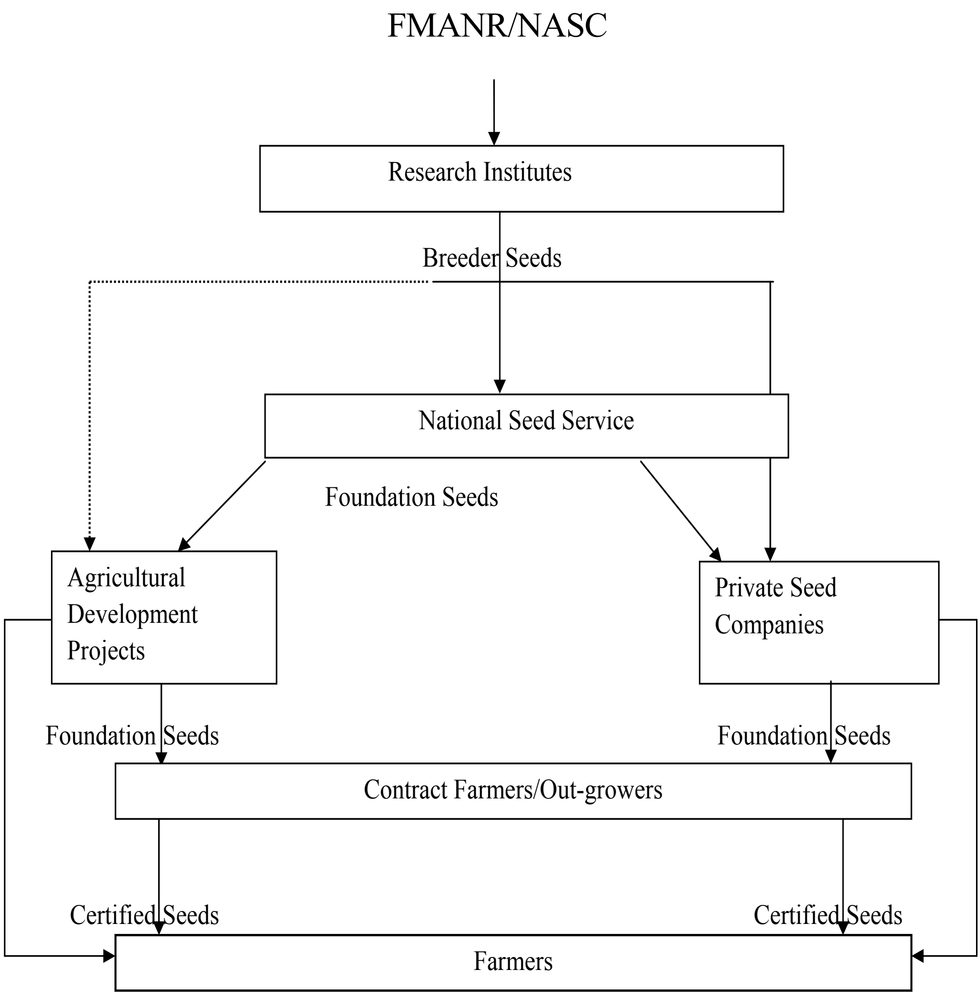


Figure 13.2. Production and distribution channels of improved seeds in Nigeria.

The research institutes/universities undertake plant breeding and breeder seed production and have contributed to the development of high yielding varieties of hybrid maize, rice, cowpea, and soybean.

Foundation and certified seed production

Breeder seeds from the research institutes are passed on to the NSS for foundation seed production. The NSS provides foundation seeds to the ADPs and private seed companies (NSS 2000). Both the ADPs and the private seed companies produce certified seeds, from their own farms or through contract farmers/out-growers, or both. The implementation structure is appropriate for effective performance as it not only ensures linkages between research institutes and NSS units, but also provides the farmers with alternative sources of certified seeds.

Constraints of the Nigerian seed program

The Nigerian seed program has a fair share of constraints militating against the efficient running of the program. Among these are the following:

- Low production of breeder seeds: Breeder seed production involves long-term research, inputs, skill and expertise, materials, and equipment. The inadequate funding of the research institutes and the NSS makes it difficult for them to engage effectively in varietal development and evaluation on a more regular basis. The output of the research institutes is thus far below what is required to meet the growing requirement for improved seeds and seed technology. Not only are the funds inadequate, they are usually disbursed late, resulting in distortions in the breeding process. Acquisition of the necessary materials and equipment has been a problem and staff working with such inputs end up demoralized after much delay.

- Poor seed certification and quality control arrangements: The laboratories required for seed testing, seed certification, and quality control are not adequate, and those available are poorly equipped. The central seed laboratory at the NSS headquarters is yet to be properly equipped and put into use. The numbers of trained staff to conduct the exercise in many localities are inadequate. As a result, there have been cases of unlabelled seeds being sold in markets and stores, and many farmers have had the misfortune of buying adulterated seeds.

- Poor seed distribution arrangement: Improved seeds produced by the public sector are often sold to the farmers through farmers' supply companies, agro-service centers, ADPs, cooperative societies, etc. Presently, some of these centers are not working in some States, with the result that farmers in such areas now get seeds mostly from private seed companies (if any) and from seed traders/dealers in the open market. Such farmers pay exorbitant prices and also run greater risks of buying unviable seeds due to poor storage and handling by the seed traders.

- Reduced activity of the NSS: The NSS has a pivotal role to play in the development of the nation's seed industry, including the production of foundation seeds, supervision, monitoring, and quality control. While the NSS has a cader of experts, activities have been slowed or hampered by inadequate and delayed funding for the performance of quality control functions and research support services. It has been reported before that many of these activities are no longer performed effectively. The NSS, for instance, has not been able to produce adequate quantities of foundation seeds from the breeder seeds received from the research institutions due to the inadequate number of trained personnel in the field. Insufficient resources for training and technical assistance to contract growers have constrained the development of the seed market. Although the Unit has representations at the Regional and State levels, its activities especially in terms of quality control and seed certification have been drastically reduced due to inadequate numbers of trained staff and financial constraints. These have resulted in low output, and hence an inadequate supply of certified seeds to the farmers and adulterated and unlabeled seeds on the market.

- Lack of resources for training and the dissemination of information: The Units charged with training and manpower to handle the technical aspects of the seed industry are constrained by inadequate finance, equipment, and logistics. Staff training has been stalled; hence there is lack of staff to assist in seed testing, quality control, and in providing technical assistance to contract growers. Information on the seed industry, especially about the availability of seeds of improved varieties, is not readily disseminated to the farmers since extension agents are inadequate.

- Poor seed distribution networks and rural infrastructure: Most rural areas are inaccessible due largely to the poor nature of the roads. This has hindered the movement and performance of staff whose activities are required in the rural communities. The supply of seeds of improved varieties in such rural areas is also affected. Hence, farmers in these communities have been deprived of the benefits of improved technology. One of the consequences of the poor rural road system is the high cost of input delivery. The few dealers who find their ways into such rural areas often exploit the farmers by charging high prices for their stock. The NSS has put in place the Community Seed Development Program with the objective of diffusing the seeds of improved varieties into rural communities. However, this scheme is not yet available nationwide (Kormawa et al. 2000)

Prospects for the Nigerian seed program

The current Nigerian national seed policy and program are in line with regional and international standards, and make provision for the withdrawal of public sector agencies in favor of the private sector in key areas of the seed industry over time. The private sector has the potential to supply inputs efficiently and cost effectively.

The development of private seed companies is vital to the Nigerian seed industry because of their reliability, sustainability, cost-effectiveness, responsiveness to farmers' needs, greater commitment to quality, and generation of employment (Joshua 1997). The private seed sector from all indications is a better partner for the production of improved certified seeds and their distribution to farmers. A conducive macro-policy environment, improved access to finance, a developed and implemented regulatory framework, the timely release of improved varieties, as well as improved human capital for market development are required.

With this approach to the development of the seed industry, Nigeria has the hope of a brighter future in seed production and will soon have improved certified seeds available in all corners and locations of the country for the benefit of farmers and the assurance of food security.

Variety releases in Nigeria

The Institute for Agricultural Research (IAR) of the Ahmadu Bello University, Samaru, and the Institute for Agricultural Research and Training (IAR &T), Moore Plantation, Ibadan, have the national mandate for maize research in Nigeria. In addition to the two institutions, the University of Maiduguri, the University of Ilorin, Obafemi Awolowo University, Ile-Ife, and the seed companies, such as the Premier Seed Company, are also involved in maize research and development. Nationally coordinated trials are conducted annually throughout the country and are a major vehicle for testing maize varieties in multi-location trials and identifying promising varieties for release. In addition to the nationally coordinated trials, varieties for release are tested on-farm for at least 2 years before release. Apart from the yield and agronomic data required for varietal release, data on consumers' preferences and from physicochemical analysis are also required for the release of varieties. A maize breeder in a public research institute or a private seed company has to go through a number of steps (Fig 13.3) to get a new variety released and registered by the National Crop Varieties and Livestock Breeds Registration and Release Committee (NCVLBRRC). The maize breeder, with the approval of the research institute where the variety is developed, submits the variety to the relevant Nationally Coordinated Research Project (NCRP) for researcher-managed, nationwide, multi-location on–station trials in the appropriate agroecologies. After the first year of these trials, if the variety significantly out-yields the commercial variety used as a check, it is submitted to the appropriate National Crop Center for multi-location on-farm trials which may run concurrently with the second year of the on-station trials to confirm the results of the first-year trials. If there is an urgent need for the release of a variety, the first-year NCRP multi-location trials may run concurrently with the on-farm testing of the variety slated for release. If the performance of the variety in the 2 years of NCRP on-station and 1 year on-farm multi-location trials is outstanding for the relevant traits, including yield and farmers' preference, the institution of the breeder in consultation with the National Coordinator of the NCRP of the crop may apply to the Registrar of NCVLBRRC for consideration of the release and registration of the new variety. The breeder then completes the relevant format with the general and specific descriptors of the variety and submits it with comprehensive data from NCRP on-station and Crop Center and/ or on-farm trials to the Registrar not later than 2 weeks before the meeting of the Technical Subcommittee (TSC) Crops and the NCVLBRRC scheduled to consider the application for the release and registration of the variety. The breeder of the variety under consideration for release has to bring a prescribed quantity of seeds of the variety for the national genebank and also to make provision for an adequate quantity of breeder seeds to be supplied to the National Agricultural Seed Council for foundation seed production.

The NCVLBRRC comprises the Chairman, appointed by the President of Nigeria, the Director of Agricultural Sciences, FMST, the Director, Federal Department of Agriculture and Rural Development, the Head of the Genetic Resources Unit, FMST, the Director, NSS, the Chairman, Committee of Deans

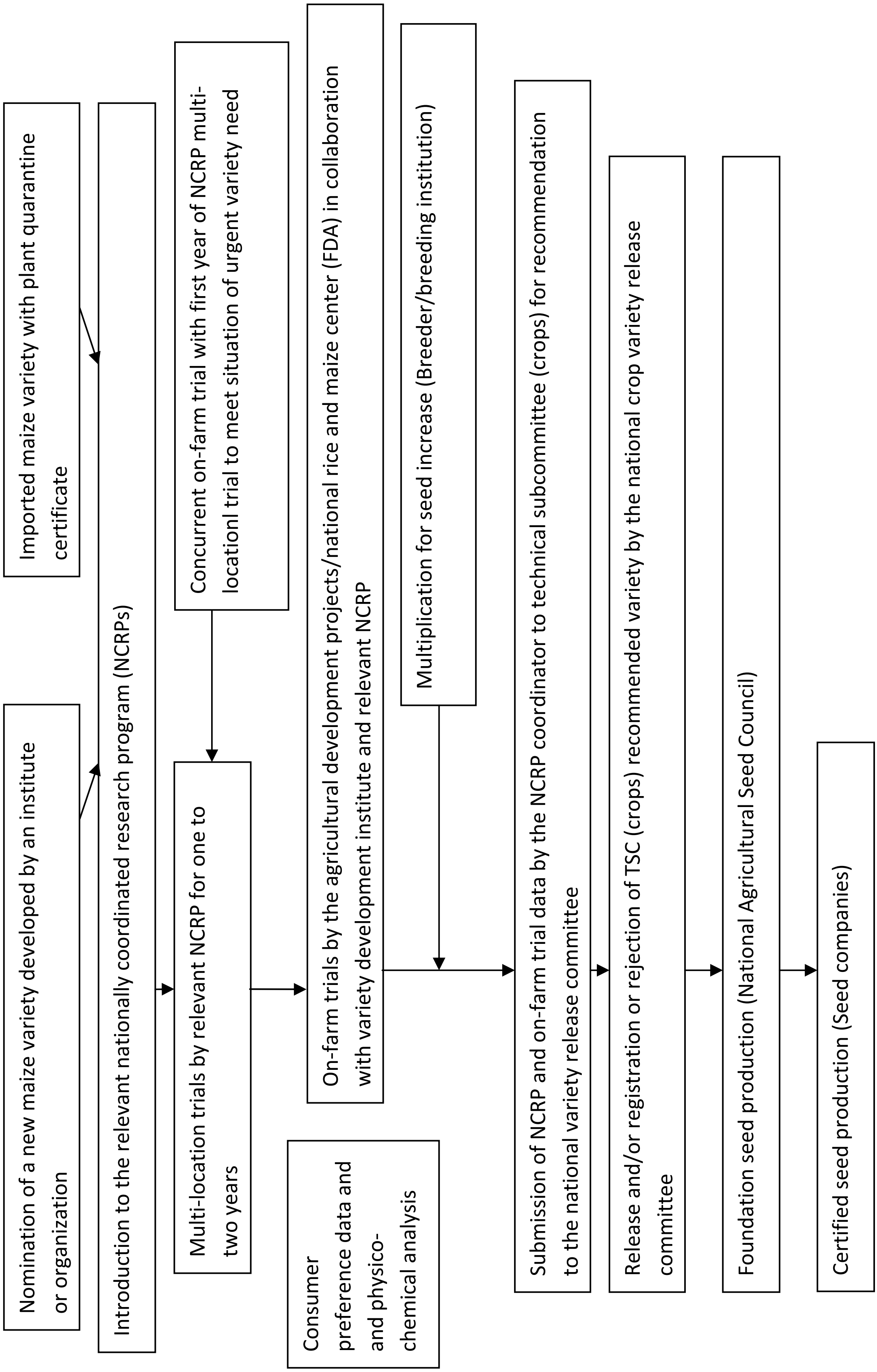


Figure 13.3. Variety release channels in Nigeria.

of the Faculties of Agriculture in Nigerian Universities, the President, Genetic Society of Nigeria, a representative of the Federal Agricultural Coordinating Unit, two experienced breeders appointed on their personal merit by the Minister, two General Managers representing two River Basin Development Authorities from different ecological areas in rotation appointed by the Minister. The Committee is expected to meet annually but because of fund limitations the meetings are not regular. Following the release of a variety, it is entered in the National Variety Release Catalog. The rate of release of new maize varieties has been grossly irregular. For example, some maize varieties were released in 2005 and no other releases were made until 2010, due to lack of funds to facilitate the meeting of the release committee.

Maize seed business management in WCA 14

The seed business is a rapidly emerging form of entrepreneurship in Africa. The sector in Africa has seen the rise and at times the demise of national and international seed companies, parastatal seed industries, and community-based seed schemes. But there has been a class of entrepreneurs who have maintained and grown seed businesses that have largely been built around maize seeds, particularly in those countries where the agricultural sector is vibrant and commercially oriented. In recent years there has been a surge of entrepreneurs entering the seed sector all over Africa, as they have recognized a market opportunity in supplying farmers with quality seeds of improved varieties. This has been stimulated by a number of factors, such as the increase in seed distribution schemes by Governments and NGOs, the activities of agencies that have worked at encouraging seed sector development, and economic forces that have highlighted opportunities in crop production and hence in seed provision. The businesses of these new seed entrepreneurs range in size, area of operation, and products (MacRobert 2009).

WCA has its own share of the current boom of emergent entrepreneurs of every size and nature in the seed business. . All manner of people are leaving their jobs and trades to enter into maize seed production and marketing by taking advantage of the enabling environment in the business created by the Governments, international and local research institutes with the availability of the numerous improved maize varieties and hybrids that have been released during the last few years in the sub-region.

Despite the interest generated in the production, marketing, and distribution of maize seeds across the sub-region, many of the new entrants face insurmountable constraints when they enter the production and marketing business and therefore many fold up within a short time when they cannot survive the challenges.

Barriers to new entrants into the seed business

- Maize seed production, marketing, and distribution in WCA over the past years have been dominated mainly by public sector institutions or parastatals with very limited private sector participation until recently. The private sector continues to face a number of insurmountable constraints whenever they venture into the seed production and trade business. Tahirou et al. (2009) reported that new entrants, especially the emerging small private companies, face the following barriers (Table 14.1, 14.2; Figures. 14.1, 14.2)
- Production constraints.
- Unfavorable seed policy environment.
- Organizational establishment limitations.
- Marketing constraints.
- Demand side challenges.

Table 14.1. Constraints to seed production identified in a survey in four West African countries.

Constraints	West Africa (n=39)	Bénin (n=4)	Nigeria (n=15)	Ghana (n=14)	Mali (n=6)
Production constraints	46.7	66.7	43	43.8	33.3
Organizational establishment	7.8	0	31	0	0
Seed policy environment	20.0	33.3	12	12.5	22.2
Demand-side challenges	7.9	0	3	6.3	22.2
Marketing constraints	17.7	0	11	37.5	22.2

Source: DTMA seed sector survey, 2007 and 2008.
(n = number of seed companies interviewed in respective countries.)

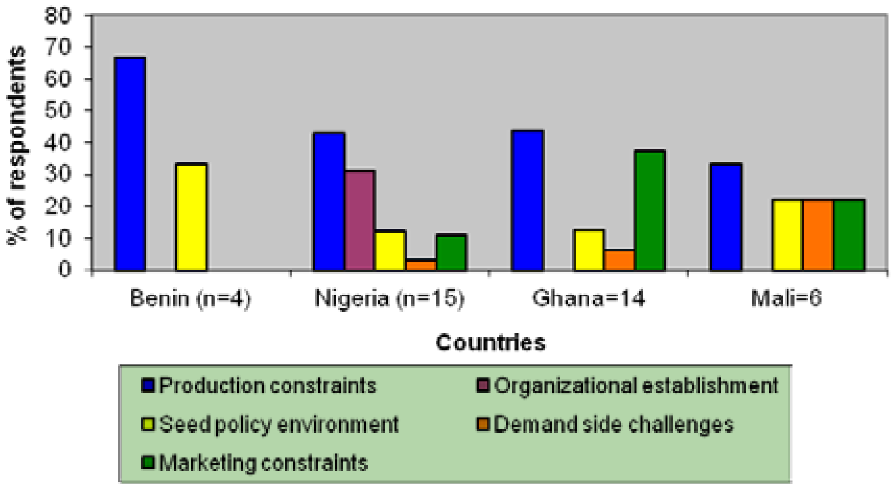


Figure 14.1. Constraints to seed deployment in four selected West African countries (Tahirou et al. 2009) (n = number of seed companies interviewed in respective countries).

- Competition from existing larger companies and public-based seed production entities.
- Lack of access to production credit and other credit facilities.
- Lack of access to seed production technology and infrastructure.

Problems affecting the establishment of seed production businesses in WCA

New seed production businesses are usually bedeviled with many problems at their initial stages. Major barriers to new entrants include the listed factors as demonstrated in a study done by IITA and shown in Table 14.2, with seed companies in four West African countries.

Decisions to be made before entering the maize seed business

It is not uncommon for many people in WCA to enter into a business venture with very limited knowledge and information about what it entails or even what the business stands for. Most people enter because they have seen a brother, friend, or neighbor successful in that kind of business. The purpose of entering into the maize seed business is to produce good quality seeds for

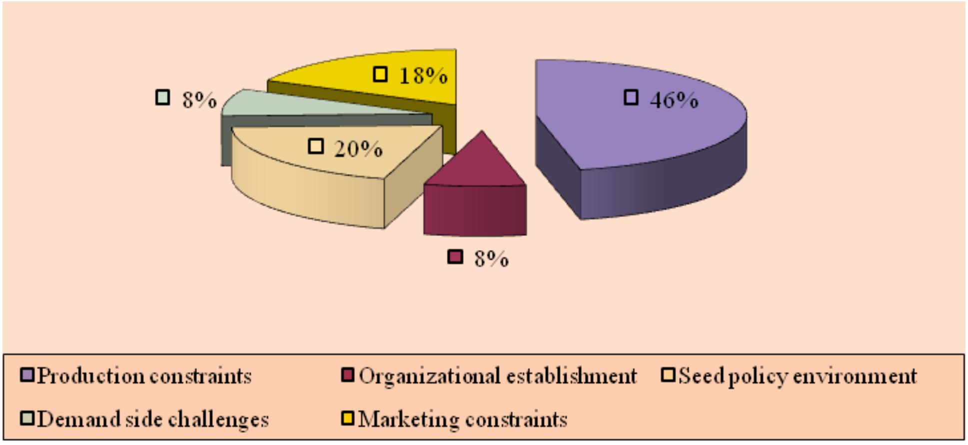


Figure 14.2. Constraints to seed deployment in West Africa.

Table 14.2. Main barriers to new entrants into the seed business in WCA.

Barriers	West Africa (N=39)	Nigeria (N=15)	Bénin (N=4)	Ghana (N=14)	Mali N=6)
Competition with larger companies	2.3	1.9	–	4.2	–
Seed marketing problems	10.2	9.6	–	12.5	11.1
Lack of access to seed production technology and infrastructure	10.2	9.6	33.3	8.3	11.1
Lack of access to production credit and other credit facilities	12.7	17.3	–	–	22.2
Unfavorable seed policy environment	5.7	9.6	–	–	–
Low adoption rate by farmers	2.3	3.8	–	–	–
Lack of access to suitable germplasm	6.8	7.7		4.2	11.1
Poor quality germplasm	2.3	1.9	33.3	–	–
Long payback period to investment	2.3	3.8	–	–	–
Lack of qualified manpower	5.7	9.6	–	–	–
Unfavorable climatic conditions	5.7	9.6	–	–	–
High initial investment outlay	14.8	11.5	–	29.2	–
Bureaucratic constraints (e.g., delay in the processing of application documents for registration of a new seed company)	1.1	–	33.3	–	–
Problem of land/land tenure policy	3.4	1.9	–	8.3	–
Isolation problems	1.1	–	–	4.2	–
Problem of infrastructure (e.g., irrigation facilities, etc.)	1.1	–	–	4.2	–
Lack of sustainable market	1.1	1.9	–	–	–
Licensing process and requirements are too difficult to satisfy	6.8	–	–	16.7	22.2
No reliable supply of good seeds	1.1	–	–	4.2	–
Lack of access to extension services	1.1	–	–	4.2	–
Restrictive subregional seed sector regulations	1.1	–	–	–	11.1
Required tax payments (e.g., VAT, etc.)	1.1	–	–	–	11.1
Total (%)	100	100	100	100	100

Source: IITA surveys, 2007 and 2008.
N = Number of respondents in member countries.

sale to farmers and also to make a living from providing this service. Another purpose is to make a profit out of the business. There is therefore the need to look at the business as a money making enterprise before venturing into it.

To survive under the enormous constraints existing in the seed market even before one makes an entrance there is the need to prepare very well and also to be familiar with the seed business terrain. Critical questions that demand personal answers must be asked before entering the seed business.

- Do I have a purpose for entering the maize seed business?
- Am I going in, full-time or part-time?
- Can I make enough profit to survive in the business?
- Can I produce and market good quality seeds that would meet the needs of farmers?
- How much do I know about the dynamics of the business before entering?
- Do I know the popular and most desirable maize varieties?
- Do I have the requisite capacity in terms of knowledge about the business?
- Would I be in the business alone or in partnership with others?
- If I would partner others, do I know enough to venture into a joint business with them?
- Do I have all I need to succeed in the business?
- Do I have the infrastructure needed for succeeding in the business?

Planning maize seed business
When all the questions have had favorable answers, planning for the business begins.

During the planning time, the vision of the business is set on its future focus. Also defined are the strategies to be adopted to achieve the set vision and finally the operational tactics through which the business would survive.

Vision, strategy and tactics
The success of a business depends on a compelling and clearly articulated vision, well-conceived strategic plans, and implementable tactical decisions on a day-to-day basis to move the company towards the vision. The vision statement of the business specifies what the company intends to achieve in the short as well as the long term. It sets the future focus of the organization and acts as a guide for all the company's activities. Without a vision, a company will fail. Therefore, to have a clear direction, coordinated activity, and motivated staff, every business must establish and communicate its vision (MacRobert 2009).

Mission or strategic planning

The mission of the business is the next step that must be defined. It is the strategic planning of the company aimed at creating the organization's future, based on what this is likely to look like, and is oriented towards the anticipated future. The mission also creates a framework for achieving competitive advantage by thoroughly analyzing the organization, its internal and external environment and potential. The strategic plan will also define the targets and measures that will be used to analyze progress towards the vision. In the case of seed business management, three strategic pillars are recognized as supporting the vision:

- The marketing strategy
- The production strategy
- The financial strategy

The three together constitute the mission or the way the business will be formulated and managed to support and reach the vision.

Starting a new seed enterprise
Before starting a new seed enterprise, the intending entrant must examine in great detail the opportunities and costs of doing business to determine if the enterprise can be successful.

- Begin with a detailed market survey;.
- Plan the operations, equipment, etc., required to produce and sell the planned products.
- Convert the planned operations into projected costs and income.
- Think about the different numbers of personnel, their various types of expertise and their specialties needed to help you to succeed.
- Plan when it is good to begin and chart the course that the different activities would follow.

Financial arrangements and strategy
The critical task is to assess financial needs and arrange the required finance. Estimate in detail the fixed and variable costs and all recurring expenses. The enterprise will fail if it lacks adequate financing. The proposed capital structure must be adequate and accurately outlined.

After operations are decided, policies are formulated, and plans for layout and equipment purchase are finalized. It is possible to compute the costs of land, machinery, buildings, equipment, staff, labor, inventories, and other expenses. The financial requirements of an enterprise are estimated by determining the amount needed for fixed capital, working capital, and the costs of organizing and promoting the enterprise. Immediate requirements plus estimates of financial needs for future operations and/or expansion constitute the bulk of funding which must be raised to start an enterprise which has financial stability and good chances of success.

Fixed capital requirements include costs of land, building, plant, equipment and other basic assets. Working capital includes the funds required for day-to-day operations, such as costs of inventory, wages and salaries, overheads, maintenance, fuel, power, services, taxes, insurance, promotion of sales (such as advertising), credit facilities, guarantees, after-sales services, etc. Financial arrangements should also include estimates of preparatory expenses and losses, if these will be incurred. After the total necessary investments have been calculated and sales forecasts made, these data are used to calculate the expected amount and rate of profit. After calculating total requirements for funds, decide how to raise these funds.

Funds can come from the personal assets of the investor or his family, from partners and/or friends, or from loans. Funds can also be raised by issuing securities, such as equity and preference shares or debentures. Promoters of large enterprises sell securities directly to investors through investment bankers, or underwriters.

General procedures for financing a new enterprise
Determine immediate and future financial needs.

- Determine how much of your own funds can be invested, and how much must come from other sources.
- Determine where you can best obtain outside funds. Classify the securities to be issued, if any.
- Acquire the funds required, from sale of securities, personal or family funds, loans, etc.

Record keeping in a seed business

One of the hallmarks of a successful enterprise is the keeping and maintenance of records of all transactions and activities. This all-important requirement is very often neglected or partially done. The accurate keeping of records enables the manager to keep track of all actions carried out and this often helps to check on those that are not being done. The seed enterprise manager should adopt the use of different notebooks and ledgers clearly labeled and dated as often as is necessary to show what has been planned by time and cost, what has been done, and what needs to be done.

Records should be kept on issues such as the following.

- Infrastructure
- Equipment
- Farmlands and other operational sites
- Supplies
- Machinery
- Vehicles
- Parent seed materials
- Production
- Distribution outlets
- Sales
- Full-time employees
- Casual labor as and when it is necessary.

Ledgers should be kept in all cases and daily transactions should be recorded as they occur.

Where necessary, a member of staff should be employed to manage the accounts of the business on a full-time or part-time basis. Samples of record-keeping charts that should be used to keep track of actions taking place in the seed business from time to time are shown in Tables 14.3 to 14.6 (Gregg et al. 2011)

Table 14.3. Keeping track of capital costs in a seed business.

Estimated capital costs

No.	Item and sub-item description	Cost of sub-item	Total item cost
I	Advance expenditures:		
1	Survey of sources of seeds and sales products		
2	Technical/market/economic survey		
3	Operations/plan formulation costs		
	Total advance expenditures		
II	Land:		
1	Cost of land		
2	Cost of site preparation		
	Total costs of land		
III	Building and civil works:		
1	Cost of operating premises		
2	Cost of administrative buildings		
3	Cost of ancillary buildings (warehouse, etc.)		
4	Cost of residential buildings		
5	Cost of civil amenities		
6	Cost of services and other civil works		
	Total building costs		
IV	Seed conditioning and other equipment:		
1	Cost of imported plant and machinery		
2	Cost of spares and parts		
3	Duties and taxes		
4	Cost of indigenous plant and machinery		
5	Cost of spares and parts		
6	Freight and insurance		
7	Local and import taxes and duties		
8	Installation costs		
9	Erection charges		
	Total plant and machinery costs		
V	Invisible expenses:		
1	Costs of patents, technical know-how		
2	Consultants' fees, etc., for services		
	Total invisible expenses		
VI	Special items not listed above:		
1	Registration fees		
2	Pre-operation interest charges		
3	Other special items		
	Total special items costs		
VII	Standing resource requirements costs		
1	Overhead		
2	Other		
	Total standing resource requirement cost		
VIII	Provision for inflation:		
1	Land		
2	Building		
3	Plant and machinery		
4	Ancillary assets		
	Total provision for inflation		
IX	Provision for contingencies and unforeseen:		
1			
	@ _____% of items I – VIII above		
	Total estimated capital costs		

Table 14.4. Keeping track of operational costs in a seed business.

Estimated operating costs

No.	Cost category	1st Year	2nd Year	3rd Year
1	Purchase and production of sale products			
2	Operating labor			
3	Supervision			
4	Energy			
5	Maintenance			
6	Sales and advertising cost			
	Administration and management costs			
	Royalty and know-how costs			
9	Insurance costs			
10	Depreciation costs			
11	Interest charges			
12	Incidental expenses			
	Total operating costs			

Table 14.5. Keeping track of seed production costs in a seed business.

Estimated seed production costs

Cost item	Estimated cost/t/kg for the crop			
Fixed costs:				
Vehicles				
Staff salaries				
Travel expenses				
Depreciation				
Electricity				
Insurance				
Repair/maintenance				
Overhead				
Sub-total				
Variable costs:				
Grower payment				
Stock (parent) seeds				
Labor				
Maintaining isolation				
Roguing				
Detasseling/emasculating/pollinating				
Fertilizer				
Insecticides				
Cultivation/weed control				
Herbicides				
Other seed field expenses (list)				
Harvest (and male removal in hybrids)				
Bags				
Seed transport and shipping				
Drying				
Storage and handling				
Conditioning/treating				
Cert./analysis tags				
Testing				
Other (list)				
Sub-total				
Total cost/t				
Cost/kg or sales unit				

Table 14.6. Keeping track of indirect costs in a seed production business. Estimated indirect costs.

Item	Amount in:												
	J	F	M	A	M	J	J	A	S	O	N	D	Total
Advertising and promotion													
Delivery and sales costs													
Salaries and wages													
Rent, buildings and facilities													
Utilities													
Interest on debt													
Travel and entertainment													
Bad debts													
Administrative, legal, accounting													
Other costs													
Totals													

Suggested practical guides for a successful seed business in WCA.

Appropriate product portfolio for farmers: A seed company must ensure a crop and product portfolio as a key component of their market development strategy. A vibrant seed industry is dependent on the constant registration and release of new varieties/hybrids. At the early stages, the new entrant into the seed industry must depend on the NARS and CGIAR centers in the subregion (IITA and CIMMYT) for the initial supply of germplasm but the seed company must nonetheless ensure that such genetic materials are either suitable for or adapted to the needs of their target farmers. In the case of public germplasm from the CGIAR, access to the genetic materials may be either directly as a finished product or as source germplasm for the future proprietary breeding programs of the company.

Productive seed grower base*:* Maize seed production requires motivated and competent seed growers who can meet the isolation requirements and production standards for seed certification and satisfy the expectations of the company. Entrepreneurial considerations for selecting seed growers should include the following.

- Large farm to enable required isolation
- Large field sizes (5–20 ha)
- High and reliable seed yields
- Capability for crop management with the availability of an adequate labor force
- Opportunity for irrigation and/or off-season planting
- Proximity to good roads and seed processing facilities

These considerations will lead to a reduction of the costs of training the growers, seed inspection, and transportation, and eventually the total cost of producing seeds which in turn will lower the seed price. There will also be a guarantee of the consistent production of high quality seeds with lower risk of contamination and fewer contractual disagreements.

Distribution network for marketing products: African farmers are widely dispersed and distant from the towns and cities where seed companies often desire to be located. Therefore, to be successful in reaching farmers who will buy the seeds, there has to be a strategic and reliable network by which farmers' access to seed is assured.

Comply with national/regional seed regulations, seed quality standards and market possibilities: There is a harmonized seed regulation for West Africa which is expected to facilitate the concurrent registration of crop varieties in all the ECOWAS countries. This implies that the seeds of a variety produced in one country could be marketed in another if all seed quality standards specified in the operating harmonized seed regulations have been adhered to. At the national level, regulatory bodies are put in place to enforce the standards set by the Government and will not hesitate to destroy seeds that fail to meet the standards and sanction the company producing such seeds. This is not only a waste of resources on the part of the company but also a dent on its image from which it may take a long time to recover.

Farm productivity influences seed demand: Seed purchase is justified only where yield levels are high or the seed:grain price ratio is low. Low yield of crops coupled with non-availability of complementary inputs, such as agro-chemicals and fertilizers, make the price of seeds a significant proportion of the value of the grain harvest. An increase in farmers' productivity is likely to favor a rapid development of the seed sector. To build trust and credibility among farmers, the company must ensure that only seeds of high quality, with high-yield potential, are sold to farmers.

Functional value-added benefits underpin seed market growth: In addition to the seeds sold to farmers, side benefits such as free consultation, information on time of planting, spacing, and fertilizer recommendations, advice on types and sources, of fertilizer and rates of use, pest control services, grain market information, etc., will facilitate the consumers' attachment to the seed company and fast-track market growth. The new company should consider putting at least some of these services in place right from inception.

Give serious consideration to seed marketing: Seed marketing is all of the following:

i. a continuous and systematic determination of consumers' needs;
ii. the accumulation of the seeds and services to satisfy these needs;
iii. the communication of information to potential consumers about the seeds and services available, and feedback from the consumers concerning the results of having used the seeds and services; and
iv. the distribution of seeds to the farmers.

In marketing seeds, the best approach is the marketing concept and not the product or selling concepts. This implies that the main objective of seed marketing should be to satisfy farmers' demand for seeds. The user-farmer rather than the product (seeds) is the focal point. To plan an effective seed marketing strategy, the following four questions must be asked.

i. What does the farmer want to buy?- **objects** of purchase
ii. Why? –**objectives** of purchase
iii. Who buys? – **organizational** context
iv. How?- **buying** operation

The objects of our concern are maize seeds of different varieties in varying package sizes. The objectives of the buyer may vary. However, the buyer wants to satisfy a need which is formed through learning, social, and economic factors. The organizational context of buying is usually the family, where various members have different roles in initiating, deciding, buying, and using seeds. The buying operation is the process by which the farmer first gets the idea of purchasing seeds. He must collect information, evaluate the information, and then decide whether or not to buy the seeds.

The perceived demand and the real demand are not the same. Farmers might need to purchase seeds but may not have the financial resources. Through market research, a realistic set of goals or sales estimates called *market demand* or real demand will be established. Market demand is the total volume of a product class which will be bought by farmers using specific technology in a defined location within a specified time period and with a certain marketing effort. *Seed demand forecast* provides figures for the volume of each crop variety to be sold of a particular quantity and package size and indicates the time of arrival of each quantity of seeds at the depot or sales outlet. To arrive at these figures, information has to be collected and analyzed. Forecasting market demand is based on (i) What people say – verbal or written survey of what people say they will buy in terms of seeds; (ii) What people do – determination of buyers' reaction, that is, container size, type, and seed treatment; (iii) What people have done – historical data – the most widely used method for an established program. *Supply of seeds* is an aspect of marketing through which the estimated demand is met. Sources of seeds for marketing are as follows.

a. The marketing organization produces the seeds on its own land or by employing contract growers. This will require advanced production planning.
b. The marketing organization purchases seeds from other organizations, seed growers not under contract, other seed enterprises, imports, etc.

In addition to ensuring the supply of seeds of improved and adapted high quality varieties to meet the demand, a company needs a marketing strategy which is concerned primarily with meeting the need for the product and being highly competitive in the seed market. Embedded in the idea of the product are not the seeds alone but also the tangible and intangible aspects, such as the genetic potential of the variety, the quality of the seeds, packaging, and other associated services. Two main components of marketing strategy are matching the consumer and the product by bridging the gaps between the business and the customer – the spatial gap, time gap, information gap, and value gap – and understanding and competing with market rivals. Seed companies face competition from farm-saved seeds as well as from growth in the number of seed companies in Africa, the so-called inter-company competition

Strategize to continually develop new products: To be successful on a sustainable basis, the seed company needs to develop and implement a strategy to continually identify and register new products to meet the demand for improved, adapted, and appropriate varieties. There are dynamic public and private breeding programs through which new maize varieties are being produced. Nevertheless, a successful seed company will require at least some kind of variety evaluation and registration of a proprietary identity for the variety. As part of this strategy, the company must gradually put in place a research division that may start by conducting variety trials sent out by NARS, IITA, and CIMMYT annually. The company's breeders could identify suitable varieties for their clients from such trials. Eventually, the company would be strong enough to conduct its own research and develop its own proprietary varieties and hybrids.

Employ a strong and reliable seed production team: A business cannot rise above the capability of its staff. Therefore, new entrants into the seed business must recruit well trained and carefully selected staff. The seed production manager must be experienced, in addition to having a sound education and relevant training. The manager must

- always pay attention to seed quality,
- constantly look at the seed business through the eyes of his customers and farmers,
- set clear, attainable goals for his team,always plan ahead,
- communicate regularly and unambiguously with his team about successes, challenges, and changes,
- stay calm especially when and where there are problems,
- create an atmosphere of open debate,
- show extra appreciation to team members when jobs are well done,
- hire people based strictly on skills, merit, and ability,
- lead by example, and
- be computer literate, especially in the use of Excel for record keeping.

Ensure regular on-the-job training for the staff: Seed production processes soon become routine to the employees, making them careless within a short time on the job. The infusion of new ideas and skills is often needed to sharpen and "fire up" such production staff. The national institutes, universities as well as IITA and CIMMYT conduct training courses in seed production and technology from time to time in the subregion. Seed companies are usually invited as participants in these courses and many have taken the opportunity to upgrade the skills of their staff.

Achieve proximity to a research institute/university: Since seed production is a highly specialized operation drawing heavily on science and technology, it is always desirable to locate a seed project near an agricultural research institute. The technical services of breeders, pathologists, entomologists, and other scientists will be thus readily available to the seed organization, as and when required.

Current initiatives and future perspectives of the seed industry in WCA 15

With reference to the resources and facilities available to the seed sector one can say that the time is ripe for the industry to make giant strides and move forward to catch up with or surpass seed programs in East and Southern Africa. The myriad constraints that have been militating against the seed industry must be boldly confronted and solved.

Tremendous opportunities exist for the establishment of a profitable seed industry especially given the availability of the many high yielding improved varieties developed and released through the collaborative efforts of IITA, CIMMYT, and the NARS.

OPVs and hybrids have been bred for high productivity under the major prevailing constraints such as drought, *Striga*, low fertility, especially soil nitrogen deficiency, maize streak virus, and rust. There is an urgent need for the willpower of the various Governments to make the varieties available to the farmers. To achieve this, countries in the subregion should take an inventory of all resources (including human), the facilities, structures, and infrastructure available to them, and decide on the best seed delivery system appropriate for adoption and use. In the area of policy, Governments should encourage financial institutions to support investors in the sector with credit facilities at affordable interest rates, while promoting farmers' cooperative schemes. The macropolicy environments of various countries should also be made conducive to attract agro-based businesses.

One way to fast-track the adoption of improved varieties by farmers is through the establishment of a well-developed seed industry to ensure that they have access to improved varieties and hybrids at affordable prices at all times. All efforts must therefore be made to increase the farmers' awareness of the economic benefits of using improved seeds to help to create a regular market that would in turn attract more investors into the business. All factors militating against the rapid achievement of this goal should be addressed to help in the seed delivery system.

To improve the delivery system and promote the release, adoption, and use of new varieties, the NARS of the various countries should be overhauled and upgraded in terms of personnel, infrastructure, and facilities. The performance of the majority is low as evidenced by the few varieties they release in a year. Their ability to release new varieties is limited and Governments should give the centers a continuous lifeline to enable them to do better. Conditions of service should also be improved for the centers to attract and maintain staff of the right caliber.

Improving the variety release process

Although most West African countries currently have varietal release committees, they are less than effective, primarily because of the infrequency of meetings to discuss and approve the release of new varieties. From lack of operating funds, the committees often meet on a very irregular basis, thus extending the time taken for varieties to be released. Regular injections of the much-needed funds to the committees for their operations should be provided to enable them to meet their set objectives.

Harmonization of variety releases across WCA

WCA countries will benefit from a free flow of germplasm across national boundaries if the regional variety release process is harmonized. Maize varieties released in one country should be considered automatically released in other countries with similar ecologies. Mega-environments cuts across country boundaries and adaptation zones and are not country-specific so varieties should be released based on mega-environments to create a larger seed market and quicken variety release. To this end, regional variety releases based on mega-environments are currently being promoted and should be vigorously pursued. Presently, studies have been conducted to identify core testing sites in West Africa to reduce the cost of variety testing and seed production. Furthermore, seed policies and regulations in West Africa are being reformed by harmonizing variety release and registration as well as seed standards and regulations to help facilitate the orderly movement of seeds across borders. The uniformity of regulations would also enhance the sale of seeds throughout the region.

Using community-based seed production as a vehicle for improved seed delivery

Despite efforts made by various Governments to promote the production, release, and registration of improved varieties as well as the delivery of quality seeds to their farmers through the formal seed sector, not much has been achieved. All the countries have failed in this venture, with the exception of Nigeria and Ghana which have some good results to show. The bulk of maize seeds that are planted annually continue to come from the informal seed sector, with IITA, through its novelty community seed production modules, assisting the various communities in their seed production and delivery efforts. The community-based seed production delivery system has thus become the immediate viable alternative that could be used to make improved seeds available to farmers across the entire sub-region. Countries that have not adopted any of the seed production models should be encouraged to do so. Improvements can be made to the schemes in countries that are already using them.

Successful community-based seed production schemes should be assisted to transform themselves into microenterprises for sustainability and also to help to champion the cause of seed delivery. This can be further facilitated by the provision of small equipment. Given that seed producers who may be skilled in production may lack skills in small business management, book-keeping, accounting, and marketing, the DTMA project is currently organizing seed business management courses for seed companies in member countries. Such training courses need to be intensified and the modules presented during the courses should include community-based seed production.

Challenges to the seed industry include the need to develop a more efficient structure for marketing. There is need for seeds to be advertised to reduce the problem of marketing due to a lack of information. Partner organizations that can assist in the collection and relay of market information to potential end-users need to be identified. It would be beneficial to package and label seed in small bags of 1 and 2 kg and to have points of seed sale at strategic points in communities. For countries that do not have seed laws, the promulgation of such laws will help to ensure that unscrupulous people do not sell grain as seeds, and that farmers have easy access to good quality seeds. Where seed laws exist and are not functional, there is a need to strengthen the system through the establishment of active inspection units. More and better organized cooperatives and agro-enterprises should be established through training and linkages to appropriate markets. Such enterprises should take into consideration the lessons learnt from current community-based seed production initiatives. Improved access is needed by seed producers to credit, inputs, and market outlets for their products. The greatest impact of the community-based seed production scheme would be in areas not currently serviced by seed companies where this system should be promoted. Educational awareness campaigns, variety demonstrations, and increased promotional activities by community-based seed producers are required to stimulate demand. Apart from making available adequate quantities of breeder seeds of improved varieties to the informal seed production system, linkage with established seed companies is required. Furthermore, a compilation of released varieties, their characteristics, adaptation, and sources of seeds is required as this information is lacking in some countries. Such lists should be regularly updated as new varieties get released. A database and GIS on community-based seed production schemes are also required.

Promotion of regional standards for PBRs

Promotion of the development of regional standards for PBRs will allow plant breeding programs to generate income from the products of their research through royalties. This will allow both sectors to benefit from the product of research and lead to more investments in variety improvement.

Current initiatives of AGRA-PASS and the DTMA project

Seeds play a major role in determining the level of investment that farmers make in their crops. But across Africa, smallholder farmers have very limited access to responsive, high yielding, locally adapted varieties of their staple food crops. They must instead rely on low quality seeds that have been saved and reused, degenerating over the course of decades. Poor seeds plus poor soils mean that African farmers produce only about one-quarter of the global average yield. A survey of the seed system in Nigeria, Ghana, Mali, and Bénin showed that during the period 2000-2006 there were only eleven seed companies in the study countries. From 1997 to 2007 there were only enough improved maize seeds to meet one-third of the farmers' demand. This masks large differences among countries. In Niger, for example, improved seeds cover only 4% of farmers' needs. Obstacles to the development of a robust seed system in Africa include a lack of access to capital; only 1% of commercial bank financing goes to agriculture. Lastly, it was found that Africa suffers from a severe shortage of seed processing equipment. For example, in northern Ghana, there is only one processing unit to service over 50 growers.

AGRA's Program in Africa's Seed Systems (PASS) is seriously engaged in increasing the capacity to breed, produce, and disseminate quality seeds of staple food crops, such as maize, rice, cassava, beans, sorghum, and millet. The initiative aims to develop seed systems that deliver new crop varieties to smallholder farmers efficiently, equitably, and sustainably. PASS operates through four sub-programs: Education for African Crop Improvement (EACI), Fund for the Improvement and Adoption of African Crops (FIAAC), Seed Production for Africa (SEPA), and the Agro-dealer Development Program (ADP). PASS operates across the seed value chain and is presently involved in the training of plant breeders to develop improved varieties of Africa's indigenous and staple food crops including maize, building the capacity of the NARS in plant breeding and seed production, and developing disease and pest resistant maize varieties and hybrids with consumer-preferred traits. The project is supporting private African seed companies and farmers' cooperatives to produce, distribute, and market improved maize seeds, strengthening the network of village-based agro-dealers to distribute the seed to remote farmers, strengthening associations of women farmers and farmers generally, and developing seed storage and processing capacity. In addition, it is promoting policies that accelerate the release of proven new varieties, strengthening seed regulatory systems, eliminating seed trade barriers, and harmonizing regional seed laws. From 2007 to 2011, AGRA-PASS committed investment amounted to $97.0 million spread across key areas in the seed value chain – training future plant breeders and facilitating the development and release of new varieties, building capacities of existing seed companies and agro-dealers and bringing new ones on board (AGRA 2012). In 2011, 60 private seed companies in Africa benefited from PASS support and produced 39,166 million t of seed with maize accounting for 57% of the seeds produced.

It is anticipated that the PASS initiative will contribute significantly to the development of the seed industry in WCA. The emphasis on hybrid seed production by existing and emerging seed companies as a means of ensuring that farmers buy improved seeds annually to ensure the sustainability of seed production and the survival of the seed companies is expected to make good quality seeds available at affordable prices. The DTMA project and AGRA are presently working in close collaboration to support the development of the industry and to strengthen the national maize breeding programs in West Africa.

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